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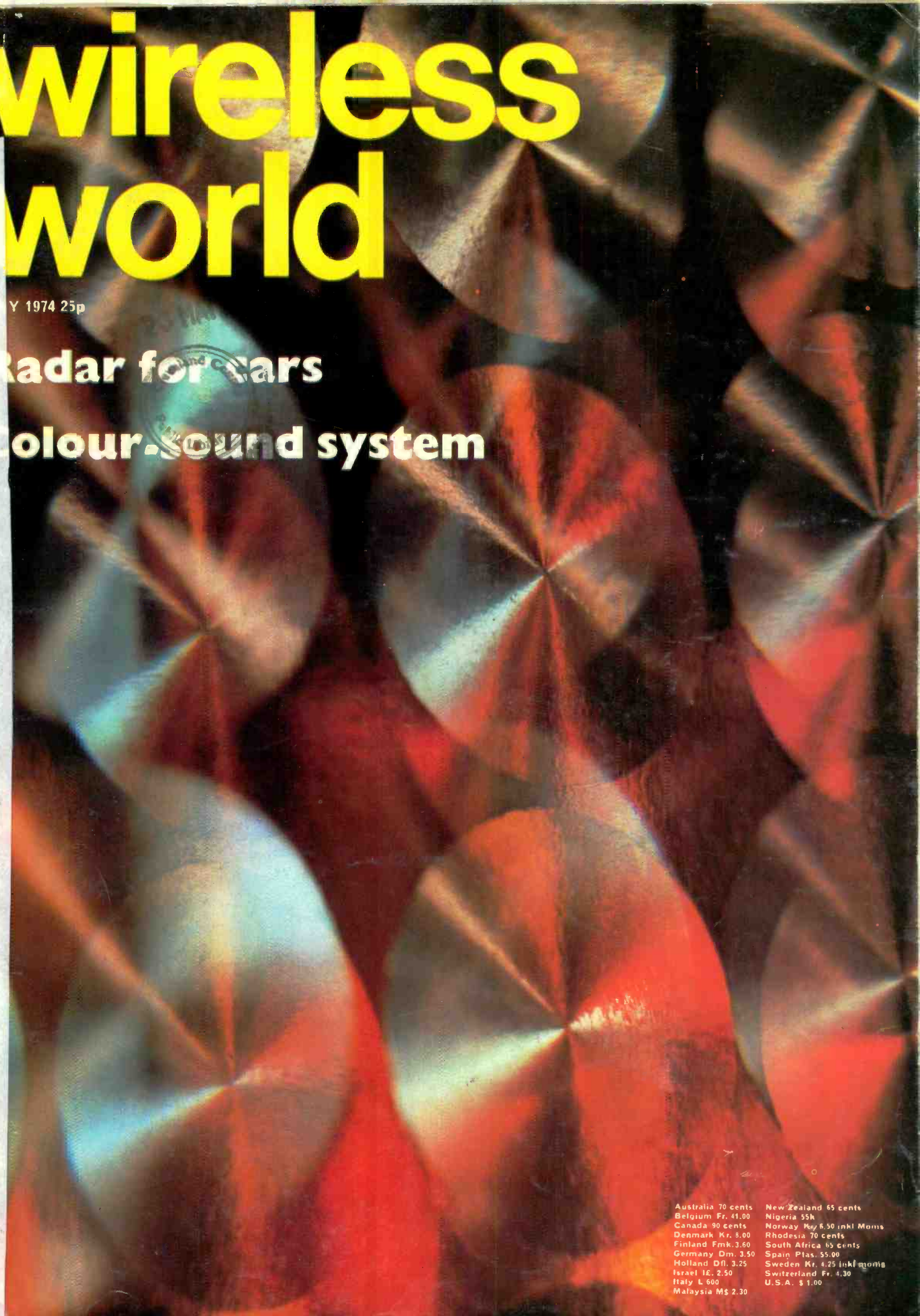

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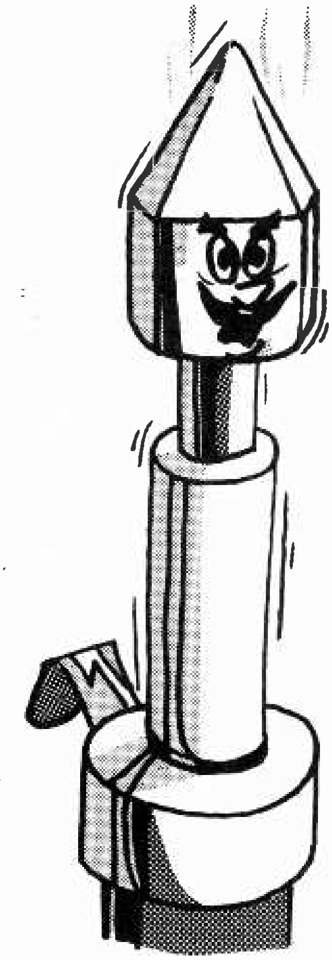

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You know his type...always blowing hot and cold... getting overheated just when you need him to be controlled and efficient. It's the same with some people's soldering irons.

Hopelessly inefficient heat control can make soldering operations a nightmare; if this is what soldering means to you it's time you woke up to Antex.

Choose a new model from the comprehensive Antex range of soldering instruments, with low-leakage characteristics, unique construction advantages and really precise heat control.

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Suitable for production work and as a general purpose iron.

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Totally enclosed element in ceramic shaft.
Fitted long-life iron-coated bit 3/32".
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Contains 15 watt miniature iron fitted with 3/16" bit, 2 spare bits 5/32" and 3/32", heat sink, solder, stand and "How to Solder" booklet.
PRICE £3.64 (rec. retail)
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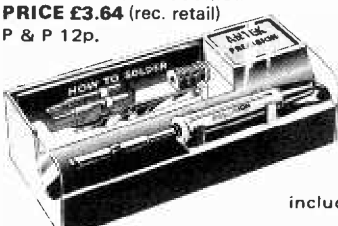

MODEL MLX KIT
Battery operated 12v. 25 watt iron fitted with 15' lead and 2 heavy clips for connection to car battery. Packed in strong plastic wallet with booklet "How to Solder".
PRICE £2.76
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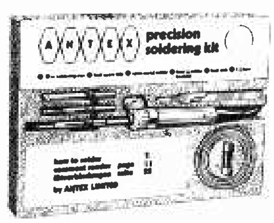
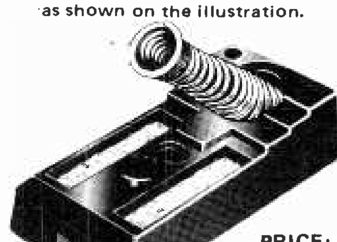


ST3 Stand — This stand is made from high grade insulation material with a chromium plated strong steel spring. It is suitable for all models and replaces all previous stands. The two sponges at the side which are easily replaceable serve to keep the soldering bits clean. Spare bits can be accommodated as shown on the illustration.



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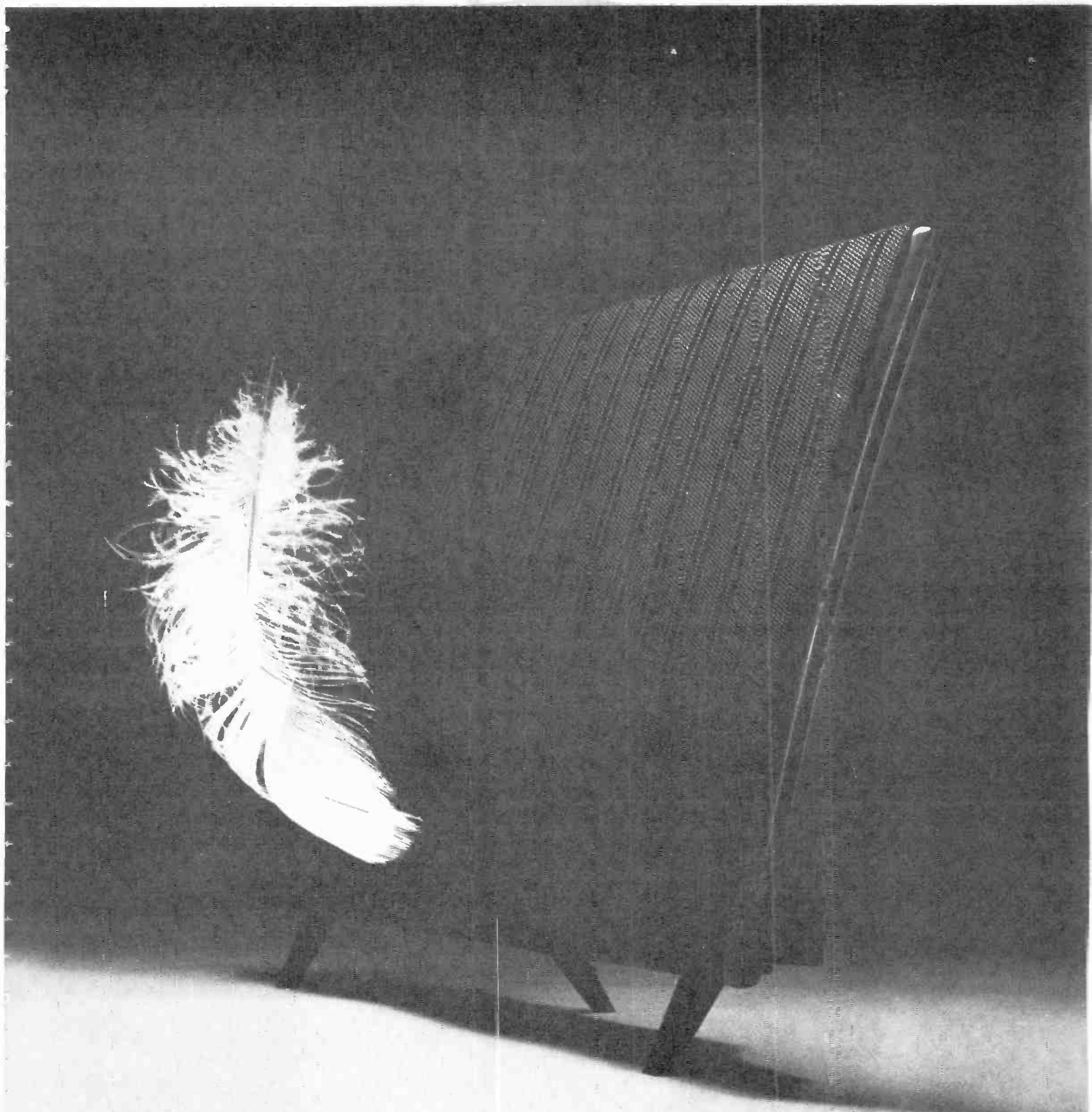

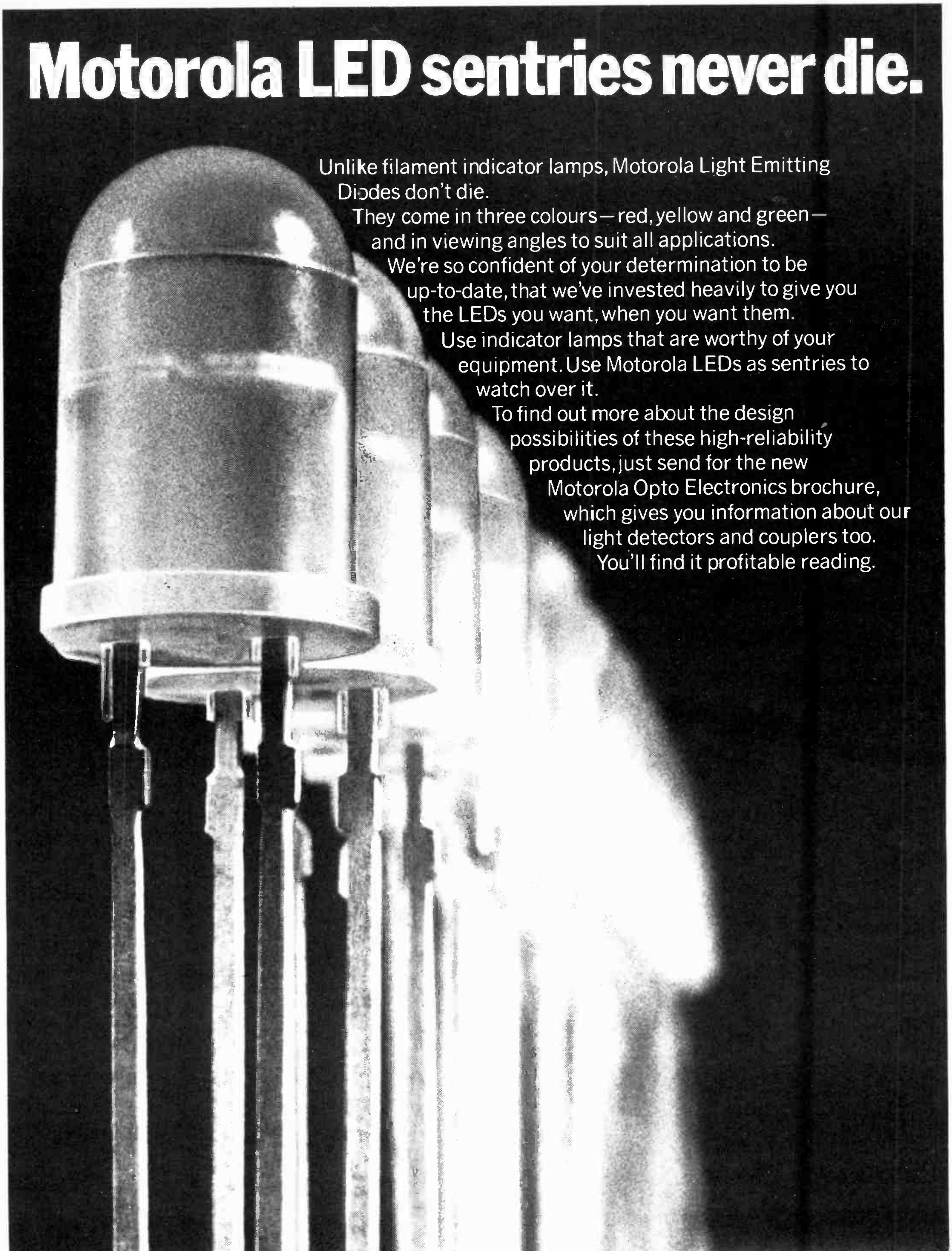
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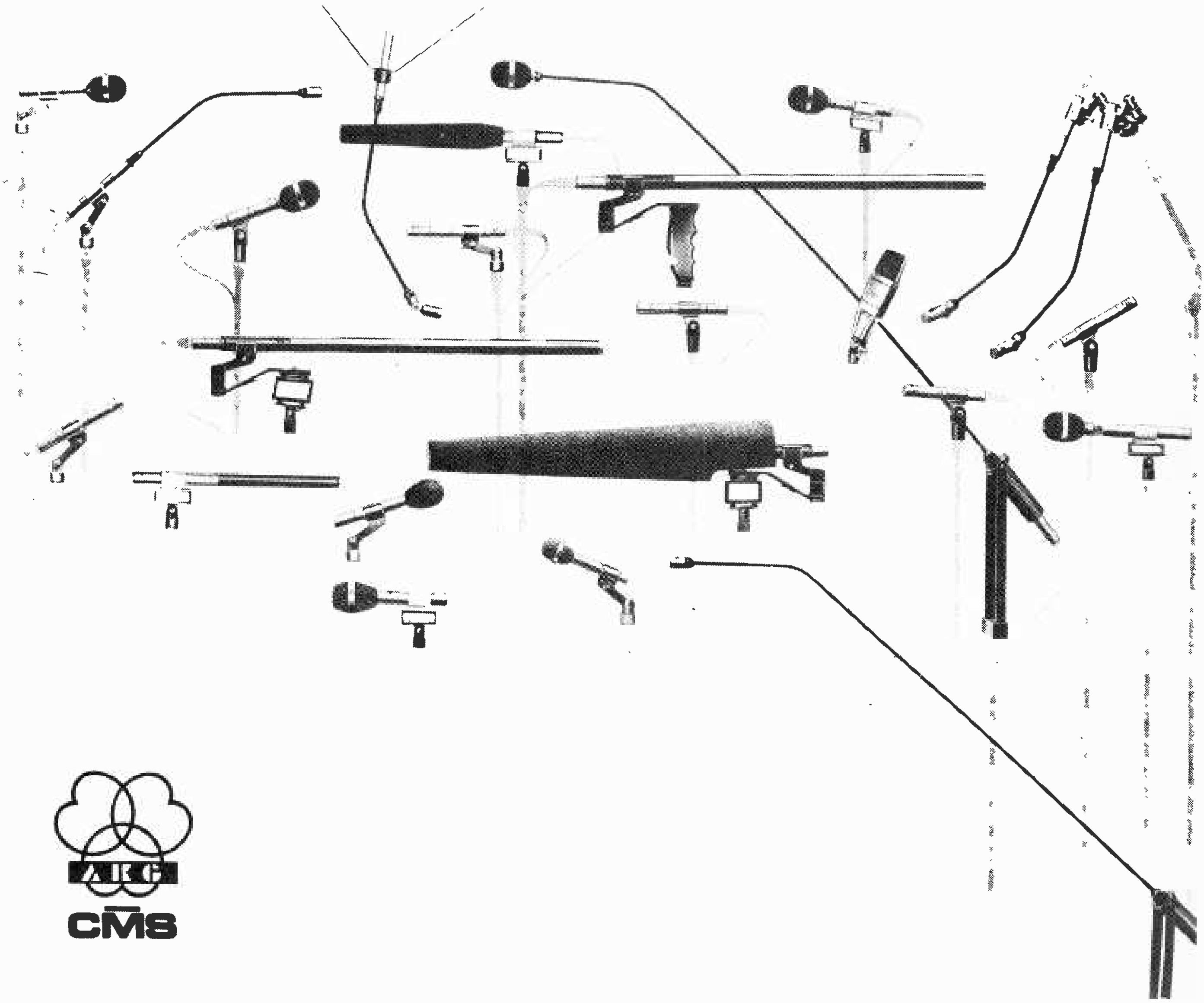

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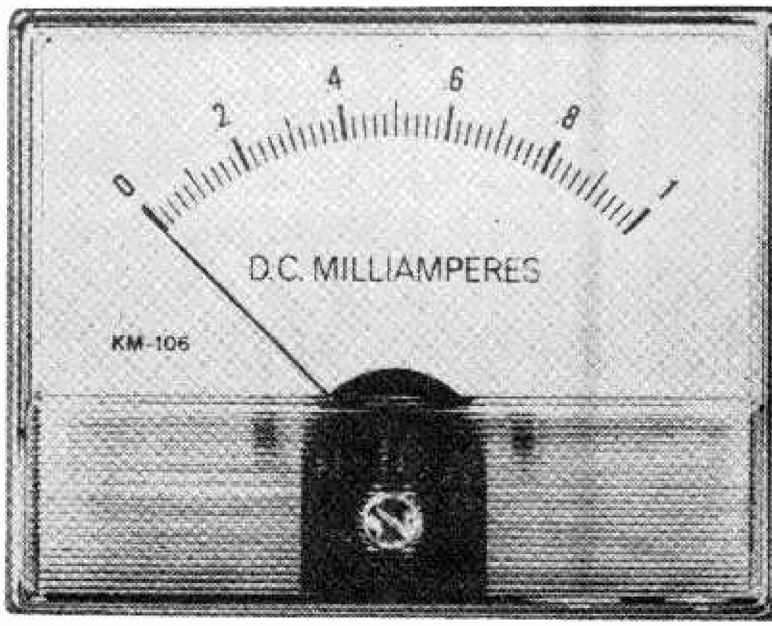

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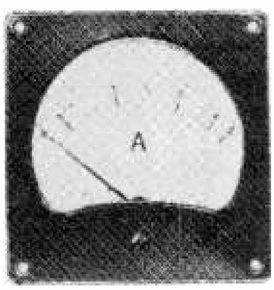
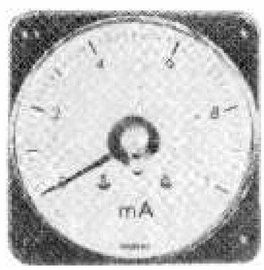
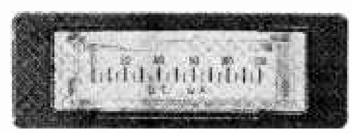


Vulcan Moving Iron. 4 models, 1·5", 1·8", 2·7", 3·7" scales. Voltmeters, ammeters and motor starting meters.



Oxford Long Scale 240°. 2 models, 5·5", 8" scales. DC moving coil and AC moving coil rectified.



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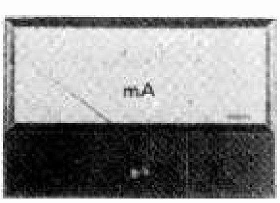

Regal Range 100° flattened arc. 2 models 2.5" and 3.2" scales. Taut band. DC moving coil and AC moving coil rectified.

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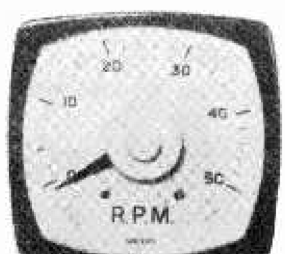
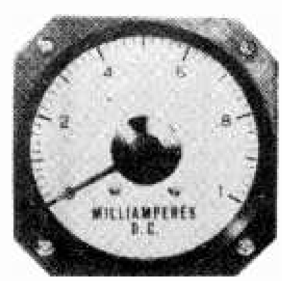


Stafford Long Scale 240 6 models, 3·5"—11·5" scales. DC moving coil, AC moving coil rectified, AC moving iron. Also 98° scale.



Lancaster Long Scale 240°. 2 models, 4", 5·5" scales. DC moving coil and AC moving coil rectified.

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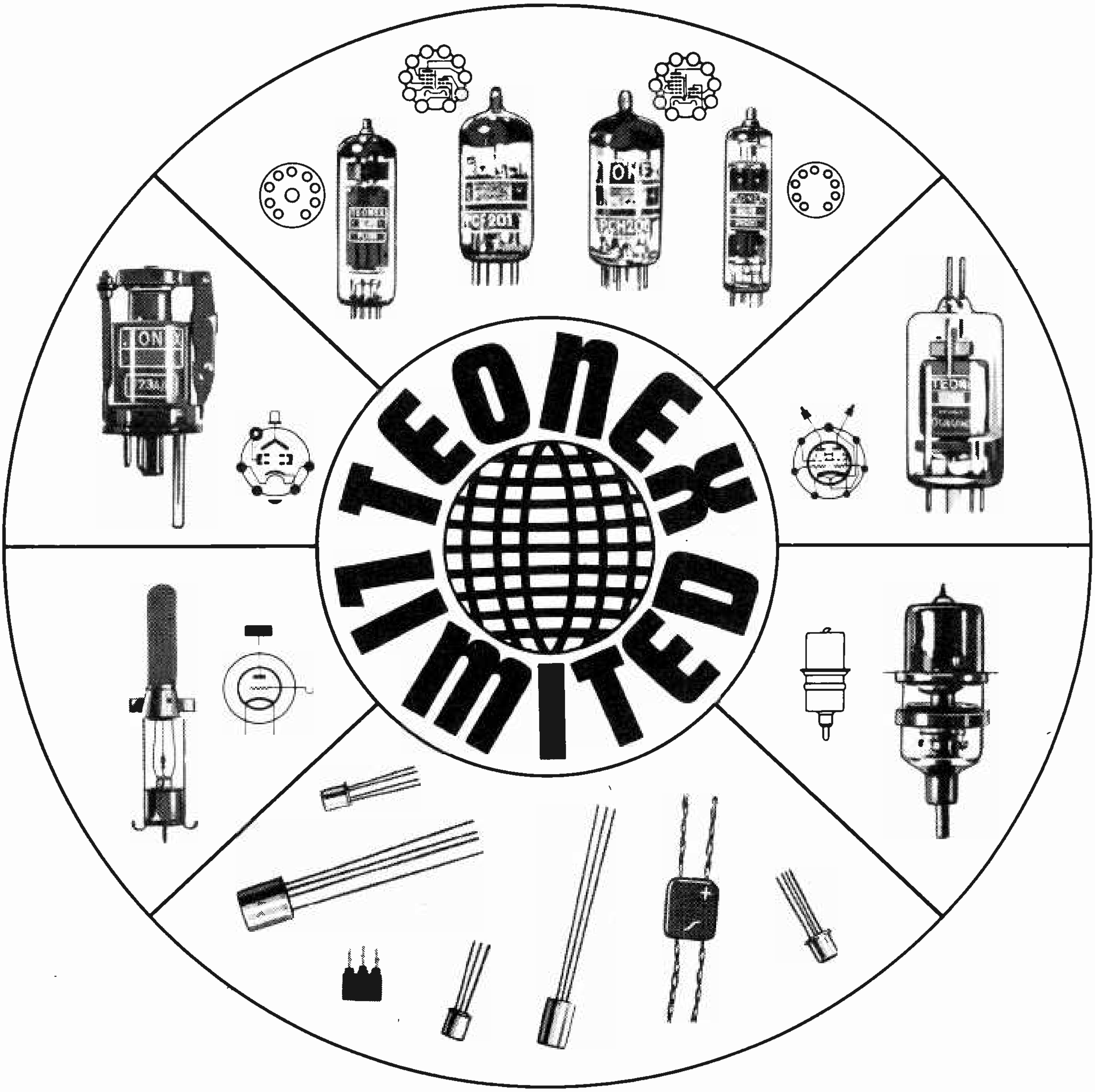

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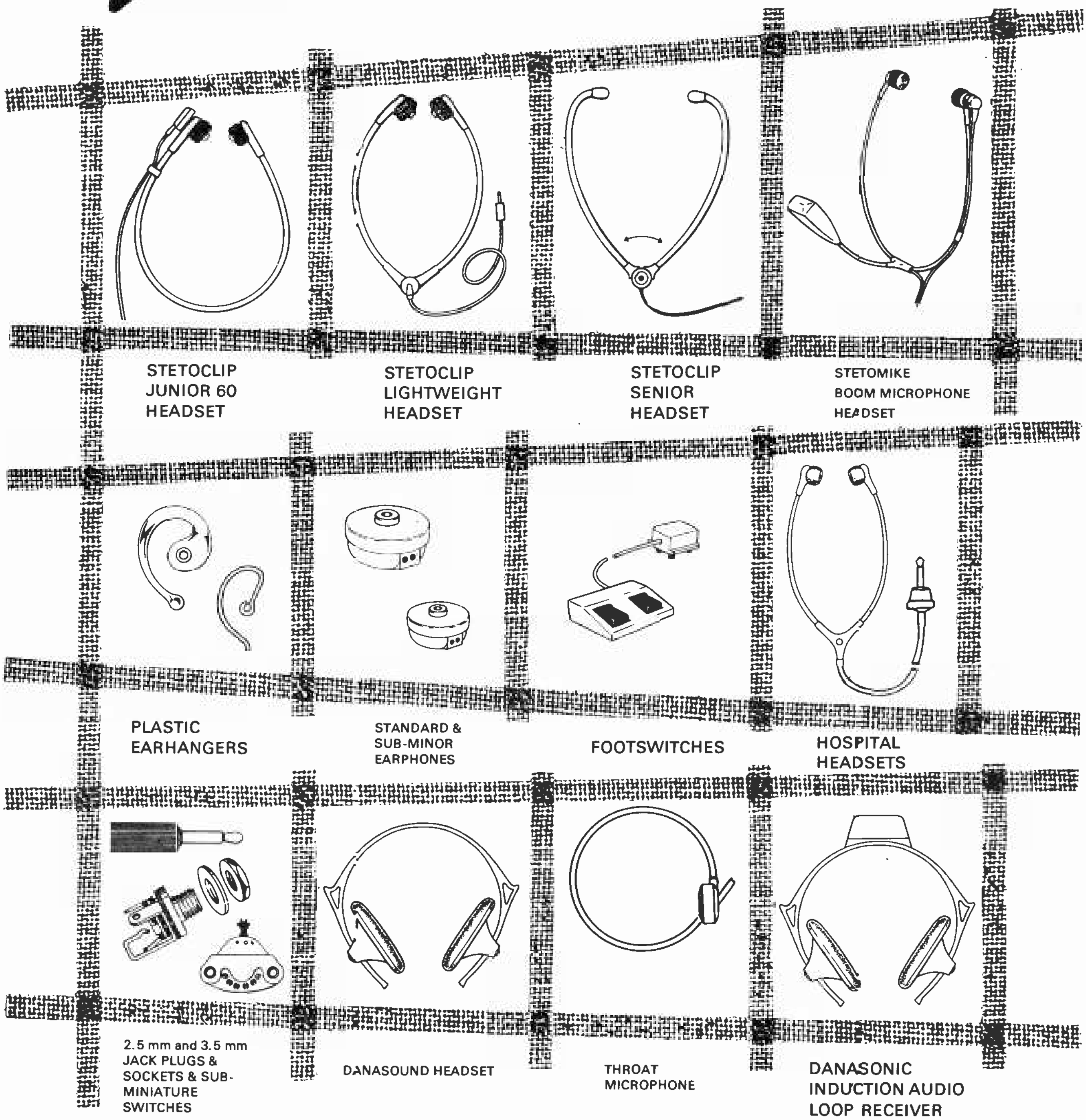

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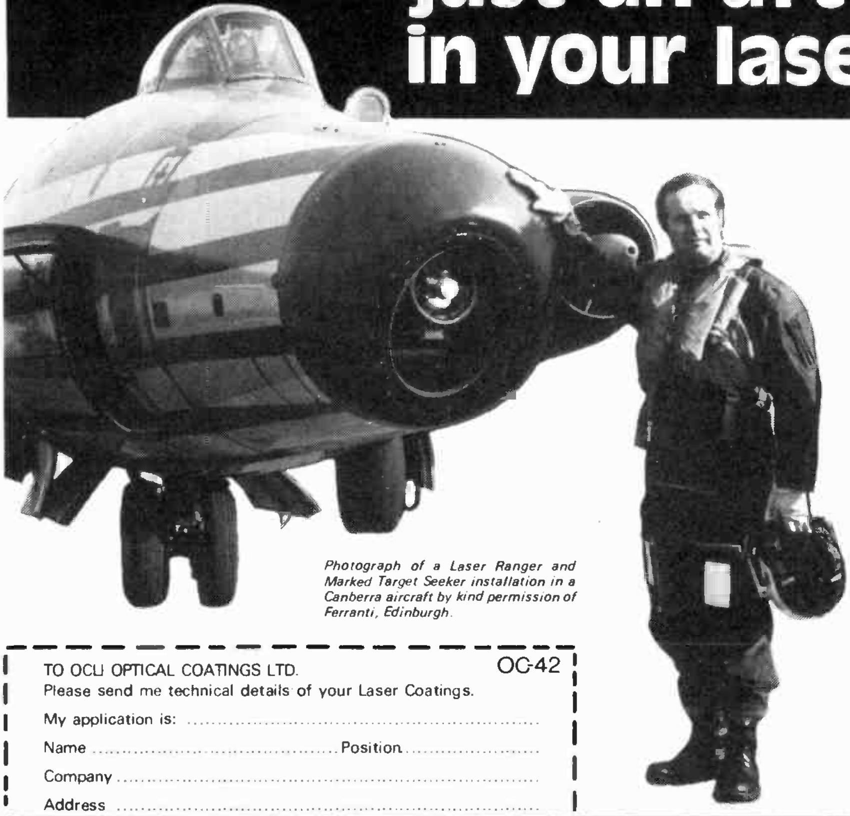
Are anti-reflection coatings just an afterthought in your laser system?



Photograph of a Laser Ranger and Marked Target Seeker installation in a Canberra aircraft by kind permission of Ferranti, Edinburgh.

Here's why Ferranti specified OCLI laser coatings at the *design* stage of their aircraft Laser Ranger and Marked Target Seeker.

Ferranti realised right at the start that it was vital to specify *high-quality* optical coatings for their aircraft laser systems if optimum performance from mirrors, lenses, prisms, and other components was to be achieved. Laser system requirements not only push the performance of optical components, including coatings, to their limits, but also make any latent shortcomings and flaws more evident. For these reasons, transmission and reflection efficiencies in Ferranti's laser systems were required to be in the 99 + % range.
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OCLI OFFERS A FULL LINE OF COATINGS AND OPTICS FOR USE IN ALMOST ANY LASER AND F.L.I.R. SYSTEM.

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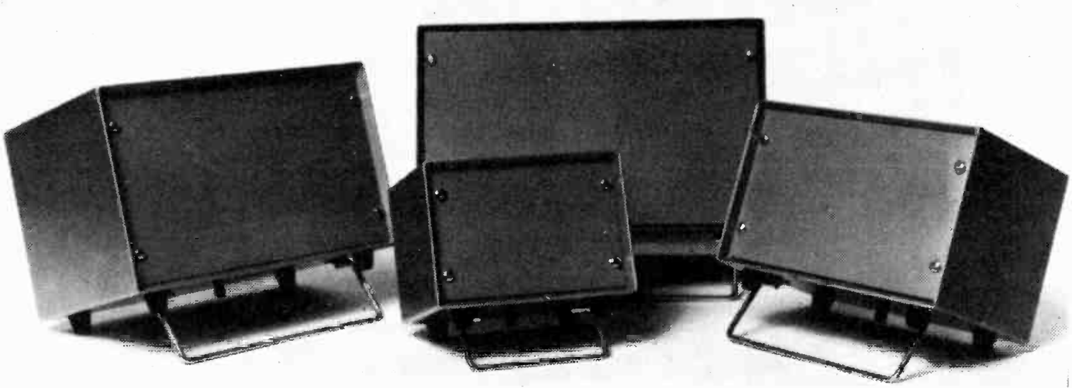

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For more detailed information about the comprehensive Greenwood range, contact the address below.

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3. Oryx SR3A desoldering tool. Ideal where components are tightly grouped. Instantly removes unwanted solder from printed circuits etc. Accurate, reliable, speedy, and safe. Price: £4.50 & VAT.

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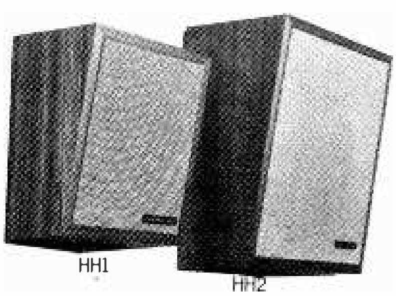

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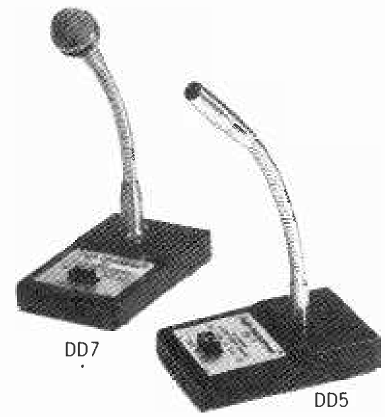

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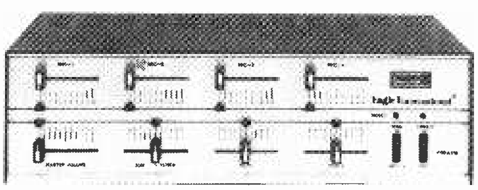

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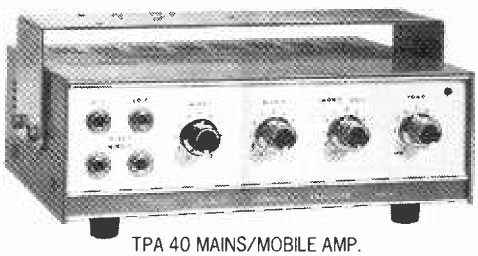
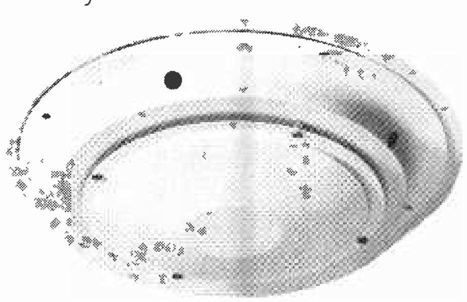


TPA 40 MAINS/MOBILE AMP.

And who knows, maybe sooner than anyone else's.



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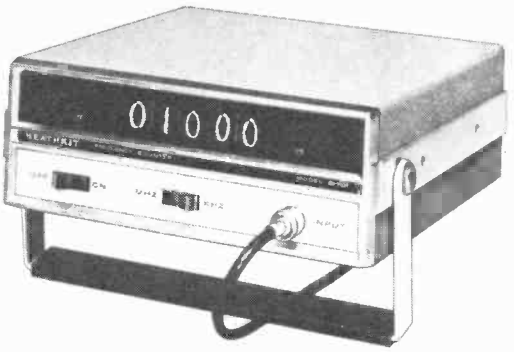
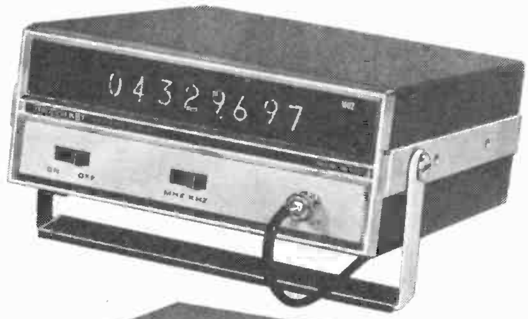
If you need specific details urgently, please don't hesitate to contact Mr. Morrow personally.





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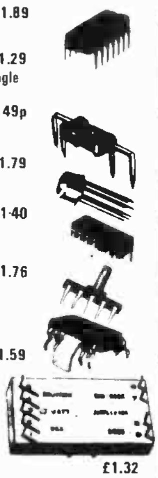

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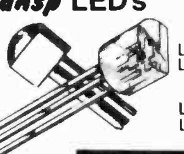
INTERNATIONALLY KNOWN BRANDS
1st. GRADE DEVICES AT NEW ROCK BOTTOM PRICES

SN7400	20p	SN7473	41p
SN7401	20p	SN7474	41p
SN7402	20p	SN7475	63p
SN7404	20p	SN7476	44p
SN7408	25p	SN7490	82p
SN7410	20p	SN7492	82p
SN7413	31p	SN7493	82p
SN7420	20p	SN74100	£2·37
SN7430	20p	SN74121	45p
SN7441	81p	SN74141	£1·10
SN7442	81p	SN74192	£2·15
SN7447	£1·45		

Cheapest Opto yet GaAsp LED's



RED
LED 2. 0·125″ 26p
LED 3. 0·175″ 17p

GREEN
LED 4. 0·125″ 69p
LED 5. 0·175″ 75p

Remember **Vat Inclusive Prices**

PRICE BARRIER SLASHED

LED READOUTS

LITRONIX DL707 SERIES

⅓″ high characters 14pin Dil Ref LED 1

also available + 1 Ref LED 1A

£1·99 + 20p VAT = £2·19

Linears

	8pin DIP	TO99	14pin Dil
709	34p	40p	35p
710	35p	40p	39p
711	—	45p	39p
723	—	96p	95p
741	42p	45p	43p
747	—	—	92p
748	42p	45p	43p

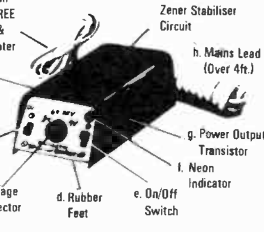
CA3046	95p	MVRSV (L005)	£1.65
CA3075	£1.65	MVR12V (L036)	£1.65
CA3082	£1.65	MVR15V (L037)	£1.65
LM101H	£1.99	NE 555	99p
LM201H	£1.15	NE 560 B	£4.92
LM301	£1.05	NE 561 B	£4.92
LM307N	66p	NE 562 B	£4.92
LM308K	£1.45	NE 565	£2.80
LM309K	£2.69	NE 566	£2.75
LM3900	77p	NE 567	£2.80
MC1330	88p	SG3402N	£3.08
MC1350	83p	SL440	£2.89
MC1351	£1.10	TAA263	99p
MC1352	£1.10	TAA293	99p
MC1357	£1.59	TAA310	£1.37
MC1358	£1.69	TAA320	99p
MC1456G	£1.75	TAA350	£2.54
MC1458CP1	£2.42	TAA370	£5.15
MC1495	£5.65	TAA550	81p
MC1496N	£1.49	TAA570	£1.65
MFC6030A	£4.95		

NEW

MM5316 – alarm clock £16.50
Liquid Crystal 4 digit display inc. socket – AN4132 £14.38
TBA810S (7 Watt) £1.70
Dual 555 (2556) £1.32
Mullard LP1400 Multiplex Decoder Module £4.96

new stabilised POWER PACK/CONVERTER

Switched 3, 6, 7½ or 9 Volts
Up to 400ma Output



Our Price £4·99 + p & p 20p
unstabilised version of above £2.99.
Other Eliminators (unstabilised)*

6 Volts @ up to 50mA	£1.65
9 Volts @ up to 50mA	£1.65
9 Volts (miniature) @ up to 50mA	£2·80
6 + 6 @ up to 50mA	£2.75
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7½ Volts for cassette Players (Small)	£2.20
3; 4½; 6; 7½; 9; 12 Volts up to ½A	£4·99
Fully stabilised car battery Converter* giving switched outputs of 6; 7½ or 9v	£5.49

p & p on all models 20p

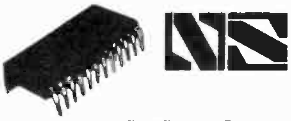
I.C. SOCKETS

Dual in line		ZIG ZAG
8pin 13½p	28pin 30½p	14pin 15½p
14pin 15½p	36pin 39½p	16pin 17½p
16pin 17½p	40pin 44p	
24pin 26½p		

CHROMASONIC electronics

Dept. 5.
56, Fortis Green Road, London, N10 3HN
883-3705

DIGITAL CLOCK



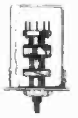
MM5314

12 or 24 hour. 4 or 6 digit 50 or 60Hz operation leading zero supression single voltage supply similar to DIGITRONIC in P.W. March 1973.
Only £7.99

INDUCTORS

LP1175 MULLARD 470khz
Block I.F. Filter
Now only £1.49

Denco (Clacton) Ltd. Maxi-Q Coils



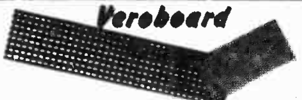
Transistor Range
Series 1T to 5T inclusive
Blue: Yellow: Red & White
All 49p each

Dual Purpose Range:
Series 1 to 7 inclusive
Blue: Yellow; Red & White
All 49p each
1 to 5 Green 53p each

Ferrite Rod Aerials Medium & Long Wave for 300pf & 500pf tuning (state which) **88p each**

R.F. Choke Range 0.1uH to 19mH
For full details ask for leaflet No. 5
p & p 5p.

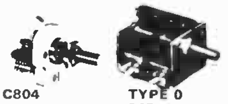
Veroboard



	COPPERCLAD 0.1″	COPPERCLAD 0.15″	PLAIN 0.15″	EXTRA P & P
2½ x 3¾″	24p	18p	12p	—
2½ x 5″	26½p	23p	13p	—
3¾ x 3¾″	26½p	23p	—	—
3¾ x 5″	30p	30p	20p	—
17 x 2½″	82p	63p	45p	10p
17 x 3¾″	£1.10	86p	60p	10p
17 x 5″	—	—	90p	10p

Dip Breadboard 4.15″ x 6.15″ £1.15
Spot Face Cutter 44p
Pin insertion Tool (State 0.1″ or 0.15″) 55p
Terminal Pins (PKS50)—State Size 55p

Tuning Gangs



TYPE C804

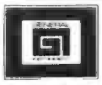
5pf	71p
10pf	71p
15pf	71p
20pf	77p
25pf	71p
50pf	77p
60pf	83p
75pf	83p
100pf	85p

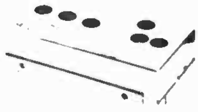
TYPE 0
365pf 83p
365 + 365pf 99p
TYPE 00
208 + 176pf with screen & trimmers 99p
Dilecon
100pf 69p
300pf 69p
500pf 69p

3½ decade DVM

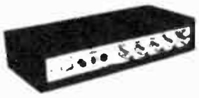
A State-of-the-Art Digital Voltmeter I.C. for only £7·79

Price includes data booklet (10p separately)

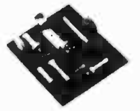




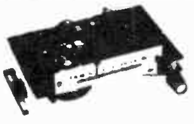
Mullard LP1186
Varactor diode tuned F.M. Tuning heart **£4.75** as described in P.E. May 1973. **LP1185** matching I.F strip **£5.50.**



THE TEXAN
20 + 20 Watt Integrated stereo amplifier Kit superb state-of-the-art design by engineers of Texas Instruments
£31.35 + p & p 49p



SGS EA1000
3 Watt amplifier module Price including handbox and **FREE HEATSINK** (Quantity Discounts)
Our Price £2.49



A1005S
F.M. tuner chassis. fully transistorised. 9 Volt positive earth operation
Our Price £8·20

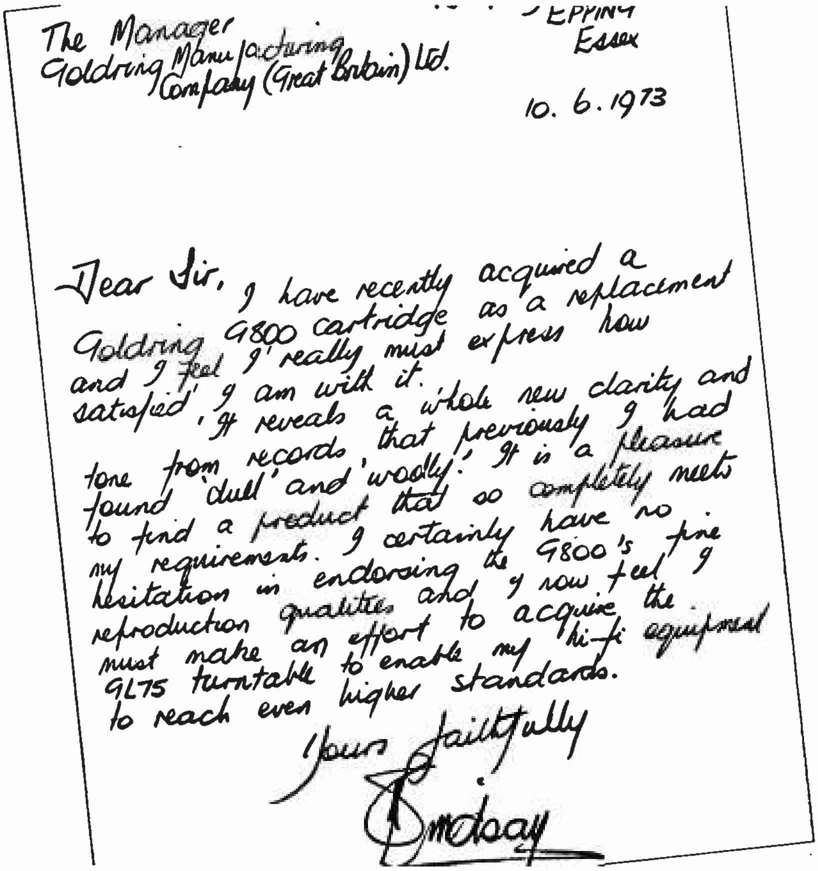
A1018
F.M. Tuner. similar to A1005S but in oiled walnut case. black & silver fascia etc
Our Price £11·39

A1005MS
Multiplex Stereo Decoder fully built & aligned to match A1005S
Our Price £6·60

VAT INVOICES ON REQUEST

UNLESS SHOWN OTHERWISE P&P ON U.K ORDERS IS 10p. OVERSEAS ORDERS AT COST

WW—035 FOR FURTHER DETAILS


... Epping
Essex

10. 6. 1973

The Manager
Goldring Manufacturing Company (Great Britain) Ltd.

Dear Sir, I have recently acquired a Goldring G800 cartridge as a replacement and I feel I really must express how satisfied I am with it. It reveals a whole new clarity and tone from records, that previously I had found 'dull' and 'woolly'. It is a pleasure to find a product that so completely meets my requirements. I certainly have no hesitation in endorsing the G800's fine reproduction qualities and I now feel I must make an effort to acquire the hi-fi equipment to enable my GL75 turntable to reach even higher standards.

Yours faithfully

One of our customers puts the achievement of the G800 on record!

This letter is typical of many received by Goldring. If you would like some further evidence, start by writing for a full descriptive leaflet on Goldring Cartridges to: Goldring Limited, 10 Bayford Street, Hackney, London E8 3SE.

Goldring

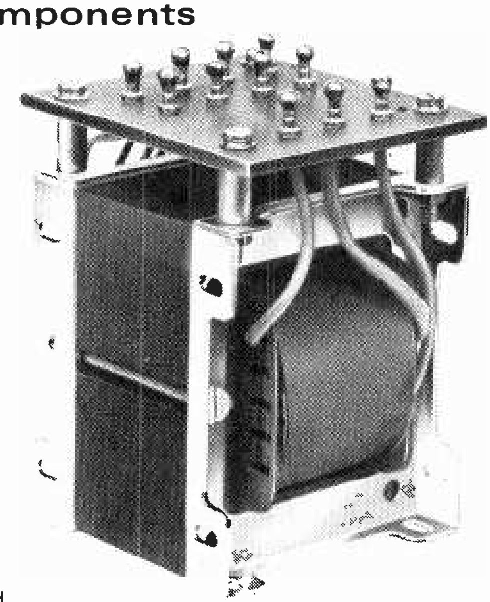
WW—036 FOR FURTHER DETAILS

transformers

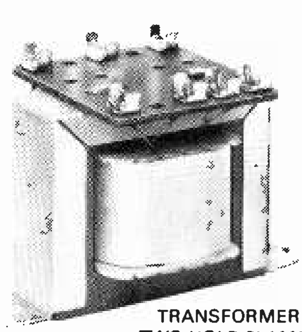
mains, audio, microphone, ferrite core and other wound components

A wide range of transformers manufactured in production quantities to customers individual requirements

Prompt Prototype Service available


TRANSFORMER WITH UNIVERSAL END FRAMES AND TURRET LUG CONNECTIONS


MICROPHONE TRANSFORMER IN MUMETAL CAN


TRANSFORMER WITH TWO HOLE CLAMP AND SOLDER TAG CONNECTIONS

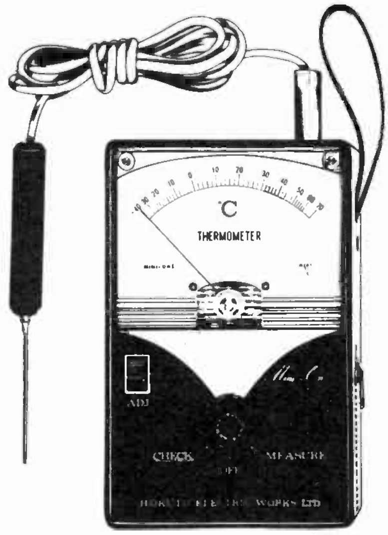
Drake Transformers Limited

Telephone:
Billericay 51155

Kennel Lane,
Billericay, Essex.

WW—037 FOR FURTHER DETAILS

ELECTRONIC INDUSTRIAL THERMOMETER



THE MODERN WAY TO MEASURE TEMPERATURE

A Thermometer designed to operate as an Electronic Test Meter. Will measure temperature of Air, Metals, Liquids, Machinery, etc., etc. Just plug-in the Probe, and read the temperature on the large open scale meter. Supplied in zippered vinyl case with transparent front and carrying loop, Probe, and internal 1½ volt standard size battery.

Model "Mini-On 1" measures from − 40°C to + 70°C, price £17.50
Model "Mini-On Hi" measures from + 100°C to + 500°C, price £20.00 (V.A.T. EXTRA)

Write for further details to

HARRIS ELECTRONICS (LONDON),
138 GRAY'S INN ROAD, LONDON WC1X 8AX
('Phone 01-837 7937)

WW—047 FOR FURTHER DETAILS

Gardners line up

Line Matching Transformers from Standard to Super Fidelity

It's easy to choose the right Line Matching Transformer from the five Gardners ranges.

The Super Fidelity Series, with a frequency response of 10Hz to 80kHz – 0·5dB, gives the widest possible bandwidth for high accuracy instrumentation and recording applications.

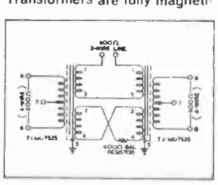
Then there's the Wide and Extra Wide-band ranges. Outstanding performers with a frequency range 30Hz – 20kHz or more – for the 0·5dB points. Used a lot by broadcasting and recording companies throughout the world.

The Miniature and Standard ranges provide excellent bandwidth for most purposes, 30Hz – 22kHz for the 1·0dB points.

Except for the very smallest in the range, all Gardners Line Matching Transformers are fully magnetically shielded, giving very high hum rejection ratios.

Prices start from £2·29 (recommended retail price) and all types are usually available from stock.

Complete technical information is given in brochure GT.5 'Audio Frequency Transformers' which we'll be glad to send on request.



So accurate is the balancing of the windings on some of these transformers that, when used as pairs in a hybrid circuit (as illustrated) we can guarantee a rejection of better than 55dB over the frequency range 50Hz to 10kHz and normal rejection of up to 75dB may be expected.

Gardners

Specialists in Electronic Transformers and Modular Power Supplies

GARDNERS
TRANSFORMERS LIMITED

Gardners Transformers Limited, Christchurch, Hampshire. BH23 3PN
Tel: Christchurch 2284 (STD 0201 5 2284) Telex 41276 GARDNERS XCH

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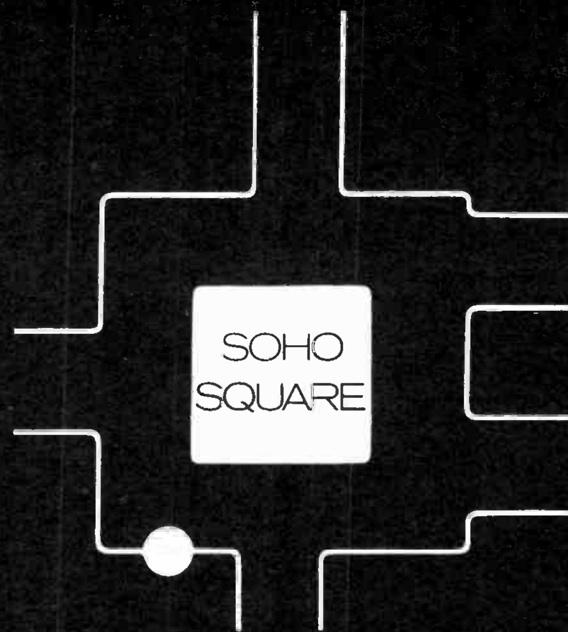


CCTV in Soho

As a result of continued expansion, Dixons Technical require CCTV engineers to work in their new showrooms and workshops.

Applicants should be fully experienced in the installation and maintenance of PalColour cameras, videotape recorders and all makes of CCTV equipment.

Salaries around £3500 can be expected along with a pension scheme and all other benefits associated with a large company.

Dixons Technical Ltd

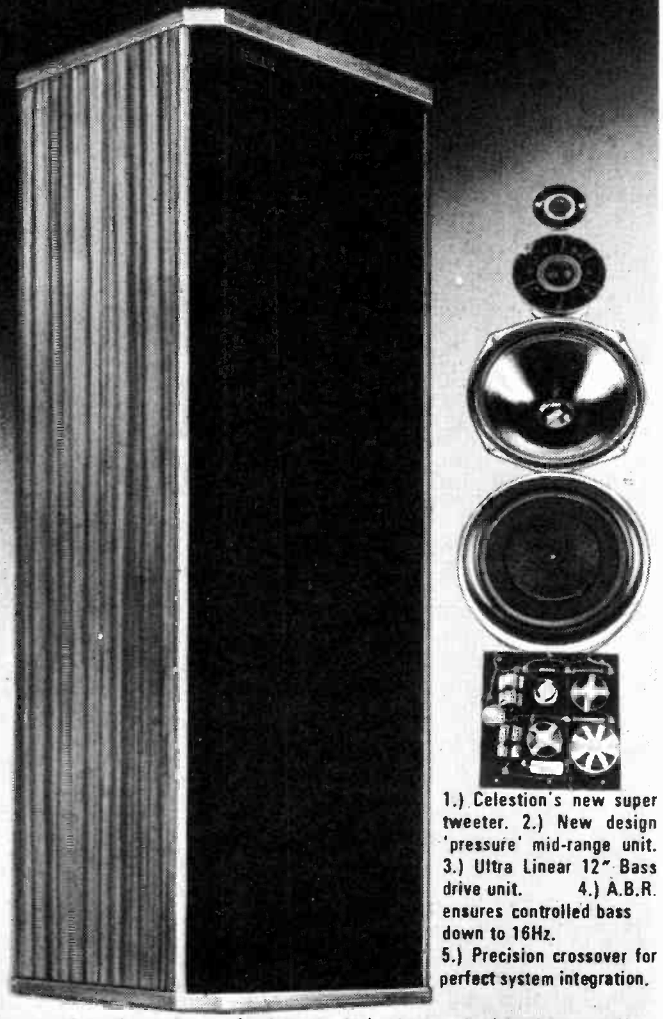
Write or telephone
Mike Biddle, Managing Director, Dixons Technical Ltd.
3 Soho Square London W1 01-437 8811

Importers of ITC Palca Fora equipment.
Agents for National Panasonic, Akai, Philips, Shibaden.

WW—049 FOR FURTHER DETAILS

Celestion Loudspeaker Engineering advances the state of the art to a new plateau.

Ditton 66 Studio Monitor



1.) Celestion's new super tweeter. 2.) New design 'pressure' mid-range unit. 3.) Ultra Linear 12" Bass drive unit. 4.) A.B.R. ensures controlled bass down to 16Hz. 5.) Precision crossover for perfect system integration.

A new Loudspeaker of advanced design suitable for studio use and for home installations of the highest quality.
UNITS: HF 2000 (dome 'pressure' type) MF 500 (Mid-range Dome 'pressure' type) Ultra linear 12" bass driver and 12" ABR. The crossover has resulted from considerable research and crossover points are at 500 Hz and 5000 Hz 80 Watts Maximum, 4-8 ohm. This monitor loudspeaker system has an exceptionally wide and flat frequency response. Very low order harmonic and inter-modulation distortion. Precise response to transients. Beautifully maintained polar response ensures absence of unwanted directional effects and provides a highly satisfactory stereo image throughout the listening area. Matched pairs.
SIZE 40 × 15 × 11½ Natural Teak or Walnut Cabinet

Celestion

Loudspeakers for the Perfectionist

ROLA CELESTION LTD.
DITTON WORKS, FOXHALL ROAD, IPSWICH, SUFFOLK IP3 8JP

WW—050 FOR FURTHER DETAILS

S single source makes sense

IF you buy electronic or electrical components, industrial or consumer fastenings . . .

As the largest stockists of Cinch, Dot & FT products we shall be happy to deliver small or assorted quantities of anything you need. Let us have your next enquiry.

Make United-Carr Supplies your SINGLE SOURCE for

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Tel: Ilkeston 78711 STD 06072 78711. Telex: 377117

WW—051 FOR FURTHER DETAILS

DO YOU WANT

a IMHz pen recorder ?

to use your oscilloscope for storage with digital readout ?

to capture one-shot waveforms ?

Then see the **datalab** range of transient recorders on stand 623—IEA, or details from:

DL901 **DL905**

Data Laboratories Limited, 28 Wates Way, MITCHAM CR4 4HR, Surrey Tel: 01-648 4643/4 Telex: 947680

WW—052 FOR FURTHER DETAILS

chart recorder

TYPE CR100

Designed and built to professional standards this British product introduces a new price/performance concept in pen-recording. Modular design and optional facilities permit an advanced system to be built up at a modest cost.

Facilities include access to a transmitting potentiometer with or without "High-Low" alarm facilities; remote control of speed selection; extension of basic speed ranges by externally generated digital pulses; ability to 'slave' one recorder to another for chart speed correlation; event marker; range of existing and projected plug-in pre-amplifiers.

Slewing rate:	400 mm/sec
Sensitivity:	50μV/cm - 500 mV/cm [with pre-amplifier]
Speeds:	1, 2, 5, 10, 20 sec/cm, 1, 2, 5, 10 min/cm
Paper size:	270 mm wide [DIN 16230]
Paper drive:	Digitally controlled stepper motor
Pen type:	Ballpoint, fibre tip, capillary
Pen drive:	Infinite resolution d.c. potentiometric servo

Compact, robust design

Basic Recorder £154
Pre-amplifier from £36
(prices subject to V.A.T.)

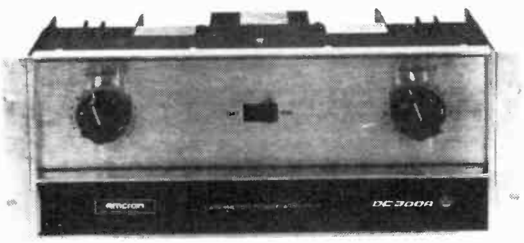
STAND No. 630
ground floor
I.E.A. OLYMPIA

INSTRUMENTS

J. J. Lloyd Instruments Limited
Brook Avenue, Warsash, Southampton SO3 6HP. Tel Locks Heath 4221
Telex No. 477042 JAY JAY - SOTON

WW—053 FOR FURTHER DETAILS

HIGH POWER DC-COUPLED AMPLIFIER



- ★ UP TO 500 WATTS RMS FROM ONE CHANNEL
- ★ DC-COUPLED THROUGHOUT
- ★ OPERATES INTO LOADS AS LOW AS 1 OHM
- ★ FULLY PROTECTED AGAINST SHORT CCT, MISMATCH, ETC.
- ★ 3 YEAR WARRANTY ON PARTS AND LABOUR

The DC300A Power Amplifier is the successor to the world famous DC300 which is so widely used in Industrial, and Research applications in this country. It is DC-coupled throughout so providing a power bandwidth from DC to over 20,000Hz. The ability of the DC300A to operate without fuss into totally reactive loads while delivering its full power, and maintaining its faithful reproduction of Pulse or complex waveforms has established the DC300A as the world's leading power amplifier. Each of the two channels will operate into loads as low as 1 ohm, and the amplifier can be rapidly connected as a single ended amplifier providing over 650 watts RMS into a 4 ohms load, and still providing a bandwidth down to DC. Below is a brief specification of the DC300A, but if you require a data sheet, or a demonstration of this fine equipment please let us know.

Power Bandwidth	DC-20kHz @ 150 watts + 1db, − 0db.	Slewing Rate	8 volts per microsecond
Power at clip point (1 chan)	500 watts rms into 2.5 ohms	Load impedance	1 ohm to infinity
Phase Response	+0, −15′ DC to 20kHz, 1 watt 8Ω	Input sensitivity	1.75 V for 150 watts into 8Ω
Harmonic Distortion	Below 0.05% DC to 20kHz	Input Impedance	10K ohms to 100K ohms
Intermod. Distortion	Below 0.05% 0.01 watt to 150 watts	Protection	Short, mismatch & open cct. protection
Damping Factor	Greater than 200 DC to 1kHz at 8Ω	Power supply	120-256V, 50-400Hz
Hum & Noise (20-20kHz)	At least 110db below 150 watts	Dimensions	19" Rackmount, 7" High, 9¾" Deep

Other models in the range: D60 — 60 watts per channel D150 — 150 watts per channel

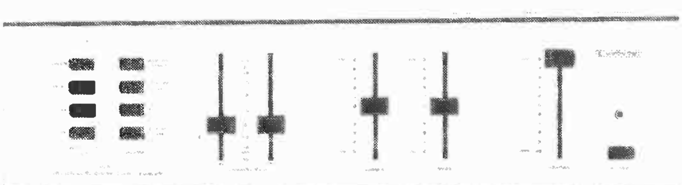
MACINNES LABORATORIES LTD

MACINNES HOUSE, CARLTON PARK INDUSTRIAL ESTATE,
SAXMUNDHAM, SUFFOLK IP17 2NL
TEL: (0728) 2262 2615

WW—054 FOR FURTHER DETAILS

A NEW STANDARD FOR SOUND REPRODUCTION

HD250 High Definition Stereo Control Amplifier



Designed for disc and tuner input and two tape machines, with complete recording and reproducing facilities.

The HD250 amplifier establishes a new standard in amplifiers for sound reproduction in the home. Improvements have been made in respect of performance, engineering design and quality of construction. We believe that no other amplifier in the world can match the specification of the HD250. Look at extracts from the specification below.

Power output.
Rated: 50 watts average continuous power per channel, into any impedance from 4 to 8 ohms, both channels driven.
Maximum: 90 watts average power per channel into 5 ohms load.

Distortion.
Pre-amplifier: Zero. (Cannot be identified or measured as it is below inherent circuit noise.)
Power amplifier.
at rated output: Less than 0.02% (typically 0.01% at 1kHz).
at 25w output: Typically 0.006%.

Overload margin.
Disc input 40 dB min.

Hum and noise output.
Disc: —83dBV Measured flat with noise bandwidth of 23kHz.
—88dBV Measured with 'A' weighted characteristic
Line: —85dBV Measured flat.
—88dBV 'A' weighted.
Size: 17 inches × 4¾ inches × 11 inches deep overall.
Weight: 21 lb.

Write or phone for leaflet which describes the design philosophy and conception of the HD250 together with a complete specification.

RADFORD AUDIO LIMITED, BRISTOL, BS3 2HZ Telephone: 0272 662301

WW—055 FOR FURTHER DETAILS WW—056 FOR FURTHER DETAIL updating from

SGS ATES

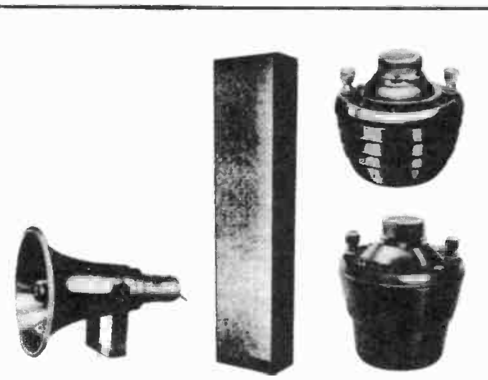
TBA 800 - TBA 820

It takes so little

to make them crow at full power

AHUJA

Public Address & Sound Communication Systems

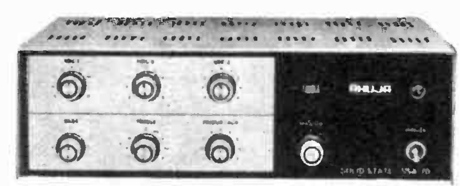


AMPLIFIERS
MICROPHONES
DRIVER UNITS
UNIT-HORN COMBINATIONS
MEGAPHONES

All AHUJA products manufactured with scientific precision for sound communication are the last word in performance reliability and finish.

And all this at money-saving prices.

With world-wide reputation AHUJA is the leading choice in over 35 countries including Western Europe.



Solid State and Vacuum Tube P A amplifiers with power output from 10 Watts to 120 Watts.

AHUJA

Manufacturers :
AHUJA RADIOS
215, OKHLA INDUSTRIAL ESTATE
NEW DELHI-110020, (INDIA)
Issued by : Engineering Export Promotion Council, Calcutta (India)

WW—058 FOR FURTHER DETAILS

WW—057 FOR FURTHER DETAILS

Problem

Where to obtain a low-cost device to use as a linear output stage for mobile and marine radio under SSB conditions.

Solution

M-OV long-life beam tetrodes.
A single TT21/22 gives 100W PEP at 1200V H.T.
and one TT100 delivers 180W PEP at 850V H.T.

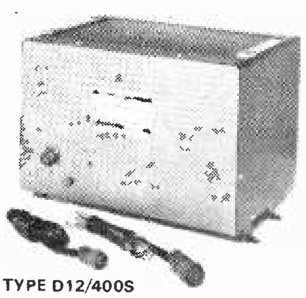
EEV and M-OV know how.

LAP 80

THE M-O VALVE CO LTD, Hammersmith, London, England W6 7PE.
Tel: 01-603 3431. Telex: 234356. Grams: Thermionic London. GEC

WW—061 FOR FURTHER DETAILS

DC/AC SINEWAVE TRANSVERTORS
(transistorised Invertors/Convertors)



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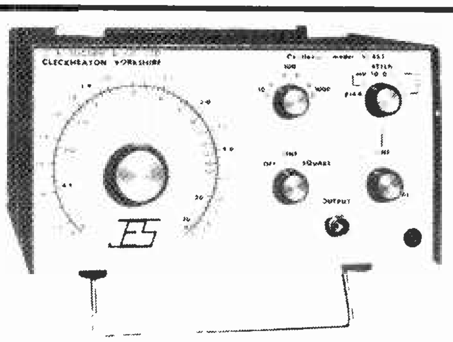

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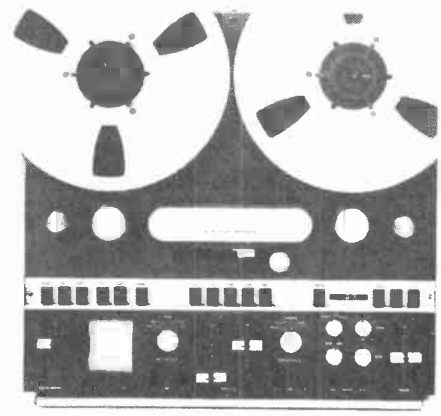

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NEW

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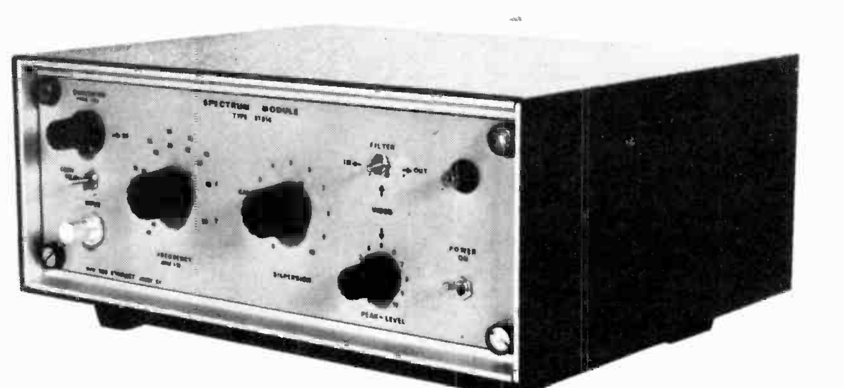
£68

The STARWET spectrum analyser module ST 858 is the latest item to stem from the STARWET design team. The result of several years work it incorporates new concepts based on a different approach to spectrum analysing. The outcome being an ultra reliable instrument with an excellent specification (by any standards) at a price hitherto thought impossible for equipment of this calibre and type.



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measure voltage/frequency/and detect and record voltage surges

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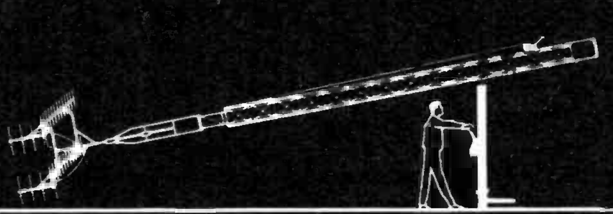

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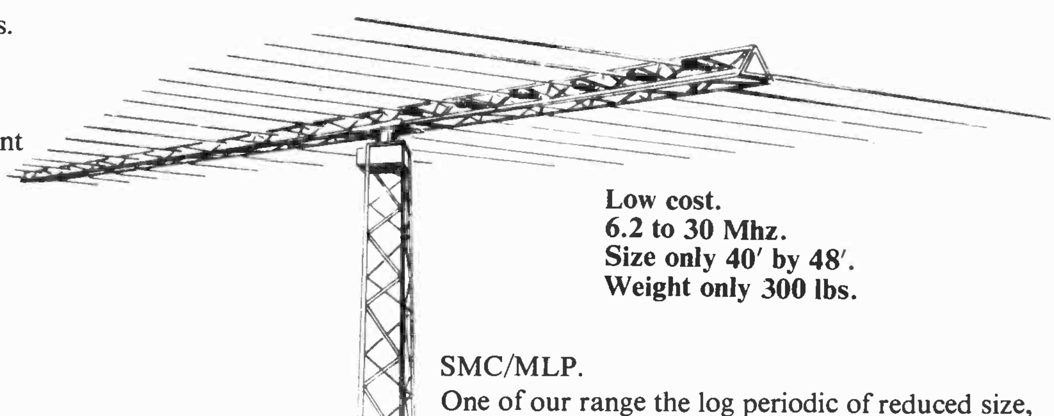

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WW—075 FOR FURTHER DETAILS

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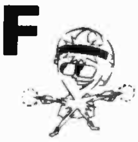
A SPARK OF GENIUS



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The above kit comprises: Ready-drilled case and metal-work, cables, coil connectors, silicon grease, printed circuit board. All 5-year guaranteed components, and full instructions to make this fascinating, very efficient capacitive discharge system in either positive earth or negative earth forms.

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Professional soldering kit. 25w iron, spare tips, tool and solder, together with 10 × BC208, 2 × WO2 bridges, and 2 × PP3055 Plastic Power transistors.

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LSL PRICE
£48
PER SPEAKER + 10% VAT
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LSL Loudspeakers Limited

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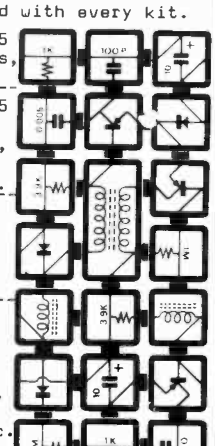
VALUABLE MANUALS included with every kit.



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DAVENPORT

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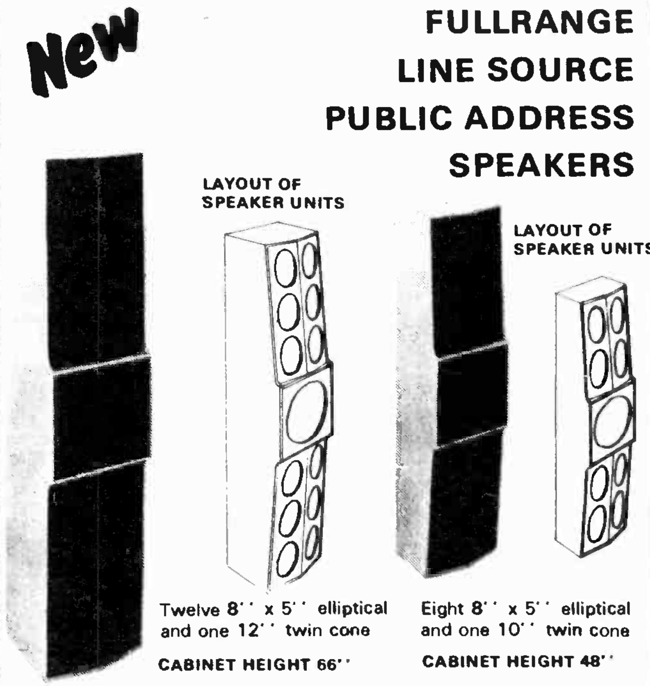

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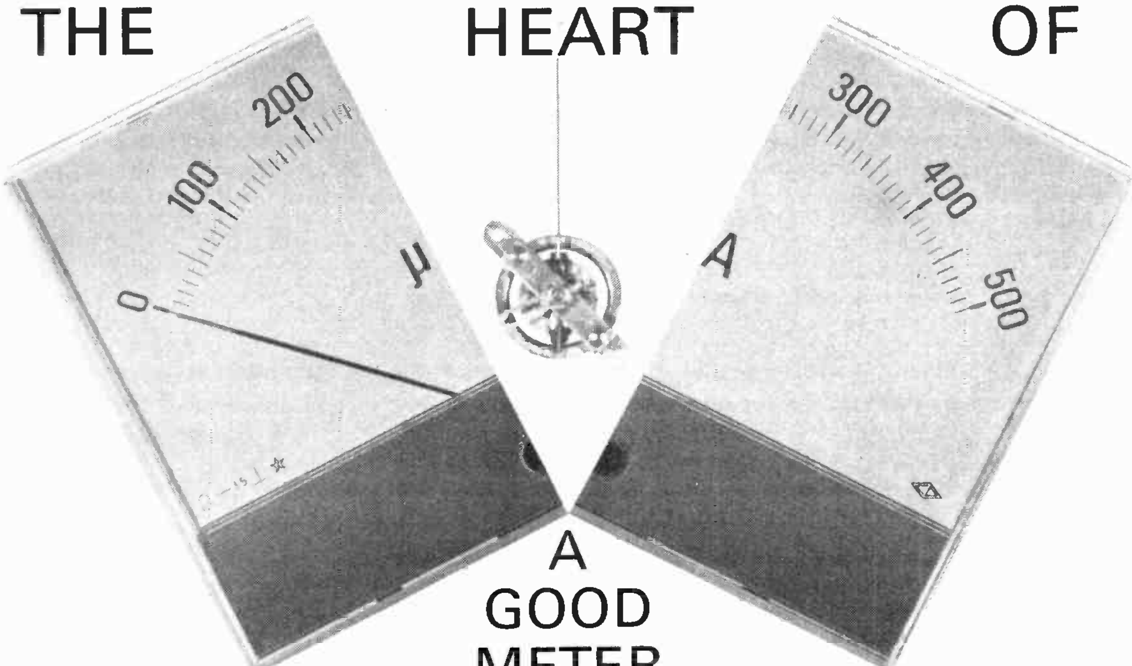

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Electronics, Television, Radio, Audio

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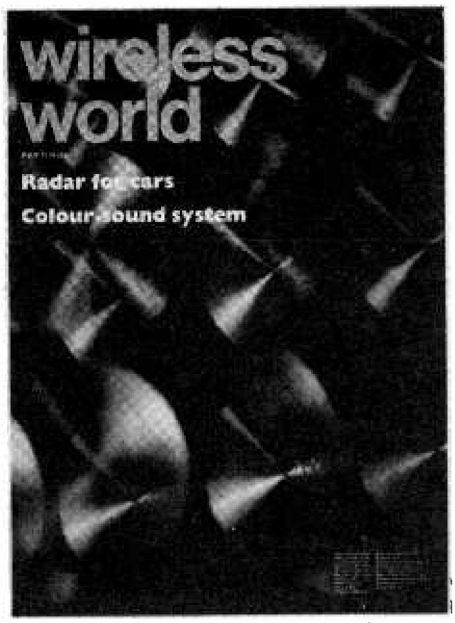

This month's cover picture is an abstract design symbolizing the colour-sound system described by J. R. Penketh in this issue.
(Photographer Paul Brierley)

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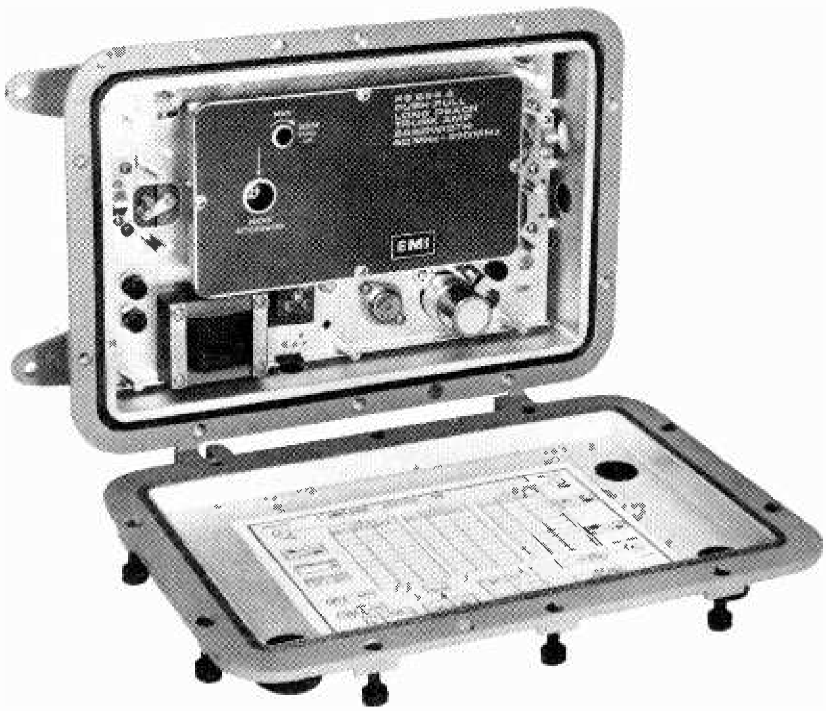
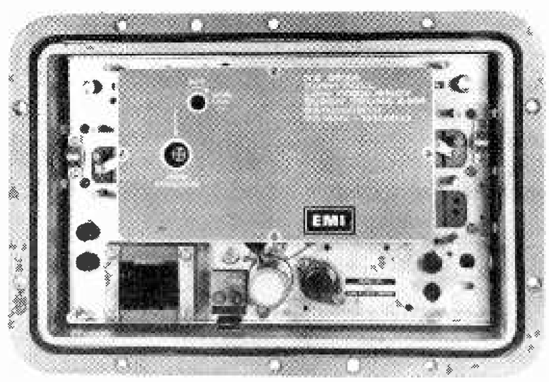
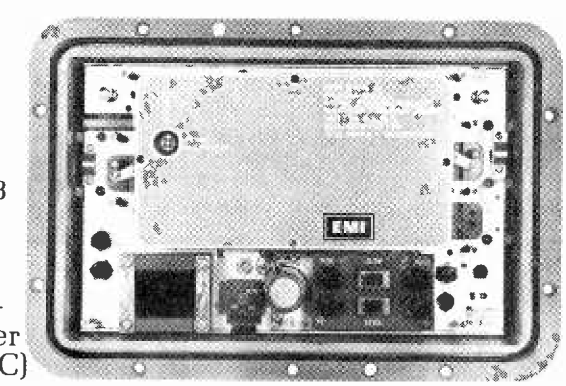
Now EMI Colorline Cable TV has even longer reach







EMI Colorline is now available with two new competitively-priced long-reach trunk amplifiers for systems with trunk routes up to 35.5 km. The RE984 Amplifier (40-270MHz) is designed for systems requiring a large number of units in cascade. The RE993 Long-reach Low Frequency Amplifier (30-120 MHz) is for Supertrunk lines, and operates on a limited band-width to achieve even longer reach. Automatic gain (ALSC) versions of both amplifiers are also available. Another new device is the EMI outlet plate (complying with the recommendations of IEC 169-2) for Colorline or other cable television systems.

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Pocket numeracy

The pocket electronic calculator is another case of a technology that has found its market. The availability of c.m.o.s. integrated circuits with their low power consumption and low supply voltage has made possible an instrument of about the same size as a cigarette-case at a price within the reach of private individuals. In one sense the product was forced on the general public, because it was one of those things by which the American semiconductor manufacturers created a new market for their devices after the cutback in spending on the Vietnam war and the space programme. On the other hand, the public seems to have been very willing to buy the product. What we don't yet know is the motivation behind the buying. Does the pocket calculator fill a real need that has existed for 2,000 years or more? Or is it being bought mainly as a new toy, or as a status symbol for impressing one's friends or colleagues, to be discarded when the novelty has worn off? Whatever the answer, the manufacturers are not worried as long as the buying continues.

One of the problems that this new tool brings with it is its effect on our mental powers. If it results in mental arithmetic being largely abandoned will our ability to manipulate numbers atrophy, putting us even more at the mercy of the machine? For example, a school-child equipped with a pocket calculator does not need to learn multiplication tables. This could mean a relief from time-consuming drudgery or it could mean a loss of an elementary and therefore important faculty in the handling and understanding of numbers. When we do mental arithmetic, perhaps with the aid of pencil and paper, we are constantly aware of our fallibility—as an animal is constantly on the alert for dangers that threaten it—and we therefore check and re-check what we have done. When we use a calculator, an error—perhaps caused by incorrect key operation or an electrical fault—could go undetected. But to set against this dependence on the machine the advantages it may bring for mental development seem greater. One school science master we know considers that because a pupil with a calculator can handle numerical data at a vastly greater rate than normal his intuitive feel for numbers will be tremendously enhanced. The same way well apply to other users. If this is so, the pocket calculator could be an important step on the road to universal numeracy—the lack of which has been so often deplored by people concerned with science and engineering education.

In the end probably a compromise will be found between usage of the brain and usage of the machine for arithmetic. It should be possible to achieve a balance between the alleviation of mental drudgery and the cultivation of a good understanding of numbers and ability to manipulate them. As with many other products of advanced technology placed suddenly in our hands, we must learn to use this new instrument wisely.

Colour-sound system design

Providing coloured illumination as functions of sound frequency and intensity

by J. R. Penketh, B.Sc., M.I.E.E.
Highbury Technical College, Portsmouth

The compact system to be described for construction provides coloured illumination of a reflecting or opalescent surface, the brightness and colour being functions of the frequency and amplitude of an audio input. The circuitry is based on the 741 op-amp and its dual version the 747. Triacs control the mean lamp power which is a maximum of approximately 2kW for each of three channels.

The sound intensity and light intensity correlation of a colour-sound system is based on the premise that related simultaneous sensory activity of ear and eye will produce a reaction to which most people will be sympathetic. The relationship between pitch and colour (that is between the frequencies of sound and light) is not at all critical, probably because of the very different responses of the brain to these phenomena—few people, except possibly physicists, consciously relate colour to frequency.

Other systems are possible. For example, a sound intensity/colour correlation may be sought, coupled with a pitch/light intensity correlation. Whilst the author is not aware of any published work in this field, it is likely that aesthetic appreciation of such a system would require a considerable training programme. This would necessarily severely restrict the enjoyment of an untrained majority of observers.

A gate pulsing arrangement is used for each controlling triac which relates the firing angle to the instantaneous peak output voltage from the appropriate filter. In this way the conduction angle is closely proportional to the sound intensity, resulting in a good correlation between brightness and sound intensity. Tungsten filament lamps form the light sources. Fluorescent tubes could be used as an alternative.

Design philosophy

A block diagram of the colour-sound system and the waveforms at the various points in the system are shown in Figs. 1 and 2.

The incoming mains voltage (V_1) is squared (V_2) and integrated to provide a linear time varying voltage (V_3) in each half cycle. This is compared with the peak rectified filter output voltage (V_4) to advance or retard the triac firing angle α in sympathy with the amplitude of the audio input to the filter. Voltage V_4 is arranged to increase towards zero from +10V for control during the positive mains half cycle and from −10V during the negative mains half cycle. The output from the level detector (V_5) is arranged to rest at zero volts when

$$(-12 + V_4) < V_3 < (12 - V_4) \qquad (1)$$

to be +10V when

$$V_3 > (12 - V_4) \qquad (2)$$

and to be −10V when

$$V_3 < (-12 + V_4) \qquad (3)$$

The positive and negative edges occurring at the times set by the above relationships (2) and (3) initiate narrow pulses (V_6) which fire the triac appropriately.

Three channels are used to cover the frequency ranges below.

Bass:	30Hz–125Hz
Mid:	125Hz–500Hz
Treble:	500Hz–2000Hz

These frequency ranges cover adequately the range of fundamental frequencies in music. The rest of the audio spectrum above 2000Hz carries principally harmonic information for aural identification

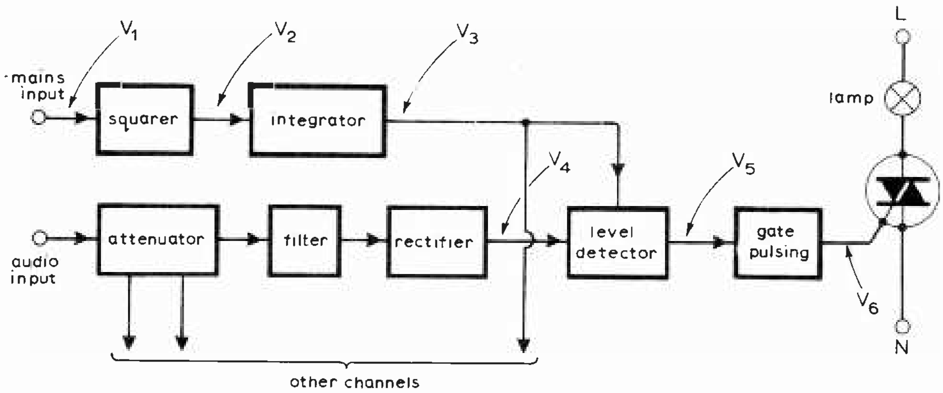


Fig. 1. Block diagram of one channel of the colour-sound system. See Fig. 2 for the waveforms marked at V_1, V_2, etc.

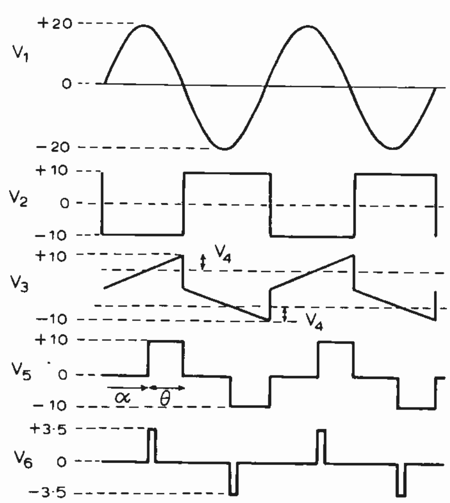


Fig. 2. Waveforms at the points indicated (V) in Fig. 1. See text for full explanation.

of particular instruments. The lower limit of the bass range is judged to be a reasonable compromise between adequate bass instrument coverage and the exclusion of mechanically originated signals such as turntable rumble. Harmonics from the bass and middle range tones of instruments cannot be excluded from the filter if they lie within the pass band. Subjective tests with various types of music indicate, however, that no serious problems arise from these harmonics.

Circuit description

The circuit diagram is shown in Fig. 3.

The filters are low pass/high pass combinations based on the voltage controlled source (v.c.v.s.) circuit. The requirement for this application is to have no pronounced peaks in the response curves of either the low or the high pass sections (see Appendix).

The filter output rectifier is of conventional design and provides two symmetrical outputs. Under no-signal conditions the outputs settle to potentials $\pm V_B$ close to ± 10V, determined by R_{15}, R_{16} and R_{17}. Voltage V_3 sets a minimum conduction angle for the triac and so provides a minimum brightness facility. This is desirable to ensure that lamps respond visibly to small input signals. Trimming is provided by R_{26} which controls the slope of the integrator output. Alternatively R_{17} may be made a preset resistor, but integrator slope control has the advantage of taking up the tolerance in the feedback capacitor. Resistors R_{13} and R_{14} are included to limit the maximum output current from the amplifier to a safe value. Time constants C_7R_{15} and C_8R_{16} are chosen as a compromise between reasonable smoothing of the lowest audio frequency and rapid decay so that musical transients are tolerably handled.

An amplifier with a non-linear feedback loop comprising zener diodes D_{11} and D_{12} squares the transformed mains waveform. The zero-resetting integrator time constant $C_{12}(R_{26} + R_{27})$ is calculated from

$$V_3 = (1/C_{12}R_T)\int_t^0 V_2 dt$$

where V_3 is the integrator output, V_2 the input square wave, and $R_T = (R_{26} + R_{27})$. With ± 12V supplies, a 741 amplifier has a useful output voltage range of ± 11V. Hence, $V_3 = 11$V at $t = 10$ms. Therefore

$$11 = V_2/C_{12}R_T \times 10 \times 10^{-3}$$

$$C_{12}R_T = 0.91 \times 10^{-3} \times V_2.$$

But $V_2 = 10$V so $C_{12}R_T = 9{\cdot}1$ms, and C_{12} is made $0{\cdot}1\mu$F and R_T 91kΩ.

Resistor R_T is conveniently formed by a series combination of 68kΩ and a preset 50kΩ. Transistor Tr_1 or Tr_2 is pulsed momentarily at the end of the mains half cycle to discharge C_{12} rapidly through R_{30}. Which transistor is pulsed depends on the direction of the square wave edge and it is arranged that the transistor with the appropriate collector polarity at this time turns on. The emitters are at earth potential because of the virtual earth property of the amplifier.

Resistor R_{30} limits the capacitor discharge current to a safe value for Tr_1 and Tr_2 but still provides a very short discharge time constant.

Diodes D_{13} and D_{14} prevent spurious reverse bias effects of Tr_1 and Tr_2 affecting the integration.

Transistors Tr_1 and Tr_2 must conduct for long enough to fully discharge C_{12} but for a short time compared with the mains half cycle duration of 10ms.

Assuming $R_{SAT} = 0$ for Tr_1 and Tr_2, C_{12} will discharge in approximately $5C_{12}R_{30}$ secs. Inserting values yields a discharge time of

$$t = 5 \times 0.1 \times 330 \times 10^{-6} = 165\ \mu\text{s}.$$

Allowing 200μs for safety, C_{11} can be estimated from a knowledge of the base-emitter resistance R_b of Tr_1 and Tr_2. The calculation will be approximate because of the non-linear nature of R_b, and the natural spread of this parameter between transistors. Resistors $R_{28,29}$ limit the peak base current.

Assuming $R_b = 3$kΩ and a base turn-on voltage of 0.7V, then the turn-off potential is $(4/3) \times 0.7 = 1$V. Therefore

$$1 = V_2 \exp(-t/C_{11}R) \text{ where}$$

$R = R_b + R_{28}$ and the applied square-wave amplitude, V_2, is 10V. Then,

$$C_{11} = t/R \log_e 10 = 22\text{nF}.$$

A standard 22nF capacitor suffices for C_{11}. Care must be taken not to make C_{11} too large since it prolongs transistor conduction and impairs the integration waveform.

The two outputs from the rectifier are compared with the integrator output using the differential input facility of the 741 amplifier.

For amplifier 3, diode D_5 holds the output (V_5) at $+10$V unless the integrator output (V_3) voltage is greater than the appropriate (positive) filter rectifier output (V_4).

When $V_3 > V_4$, V_5 falls to a value $V_4 - V_z$ where V_z is the zener voltage of D_6.

A similar result but inverted is obtained

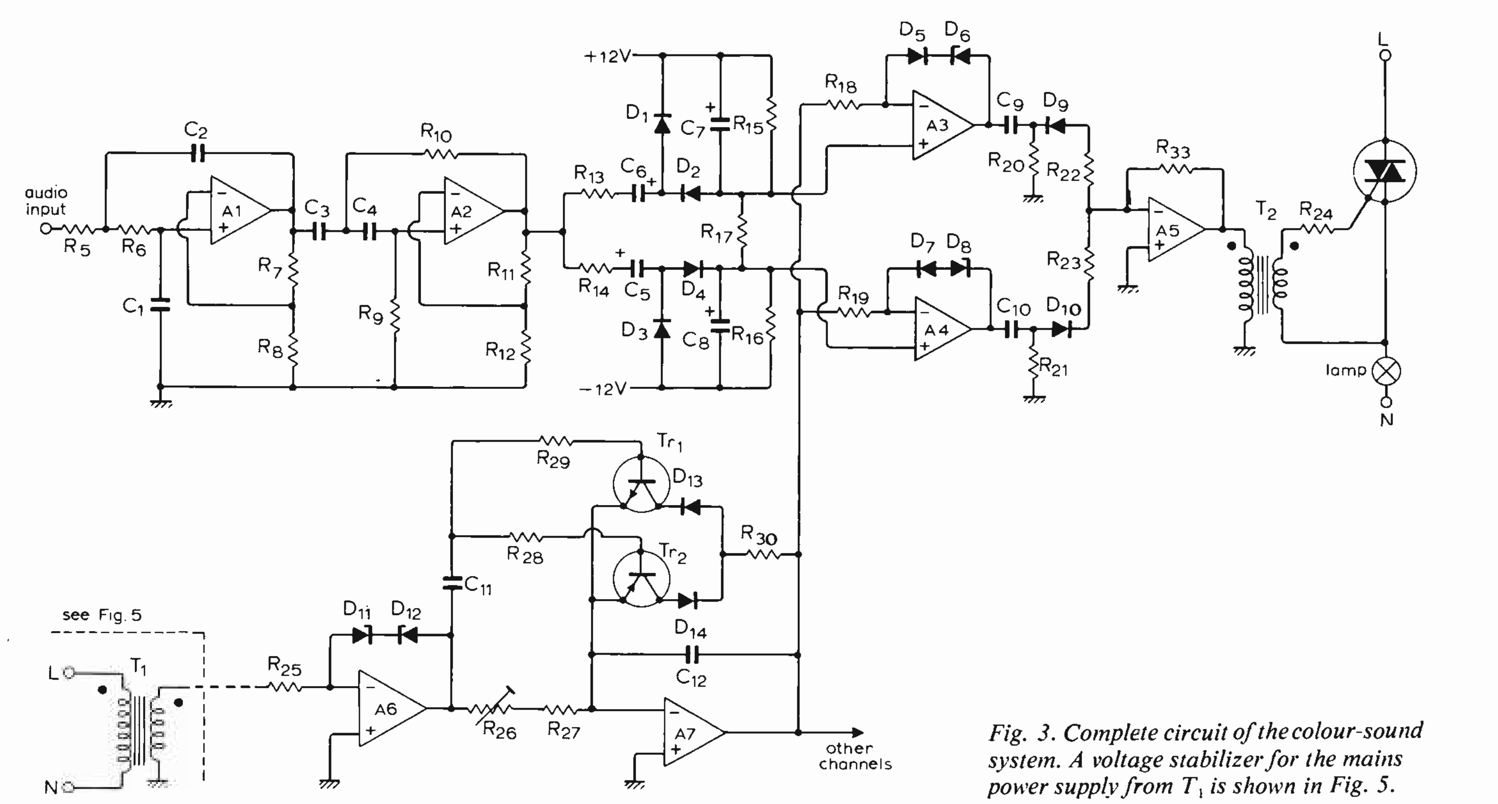


Fig. 3. Complete circuit of the colour-sound system. A voltage stabilizer for the mains power supply from T_1 is shown in Fig. 5.

from amplifier 4 when the negative rectifier output falls below V_4, in the negative half cycle.

Resistors R_{18} and R_{19} provide the zener current and should not be large. A value of 1kΩ is satisfactory.

The networks C_9, R_{20}, D_9 and C_{10}, R_{21}, D_{10} provide short negative and positive pulses respectively generated from the leading edges of the level detector outputs. These are summed and squared by amplifier 5 which provides gating pulses to the triac.

Transformer coupling to the triac (T_2 in Fig. 3 and T_{2-4} in Fig. 8) is used to provide isolation of the control circuitry from the mains.

It is useful to have a separate manual gain control for each channel. Since the audio input comes from a low-impedance (i.e., loudspeaker terminals) a simple network such as that in Fig. 4 gives excellent results.

The current demand per channel is approximately 20mA. A regulated power supply based on zener diode stabilization of the base of a transistor is shown in Fig. 5.

It is desirable when using linear i.cs to decouple the supply rails close to the amplifier. Capacitors C_x of value 0.1µF are used for this as shown and are placed close to the filter amplifier in each channel, and close to the integrator.

Components

Resistors—*R*

1	100 lin 1W	11,12	10k
2,3,4	1k lin ½W	13,14	470
5	12k low range	15,16	22k
	3.3k mid range	17	150k
	820 high range	18,19	1k
6	12k low range	20,21	2.2k
	3.3k mid range	22,23	10k
	820 high range	24	47 ¼W
7,8	10k	25	6.8k
9	56k low range	26	50k lin preset
	12k mid range	27	68k
	3.3k high range	28,29	1k
10	56k low range	30	330
	12k mid range	31,32	560
	3.3k high range	33	100k

All resistors ⅛W 5% unless stated otherwise.

Capacitors—*C*

1,2,3,4	0.1µ ±20%	12	0.1µ ±20%
5,6,7,8	10µ/25V	13,14	1000µ/25V
9,10	0.1µ ±20%	*x*	0.1µ ±10%
11	22n ±20%		

Diodes—*D*

1–5	OA200	11,12	BZY88–C9V1
6	BZY88–C9V1	13,14	OA200
7	OA200	15,16	OA210
8	BZY88–C9V1	17,18	BZY95–C12
9,10	OA200		

Transistors—*Tr*

1	BC108	3	AC176
2	2S303	4	AC128

Triacs

All MAC11

Op amps

All 741 8-pin d.i.l.

Sockets—*SK*

1,2,3 2-pin 250V 5A 4 jack

Transformers—*T*

1 Radiospares 12V miniature

2,3,4 primary 300mH and <5Ω turns ratio 3:1.
Insulation to withstand 1000V flash test between prim. and sec.

Suppression

R_s 47 ¼W
C_s 0.05µ/400V
L_s 0.2mH non-saturating up to full load current

Heatsinks, switch, stripboard

Triac sinks—aluminium 150mm × 40mm × 16 s.w.g.
Tr_3–Tr_4 sinks—aluminium 80mm × 40mm × 16 s.w.g.
Switch—250V, 5A
Stripboard—0.1in pitch 34-way

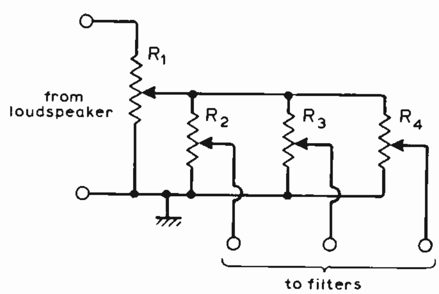


Fig. 4. Input attenuator which can provide separate manual gain control for each channel.

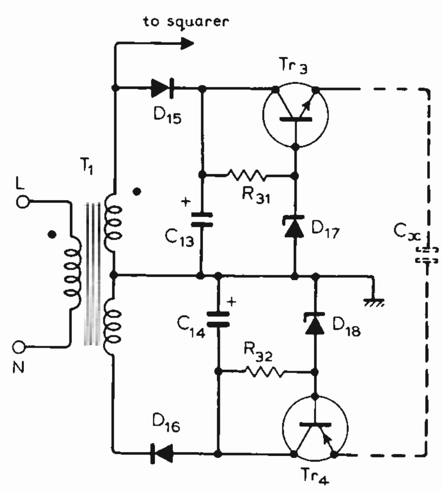


Fig. 5. Regulated power supply based on the zener diode stabilization at the base of a transistor.

Triac circuitry and layout

Triacs are constructed usually with the A_2 anode in contact with the heat sink. To simplify the mounting of the three triacs a single heat sink is used and all anodes are thus in contact. The lamps are placed in the A_1 anode leads and the gating transformer secondaries connected between gate and A_1 anode. The electrical arrangement appears in Fig. 6.

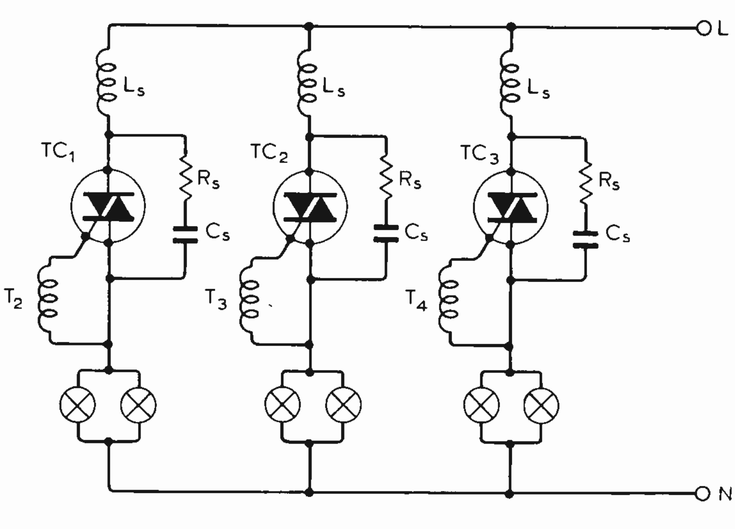
The main system (filter channels, resetting integrator and power supply) are conveniently laid out on a single 0.1in pitch stripboard. The prototype main system used single 741 amplifiers and was laid out as in Fig. 7. The input attenuator, triacs, mains transformer, input and output sockets are mounted separately to suit the installation. The prototype used the layout in Fig. 8.

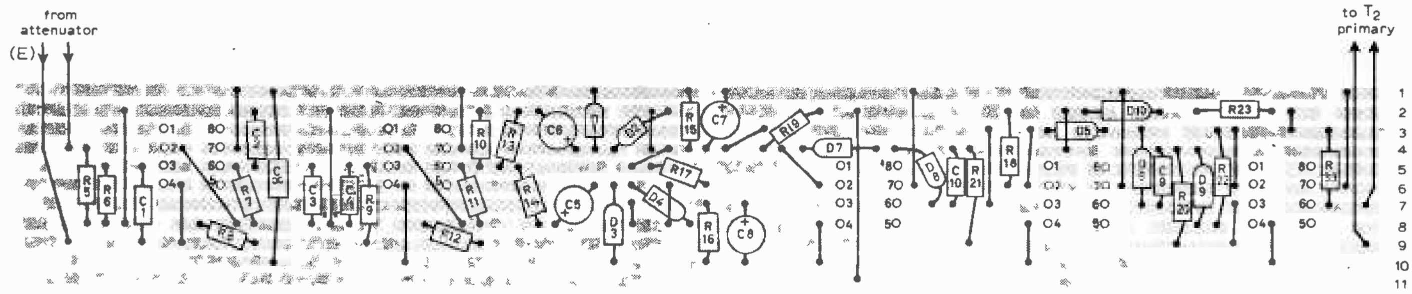
Lamps and displays

The triacs specified are capable of handling up to 8A r.m.s. which corresponds to approximately 2kW per channel. Filament lamps of this order of power tend to have long thermal time constants and do not follow a sound intensity pattern as well as do lamps of lower power. Very satisfactory results are obtained with filament lamps up to 150W. Three of these are considered adequate for a domestic installation (i.e., one per channel). For larger installations in dance halls, discos and exhibitions, banks of 150W lamps are recommended.

The author has found it more satisfactory to use a reflecting surface than a transmitting opalescent medium for display since attention tends to be drawn

Fig. 6. Lamp and triac circuitry. Mounting the three triacs is simplified by using a single heat sink.





AMPLIFIER PIN CONNECTIONS

null (not used)	O1	O5	null (not used)
inverting input	O2	O6	output
non-inverting input	O3	O7	positive supply
negative supply	O4	O8	no connection

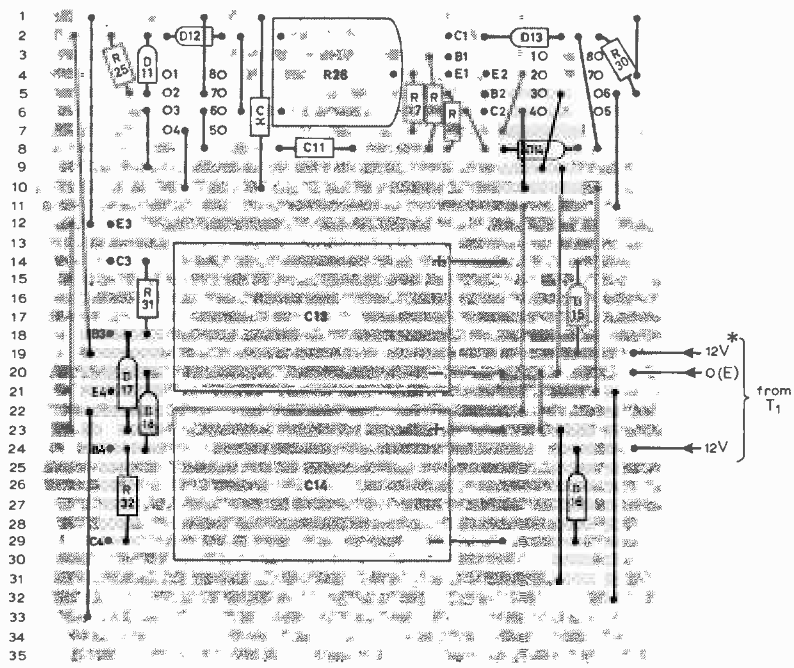


Fig. 7. Layout of one filter channel (top), resetting integrator and power supply from the component side. Strips 1–11 (top) are continuous to 35 (not shown) to facilitate the remaining two channels. These strips (1–35) are continuous with the lower diagram.
** 12V from T_1 secondary in phase with line (mains) input.*

to the brightest parts of a transmitting system, namely the lamp filaments. A simple but effective display for domestic purposes consists of three lamps mounted separately in ventilated boxes with gelatine colour filters on the fronts and aluminium foil reflectors behind the bulbs. Set about a yard apart and tilted upwards to illuminate a white or cream wall some pleasing results are obtained.

The rapid switching of triacs every half cycle gives rise to a wide spectrum of harmonics in the mains current waveform. These must be properly filtered to prevent interference with television reception. Present practice with lamp dimming circuits is to employ an r.f. choke/capacitor arrangement as shown in Fig. 6.

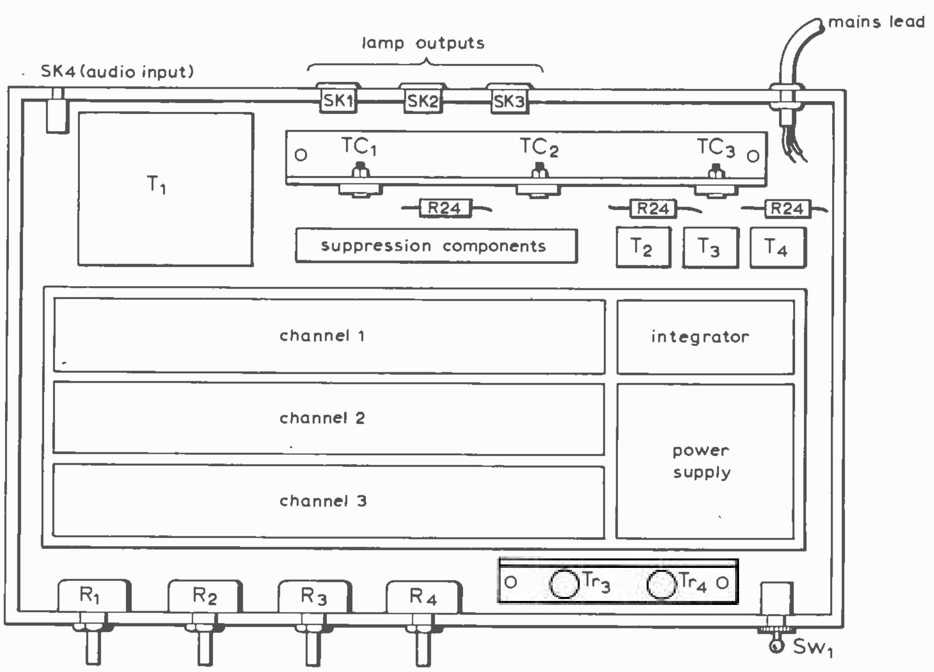


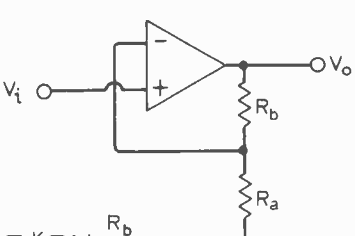
Fig. 8. Layout in the prototype.

Appendix

Filter design

The v.c.v.s. (Fig. 9) is chosen for this application because of its very high input impedance and low output impedance, and its tolerance of variations in component values.

Moreover, the parameter H_o (see below) in the filter transfer function is a free parameter equal to the v.c.v.s. gain constant K. This makes mid-band gain simple



$$\frac{V_o}{V_i} = K = 1 + \frac{R_b}{R_a}$$

Fig. 9. Configuration of the voltage-controlled voltage source circuit.

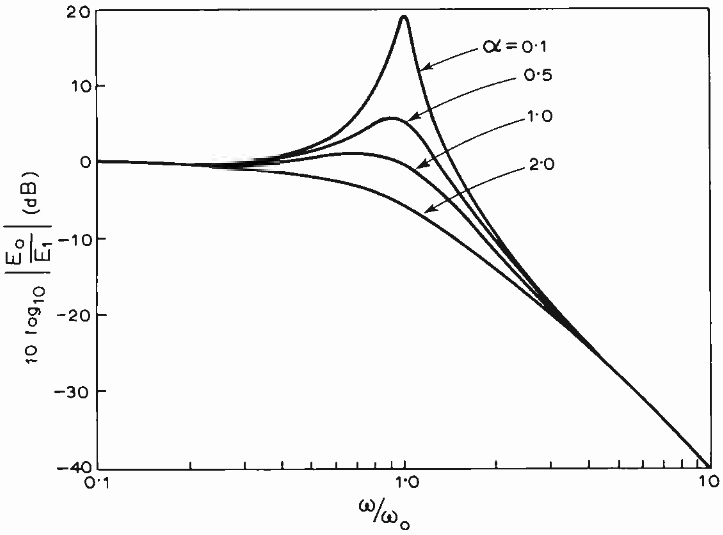


Fig. 10. Response curves for various values of $\alpha = 1/Q$. The equivalent high pass case is given by ω_o/ω.

to control for the cascaded sections. The design equations are:

$$V_o/V_1 = K = 1 + R_b/R_a$$

$$H_o = K$$

Low pass section:

$$R_6 = \frac{\alpha}{2\omega_0 C}\left(1 + \sqrt{\frac{1 + 4(H_0 - 2)}{\alpha^2}}\right)$$

$$R_5 = 1/\omega_0{}^2 R_6 C^2$$

High pass section:

$$R_9 = \frac{\alpha}{4\omega_0 C}\left(1 + \sqrt{\frac{1 + 8(K - 1)}{\alpha^2}}\right)$$

$$R_{10} = 1/\omega_0{}^2 R_9 C^2 \text{ where } \alpha = 1/Q$$

and ω_o is the undamped natural frequency of the two-pole filter.

The curves of Fig. 10 show the generalized responses for various values of K. From this it is clear that $\alpha = 1$ provides the type of response suitable for the present application.

The input voltage will be that appearing across the terminals of a loudspeaker. Adopting a nominal 2V r.m.s. for full brightness the overall mid-band gain of the filter should be, by assigning the same value K to each section and assuming a peak output of 11V from amplifier 2,

$$K^2 = 11/2\sqrt{2} = 3{\cdot}89.$$

This leads to a nominal K value per section of 2. Inserting these results in the above formulae gives:

low pass: $R_2 = 1/\omega_o C$ and $R_1 = R_2$

high pass: $R_1 = 1/\omega_o C$ and $R_2 = R_1$.

The procedure is now to choose C for convenience and calculate R_1 and R_2. Resistors R_b and R_a are chosen for a K value of 2 and for minimal output loading of the amplifiers.

The design of these sections has been such as to ensure overlap of responses between the three bands. Some frequencies, therefore, will excite responses from two adjacent lamps. Additive or subtractive combinations of colours can be so produced to the requirements of a particular installation. Should wider band separation or different bandwidths be required for a particular application it is a simple matter to apply the above formulae. Only four resistors per channel need be altered to tailor responses to suit these requirements provided the 0.1µF filter capacitor value is unchanged.

AES Convention—Copenhagen

Copenhagen's Scandinavia Hotel was the site of the 1974 European Section Convention of the American Audio Engineering Society held from March 23rd to 30th. The choice of Copenhagen this year was particularly apt as the work of Valdemar Poulsen "the father of magnetic recording", P. O. Pedersen, Holger Lauridsen and other Danish engineers, has given Denmark a surprisingly large contribution to the history of audio technology development.

Seventy-nine papers in 12 sub-groups were presented to members (compared with fewer than 50 at the 1973 Convention in Rotterdam). The papers covered subjects ranging from "Acoustics and Psychoacoustics" through "Design Considerations For a Multi-Track Sound Recording Vehicle" to "Digital Techniques in Audio".

While space does not permit detailed comment on the material read, it was interesting to note that some papers dealing with quite basic subjects had universal interest. James Moir described a method of sound power measurement which avoids the complication of calculating power from the output of a hemispherical multimicrophone array at many frequencies or the equally difficult alternative of using a single microphone in a very large reverberant room of special design. Moir's method involves introducing an amount of noise from a calibrated amplifier/loudspeaker combination until the sound pressure level of both the signal under test and the calibrated source is 3dB higher than the pressure level created by the signal under test alone. The method offers independence from room acoustics and can be used when checking loudspeaker efficiency and sound power output of permanently sited industrial machinery.

Hugh Ford presented a paper of great topical interest—especially in the United States—on the Admissibility of Magnetic Tapes as Evidence in Law. Mr Ford's extensively researched paper concluded that while it is possible to detect alteration to recordings in some cases, present techniques are not able to detect interference with the material in every case.

Automation in multi-track studio recording and quadraphony have both excited a great deal of attention at past AES conventions. Both fields were treated cursorily in Copenhagen although both Sansui and Nippon Columbia operated demonstration suites equipped with their respective systems.

Forty-six companies exhibited commercial audio equipment. The exhibits representing the greatest commercial value were those relating to multi-track sound recording. European tape-machinery of this category was exhibited by Lyrec, Studer and Telefunken and American 3M, Ampex and MCI multi-track machines were also shown. Twenty-four track, two-inch tape recording seems well established now in spite of its departure from the four-track/half-inch, eight-track/one-inch, sixteen-track/two-inch progression.

Electronic tape-noise reduction equipment by Dolby and DBX Inc., was shown. The DBX system claims to improve the signal to noise ratio of a transmission medium by some 39dB —more than enough to defeat the 16dB noise build-up encountered when mixing down 24-track master tapes. Discs encoded with the DBX noise reduction system demonstrating this figure of noise reduction, were played in the JBL loudspeaker booth.

BASF, again, showed the "Unisette", their extremely well engineered 6.3mm professional tape cassette. The Unisette has no internal tape guides as it is intended that these be built into the transports with which the cassette is used. Although the intended area of application is audio, the cassette is sure to find use in data recording when suitable transports are available.

Frequency allocations wallchart

A wallchart showing frequency allocations for the UK and Europe is the subject of a special offer to be made by coupon in the June issue. Designed by *Wireless World* and printed in colour, the chart covers the electromagnetic spectrum from 3kHz to 300GHz. It is scaled on eight logarithmic bands containing 15 main categories of transmissions identified by colours. All the important spot frequencies are marked, as well as "special interest" frequencies. The special-offer price, available only to readers of *Wireless World*, is 30p including VAT, postage and packing. Normal price is 80p including VAT, postage and packing. See the June issue for details of how to order the wallchart.

News of the Month

TV information service

A unified system for a broadcast television information service of the CEEFAX or ORACLE type (see May and July 1973 issues) has been agreed by a working party representing the BBC, the IBA, BREMA and the MPT.

A bit rate of about 7 Mbits/sec will allow each 40-character row of the display to be accommodated on a single television line. Information will be transmitted on lines 17 (330) and 18 (331) of the television waveform. Thus every television field will convey two rows of the display. The alphanumeric characters will be represented by a seven-bit ASCII code with an additional parity bit for error protection. Each of up to 99 pages will have 40 characters per row and 24 rows per page. Complete pages will be transmitted in sequence so it will take some 15 seconds to transmit a complete "magazine" of say 60 pages. Each page will have a page heading followed by 23 rows of text. The page heading will also show the time to the nearest second.

Among refinements of the system are arrangements for news flashes and subtitles to be displayed along with the normal programme. The system is very flexible and allows for differing amounts of complexity to be incorporated in the receiver. The simplest receiver might use only capital letters, the most complex would use capital and lower case letters and make use of all the other refinements that are possible.

There will be full-scale tests of the new standard in the autumn or winter of this year, as soon as a supply of prototype receivers has been produced by the industry.

Automated satellite station

By means of a new telemetry and command control station for communications satellites one engineer can monitor the flight behaviour of up to three satellites at one time. The station, designed by Hughes Aircraft in the USA, has a display panel that presents the satellites' spin-speed, temperatures, antenna-pointing accuracy, spin-axis inclination, information from transponders and the quantity of jet-thruster fuel remaining aboard each spacecraft. While the information is being monitored by an engineer it is simultaneously recorded into a computer.

The most critical time for use of the equipment is when the satellite separates from the rocket booster after launching. From then on the spacecraft's behaviour must be known precisely and continuously in order to determine when to fire the on-board apogee motor to shift the satellite from its elliptical transfer orbit into the final circular orbit 22,300 miles above the equator.

Colour recording by laser

Images in colour and other multi-spectral data can be recorded on black-and-white film by a laser system developed by RCA. The system can be used to display and interpret information generated by sensors used in aircraft and spacecraft, and can also be used with other colour scanners in facsimile systems. Recording is accomplished by combining three modulated video signals to drive a single light modulator. The modulated laser beam is expanded and focused via scanning mirrors into a small spot on the film. At present a laboratory model records the information on long lengths of five-inch-wide film.

A simple, portable display device enabling the recorded images to be viewed in full colour has also been developed. This viewer is small enough to fit in a typewriter case and weighs 11 lb. It contains three lamps, each with a filter so that three primary colours are provided. Colour balance is achieved by thumbwheels which adjust the brightness of the lamps.

Portable colour camera

A portable version of their Mark VIII colour television camera has been produced by Marconi Communication Systems. In its hand-held form the camera fits on to a harness which rests on the operator's shoulder. A light-weight tripod is also available, while an alternative mounting unit permits the use of studio tripods and heads. A range of lenses is provided, and lens changes are made by a quick-release coupler.

The camera head contains the optical assembly, three one-inch light-weight scanning yokes and four printed circuit boards carrying the scanning circuits, tube supplies and amplifiers. The design retains the Mark VIII features of automatic alignment and automatic colour balance, which are particularly important for portable cameras because they are sometimes subjected to rough treatment. Brightness and contrast controls are provided for the cameraman and there is a built-in "crispening" circuit for enhancing the sharpness of the picture. The viewfinder is a removable unit, using a high-definition one-inch c.r.t. with an optical magnifier to obtain the required image size.

Up to 150ft of 13mm cable may be used between the camera and its auxiliary pack, which is designed primarily to be mounted on a trolley but may be carried on a harness by the cameraman or his assistant.

The new Marconi portable colour television camera.

Call China by satellite

Britain's telephone service with the People's Republic of China, which had been available for only three hours a day, has now become full time with a change to satellite working. The move follows the opening in China of a satellite earth station using the INTELSAT-IV communications satellite positioned 22,300 miles above the Indian Ocean. Telephone calls from Britain to China are now transmitted from the Post Office satellite earth station at Goonhilly Downs, Cornwall, and received by China's new earth station near Peking.

The satellite link replaces a high-frequency radio route (08.00–11.00 hours GMT) and gives an immediate improvement in service. Clarity of speech is much greater, while continuity of communications—always difficult to maintain on h.f. radio, which can be affected by weather conditions—is greatly improved. The satellite link consists of one telephone circuit but can be readily increased to three if there is sufficient demand.

The cost of telephone calls to China remains unchanged, with a minimum charge of £3·75 for the first three minutes and £1·25 for each additional minute (plus VAT at standard rate of 10 per cent).

Queen's Awards for 1974

Technical innovations in the electronics industry which have this year received the Queen's Award to Industry encompassed the fields of solid state TV, sound and vision transmission and production of high-performance silicon integrated circuits.

A two-dimensional self-scanned photosensor array which forms the heart of a miniature solid-state TV system is the award-winning development from Integrated Photomatrix. The prototype camera contains a ¼in sq. light-sensing array. At present, this technology has applications from screening of medical slides to dimension monitoring in inspection systems but will result eventually in a complete miniaturized solid-state TV camera.

The now well-known "sound in syncs" system developed by the BBC for the transmission of sound and vision signals over a single vision link has also received an award. The system was brought into use progressively throughout the country in 1972 and is already in regular use for the international exchange of television programmes over much of the Eurovision network.

An award for a new production process which permits the production of integrated circuits of greater complexity and with improved performance was made to Plessey for their Bipolar Process III, first reported in *Wireless World*, News of the Month, March 1973.

Congratulations to all award-winning companies for their outstanding contributions to Britain's industrial development.

Display terminals for news pages

Composition of display advertisements and full newspaper pages can be built up on a new video display system and then stored for use in automated typesetting and printing processes. The system is known as CAM (for Composition and Make Up). In use, an operator calls up copy and graphics from a computer store which are displayed on a video display. The displayed material is then positioned by means of the equipment's keyboard, a cursor, and a table of digital/graphic information. When the most effective composition is obtained, the presentation is stored for later use.

Raytheon Company's equipment division, Massachusetts, is to develop the CAM terminal for the automated full-page composition system being developed by the Newspaper System Development Group. The first CAM system, consisting of three operative terminals, should be delivered for testing in early 1975.

Electrical measurements seminar

A residential specialist seminar on "Electrical Measurements in Europe" will be held at the Université Libre de Bruxelles, Belgium, from September 2–5, 1974. It is being organized jointly by the Institution of Electrical Engineers and the Société Royale Belge des Electriciens in association with the British Calibration Service.

The seminar will provide a forum for a supranational review of electrical measurements in Europe and is intended to promote harmonization in this field of technology by surveying the scene, identifying industrial needs, highlighting problems and postulating solutions to such needs and problems. The five half-day sessions will be devoted to specification and certification, national standards and problems of traceability, national calibration facilities, the market for electrical instruments, and prospects of European co-operation.

Attendance will be by invitation, and those wishing to be considered are asked to write to the Divisional Secretary LS(S), IEE, Savoy Place, London WC2R 0BL, England.

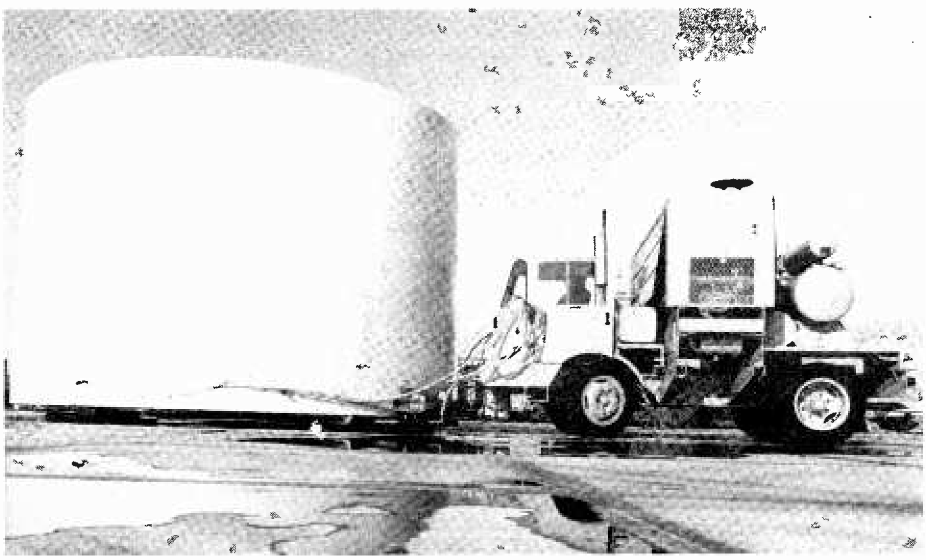
Picture telephone system

An experimental picture telephone system is being tried out in Holland between establishments of the Dutch PTT and the Philips company. It interconnects offices and laboratories at Waalre (20 subscribers), Eindhoven (10 subscribers), Hilversum (11 subscribers), The Hague (4 subscribers) and Leidschendam (9 subscribers). The PTT provides the transmission paths via radio relays and cables, while Philips Telecommunicatie Industrie supplies the equipment. For the local sections of the network, transmission is over the conductors of existing telephone cables.

In order to reduce the bandwidth from the 5MHz television standard to about 1MHz, the number of lines used in picture scanning has been reduced from 625 to 325. The number of picture elements per line has been reduced proportionally. This has resulted in a bandwidth of 1·3MHz.

During frame flyback a digital code word is transmitted which accurately defines the end of the past frame period and the start of a new one. During part of the line flyback a series of short pulses ensures that an oscillator in the receiver remains in synchronism with a similar oscillator in the transmitter. The remaining part of the line flyback time is used on a "sound in sync" basis to transmit a delta-modulated sound signal. The visual information is transmitted in the conventional way by an analogue signal. Transmission of the combined picture, sound and sync signals takes place on one pair of conductors for each direction. Thus a four-wire connection is available for the sound signal, which means that crosstalk will not occur in the transmission path.

The camera has an automatic lighting control system, which adapts the camera to any changes in lighting conditions. The picture tube has a screen size of about 19cm × 14cm.



Floating a 70ton load on air. Application of the hovercraft principle allows the British Post Office to move cable loads with ease. The system is to be used at the new cableship depot being built at Southampton.

Data Act

The Swedish Data Act, a comprehensive piece of legislation directed against misuse of computerized files, has aroused widespread interest abroad. This has prompted the Federation of Swedish Industries to publish in English a 22-page booklet on the Act.

The Swedish Data Act is divided into five parts. The first is concerned with the definition of terms. The second prescribes basic regulations on the issue of permits to create a personal information file. The third lays down the obligations and duties of those holding such files. The fourth specifies how the files should be supervised. The fifth deals with penalties, award of damages, etc.

Two important provisions of the Act—part of which came into force on July 1, 1973, the rest becoming operative a year later—are that permits to create a personal information file must be issued by a special body, the Data Inspection Board, and that organizations holding files must inform those recorded in them of their contents.

Pro-Electron goes passive

The Pro-Electron system of codification of active devices in operation in Europe is to be extended to include all passive components. The eventual object is to achieve a standard codification for both active and non-active components for all consumer, professional and government interests in the latter half of this decade. This was decided when the Pro-Electron association held its eighth general meeting in Brussels.

Clutter-free radar for cars

by J. Shefer, R. J. Klensch, G. Kaplan and H. C. Johnson
RCA Laboratories, New Jersey

A radar system using second harmonic reflection that monitors the distance and closing rate of the car in front as well as the ground speed of the driver's car but remains immune to "blinding" and "clutter" from surrounding objects.

During 1970, in the USA, there were 12.3 million collisions involving two or more vehicles. Of this number, 3.8 million, or close to one-third, were rear-end collisions.[1] An experimental car radar has been demonstrated which is designed to avoid rear-end collisions. A completely passive reflector, mounted on the back of vehicles, returns the second harmonic of the frequency transmitted from the trailing vehicle. The radar is immune to clutter since its receiver is tuned to the second harmonic frequency only. It is also immune to blinding by cars travelling in the opposite direction, as well as to other interference problems inherent in a "dense" environment.

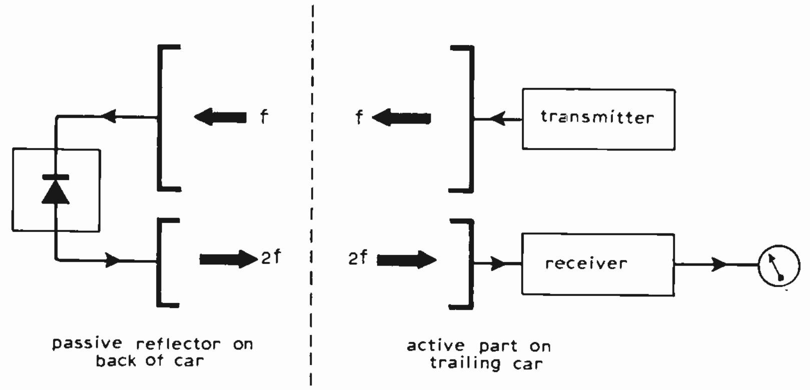


Fig. 1. Harmonic radar configuration.

System considerations

RCA Laboratories have developed a radar system that will aid the driver in maintaining a safe distance from the car in front by constantly monitoring the distance and the closing rate, as well as his own ground speed. The driver would be warned by sound or light signals whenever the combination of these parameters indicates that the separation between his car and the car in front becomes unsafe. As a further step in the system's development, the brakes would at the same time be activated automatically. Throttle control can eventually be added for completely automated headway control.

A viable radar for cars on highways must first be immune to clutter, which includes reflections from the roadway, trees, highway signs, overpasses, bridges, and similar highway fixtures. The seriousness of clutter can be assessed when it is recognized that the radar cross-section of an overhead sign can be 30dB larger than the radar cross-section of the back of a small car. Other car radar systems try to cope with this problem by excluding any returns from objects that are stationary with respect to the ground. That kind of processing does eliminate clutter from stationary objects. Unfortunately, it also eliminates the return from a car standing in one's own lane. This is a serious deficiency, especially since a majority of all rear-end collisions occur at a time when the car in front has completely stopped. When we add to the picture a large number of other cars carrying the same kind of radar and travelling in both directions of a highway, a whole new family of mutual interference problems arise. These can be characterized as blinding, masking, and cross-talk types of interference, which can cause false alarms or mask true alarms in conventional radar systems. In the harmonic radar system, however, they have been completely eliminated. Minimizing the incidence of false alarms is of prime importance if automobile radar systems are ever to become a reality. When false alarms occur more often than at a very low threshold rate, users are likely to lose faith in the system and either override it or shut it off completely.

The harmonic radar concept

The radar receiver shown in Fig. 1 is tuned to the second harmonic of the transmitted frequency and the car in front is equipped with a special reflector that efficiently returns the second harmonic only. (In extensive testing so far we have not found any natural objects that will produce a detectable second harmonic frequency.) Thus clutter is eliminated because the sources, such as signs and overpasses do not produce radar echoes at the second harmonic. Blinding is eliminated because all radar receivers respond only to signals at the second harmonic of the transmitted frequency.

Blinding interference

Car A in Fig. 2 is travelling behind car E, with its conventional radar measuring distance to car E. Car D, going in the opposite direction, will deliver an enormously large signal to car A's receiver, compared with the reflection from car E. Quantitatively, the blinding signal can be 50dB or 60dB higher than the echo being looked for. This blinding transmission will therefore be seen from a long distance ahead and may cause a false alarm, as well as saturate the receiver of car A. The side-lobes from cars B and C may have the same effect. In the harmonic radar system, however, the receiver of car A will reject all signals other than the second harmonic of its transmitted frequency.

Cross-talk interference

Indicated in Fig. 3 is another kind of interference, inherent in conventional radar, which may be called cross-talk interference. Car C in Fig. 3(a) may receive a false alarm even though it is in no danger of running into car B. With a harmonic radar, as in Fig. 3(b), the return signal is shaped into a well-defined beam, covering the width of one lane only.

In the situation on a curve, as in Fig. 4(a),

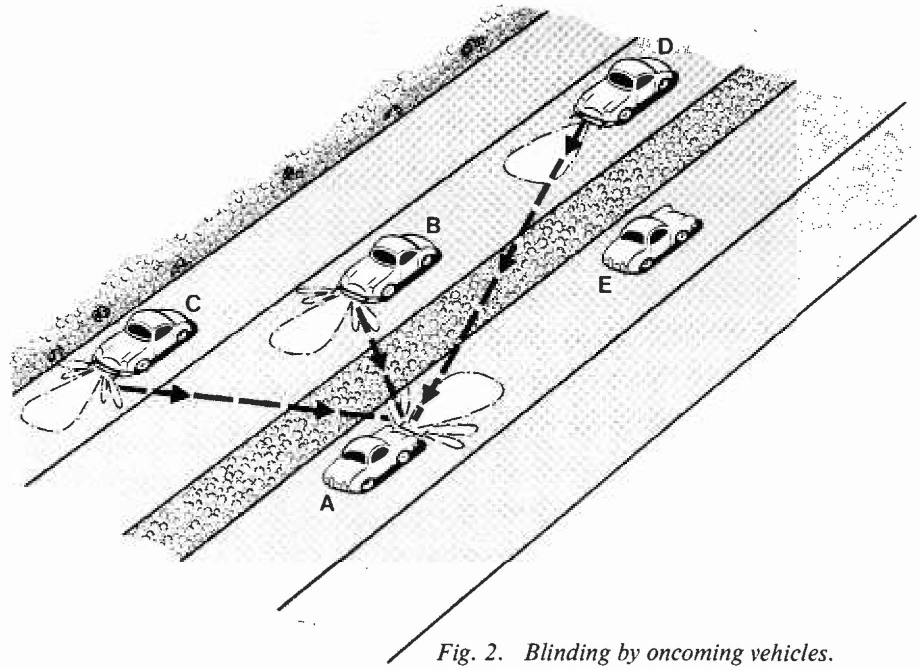


Fig. 2. *Blinding by oncoming vehicles.*

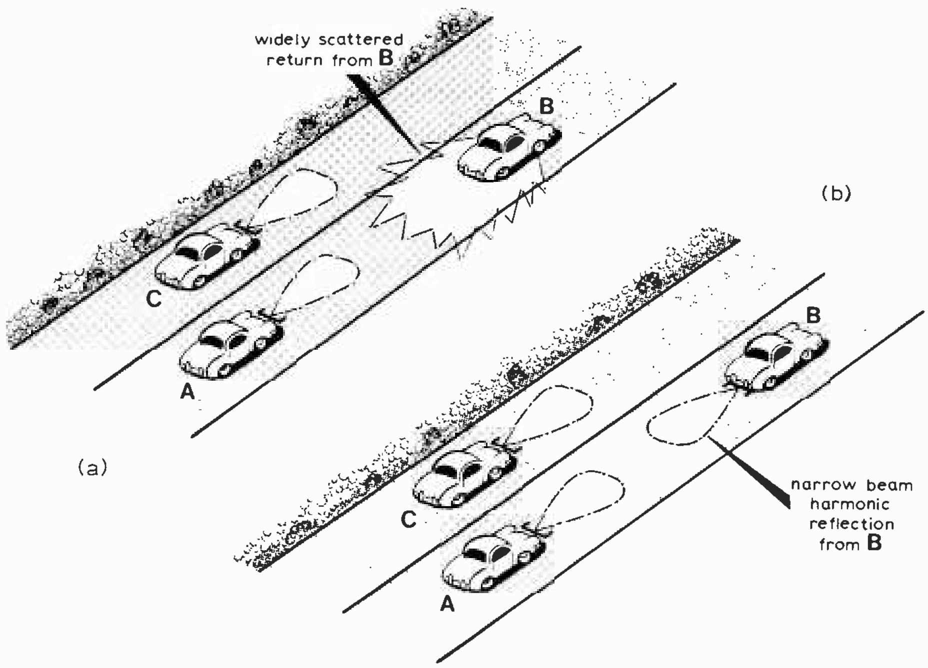


Fig. 3. *Conventional versus harmonic radar: "cross talk" from adjacent lanes.*

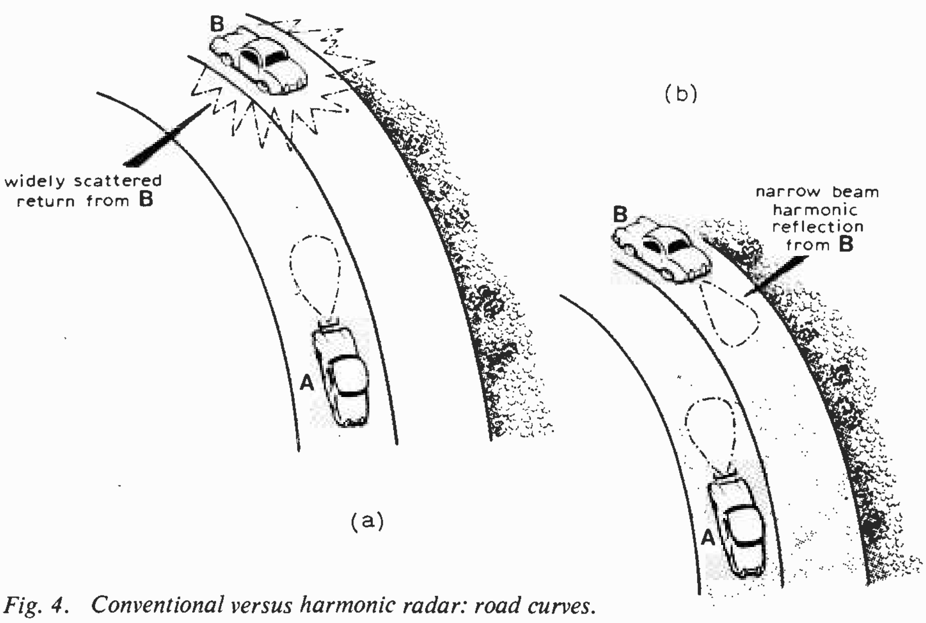


Fig. 4. *Conventional versus harmonic radar: road curves.*

quite evidently we do not need a third car to produce a false alarm. The skin of car B will respond to the transmission from a fundamental radar and may cause a false alarm at car A. Fig. 4(b) shows that with a well-defined narrow beam reflected from car B, if any reflection occurs at all, the possibility of a false alarm is drastically reduced.

Masking interference

Illustrated in Fig. 5 is yet another problem inherent in a conventional radar which uses the car's body as the reflector. Radar cross-sections of rears of cars can vary tremendously: the back of a lorry may have a radar cross-section several hundred times larger than a small car. The effect is then the masking of the desired return from a close vehicle by a larger vehicle much farther down the road. With the harmonic radar, all radar cross-sections of reflectors are the same, unless designed otherwise. If all reflectors are mounted at a standard height, only the nearest reflector can be "seen" while all others will be blocked.

The radar system described in this paper is unique in its ability to eliminate false targets and clutter, in its immunity to blinding by radars of similarly equipped vehicles, and in its potential of providing automatic braking for specifically "tagged" objects, such as known off-highway collision hazards or wrong-way entrances to one-way streets and highway access ramps.

When in general use, it also has the potential for safely providing higher traffic packing densities without running the risks of massive "pile-ups".

Although it is a co-operative system, in that all vehicles must carry the harmonic reflector, the reflector is completely passive, quite inexpensive in mass production, and can easily be fitted on existing vehicles. The co-operation required is not more burdensome than the requirement for red tail-light assemblies; and the purpose is the same—to aid in preventing collisions.

The radar uses solid-state components throughout, and is easily adaptable to integration and printed circuit techniques. It uses a frequency spectrum region that is still not crowded and, with a power density over the antenna aperture of $0{\cdot}15\,\mathrm{mW/cm^2}$, it does not constitute a radiation hazard even in the immediate vicinity of the radar.

General description of harmonic radar system

The harmonic radar system is shown in the block diagram of Fig. 6. A varactor-tuned transferred-electron oscillator (t.e.o.) generates c.w. power at X-band. A triangular waveform is used to frequency modulate the t.e.o. with a total frequency excursion of ΔF at a rate of f_m as shown in Fig. 7. The frequency-swept power is radiated from antenna A_1 mounted on the front of the trailing car (see Fig. 6). This power impinges on a similar antenna A_2 which is a part of the harmonic reflector mounted on the back of the front car. The passive doubler generates the second harmonic frequency of the power incident on

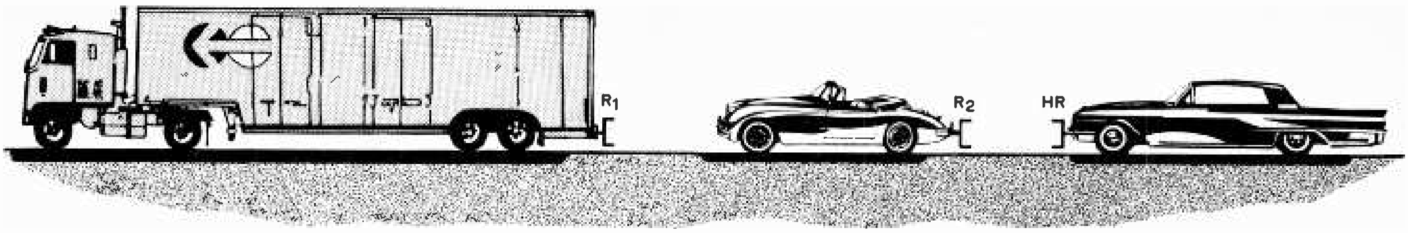


Fig. 5. Conventional versus harmonic radar: masking.

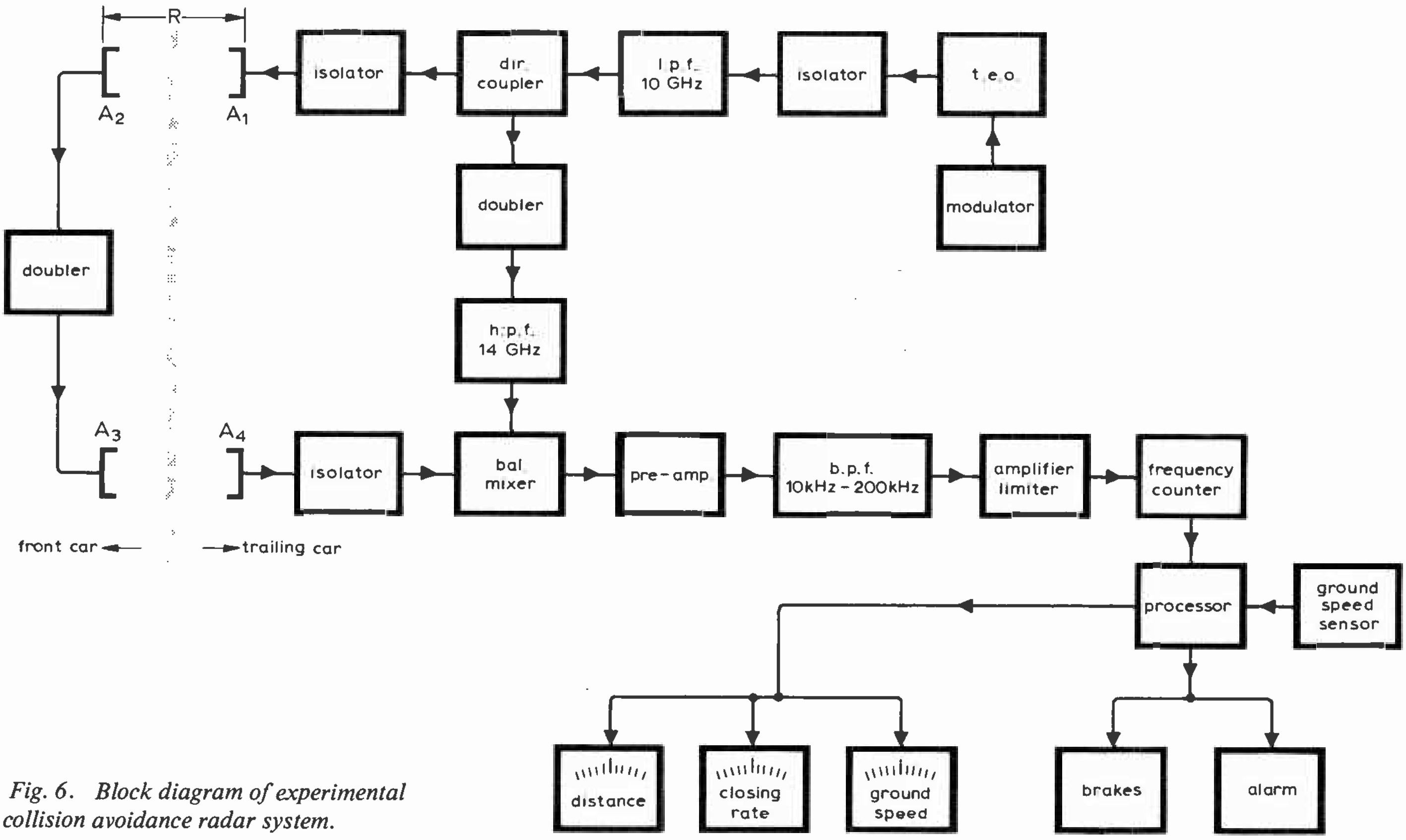


Fig. 6. Block diagram of experimental collision avoidance radar system.

antenna A_2 and radiates it back to the trailing car via antenna A_3. This frequency is in Ku-band. The receiving antenna A_4 delivers the received power, which is at the second harmonic frequency, to the mixer, where it is mixed with a sample of the doubled frequency of the transmitter power.

The returned signal is shifted in frequency from the second harmonic of the transmitted frequency due to the round trip time delay $\tau = 2R/c$ (R is the distance between cars and c is the velocity of light). The frequency shift (or difference frequency, f_R) is given by

$$f_R = \frac{df}{dt} \cdot \tau = \frac{8 \Delta F f_m R}{c}$$

A measurement of the frequency shift yields the range since the time delay is proportional to the distance between cars.

Two techniques for measuring this frequency shift have been investigated for the automotive radar. The first, for which the bulk of the experimental effort has been carried out, will be described first.

The output of the mixer is amplified, filtered and then fed into a counting circuit. This counting circuit develops a voltage which is proportional to the rate of zero crossings of the input signal and therefore the range. In addition, the radar processing circuitry derives a voltage which is proportional to the first derivative of the range, i.e., the closing rate. To make a proper decision for a "safe distance", a third piece of information—the ground speed of the vehicle—is used. The ground speed is derived from an independent microwave Doppler speed sensor. The radar processor combines the three measurements of range, closing rate and

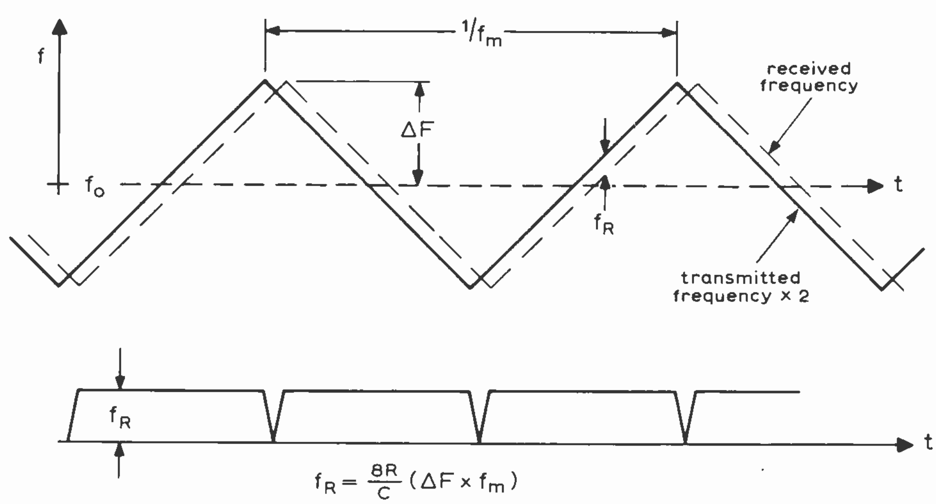


Fig. 7. Modulation scheme of harmonic radar.

ground speed in a predetermined fashion, depending on the criteria chosen for "safe distance", which are, of course, dependent on weather and road conditions. When a dangerous driving situation is detected, an audible warning is sounded and a light is flashed. In our experimental unit, with the system switched to the automatic braking mode, the brakes are also applied for dangerous driving situations. The range, closing rate and ground speed are displayed on three panel meters mounted on the dashboard. In an operational system, it is not expected that these measured quantities would be displayed.

Quantization effects

As shown in Fig. 7, the difference frequency f_R is given by

$$f_R = 8\Delta F f_m R/c \qquad (1)$$

where R is the distance between vehicles, ΔF is the total frequency excursion at X-band, and f_m is the modulation frequency. The choice of parameters ΔF and f_m is closely related to the presence of a step error (or quantization error) in distance measurements with frequency modulated radar. The conventional signal processing technique[2] which measures the return frequency by counting the number of zero crossings that occur within a fixed time interval leads to a result which is quantized in frequency and therefore in range. The quantization arises because the difference frequency waveform is periodic in f_m. Therefore the average measured frequency (as measured by using the entire waveform and counting zero crossings in a fixed time interval) must be a multiple of f_m. The quantization step in range ΔR is therefore (from equation (1)) equal to

$$\Delta R = c/8\Delta F$$

To minimize this basic "granularity" in distance readings, ΔF should be chosen as large as possible. In practice, bandwidth limitations in the doubler and mixing circuits, as well as regulations requiring the efficient use of frequency spectrum do not allow ΔF to exceed a few tens of MHz. In the experimental system, a good compromise was found to be ΔF equal to 25MHz, resulting in a range quantization of 1·5 metres. This quantization error can be tolerated in a distance measurement for collision avoidance where the relative motion of the two vehicles tends to have an error-smoothing effect.

A different processing technique has also been investigated. This technique processes the difference frequency waveform in a digital manner allowing accurate range measurements to be made without the quantization limitation just described. This technique can allow the radar to operate with a smaller frequency deviation ΔF which in turn simplifies the bandwidth requirements at the t.e.o., mixer, doubler, etc., as well as conserving r.f. spectrum.

To understand how this signal processor overcomes the quantization limitation refer to Fig. 8, which depicts a typical difference frequency versus time waveform. The number of zero crossings in a given time interval is quantized, with the quantization effects arising because of the phase reversals occurring every $1/2 \cdot f_m$ seconds. However, if we restrict our attention to portions of the difference frequency waveform that are removed from the phase reversals, then we see that the time between zero crossings of this restricted portion of the waveform is not quantized.

If an accurate measurement of this time period (p_0) were made, then a non-quantized frequency ($1/2p_0$) could be found by generating the reciprocal of the measured period. This non-quantized frequency could then be converted to range via the relationship shown in eq. (1). Further details of the non-quantized signal processing technique are presented in the video circuits and signal processing sections of this paper.

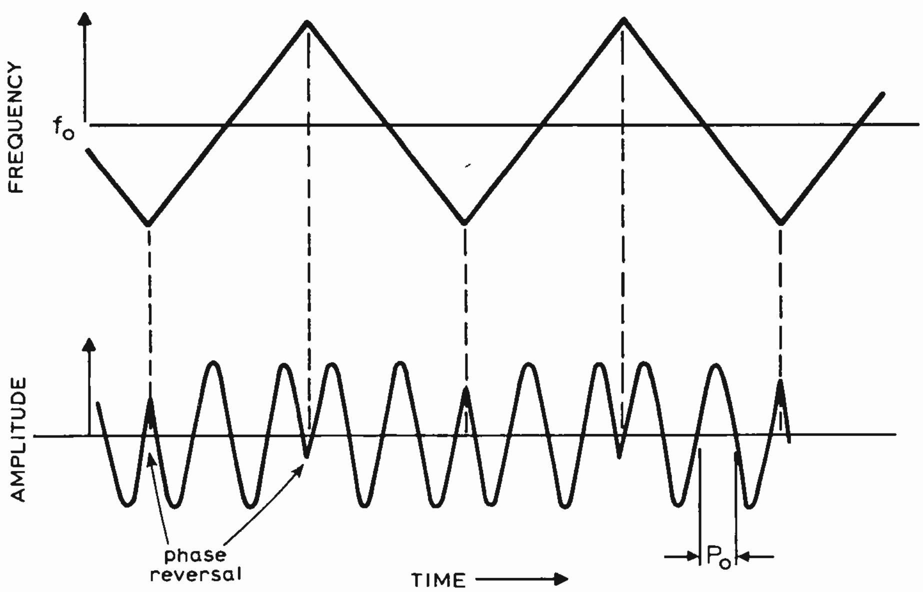


Fig. 8. Typical difference frequency waveform.

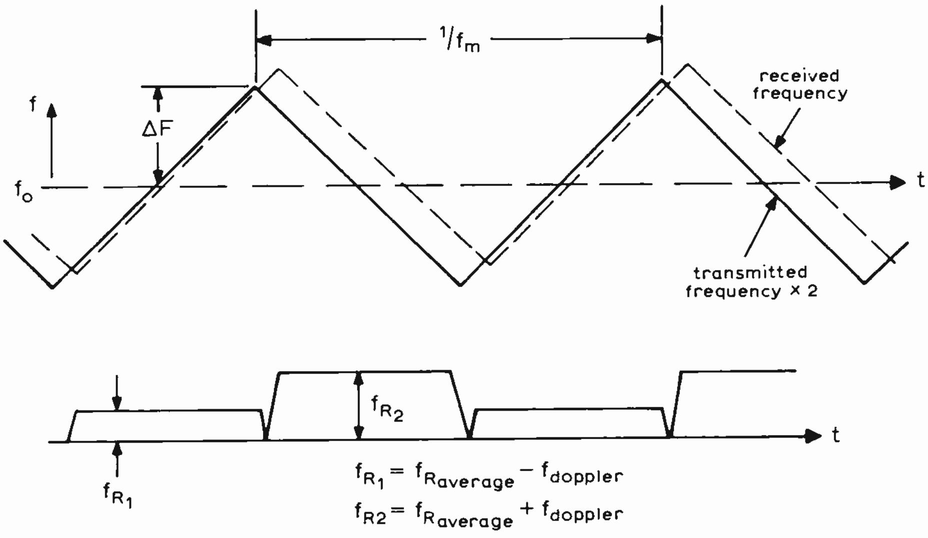


Fig. 9. Doppler shifts with moving vehicles.

Modulation parameters

The frequency excursion at X-band is 25MHz while the modulation frequency is 3kHz. This was chosen as a compromise because if f_m is made very high, the video bandwidth needed to accommodate the expected variation in range becomes very large while if f_m is made very low, there are various components of noise (in excess of thermal noise) which behave as $1/f$ noise, limiting system performance. For the parameters chosen, the frequency versus range slope is 2kHz/m resulting in a 10kHz–200kHz range for the difference frequency as the distance varies from 5 to 100 metres.

Doppler shifts

As seen in Fig. 9, relative movement between vehicles will have the effect of shifting the difference frequency by an amount equal to the Doppler frequency. It will be a positive shift during one half of the modulation cycle and an equal but negative shift during the other half. The average difference frequency (averaged over many cycles of f_m) will be the same as for a stationary car at the same average distance. The range reading is therefore independent of the Doppler shifts. An up-down counter switched in synchronism with f_m could be used to detect the closing rate. In the present system, however, the closing rate is derived by differentiation of R.

Frequency doubler

The success of the harmonic radar concept was critically dependent on developing an efficient, passive harmonic reflector, i.e., finding a solid-state device which in a suitable circuit will generate the second harmonic with the required efficiency. For the car radar application it was felt strongly that the reflector must be completely passive, with no wiring to the car's electrical system to insure reliable operation and inexpensive installation.

The above needs have been met by the device shown in Photo 1. A silicon Schottky barrier diode is mounted in a microstrip circuit. A 0·8thou'-diameter diode chip is seen connected across a gap, located for best impedance match in a $\lambda/2$ (fundamental resonator). Input at X-band is coupled at a voltage maximum point of the fundamental frequency, output is coupled at a voltage maximum point of the second harmonic, with a $\lambda/4$ open section coupled to the output line to reflect the fundamental frequency back into the circuit. Fig. 10 shows the conversion efficiency of the doubler circuit. As one would expect, at the lower levels the power output at the second harmonic varies as the square of the power input at the fundamental, following a law of

$$P_{out} = KP_{in}^2$$

with K equal to 2500 W^{-1}. The bandwidth of the doubler is approximately 75MHz, centred within the Ku-band in the experimental unit.

A similar doubler circuit is used to provide a sample of double frequency transmitter power to the local oscillator port of the mixer, but this circuit is operating at high power levels. A 50mW input at X-band yields a conversion efficiency of 10% over a 200MHz band.

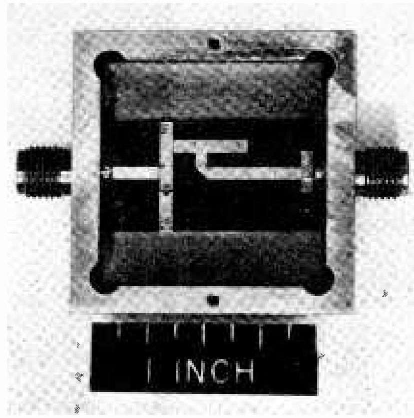


Photo 1. Frequency doubler microstrip circuit.

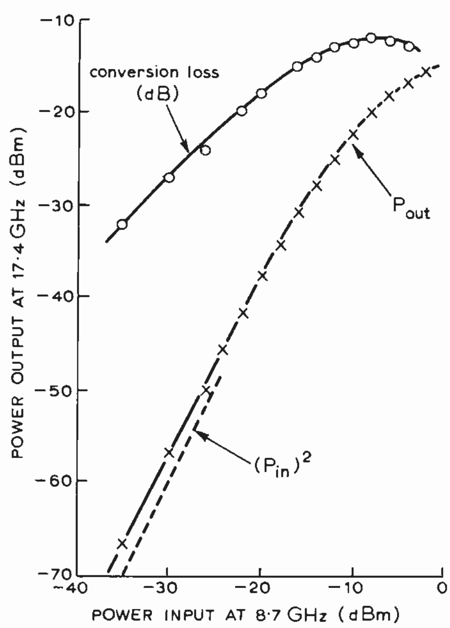


Fig. 10. Harmonic generation efficiency of frequency doubler.

Antennas

The choice of antennas and the r.f. frequency are closely related. For reasonable traffic-lane discrimination, a maximum horizontal beamwidth of 5° requires a horizontal aperture width of ten wavelengths. To achieve this aperture in a 12in physical size (approximately licence plate size) necessarily places us somewhere in X-band. A $10\lambda \times 10\lambda$ aperture with 50% efficiency has a gain of 28dB, which makes transmitter power requirements quite reasonable. Also, solid-state power sources at X-band frequencies are readily available, and spectrum space at X-band is still under-utilized.

Printed antenna design was found quite suitable for our system. The X-band antenna has an aperture of 13 × 7½in, a gain of 26dB at 9GHz, and a 10% bandwidth. It consists of 128 fan-shaped dipoles printed on both sides of a 1/32-in thick polyethylene sheet, phased into a 50Ω input through a succession of quarter-wave balanced transmission lines. An 18GHz antenna has been produced by scaling up in frequency from the X-band design, with similar electrical characteristics.

By using a polarization of the Ku-band antenna at 90° to the polarization of the X-band antenna, we get additional rejection of spurious second harmonic power generated at the source and received either directly from an oncoming vehicle or reflected from "nontagged" objects. This is in addition to second-harmonic filtering at the low-pass filter and isolators in the transmitter circuit. Total rejection of spurious second harmonic amounts to 150dB, reducing it to well below receiver noise level.

Doppler speed sensor

A low-power microwave Doppler speed sensor was developed for use on cars and lorries to provide true ground speed for both anti-skid braking and speedometer applications. In an anti-skid system, the true ground speed and wheel speed are compared to accurately determine wheel slip during braking.

The speed sensor, which is shown in photo 2 and diagrammatically in Fig. 11, is a completely self-contained radar including transmitter, receiver, antenna, d.c. and signal processing circuits. A smaller version of the printed antenna in the collision avoidance radar is used for transmitting to and receiving signals from the road surface. The radar is mounted on the vehicle so that the beam lies in a vertical plane, with the vehicle's velocity vector at an acute angle θ (typically 45°) to the road surface. Part of the transmitted signal is diffusely reflected from the road surface back to the antenna. If the vehicle is moving with a velocity v, the reflected signal is shifted by the Doppler effect and the difference between transmitted and reflected frequencies is given by $F_D = 2v \cos\theta/\tau$ where τ is the wavelength of the transmitted signal. This difference frequency is extracted from the mixer and is converted to a series of fixed width pulses having a repetition rate proportional to speed. The pulses may be counted to indicate total distance or may be averaged for analogue speed information as is the case for the collision avoidance system. These radar speedometers have an operating

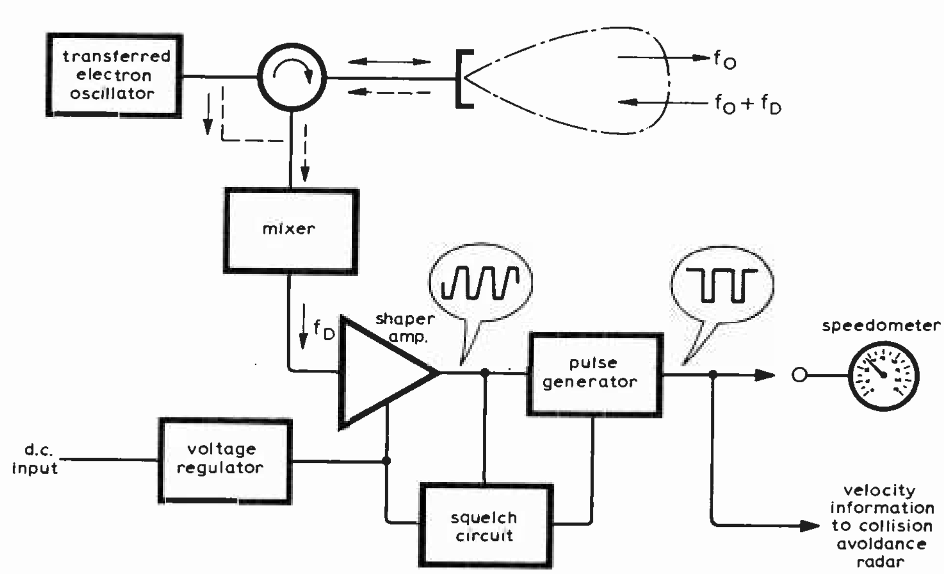


Fig. 11. Block diagram of Doppler radar module.

temperature range of -60 to $+75°C$ and, once calibrated, have demonstrated inaccuracies of about 1% or less on dry road surfaces for speeds of 20–70 m.p.h.

Signal propagation

Assuming free-space propagation conditions, effective antenna apertures of A_f and A_{2f} for the X-band and Ku-band antennas, respectively, a target at distance R will present to the receiver a signal power of

$$P_r = (4K)P_0^2A_f^4A_{2f}^2/\lambda^6R^6 \qquad (2)$$

where P_0 is the transmitter power at the fundamental wavelength λ and K is the doubler coefficient when operating in its square law region where P_{out} equals $K(P_{in})^2$.

The signal strength at the receiver is modified by ground reflections. Power will reach the antennas via a ground reflection in addition to the direct path. For the car, radar angles of incidence are between 5° and 0·5°. At such small angles, the reflection coefficients for horizontal and vertical polarization are similar (about 0·7 to 0·8 in magnitude and a phase shift of close to π radians). As a result of the ground reflected component, the range equation (2) has to be modified. Assuming an ideal case (not far from reality) where the reflection coeficient is equal to -1,

$$P_r' = P_r[64\sin^4(2\pi h_1h_2/\lambda R) \times \sin^2(4\pi h_1h_2/\lambda R)] \qquad (3)$$

where h_1, h_2 are heights above ground of the active radar and passive reflector antennas, respectively, and λ is the fundamental wavelength. As R changes, we expect a series of reinforcements and partial cancellations of signal strength. A partial cancellation will occur wherever $R = 4h_1h_2/n\lambda$, where $n = 1,2,3 \ldots$ and for the values $h_1 = h_2 = 0{\cdot}52$m of the experimental radar. A signal minimum is expected at $R_{n=1}$ equals 32m and $R_{n=2}$ equal to 16m, with more below R_{min}.

For distances where $R > 10h_1h_2/\lambda$, the trigonometric functions in eq. (3) can be replaced by the arguments, resulting in a received signal of

$$P_r'' \alpha P_0{}^2A_f^4A_{2f}^2(h_1h_2)^6/(\lambda R)^{12}$$

indicating a drop-off with distance as steep as R^{-12}.

It is obviously more advantageous, relative to conventional radar systems, to increase the source power, and, for a given total aperture, to allocate the larger area to the fundamental antenna. In our radar, this aperture ratio is 4:1, giving the same gain to the two antennas. The very steep decrease of signal strength with distance has an advantage in that interference effects caused by out-of-range targets will be greatly reduced.

Measured signal strength as a function of distance is shown in Fig. 12 for the experimental radar over dry asphalt.

Source of noise

There are several sources of noise in the present radar system which limit the range. These sources include thermal noise, essentially "white" across the system-bandwidth

$$B = f_{Rmax} - f_{Rmin}$$

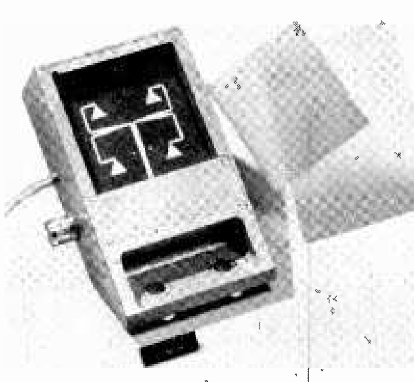


Photo 2. Doppler ground speed radar.

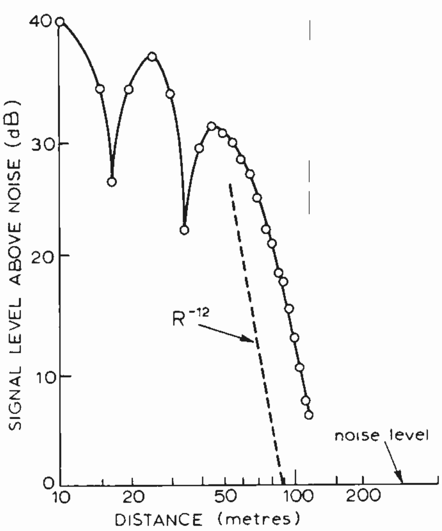


Fig. 12. Signal strength versus distance. (Antenna is 21in above road surface.)

Local oscillator noise, generated by beat products of the t.e.o. noise spectrum in a bandwidth B away from the carrier[3,4]. This noise source varies with the "corner" at $f = 100$kHz. It is possible to reduce the effects of noise source by using a balanced mixer. For the radar parameters, with a mixer balance reduction of 20dB, the local oscillator noise becomes less than thermal. Amplitude modulation at the local oscillator, caused by the dependence of t.e.o. output power on frequency as frequency is varied over a range ΔF. This noise source has frequency components at f_m and its harmonics. Use of a balanced mixer and a t.e.o. power variation of less than 0·1dB over ΔF ensure that this noise source is of minor importance. Mixer sensitivity and balance are strongly dependent on frequency. This is partly caused by the fact that the isolation between the r.f. ports is rather poor (~ 6dB), causing multiple reflections of the local oscillator power and its harmonics at the imperfectly matched isolator, antenna, and high-pass filter (see Fig. 6). When swept over a range of frequencies ΔF, a noise signal at f_m is generated at the i.f. output port, the harmonics of which enter the video band, f_{Rmin} to f_{Rmax}, of the system. The magnitude of this noise signal varies with the mixer diodes in use and the choice of centre frequency. With careful matching of components and adjustment of cable lengths it can be reduced, but in practice it is the dominant noise source, exceeding the first two contributions by 10–20dB. Therefore, the current design is not operating at its theoretical Johnson noise limit regarding signal-to-noise ratios, and consequently its maximum range of 100m is below a theoretical noise limited system.

Improvement in the future can be achieved by using a balanced mixer design which has better isolation and is less prone to generating spurious signals at f_m and its harmonics. One could also attempt matched filtering in the video amplifier chain to improve matching between the amplitude and range characteristic of the radar system. Should increased range become necessary a more sophisticated and complex design may be used, incorporating a tracking, narrow-band filter.

In the present design, a signal of P_{min} equal to -80dBm is required at the receiver input for a 10dB overall s/n ratio.

(To be continued)

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2. Luck, D. G. C., "Frequency Modulation Radar", McGraw-Hill (1949).
3. Narayan, S. Y., and Sterzer, F., "Transferred Electron Amplifiers and Oscillators," *IEEE Trans. on Microwave Theory and Techniques* (November 1970).
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Sixty Years Ago

In these days of "light current" electronics, and the professional, highly qualified radio engineer, it is worth remembering that it was not always thus. This extract from *Wireless World*, May 1914, may give some inkling of the sort of thing your average engineer came up against.

'Wireless Engineer' sends us the following two recipes for a cheap mixture for covering boilers in order to prevent loss of heat:

(1) Take 1 bushel of fireclay, 1 bushel of ordinary clay, 1 bushel of cow-dung, $\frac{1}{4}$ bushel of ashes (not the finest dust), $\frac{1}{2}$ gal. of coal-tar, and a little plasterers' hair as a binder; mix well together . . ."

And now we grumble when integrated circuits are in short supply!

Circuit Ideas

Ten-digit code-operated switch or combination lock

The circuit is that of a switch which is only operated by the insertion of a ten-digit code. On pushing either the "1" or "0" button, a positive-going clock pulse is applied to the clock input of the shift registers which then clocks into the first bit whatever is present at the serial input. With the serial input connected as shown, it is clear that pushing the "1" or "0" button will clock into the shift registers a "1" and "0" respectively. One requirement of the shift registers is that the information be present at the serial input before the clocking pulse occurs. This is clearly achieved in this design. The pair of cross-coupled NAND gates associated with each switch is to prevent the undesired effects of contact bounce.

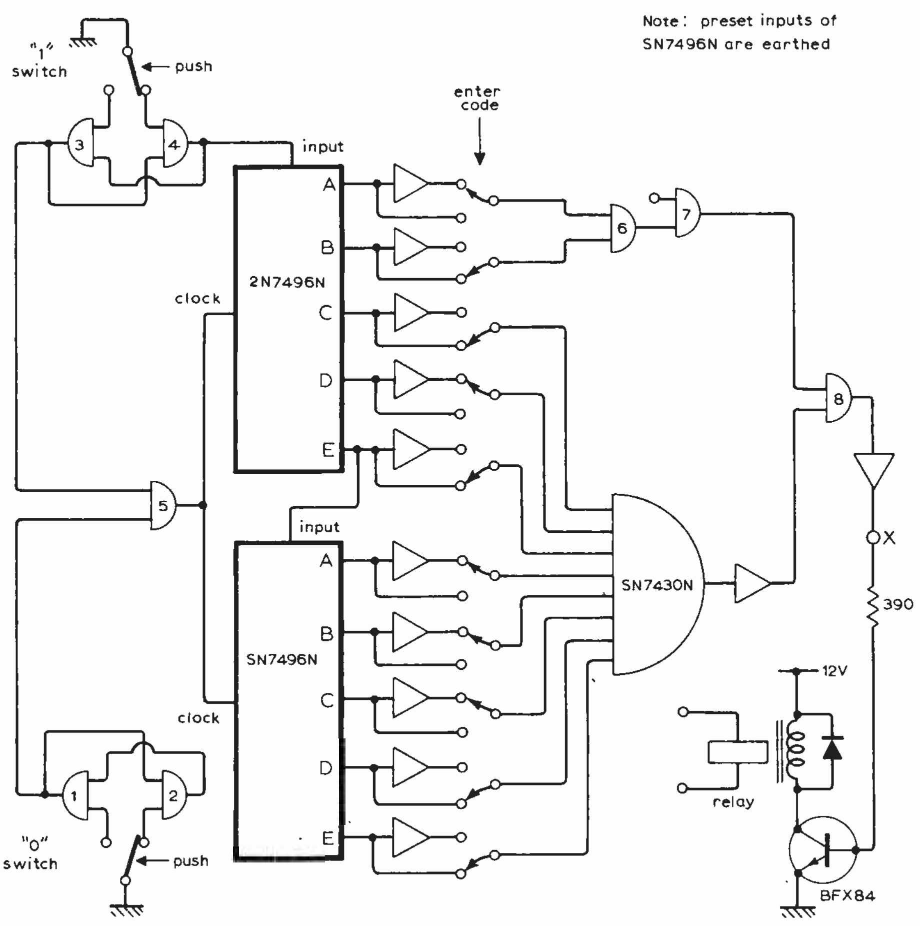
Each output of the shift registers is applied either directly or through an inverter to a NAND gate which, when all inputs are high, will cause the point X to go high. Thus the insertion of an inverter between a shift register output and the NAND gate will make it necessary for that particular output to be "0" before X goes high. As two five-bit shift registers are used, then clearly a ten-digit code will be required to operate the switch. Though the shift registers have a "clear" input, it was found that its use was unnecessary as any states present at switch-on are virtually no help in obtaining the code.

The theoretical probability of obtaining the correct code is one in 2^{10} or 1 in 1024, assuming that one knows that ten digits are required. The average code breaker will not know this, and so the odds against him will be much larger.

Seven Texas monolithic positive-logic chips are used in the present design. The NAND gates 1, 2, 3, 4, are part of a SN7400N package. Likewise are gates 5, 6, 7, 8. The 12 inverters are formed by using two SN7404N packages, each of which contains six inverters. The eight-input NAND gate is a SN7430N, and each of the two shift registers is a SN7496N.

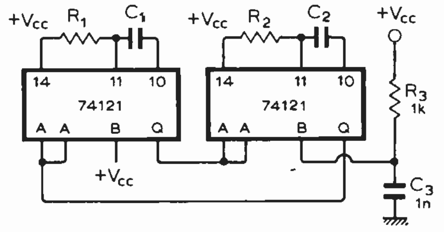
If one chooses a code with only four zeros, then only one SN7404N will be required. The system operates with a 5-V supply rail and consumes 100mA, excluding relay current.

K. E. Potter,
University of Sheffield.



Stable t.t.l. oscillator

This circuit satisfied my requirements for a self-starting t.t.l. oscillator which was more than the usual Schmitt trigger circuit. Components R_3,C_3 provide a starting pulse at switch on.



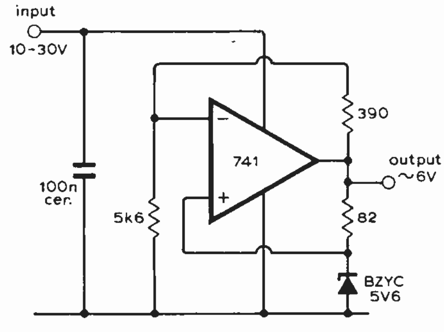
Period of oscillation is approximately $\log_e 2(C_1R_1+C_2R_2)$ + sum of propagation delays (about 45ns each).

Stability is approximately 0·07% change in frequency for a supply change from 4·75 to 5·25V, and approximately 0·015%/degC for a 1MHz oscillator. For reliable operation $R_1C_1 \approx R_2C_2$.

M. Walne,
Brighouse,
Yorks.

High performance reference

Using only six components this reference circuit has exceptionally good characteristics. Current through the zener diode is held constant because it is derived from the stabilized output. With the equipment at my disposal I have been unable to measure most of the parameters of the circuit and so can only quote limits to these values.



Regulation <0·005% i.e. when the input rose from 10 to 30V the output changed by less than 1mV.
Output resistance approximately 0·1Ω.
Short-circuit current approximately 20mA.
Ripple rejection <80dB; with an input ripple of 10V pk-pk output ripple was less than 1mV pk-pk.
Temperature coefficient typically 0·003%/degC although this can be reduced to zero by adjustment of the resistors.

Circuit can be rearranged to give either positive or negative outputs, and other values of output voltage.

M. Walne,
Brighouse,
Yorks.

Novel stereo f.m. tuner

2—Stereo decoder, assembly and setting up

by J. A. Skingley and N. C. Thompson

Plessey Company Ltd, Swindon

Using a ready-made front-end, integrated circuits and only one inductor, this tuner design is simple to operate, construct and set up. Part 1 gave novel circuitry for inter-station muting, a.f.c. restricted to less than station spacing, a single-lamp tuning indicator, and temperature compensated varicap tuning allowing stations to be preset. This second article gives a stereo decoder circuit that uses active filters to eliminate "birdies" and subcarrier harmonics, assembly instructions, setting up procedure and a linear-scale frequency meter circuit.

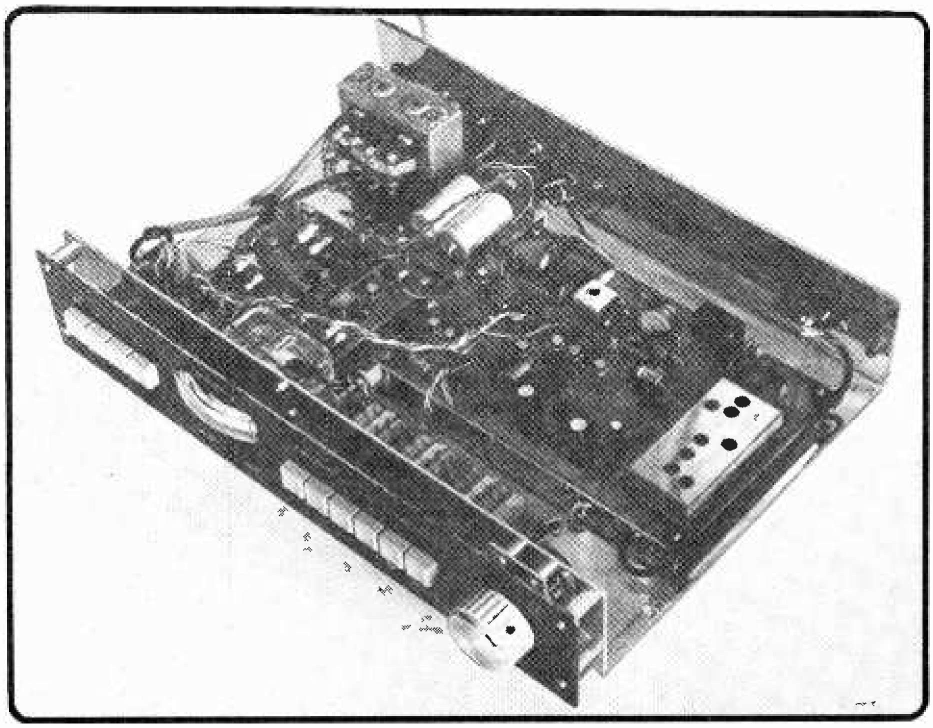
Fig. 7 shows the internal circuit of the SBA750. Pins 3 and 4 receive the input from the i.f. which is passed along the chain of five limiting amplifiers to pins 6 and 7. From here the signal is passed internally direct to the quadrature detector, and also externally via the quadrature coil and pins 8 and 9. The demodulated signal is then available at pins 10 and 11, and it is from here that the drive for the a.f.c. and tuning indicator is taken. This audio signal is taken internally to an amplifier giving a single-ended output on pin 12.

The stereo signal is taken from this pin and fed to the stereo decode board. It is also coupled via C_{11} to pin 1, and after further amplification is available de-emphasized as a mono signal on pin 15. De-emphasis is accomplished by C_{13} on pin 16. Both stereo and high-level mono outputs are therefore available.

The amplifier output to pin 12 can be attenuated by varying the current fed into pin 13. In this design pin 13 is open circuited to fully mute the amplifier while preserving the a.f.c. drive from pins 10 and 11. This ensures that the receiver captures a station from the muted condition.

Improved stereo decoder

The stereo decoder is shown in Fig. 8. When this decoder integrated circuit was first used "birdy"-type interference was experienced under certain conditions. The causes of this have been reported elsewhere, but it is worthy of further explanation judging by the lack of effort to remove it in expensive receivers.



The nature of a frequency modulated signal is such that a bandwidth many times that of the deviation is needed for accurate transmission and reception, around 300kHz often being used. The spacing of broadcast programmes is however only 100kHz and this inevitably results in frequencies from one station arriving at the detector of a tuner receiving an adjacent station. The products from the detection are however normally supersonic and therefore inaudible.

This is fine until we introduce stereo reception which involves demodulation of the stereo channel at 38kHz usually using square-wave switching. This process also demodulates signals around the odd harmonics of 38kHz, i.e. 114, 190, 266kHz etc. The first two of these will produce audible signals from the adjacent channels at 100 and 200kHz away from the wanted station, giving interference centred on 14 and 10kHz respectively. These sound like high-pitched twittering sounds commonly called birdies.

Knowing the cause, the effect can be greatly reduced, if not completely eliminated. The wanted stereo information extends up to 53kHz, so by filtering the signal above this frequency before the stereo decoder, the unwanted adjacent channel signals can be attenuated. This also brings about an improvement in signal-to-noise ratio during stereo reception, as noise above 53kHz is also reduced. Such noise can be demodulated down to the audio band by the harmonics of the 38kHz switching frequency in a similar fashion to the adjacent channel signals if it is not removed.

The filtering required is carried out by Tr_1 in Fig. 8, which also shows the complete stereo decoder. (This circuit has been built on a separate board, and for this reason the components have been numbered independently). Transistor Tr_1 forms an active filter of the Sallen and Key type and provides a second-order response. There is an additional pole supplied by C_{10} between pins 10 and 11 of the SBA750 and this, together with the two poles of the active filter, combine to give a three-pole optimally flat response up to 53kHz, followed by a sharp roll off of 18dB per octave. This transistor is directly coupled and biased from pin 12 of the SBA750, and its output fed to the input of the decoder integrated circuit.

This decoder is of the phase-locked loop type, and in appreciating the advantages of this form of decoder, it is worth looking briefly at the conventional type. These decoders work by generating the necessary 38kHz switching frequency either by converting up the 19kHz pilot tone, or by phase locking a local oscillator to this pilot tone. The 38kHz signal may then be used to switch the multiplex signal into its two separate paths. Obviously, this switching must not only be at the correct frequency but it must also be in synchronism with the original coding. In other words the phase of the coding and decoding signals must be identical. If a tuned circuit is used as in the conventional decoder to separate the 19kHz from the audio, then a high-Q tuned circuit must be used to avoid phase jitter from the residual audio. A high-Q tuned circuit however has a high phase shift for a small amount of mis-tuning. For this reason a low Q would be required. Hence there is a compromise.

The phase-locked decoder operates by generating a 38kHz signal (in this case a 76kHz signal divided by two). This is divided by two to give 19kHz which is compared in phase with the pilot tone. The difference between the two is used to provide

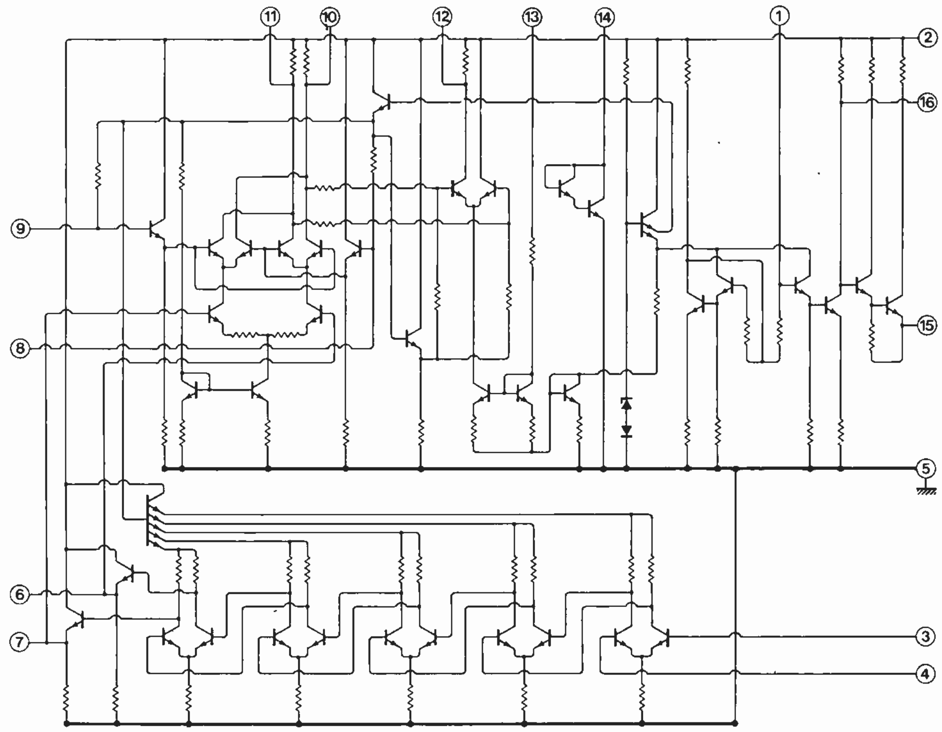


Fig. 7. Internal circuit of SBA750A i.c. includes circuitry i.f. amplifier (below) balanced quadrature detector and a.f. preamplifier (used on mono only). Signal to unmute output is applied from Fig. 4 to pin 13. Drive for a.f.c. and indicator circuit is taken from pins 10 and 11 via circuit of Fig. 5 and drive for mute circuit is taken from pin 6.

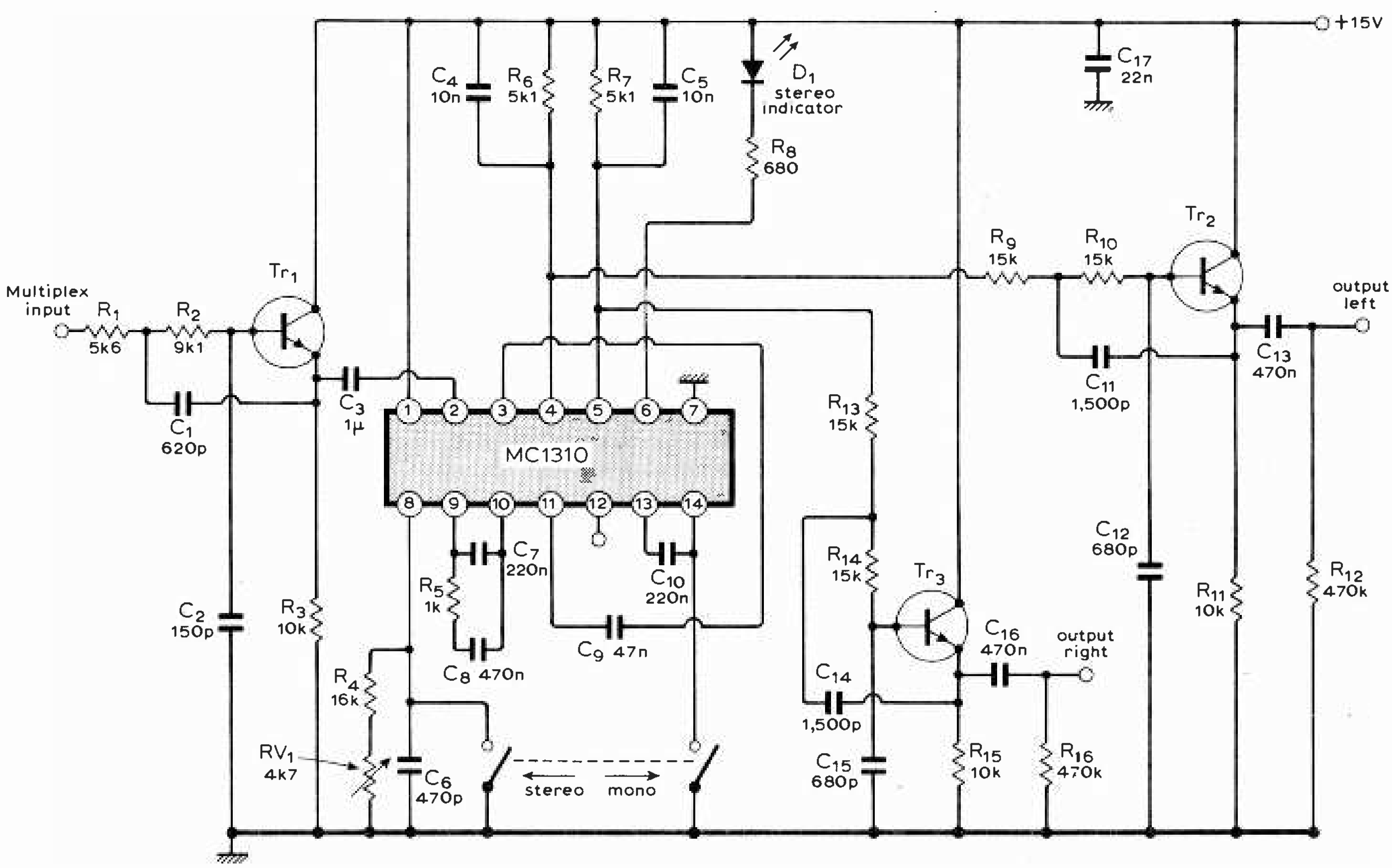


Fig. 8. Decoder circuit includes an active filter to roll-off response at 18dB per octave above 53kHz to prevent "birdies" that result from interference between odd harmonics of 38kHz and adjacent carriers. Two further active filters remove the 38-kHz harmonics from the outputs.

feedback, and hence phase lock the local oscillator to the pilot tone. The time constant of the feedback path may be made long so as to reduce the phase jitter to a negligible amount. This is equivalent to producing a high-Q tuned circuit, but one which cannot drift in phase provided the loop gain of the feedback path is high. This system also has the advantage that no coils are required. The complexity required dictates the use of integrated circuits on economic grounds, which has the added advantage that fewer corners need be cut in the design stage, so that the full potential of the system may be realized.

Two more active filters have been added, one per channel, formed by Tr_2 and Tr_3 (Fig. 8) and these are directly biased from the integrated circuit. Their function is to remove unwanted signals from the outputs, such as the 38kHz sub-carrier and its harmonics, which could otherwise cause trouble when tape recording.

The MC1310 has a direct output for a stereo indicator lamp and the facility for disabling the decoding process if desired. In the tuner described this is implemented by a second pole to the switch which also stops the oscillator to prevent any possible interference. The stereo decoding may need to be stopped if the signal is weak and a poor signal-to-noise ratio is obtained. Reverting to mono reception will provide an improvement. You may prefer to use the mono output provided from the receiver board, but this will need attenuation to give a compatible level when switching to mono. The tuner will, of course, automatically give a mono output in the absence of a pilot signal.

Construction

Layout and general presentation of the tuner is largely a matter of personal choice, and in this connection the mechanics described represent only our solution, offered as a suggestion. The layout of the printed boards are critical, and it is strongly advised that the board design offered here is used. The system employs a generous amount of gain at high frequencies and even small deviations from the layout given could prove troublesome. This layout, given in Figs 9 and 10, follows good engineering practice and ensures stable performance.

When assembling a board of this complexity it is a good idea to insert a few components at a time, solder these and clip their leads before inserting a few more. Start with the passive components and finally the transistors, integrated circuits, filter and front end. There are four wire links and these are made using discarded resistor ends. The single coil is 15 turns of 33 s.w.g. cotton cord wire, close-wound on a Neosid type A screened assembly using an F16 screw core. Before soldering the wire ends of this, insert the capacitor C_9 (100pF) into the same pins

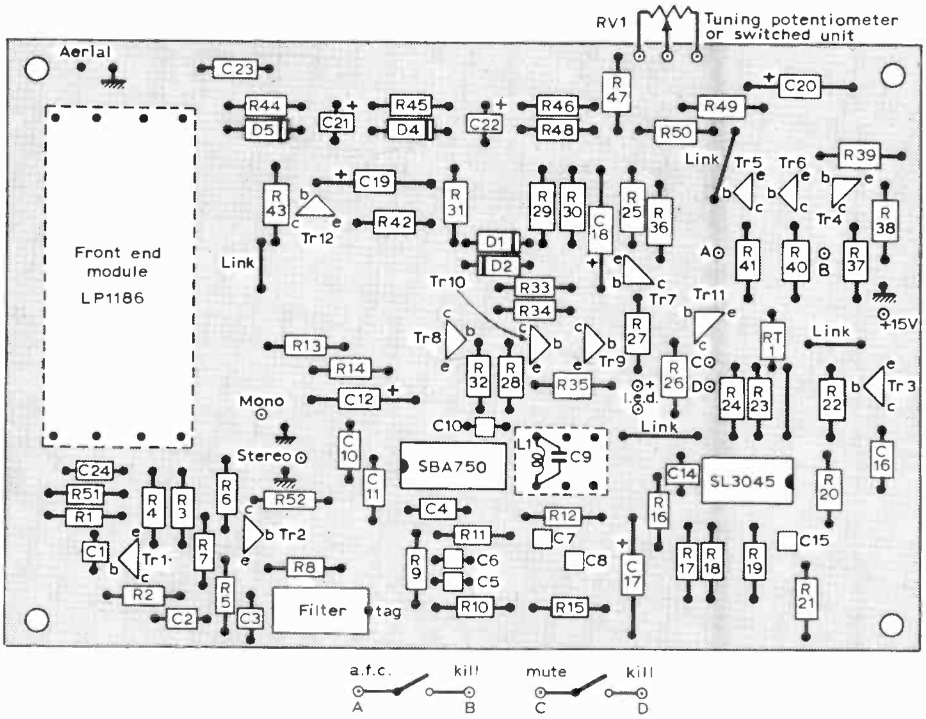


Fig. 9. Component layout for Fig. 6 is critical and p.c. board shown in Fig. 10 should be used. Points A and B connect to the a.f.c. switch and points C and D to the mute switch.

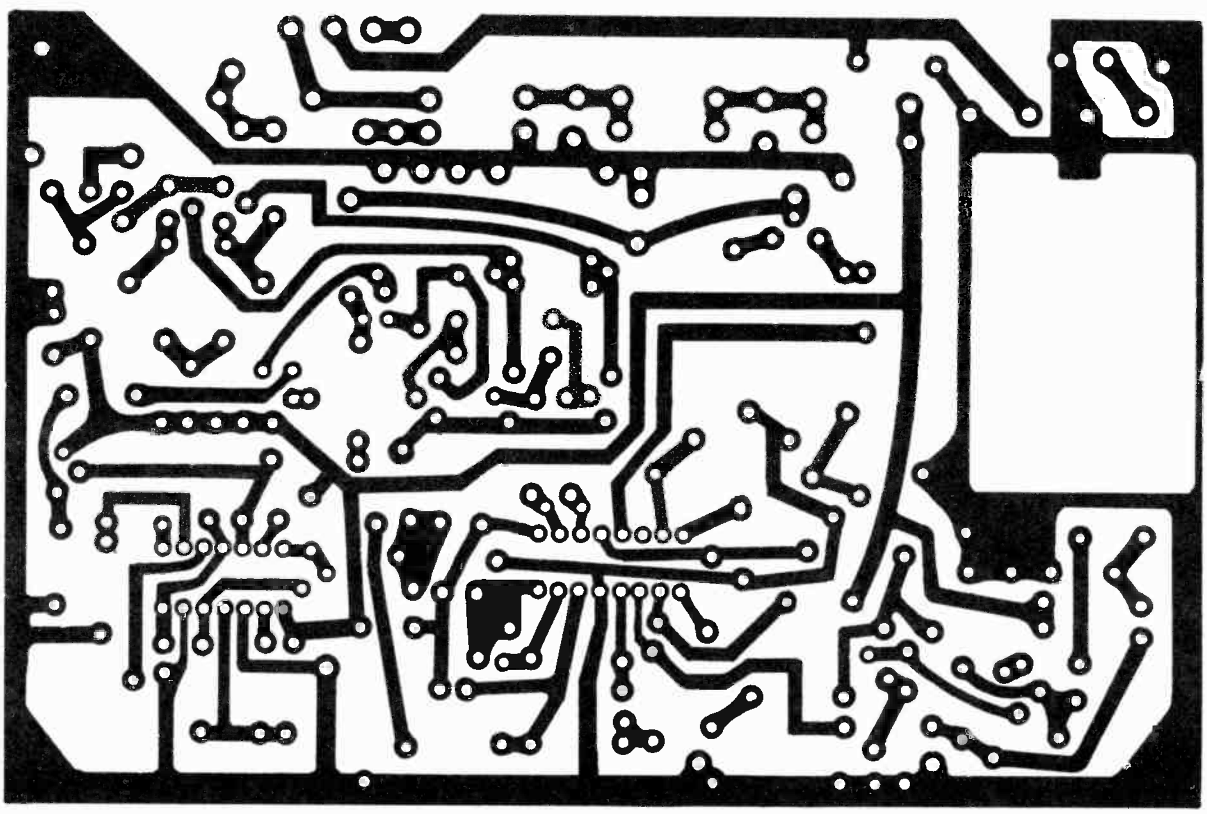


Fig. 10. Copper side of printed board, actual size. Component side shown above.

as the coil. This capacitor is slim and is easily accommodated within the can.

The emitters of the transistors are adjacent to the tag on the can. Transistors Tr_1 and Tr_2 are an exception to this. Insert so that the flat face of the plastic package is on the *opposite* side to the base of the triangle. If the centre (case) lead is bent forward towards the flat all these leads will fall into place.

Finally, solder twisted-pair wires at points A and B for the a.f.c. switch and C and D for the mute switch, together with pairs for the tuning indicator lamp (observe polarity), audio outputs and 15-volt power supplies. Mount the two boards on $\frac{1}{2}$in brass pillars at the four corners, preferably on a metal chassis to ensure good earthing and screening.

The chassis system (Fig. 12) was constructed from 16 s.w.g. aluminium sheet, a piece 11in square being required. After drilling the chassis is bent into a U-shape where shown, and the front panel fitted on $\frac{1}{2}$in brass pillars. This can be made of aluminium, sprayed and marked with Letraset. Alternatively, perspex may be used, marked in mirror image and sprayed on the reverse side. There are many ways open to home constructors these days, and the production of a professional finish is largely a matter of ingenuity and personal taste.

The front panel is made $\frac{1}{4}$in deeper than the front edge of the chassis to allow the use of rubber feet on the chassis, yet leaving a smaller clearance beneath the front panel. A false front panel has the advantage of hiding most of the screws and allowing the push buttons and meter to protrude the correct distance. It also allows space for a hidden pilot lamp to illuminate the meter. A cover made of polished wood or sprayed metal may easily be made to fit over this chassis, consisting of inverted U-shape forming the sides and top. This should be about 8 or $8\frac{1}{2}$in from front to back, depending on the front and back overhang desired, and the sides the same drop as the front panel.

The only difficulty is in mounting the ten-turn potentiometer which has a short spindle and must be brought forward $\frac{1}{4}$in from the chassis. This is achieved by cutting a clearance hole in the chassis 1-in square and mounting the potentiometer on a strip 1 × 2in held on $\frac{1}{4}$in pillars, or long srews and double nuts. The spindle will then protrude from the front panel by the correct distance.

The prototype used six push buttons for pre-selected stations mounted on a printed board with the pre-set potentiometers between them. This resulted in a compact switch unit, but the method necessitated a minor trimming of the width of the potentiometer by rubbing their faces with emery paper until a sliding fit was obtained. This board also held a drive circuit for the meter used to display the frequency. This is shown in Fig. 13, and the p.c.b. in Fig. 14. This unit may be mounted on 0.1in pitch Letrokit board and hand wired if preferred, using the p.c.b. layout as a guide.

The meter drive circuit is basically an emitter follower driven from the tuning voltage, but the addition of a Plessey SL301 matched pair as shown results in a tempera-

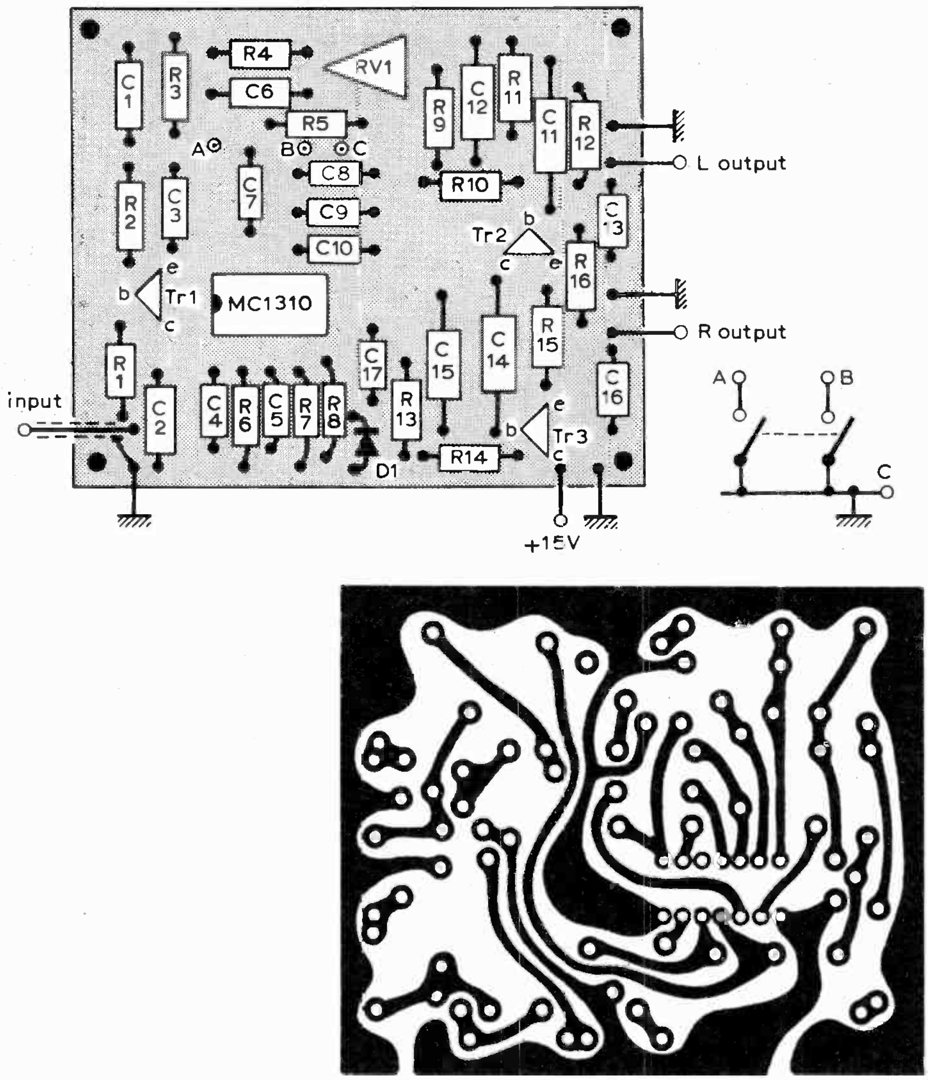
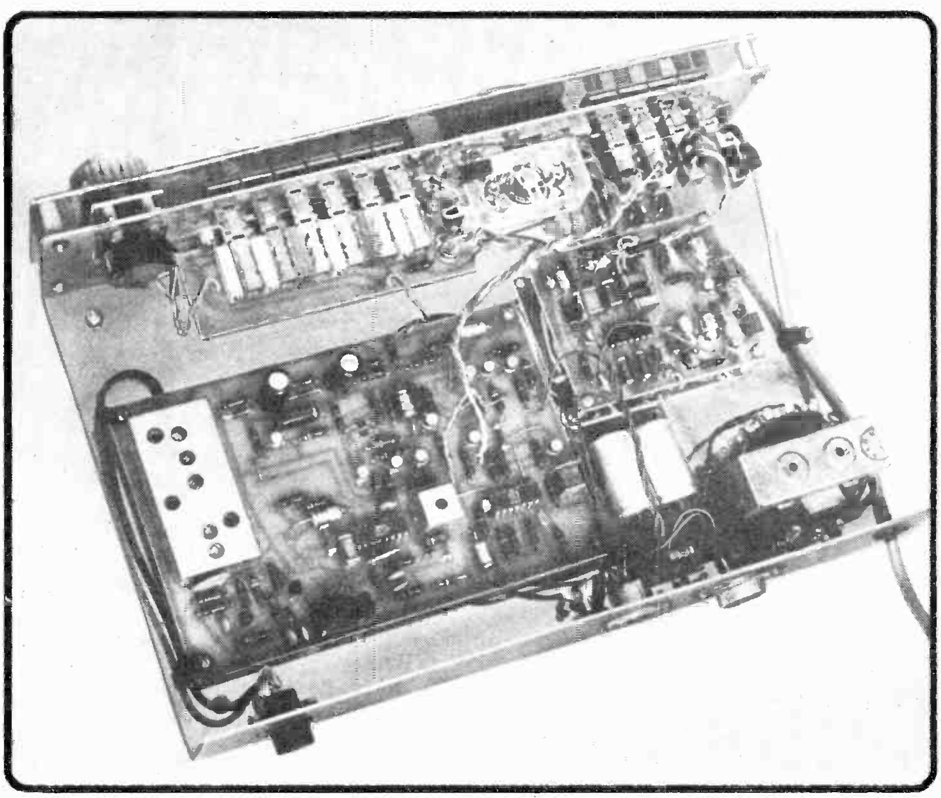
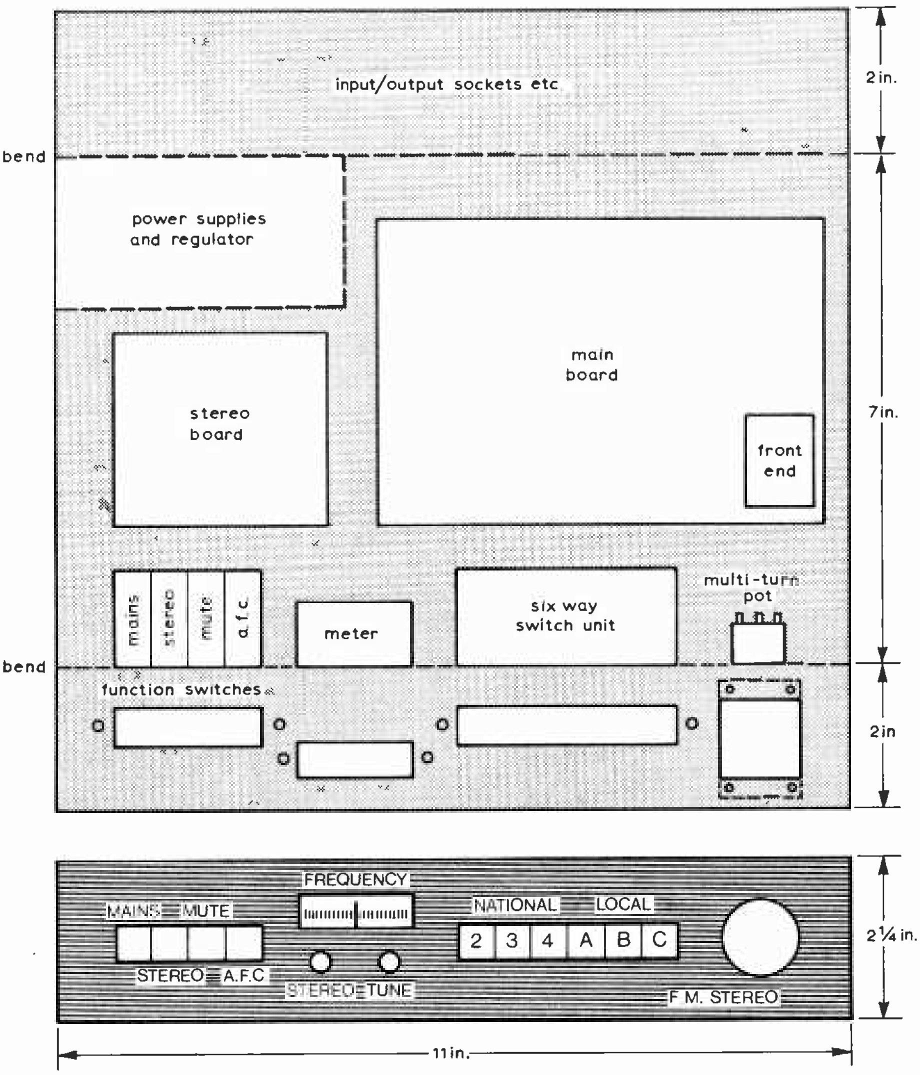


Fig. 11. Stereo decoder layout. Points A, B and C connect to mono/stereo switch shown actual size.





ture-stable law-bending circuit producing a linear frequency scale from the non-linear law of the front-end varicaps. The meter is and RS Components miniature edge meter MR42A, 25-0-25 μA. By removing the two screws the case may be removed and the scale lifted from its mounts. A wipe with acetone or nail varnish remover removes the lettering which may then be replaced with a suitable frequency scale using Letraset—or free-hand if you have a steady one! Take care to avoid damage to the pointer, and the case should be replaced to exclude dust while the scale is being redrawn. Final calibration is done by mechanical adjustment of the zero adjuster while receiving a known station.

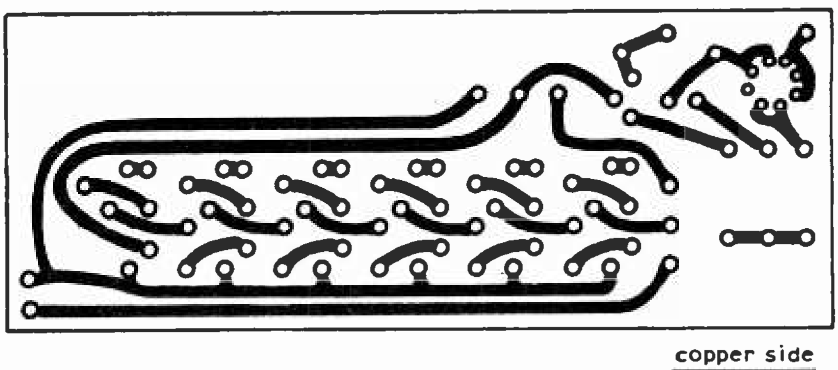
It is important that the power supply should be free of ripple and temperature stable, and this is achieved by a regulator integrated circuit RS Components MVR15V. This, together with bridge rectifier REC70, 1000 μF capacitor, and transformer (634) from the same supplier complete a stable power supply for little effort.

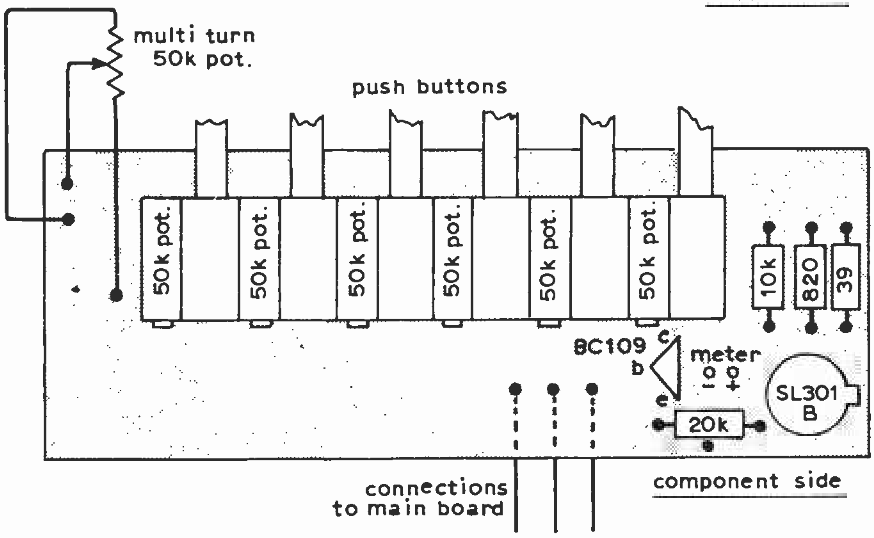
Top-grade components were used to ensure reliability and consistency of performance. It is strongly recommended that the components specified are used. There are parts of the circuit which require 2% resistors, for example, to ensure correct biasing and balance of the tuning point and a.f.c. circuitry.

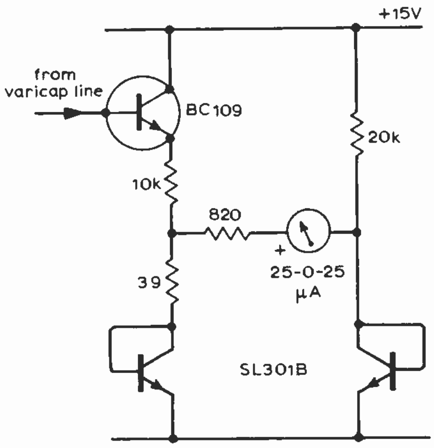
Setting up and testing

When the boards have been wired and mounted make the appropriate interconnections. Connect l.e.ds and switches and check everything before switching on. Put switches in the a.f.c.-off and mute disabled

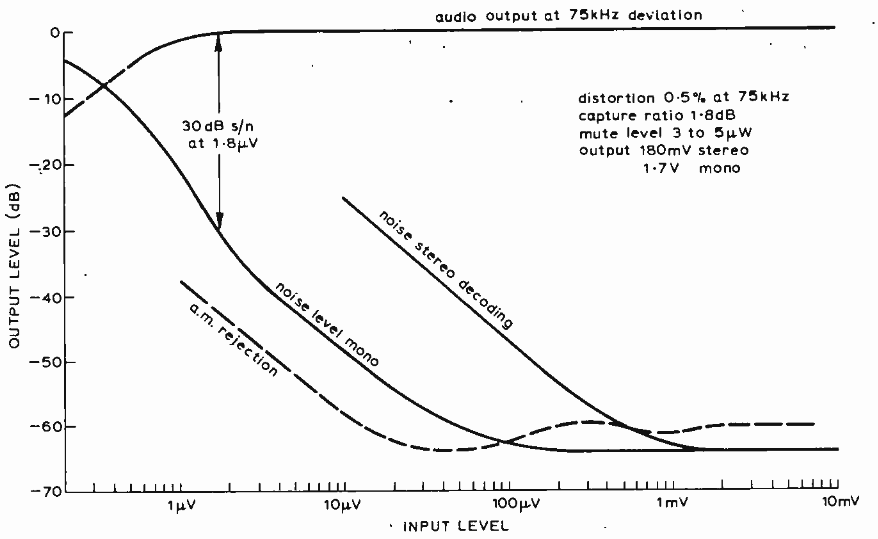
Chassis for complete receiver can be made from an 11in square 16-s.w.g. sheet of aluminium, bent into a U-shape (Fig. 12, above). Separate front panel and cover improve appearance. Drive circuit for frequency meter gives linear frequency scale, varicap non-linearity being matched by matched-pair integrated circuit (Fig. 13, below). Layout on right shows pre-set potentiometers and frequency meter components (Fig. 14).

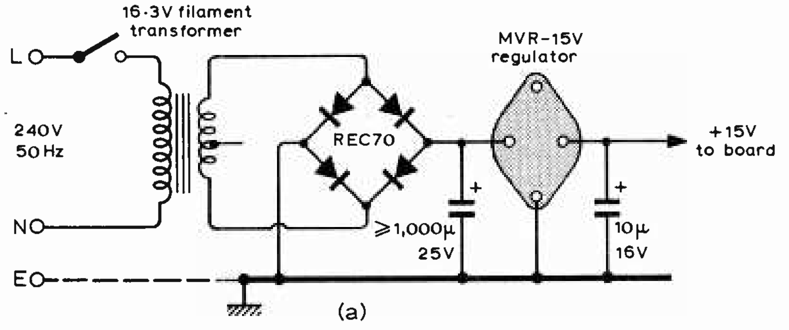


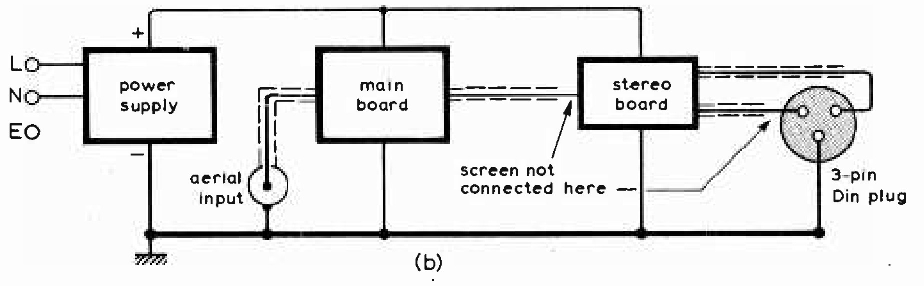




Tuner performance







Components for suitable power circuit, above, were listed in part 1.

Components (stereo decoder)	
Transistors BC109	
IC MC1310	
Diode 5082–4403 (l.e.d.)	
Resistors	
R_1	5.6kΩ
R_2	9.1kΩ
R_3, R_{11}, R_{15}	10kΩ
R_4	16kΩ
R_5	1kΩ
R_6, R_7	5.1kΩ
R_8	680Ω
R_9, R_{10}, R_{13}, R_{14}	15kΩ
R_{12}, R_{16}	470kΩ
RV_1	4.7kΩ
Capacitors	
C_1	620pF (polystyrene)
C_2	150pF (polystyrene)
C_3	1µF (polycarbonate)
C_4, C_5	10nF (polycarbonate)
C_6	470pF (polystyrene)
C_7, C_{10}	0.22µF (polycarbonate)
C_8, C_{13}, C_{16}	0.47µF (polycarbonate)
C_9	47nF (polycarbonate)
C_{11}, C_{14}	1.5nF (polystyrene)
C_{12}, C_{15}	680pF (polystyrene)
C_{17}	22nF (polycarbonate)

positions, and leave the aerial unconnected. Do not adjust the front-end module which is pre-aligned and should not be touched. Under these conditions there will be a band of noise defined by the i.f. filter passing through the limiting amplifier to the detector. If the core of the single coil is adjusted until the tuning lamp responds and be trimmed for maximum brilliance, the detector will be correctly adjusted to the centre of the i.f. pass band.

Now connect an audio amplifier and speaker. A loud smooth hiss should be heard. If the mute switch is operated this hiss should be silenced and the tuning lamp extinguished. Connect the aerial—a short length of wire may receive several stations—and, with all push-buttons out, adjust the ten-turn potentiometer to find stations. Observe a.f.c. action by mis-tuning a station until the tuning indicator is just extinguished and the output muted. Switching in the a.f.c. should recover the station.

A good aerial will now reveal anything around a dozen stations. The three least noisy should prove to be the national stations, and the frequencies of these are given in the local Radio Times. Trim the meter using the internal adjuster and obtain pre-set stations by pressing the appropriate button and adjusting the adjacent pre-set potentiometer. If this adjustment procedure cannot be achieved switch off and check all components and interconnections. Particularly check for incorrect polarity l.e.ds and capacitors, misplaced n-p-n an p-n-p transistors, capacitors omitted in coil assembly or wrong number of turns.

If the alignment of the main board is achieved set the stereo decoder. This involves adjusting the oscillator using the single pre-set potentiometer. First find a transmission known to be stereo; check with the *Radio Times*. Ensure that decoding is not disabled by the switch provided and adjust until the stereo indicator lights. Now release and pre-press the stereo switch and adjust the potentiometer until the l.e.d. lights in the shortest possible time after the switch is pressed. This is the correct setting.

Finally, a word about aerials. This tuner will receive stations on a few feet of wire, but if the full potential and maximum signal-to-noise ratio is to be obtained, a good aerial is essential. Any system can only be as good as its signal source, be it a pick-up cartridge, tape head or radio aerial, and this can easily be the weakest link in the chain.

Tuner kit. A kit of parts will be available for this tuner from Icon Design at 33 Restrop View, Purton, Wilts SN5 9DG. See advertisement on page 40 for details.

Modification. A resistor (R_{53}) of 2kΩ should be added in place of the wire link shown just below R_{43} in Fig.9. Because Motorola have altered the specification for the MC1310, a 150-Ω resistor should be added in the supply line to the decoder board, returning the l.e.d. current directly to the +15V rail. Increase C_{17} to 20µF to decouple this.

An introduction to digital counters

—to accompany series 14 of Circards

by J. Carruthers, J. H. Evans, J. Kinsler & P. Williams

Paisley College of Technology

A digital counter comprises an interconnection of bistable or two-state memory circuits or, colloquially, flip-flops. The counter embraces those circuits which accumulate pulses according to a specific code as they appear at the input, frequency dividers, sequence generators and pulse waveform generators. The application requirement will generally determine how the collection of flip-flops is identified, but in this article the generic name of counter will be used.

The basic flip-flop has one or two control inputs, and two outputs termed Q and $\bar{Q}$ (not -Q), where $\bar{Q}$ represents the opposite state of Q. The logic state of these outputs may be termed set or reset, high or low, 1 or 0, and the change of state may occur on 0 to 1 or 1 to 0 transitions at the input, depending on the type used. The varieties of flip-flops used in counters are normally described by the control inputs and are termed D-type, T-type, RS and JK. The triggering input, called the clock-pulse input, ensures that a change of state will only take place on the occurrence of a pulse at the clock-input. Other facilities that may be available are preset and clear inputs which allow a flip-flop to be set (Q = 1) or reset (Q = 0), independently of the control inputs. Typical symbols for these flip-flops are shown in Fig. 1. Other variations include operation by positive or negative logic, triggering on positive or negative pulse edges or a combination of these as in master-slave flip-flops.

A basic RS flip-flop using NAND gates is shown in Fig. 2. To represent the dependence of the Q output on the control inputs when a clock pulse occurs, a truth-table is used to demonstrate the state of Q at the *n*th clock pulse (Q_n), and after the next clock pulse (Q_{n+1})—Fig. 3. For example, if S and R are both at logic zero when a clock pulse occurs, the output Q will not change state, but remain as it was before the clock pulse. However, if S = 1, R = 0, then Q becomes logic 1, i.e. if it was previously logic 0 a change of state occurs, and if it was logic 1, it remains so.

The indeterminate state of Q for the condition that R = S = 1 exists because of a race condition between gates and is one disadvantage of this flip-flop—such a condition must be avoided. The JK flip-flop, however, does not have this disadvantage—all output conditions are predictable, as shown in Fig. 4. The last combination of J = K = 1 permits a useful toggle action in which the output changes state on the occurrence of every clock pulse.

Counters are generally classified as asynchronous or synchronous. The basic asynchronous circuit is implemented with cascaded toggle flip-flops, where the output of a previous flip-flop is the clock-input for the next in sequence. Alternatively, the drive inputs may come from Boolean combinations of other outputs. In either case, a disadvantage is that each flip-flop changes state at a different time in a sequence. For each flip-flop a propagation delay exists between the occurrence of a trigger pulse and the next state of the output, and this delay "ripples-through" the counter. This restricts the maximum operational speed of the counter, since the maximum ripple-through delay must be less than the time between input pulses.

In integrated circuit technology, these counters have the advantage that each flip-flop operates at half the frequency of the preceding one. This allows a trade-off in high-speed (high-power dissipation) circuits to be used in the first stage, with lower speed (low-power) configurations being used in later stages. The maximum count (including zero) of a counter containing *n* flip-flops is 2^n, feedforward or feedback techniques allowing counts less than this to be achieved. The number of distinguishable states through which the counter cycles is known as the modulus of the counter, and this may be fixed when implemented with individual flip-flops, but some m.s.i. packages are available that permit variation of the modulus by a simple connection or change or simple gating. If the outputs of ripple-counters are to be

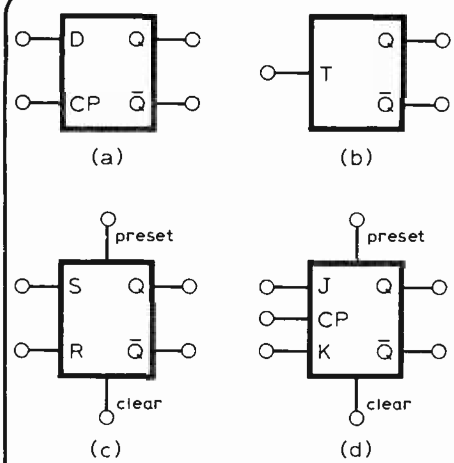


Fig. 1. Four basic types of flip-flop.

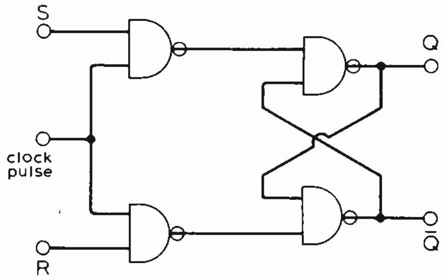


Fig. 2. Nand-gate RS flip-flop.

S	R	Q_{n+1}
0	0	Q_n
1	0	1
0	1	0
1	1	undefined

Fig. 3. Truth table for Fig. 2.

J	K	Q_{n+1}
0	0	Q_n
1	0	1
0	1	0
1	1	$\bar{Q}_n$

Fig. 4. Truth table for JK flip-flop.

decoded, care must be taken to ensure that the decoder network is enabled only when it is certain that all intermediate state changes have occurred.

The disadvantage of the asynchronous counter is avoided by the synchronous or parallel counter, in which all flip-flops change state in synchronism with a common clock-pulse. The speed of operation is limited by one flip-flop delay and that of any gating necessary, and these will depend on the type of hardware being used, e.g. c.m.o.s., t.t.l., e.c.l. Recent Schottky synchronous counter packages have internal circuitry which eliminates all external gating, and counting speeds up to 70MHz are claimed, and e.c.l. packages are available for speeds up to 110MHz.

Any sequence may be generated using individual JK flip-flops and associated gating. The design is more complicated than the asynchronous types, but one technique simplifies the design problem using Karnaugh maps.[1]

The map is a two-dimensional representation of all possible combinations of a number of variables, where each square is one unique combination and adjacent squares are identical except for one variable. The rows and columns are arranged in accordance with the Gray code representation of decimal numbers, in which only one bit changes as we progress through adjacent numbers (Fig. 5). A Karnaugh map for four variables, A, B, C and D, is shown in Fig. 6, where a 1 in a square means the existence of logical "ANDed" variables, identified by the row and column common to that square.

The 1 squares are connected by the logical OR function, and the Boolean expression represented by Fig. 6 is $F = \overline{A}.B.\overline{C}.D + A.B.\overline{C}.D + \overline{A}.B.C.D + A.B.C.D$. A 0 in a square indicates that this particular combination does not exist. The advantage of the map is that minimization of the Boolean expression is simplified by being able to group adjacent squares in pairs, fours, etc. Two squares can be combined to eliminate one variable, and these two squares can be combined with another two adjacent squares to eliminate one more variable. The four squares may be looped as shown, because of their adjacency, thus A and C become redundant as both states of each are included in these squares reducing the function to $F = B.D$. This can be confirmed by a Boolean minimization. Note that adjacency of squares exists at the extreme ends of horizontal rows, and at the extreme ends of vertical columns.

A design of a modulo-6 Johnson counter is considered as an example of the technique. The maximum modulus of an m-stage Johnson counter is $2m$, hence a minimum of three flip-flops is required. It is assumed that the outputs are taken from the Q output of the flip-flops designated A, B and C, and the map is used to minimize the gating necessary to obtain the prescribed sequence Fig. 8. As all possible combinations of the variables are not used, the "can't happen" or redundant states are denoted by a combination of one and zero (①) in the state table (Fig. 9) because the states are not specified and may be made 1 or 0 at will. In this case they will be considered as 1s. The state table shows the desired outputs at A, B and C on the occurrence of the numbered clock pulse, where 0 and 6 are equivalent, i.e. the 6th pulse resets the counter to zero. It will be assumed that the counter commences from the zero state.

The design technique requires the preparation of a Karnaugh map for the J and K input of each flip-flop to determine the control levels required at each input for every step of the sequence, by deriving a minimal Boolean expression for each map, though as these are derived independently the circuit may not necessarily be minimal. This then determines the internal gating required.

An excitation table for the JK flip-flop is derived from the JK truth-table shown earlier. This table (Fig. 7) shows the necessary J and K inputs to either hold the flip-flop in a 1 condition or a 0 condition, or to cause a 1 to 0 or 0 to 1 transition, all on the occurrence of an input clock-pulse. The X indicates that it does not matter what that particular J or K state is, provided the other control input is in the correct state.

For example, if it is assumed that $Q = 1$, and a transition to logic 0 is required on the occurrence of a clock-pulse, then from the truth-table either

DECIMAL	GRAY-CODE A	B	C	D
0	0	0	0	0
1	0	0	0	1
2	0	0	1	1
3	0	0	1	0
4	0	1	1	0
5	0	1	1	1
6	0	1	0	1
7	0	1	0	0

Fig. 5. Gray code for decimal numbers.

CD \ AB	00	01	11	10
00				
01		1	1	
11		1	1	
10				

Fig. 6. Karnaugh map for four variables.

Q_n	Q_{n+1}	J	K
0	0	0	X
0	1	1	X
1	0	X	1
1	1	X	0

Fig. 7. Excitation table for JK flip-flop.

C	B	A	input pulse no.1
0	0	0	0
0	0	1	1
0	1	1	2
1	1	1	3
1	1	0	4
1	0	0	5
0	0	0	6

Fig. 8. Johnson counter sequence.

C \ AB	00	01	11	10
0	0	①	2	1
1	5	4	3	①

Fig. 9. State table for Fig. 8.

C \ AB	00	01	11	10
0	1	①	X	X
1	0	0	X	①

$J_A = \overline{C}$

C \ AB	00	01	11	10
0	X	①	0	0
1	X	X	1	①

$K_A = C$

C \ AB	00	01	11	10
0	0	①	X	1
1	0	X	X	①

$J_B = A$

C \ AB	00	01	11	10
0	X	①	0	X
1	X	1	0	①

$K_B = \overline{A}$

C \ AB	00	01	11	10
0	0	①	1	0
1	X	X	X	①

$J_C = B$

C \ AB	00	01	11	10
0	X	①	X	X
1	1	0	0	①

$K_C = \overline{B}$

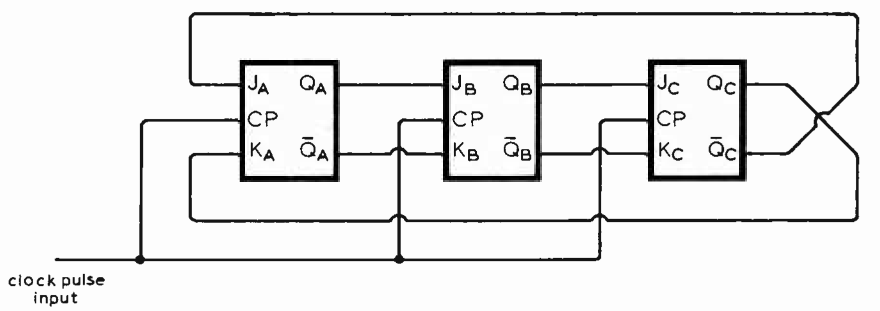


Fig. 11. Implementation of modulo-6 Johnson ring counter.

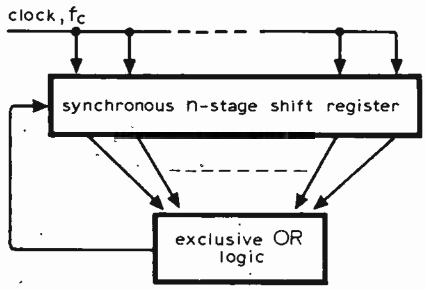


Fig. 12. M-sequence generator using exclusive-OR gates.

J = 0, K = 1, or J = 1, K = 1 will cause this change, i.e. provided K = 1, J may be either 0 or 1. As each input pulse occurs, the flip-flops should change in accordance with the truth-table of Fig. 8. The steps involved in filling the JK maps are as follows.

The can't-happen conditions of the state-table are transferred to equivalent squares on the separate J and K maps. Consider the J_A and K_A maps. On the occurrence of the first pulse, Q_A should hold at logic 1, hence an X is put in the J_A map square representing pulse no. 1, and a 0 in the K_A map square. This is repeated for pulse no. 2. At pulse no. 3 a 1 to 0 transition is required, hence an X is put in J_A map square for pulse no. 3, and a 1 in K_A map. A 0 is maintained for pulse no. 4, hence a O in J_A and X in the K_A square for pulse no. 4 is necessary. This is continued until all squares for each map are filled.

As an example of the minimization, notice that symbols ⓪ or X may be 1, hence a loop of four adjacent squares is available in the J_A map, i.e. the minimal solution for J_A is given by $\bar{C}$. Similar loops of four are obtained for each of the other maps, the circuit being implemented in Fig. 11. No external gates are required in this circuit, because the complemented outputs are already available from each flip-flop.

Common arrangements using this technique are b.c.d. counters, decade counters, up-down counters, though some are also available in m.s.i. packages.

The implementation of Fig. 11 has been described as a modulo-6 Johnson ring counter. However, examination of Fig. 8 shows that each output Q_A, Q_B and Q_C has one pulse for every six of the input so that the device could be regarded as a divide-by-six frequency divider. Most frequency dividers, on the other hand, allow one to divide by an arbitrary number so it cannot be regarded as a very good frequency divider.

The device of Fig. 11 can also be regarded as a sequence generator, in that, given an input pulse sequence, one obtains a different output pulse sequence—admittedly not a very interesting one.

There is an infinite number of sequence generators that one could build but of particular interest are those which produce so-called maximal length binary sequences (M-sequences). Used in many areas, such as data communication system identification and correlation methods, M-sequences are generated by synthronous shift registers with feedback from various stages being used to determine the next state to be fed in. Feedback complexity is not proportional to the register length and very long sequences can be generated by very simple feedback arrangements. Feedback is performed by modulo-2 addition, i.e. via exclusive-OR gates (Fig. 12).

The properties of these sequences depend on the clock rate, f_c, and on the number of stages in the shift register, n, but all of the sequences possess to some degree properties close to those of band-limited white noise. (Hence the name pseudo-random binary sequences or p.r.b.s.) The signal bandwidth is given approximately by $f_c/3$ and the greater the value of n the more closely do the properties resemble those of random noise. The sequences are not in fact random because they are binary in nature and because they are cyclic, the cycle length being 2^n-1 clock periods. The binary nature of the signals is easily removed by passing them through simple first- or second-order filters so that the signal becomes continuous and has a probability density function which is close to Gaussian. The cyclic nature of the signal is in fact one of the advantages of M-sequence and is one of the non-random features one would wish to retain. This is because experiments can be repeated for checking purposes over a cycle length without the statistical difficulties of genuine random noise. From this point of view it is therefore desirable to limit n.

Design is greatly facilitated by tables which indicate what feedback paths are necessary to produce an M-sequence of given length.[2] The problem comes down to one of choice of f_c and of n for the particular application in mind.

References

1. Dean, K. J., "Design of bidirectional coherent counters". *Proc. IEE,* vol. 113, 1966, pp. 1751–54.
2. Davies, W. D. T., "Generation and properties of M-sequences", *Control,* June, July and August 1966.

Titles or cards in series 14 are:

Basic binary counters
One out of *n* ring counter
Johnson counters
Reversible counters
Reversible Johnson counter
Divide by *n* counters
High-power counters
High-speed counters
Low-power counters
Decade counters
M-sequence generators
Glossary: flip-flops and b.c.d. codes

Horn loudspeaker design—2

Continuing the development of design theories and techniques

by J. Dinsdale, M.A., M.Sc.

Cranfield Unit for Precision Engineering

The previous sections have outlined the physical principles underlying the operation of horns, and have shown how, provided certain basic rules are followed, sound reproduction of startling clarity and realism is possible from horns. However, it will also be clear by now that, unless one is prepared to accept extremely large and costly structures, it is all too easy to lose many of the potential qualities of horns through attempts to reduce the size to more acceptable proportions. This section now considers the procedures to be adopted in designing a domestic horn enclosure.

It has already been stated that the horn behaves as a transformer, converting acoustic energy at high pressure and low velocity at the throat to energy at low pressure and high velocity at the mouth. As with the analogous electrical transformer in which electrical voltage and current correspond to acoustical pressure and velocity, the basic requirements of the acoustical horn are that: (a) the primary (throat) should be correctly matched to the signal source (loudspeaker motor); (b) the secondary (mouth) should be correctly matched to the load (listening room); (c) the horn should be designed to handle the specified power level and frequency range. There are four principal parameters of the horn, namely mouth area, throat area, flare contour, and axial length. Any three of these will determine the fourth, and hence the characteristics of the horn itself. Once non-circular cross-section and non-linear axes are adopted, the problem becomes far more complex, and mathematical and physical concepts are no longer sufficient to design a horn. Nevertheless, the basic characteristics even of folded horns are determined to a large extent by known acoustic principles, and the most effective method of design is to work from these principles, ensuring that any deviation from theory is made on scientific grounds where possible.

Flare profile

Previous sections discussed the most commonly considered flare profiles, and it was concluded that a contour which allowed an exponential increase of the area of the wavefront as it travelled from throat to mouth provided the best compromise between the extremely gradual expansion of the hyperbola (giving optimum loading of the motor, but excessive throat distortion) and the rapid expansion of parabolic and conical horns (giving minimum throat distortion but poor loading of the motor). However, the exact shape of the wavefront within a horn of curved profile is uncertain, and therefore assumptions have to be made, ranging from Wilson's modified exponential (lying a little inside the true exponential) to Voigt's tractrix, (which commences in a virtually identical manner to the true exponential, but departs substantially outside it in the region of the mouth). Which contour one adopts must be largely a matter of personal preference based preferably on careful listening experience.

Mouth geometry

The mouth of the horn couples the horn itself to the listening room. One of the commonly raised disadvantages of horns is that they require a very large mouth area if bass notes are to be properly reproduced. To some extent this is true; one cannot get a double bass out of a piccolo. However, there are a number of ways in which the mouth area may be reduced to manageable proportions without significantly sacrificing bass response.

As a sound wavefront travels up the steadily increasing bore of the horn, it should not meet any major discontinuity. However, it is clear that, unless the length and mouth diameter of the horn are infinite, there must be some discontinuity as the wavefront emerges and is no longer constrained by the walls of the horn. Although the cut-off frequency of the exponential horn is determined by the flare constant, the linearity with frequency of the acoustical resistance and reactance are determined by the mouth area, which, for a given throat area and flare constant will also determine the overall length of the horn. Strictly speaking, for no discontinuity, the mouth should have infinite area. However, Olson[3] has shown that provided the perimeter of the mouth of an exponential horn is greater than four times the cut-off wavelength,

i.e. $p_m > 4\lambda_c$

there will be no significant deviation of mouth resistance from that of the infinite horn.

A more important result is that for only 6dB variation in acoustic resistance, the mouth perimeter may be made equal to the cut-off wavelength, i.e. mouth area = $\lambda_c^2/4\pi$ where λ_c is the cut-off wavelength. As the mouth area is reduced below this value, the non-linearity of the acoustical resistance and reactance will increase.

Now these figures refer to the situation where the horn is suspended in free space, i.e. it radiates into an angle of 4π solid radians. In practice, this situation never occurs: even if the horn were placed on the ground at the centre of an infinite field, the mouth would only radiate into half a solid angle, or 2π solid radians; against the centre of a wall the mouth would be loaded by π solid radians, and in a corner formed by two walls and the floor the mouth will be loaded by only $\pi/2$ solid radians. The significance of this is that, whereas the minimum mouth area for a circular horn has been shown to be $\lambda_c^2/4\pi$ when loaded by 4π solid radians, *this value may be divided by a factor of two each time the solid angle is halved.* Thus the mouth area may be reduced to a size more in keeping with domestic conditions, e.g. a horn with a cut-off frequency of 56Hz (wavelength 20ft) would require a mouth area of 32 sq ft in space, but only 8 sq ft against a wall and 4 sq ft in a corner position, to give variations in loading of less than 6dB.

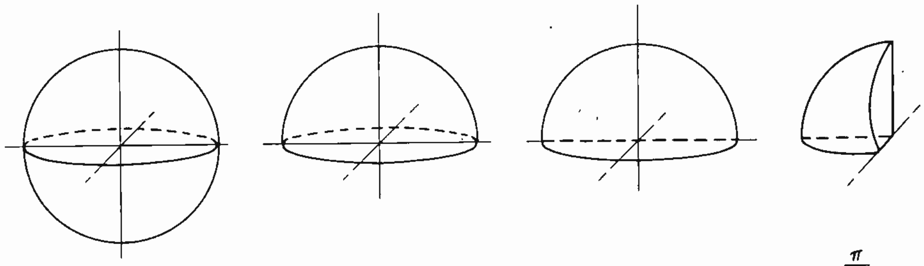


Fig. 8. Solid angles presented to a horn in different positions.

This situation which is illustrated in Fig. 8 may be compared with the mouth of a single horn placed at the intersection of eight rooms: four on the ground floor and four on the first floor. The bass response of the original horn will not be impaired, even though a listener in each room will see only one eighth of the total mouth area. One seldom gets anything for nothing in this world, and those who adopt corner speaker positioning in order to obtain a purer extended bass response from as small an enclosure as possible, may have to live with the eigentones such a position produces.

A plan view of a corner horn shows that the room itself provides a natural extension of the horn mouth. Many listeners have observed that corner horns can provide bass notes from fore-shortened horns, well below the limit dictated by the mouth area[25]. It is tempting to reduce the mouth area still further below the 3dB limit established earlier and rely instead on the corner placement itself to supply the additional mouth area and horn length. In the author's experience, this technique cannot be justified because although the bass response is undoubtedly there, careful listening reveals an uneven response over the first two octaves above the cut-off frequency which will often detract from the realism offered by the horn. It is therefore recommended that in cases where overall enclosure size is a limitation, a correctly-designed horn with a cut-off frequency of (say) 80Hz will give a more satisfying and linear response than a fore-shortened horn whose expansion constant has been set to 40Hz but whose length has been limited to give a mouth area corresponding to 80Hz.

Most domestic horns will be of rectangular cross-section for ease and cheapness of manufacture. The foregoing comments regarding horns of circular section apply also to rectangular sections, although it is clear that the wavefront must behave in a most complex way at the corners, thereby reducing slightly the effective cross-sectional area. Provided that the ratio between the major and minor axes at the mouth does not exceed 4:3, rectangular horns may be employed to good effect.

Tabular design data is given for horns of both round and square section, with mouth areas computed for both corner positioning ($\pi/2$ solid radians) and wall positioning (π solid radians).

Throat geometry

The throat of the horn couples the wavefronts from the loudspeaker, which should ideally be plane at this point, to the horn itself. It has previously been shown that the horn is an acoustic transformer, converting acoustic radiation of high pressure/low velocity at the throat to low pressure/high velocity at the mouth. It is clearly of advantage to have a high pressure (and hence a low velocity) at the throat, because the low velocity will result in smaller movement of the loudspeaker cone, thus reducing the distortion produced by non-linearities in the magnetic field and the suspension. One way of increasing the pressure, and also of ensuring a higher degree of "plane-ness" of the wavefronts is to employ a throat area substantially smaller than that of the loudspeaker itself. Tests carried out on a number of loudspeakers have shown that the "equivalent piston area" is approximately 70% of the speech cone area, i.e. the loudspeaker diaphragm in the shape of a truncated cone gives the same acoustic output as a plane piston with 70% of its area.

There are a number of practical reasons why modern loudspeakers are not manufactured as plane pistons; one of the unfortunate results of employing conical diaphragms is that the resulting wavefronts are in general not planar. However it has been found empirically that a throat area of between one quarter and one half the "equivalent piston area" of the loudspeaker provides satisfactory coupling between the loudspeaker and the horn, and also gives an approximation to plane wavefronts at wavelengths well in excess of the throat dimensions. It must be emphasized that for higher frequencies, where the wavelengths are of the same order as the physical dimensions of the loudspeaker diaphragm, the throat area should be made the same as that of the loudspeaker, and the horn should be of circular section, at least at the throat, so as to minimize standing waves across the horn itself.

The phenomenon of air overload distortion is caused by the non-linear relationship between pressure and volume of the air in the throat of the horn as it undergoes adiabatic compression and expansion. Beranek[4] has derived the relationship for 2nd harmonic distortion at the throat of an infinite exponential horn as:

$$\%\ \text{2nd harmonic distortion} = 1.73(f/f_c)I_t \times 10^{-2}$$

where f = driving frequency f_c = cut-off frequency I_t = intensity (watts/sq in) at the throat.

This expression is also closely correct for finite horns because most of the distortion occurs near the throat. This expression has been plotted in Fig. 9 from which the throat area for given power and distortion may be obtained.

It is important to appreciate that the *acoustic* power radiated by musical instruments is extremely small[26], and that the higher the frequency the lower is the acoustic power to give the same subjective effect at the human ear. With the exception of full orchestra and pipe organ, which in the author's view it is futile to attempt to reproduce in domestic surroundings at anything approaching normal volume level, the acoustic power levels are extremely small, and an aim-point of (say) 3 watts and 1% distortion at the cut-off frequency, reducing to 0.05 watts and 0.5% distortion at four times the cut-off frequency, is likely to prove entirely satisfactory for domestic listening[27].

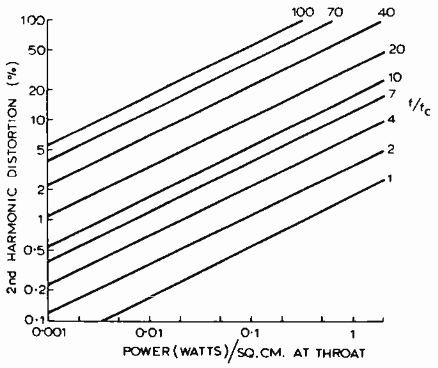


Fig. 9. Distortion caused by air overload at the throat.

The above proposals for power and distortion give a throat area of around 10 sq cm, from Fig. 9, which compares not unfavourably with the effective piston area of 43 sq cm for a $3\frac{1}{2}$in loudspeaker, one quarter of which is a little over 10 sq cm. Of course, if the throat area is increased, as would be the case with larger loudspeakers, the available power for a given level of distortion will also increase.

Having established the throat and mouth areas and the flare profile, the length of the horn and hence its area at any point may be obtained mathematically or graphically.

The horn as a filter

The foregoing sections have indicated how the horn can act as a bandpass filter— the lower pass frequency of which is determined by the expansion coefficient and the upper by the volume of the cavity between the loudspeaker and the throat of the horn. It is important that the response should be as linear and free from distortion as possible over this passband, and as far as the lower frequencies are concerned, careful choice of mouth area, in conjunction with a knowledge of the solid angle into which the horn will radiate and the flare constant, can ensure that non-linearities in the frequency response are kept to a satisfactorily low level.

However, with regard to higher frequencies, non-linearities of increasing amplitude become apparent at frequencies exceeding about four times the cut-off frequency, due to internal cross-reflections and standing waves set up within the horn itself. These non-linearities will be more serious if the material of which the horn is constructed can resonate, and they are also accentuated if the horn is folded, when wavefronts at the higher frequencies will be distorted at bends. In fact, there is also a practical limit beyond which folding becomes undesirable: folding should not occur beyond the point at which the lowest wavelength (highest frequency) to be transmitted exceeds 0.6 of the diameter of the horn. More will be said of this limitation during the discussion on folding, but it clearly points to a practical limit on the highest frequency a horn may accurately transmit.

Yet a further limitation becomes apparent from the graph of throat distortion versus frequency (Fig. 9). As the frequency increases, the percentage distortion for a given power density at the throat will also increase, and although it is generally true that in the majority of complex musical sounds the energy level reduces with increasing frequency there will still be a frequency above which throat distortion becomes unacceptable.

A commonly used and quite adequate rule of thumb is that a horn should not handle frequencies higher than four octaves above its cut-off frequency, although purists may prefer to limit at only three octaves in order to ensure lower distortion levels.

The complete multi-horn system

The maximum frequency range to be handled by a wide-range high-quality loudspeaker is about 9 octaves, i.e. 40Hz to 20kHz. This is clearly too wide a range to be handled by a single horn, for the reasons already noted, but it can conveniently be divided into three ranges, i.e. 40Hz to 320Hz, 320Hz to 2.5kHz and 2.5kHz to 20kHz. In practice, a 10% overlap should be allowed to ensure that there are no troughs in the response at the crossover points, and a case could be made for a four-horn system to cover a wider range.

It is worth considering a more modest instrument. If the cut-off frequency is limited from 80Hz to 18kHz and a two-horn system is considered with each horn handling a little under four octaves, the frequency ranges become 80Hz to 1.2kHz and 1.2kHz to 18kHz. Again, about 10% frequency overlap should be allowed.

The great attraction of a two-horn system is that only a single loudspeaker is required: the bass horn will be loaded from the rear of the loudspeaker; while the middle and treble horns will be loaded from the front of the loudspeaker, to eliminate interference and diffraction effects caused by the frame and magnet assembly at lower wavelengths. It has already been emphasized that the throat of the horn should match exactly the loudspeaker dimensions at these higher frequencies, and this arrangement is particularly attractive if a twin-cone speaker is employed. Treble wavefronts may be prevented from going down the bass horn by the cavity. To show the ease and utility of this approach, this article will include the design of a "mini-horn" utilising both sides of a single loudspeaker in a cabinet of reasonable size and cost for small domestic living rooms.

Purists may claim that the curtailed frequency range of 80Hz to 18kHz is inadequate. It is however the author's experience that the flat relatively distortionless response between these limits, together with the sense of presence afforded by the horn's transformer action, make the mini-horn sound more attractive than many commercial loudspeaker systems of similar size but two or three times its price.

Once one adopts a multi-horn approach, there will be a number of frequencies which fall within the compass of two horns, i.e. 320Hz and 2.5kHz in the case of the three-horn system, and 1.2kHz for the two-horn system. It is essential that the radiation from the relevant pair of horns should be reasonably in phase at the crossover frequency, to avoid the presence of troughs in the frequency response, because the bass horn will be folded to bring its mouth adjacent to the other horns (it is not normally necessary or desirable to fold the middle and treble horns). This requirement places a restriction on the length of the horn, which has until now been regarded as a parameter to be determined solely by the throat and mouth diameters and the flare constant, and it is now apparent that the length of the lower horn of each pair should be either an odd or even number of half wavelengths of the crossover frequency, depending on whether the radiation wavefronts at the throats of the two horns are respectively in or out of phase.

Thus, if separate loudspeakers are used and the voice coils are connected in phase, the combined length of the horns from the loudspeakers to the plane of the mouths should be an even number of half wavelengths. Conversely, if a single loudspeaker is used to feed two horns, the radiation from the front and rear of the cone will be out of phase and the combined length of the two horns should be an odd number of half wavelengths. In practice, the lower horn will be considerably longer than the upper, and will effectively determine the design.

Folding, cabinets and room placing

Hitherto, discussion has been confined to ideal horns, of circular cross-section and straight axis, constructed of very stiff material. Although typical dimensions for practical horns have not been calculated formally, it will be clear from many of the tables and diagrams that the dimensions of bass horns are almost certainly too large for comfortable accommodation in an average living room. Two further points must therefore be added to the design procedure, adoption of rectangular sections and folding the horn into a compact size.

Rayleigh showed that bends in tubes of constant cross-section will have no effect on transmitted sounds if the wavelength is large compared with the diameter, but that any cross vibrations set up will have a fundamental wavelength of 1.7 times the tube diameter. Wilson[11] has summarized the three principal rules of folding horns as follows: the wavefronts must not be twisted across the horn; the horn diameter (or width if rectangular) must be less than 0.6 times the lowest wavelength to be transmitted by that horn; the wavefront should be accelerated round bends to preserve its form.

As soon as one departs from the straight horn of circular cross-section, the scientific design principles described cease to be so relevant and become of more approximate value, although the three basic rules quoted above, together with the choice of a suitably stiff material for construction, provide very acceptable results.

A folding technique which twists the wavefront across the horn is difficult to achieve in practice, and may be eliminated by folding always in one plane. The requirement to "accelerate the wavefront around bends to preserve its form" is difficult to achieve when more than one fold is involved, since it requires a rectangular cross-section before the bend to become trapezoidal around the bend itself[11], and then revert to a different rectangular section after the bend. If one considers a multi-fold horn, concertina-fashion within an overall rectangular enclosure, this is not really a practical proposition, and is unnecessary because

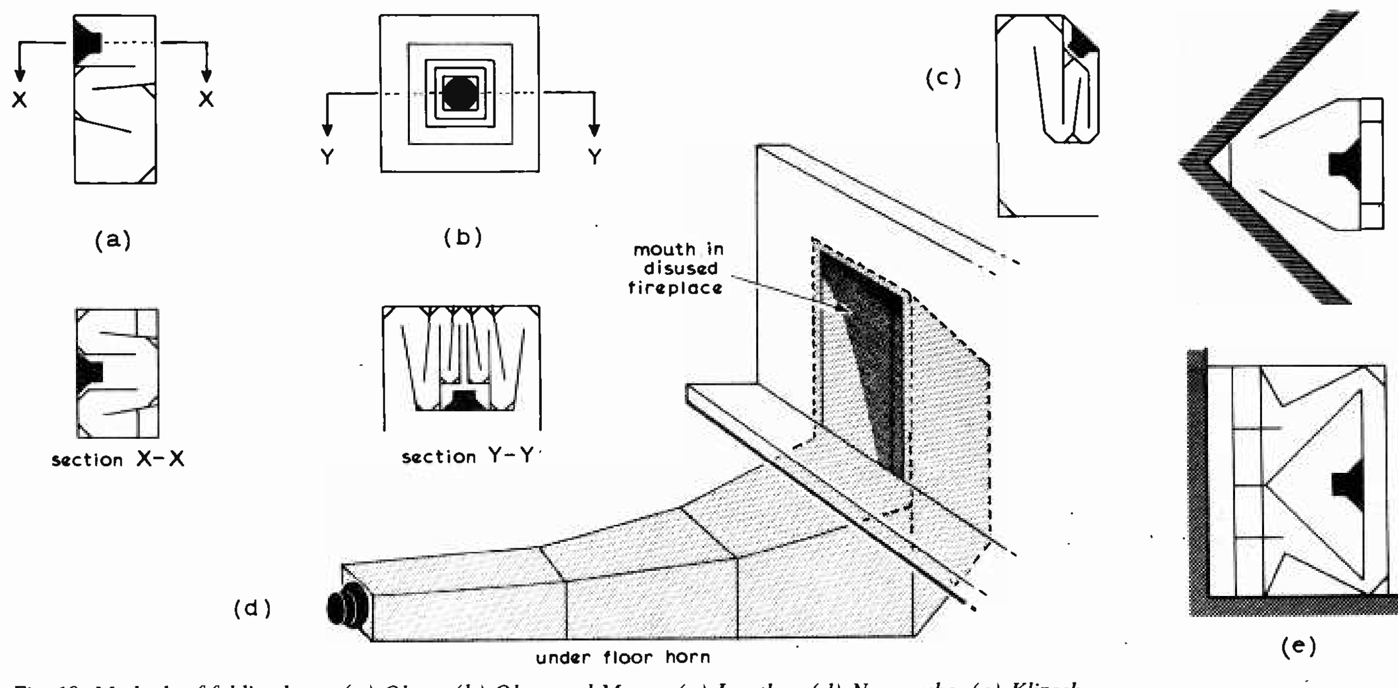


Fig. 10. Methods of folding horns (a) Olson, (b) Olson and Massa, (c) Lowther, (d) Newcombe, (e) Klipsch.

subsequent bends correct the waveform. But for single bends it can be adopted, and the mini-horn design described later could utilize this feature.

Examination of the Patent Office records for folded horn designs registered during the 1920s and 30s provides a fascinating monument to the ingenuity of acoustical designers, and Fig. 10 illustrates a number of the more well-known methods of folding. The restriction of horn width at a bend to 0.6 times the highest wavelength to be transmitted suggests initially that folding can only be attempted over the first few feet of the length of a horn; after that point the width will have reached the limiting value. However, this limitation may be overcome by bifurcating the horn (splitting into two equal channels) at each point when the width limits. Thus the mouth of a horn may comprise four equal mouths (brought together for convenience and to ensure audio realism) and the four "quarter-horns" may be folded far closer to the mouth than would otherwise be possible. Rayleigh has shown[7] in Art. 264 that bifurcating a conduit will have no effect on the transmission of sound provided the lengths of the two portions are equal and the sum of their areas at corresponding points is equal to that of the original conduit.

In many cases, the front side of a loudspeaker, whose reverse side is horn loaded, will be physically close to the mouth of the horn itself, and it is commonly feared that there will be concellation at certain frequencies caused by interference between the two radiations in anti-phase. However, the direct radiation from the unloaded front of the cone is only a few percent of that through the horn, and so the amount of cancellation is negligible.

Frequency handling

Although it has been shown that each horn acts as an acoustic bandpass filter, the lower cut-off frequency being determined by the expansion coefficient and the upper cut-off frequency by the throat cavity, there are important reasons why the full audio signal should not be applied directly to all horns regardless of their frequency handling capability. At the low frequency end of the spectrum, examination of Fig. 3 (Part 1) shows that the horn provides the loudspeaker with no resistive acoustic loading below its cut-off frequency. Thus any applied signals below this frequency will cause excessive movement of the loudspeaker diaphragm, which will be constrained only by the mechanical and electro-magnetic factors. This excessive movement can cause unpleasantly high intermodulation distortion, and can also lead to further non-linear distortion when the loudspeaker moves outside its linear range. At the upper frequency end, signals of excessive power can also give rise to distortion products due to deficiencies in the cavity/throat relationship. It is therefore beneficial to restrict the bandwidth of the electrical signal reaching each loudspeaker to match the acoustic bandwith of its corresponding horn.

Although most commercial multi-unit loudspeaker systems use passive *LC* cross-over networks between power amplifier and loudspeaker to route signals of the appropriate bandwidth to each loudspeaker, careful comparative listening tests show that these units undoubtedly introduce a "dullness" or loss of "brilliance" into the audio output. Many explanations have been offered for this situation; in the author's opinion, the most likely reason being the loss of "direct drive" from the output of the amplifier, allied with a significant reduction in the degree of electro-magnetic damping afforded by the low output impedance of the amplifier.

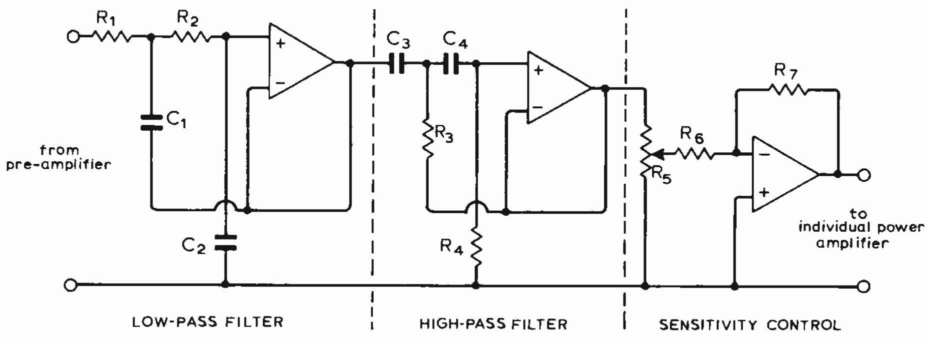


Fig. 11. Circuit for an active filter network. See appendix for component details.

Recent correspondence in *Wireless World*[28] and elsewhere has extolled the virtues of splitting the frequency range at low signal level, and employing a separate power amplifier directly coupled to each loudspeaker. The author has devised such a circuit, which consists of three (or four) parallel frequency-selective channels comprising Sallen & Key active filters giving preset low and high-pass characteristics in series in each channel, together with some gain adjustment to allow for the inevitable differences in sensitivity of each loudspeaker/horn combination. The active filters provide 2nd order Butterworth characteristics, a response which appears to give the least displeasing effects at the cross-over frequencies. (There will inevitably be phase-shifts associated with any filter circuit, and the effects of these on transients can produce a marked difference in their character.) This circuit is in Fig. 11 and the Appendix.

Thus, some form of electrical cross-over is generally necessary in addition to the acoustic cross-over provided by the horn itself. An exception is of course the case where a single loudspeaker drives two horns: one loading the front and one loading the rear of the diaphragm. In this situation, some compromise will be necessary in the acceptable distortion level and bandwidth of the loudspeaker system.

Directional horns

This article has extolled the ability of the horn to propagate wavefronts that are nearly plane at its mouth. However, there are situations where it is desirable to propagate wavefronts with different characteristics in the vertical and horizontal planes, particularly when middle and treble horns are used in stereophonic systems; it is often desirable to spread the wavefronts in the vertical plane while preserving more of a "point-source" in the horizontal plane. There are a number of different techniques for achieving this, based on diffraction and refraction effects at the horn mouth with the comparatively short wavelengths (a few inches or less) with which these high frequency horns are concerned.

The design and manufacture of multicellular horns, distributed-source horns, diffraction horns and reciprocal-flare horns is beyond the scope of this article, and with the exception of the first two mentioned is probably outside the capability of most amateur constructors. Those interested should refer to the papers by Smith[29], Winslow[30] and to the relevant chapters by Olson[3] and Cohen[5].

Klipsch[16,17] has described the design of his high frequency horn, in which the length/breadth ratio of the (rectangular) mouth assumes a value in excess of 4:1 c.f. the ratio of near unity advocated for bass horns). The optimum dimensions, length/breadth ratio, and apportionment of flare to the long and short axes depend on a number of complex factors, however, an aspect ratio between 2:1 and 4:1 with the flare apportioned in similar ratio has been found to give good practical results, and these parameters have been adopted for the "no-compromise horn" to be described. Although the high frequency horn of the "mini-horn" system is specified as circular (in view of its handling the relatively large wavelengths at 1kHz) an alternative rectangular mouth with aspect ratio of 2.5:1 has also been described.

Detailed design procedure

The previous sections have dealt in some detail with the basic theory of the horn, and the essential design procedures have been outlined for a series of horns which can cover the complete audio range. The final sections will consider the detail design of two horns: a "mini-horn" and a "no-compromise horn".

Because all horns are designed to slightly different requirements, and inevitably many readers will wish to "bend" the specification to a greater or lesser extent in order to satisfy their own needs, the designs are presented here by means of tables so that they represent a comprehensive design code for a wide range of horns.

Bass horn design

The bass horn should be examined initially, commencing with the mouth. Tables 1, 2 and 3 indicate the relationship between

continued over page

Table 1

Freq. (Hz)	Wave-length (ft)	Diameter (ft)	Area (sq. ft)
30	37.5	11.94	111.98
40	28.13	8.95	62.92
50	22.5	7.16	40.27
60	18.75	5.97	28.0
70	16.07	5.12	20.59
80	14.06	4.48	15.77
90	12.5	3.98	12.44
100	11.25	3.58	10.07
110	10.23	3.25	8.30
120	9.38	2.98	6.98

Table 1. Minimum mouth dimensions for bass horn (free loading).

Table 5

Freq. (Hz)	Cut-off freq. (Hz)	Flare coeff. (ft^{-1})	Area increase (% ft^{-1})	Doubling dist. (ft)
30	25	.278	32	2.49
40	33	.366	44	1.89
50	42	.466	59	1.49
60	50	.555	74	1.25
70	58	.644	90	1.08
80	66	.733	108	.945
90	75	.833	130	.832
100	84	.932	154	.744
110	92	1.02	178	.679
120	100	1.11	205	.624

Table 5. Exponential constants for bass horn.

Table 7

Nom. dia. (in)	Area (sq. in)	Effective area (sq. in)	Throat area (sq. in)	Throat area (sq. ft)
3½	9.62	6.74	2.02	.014
5	19.64	13.75	4.12	.029
6½	33.19	23.23	6.97	.048
8	50.27	35.19	10.56	.073
10	78.55	54.99	16.50	.114

Table 7. Throat dimensions.

Table 2

Freq. (Hz)	Area (sq. ft)	Dia. (ft)	Sq. side (ft)	Rect. sides (ft)	
30	28	5.97	5.29	4.69	5.97
40	15.73	4.47	3.96	3.52	4.47
50	10.07	3.58	3.17	2.81	3.58
60	7.0	2.98	2.64	2.34	2.98
70	5.15	2.56	2.27	2.01	2.56
80	3.94	2.24	1.98	1.76	2.24
90	3.11	1.99	1.76	1.56	1.99
100	2.52	1.79	1.58	1.41	1.79
110	2.07	1.62	1.44	1.27	1.62
120	1.74	1.49	1.32	1.17	1.49

Table 2. Minimum mouth dimensions for bass horn (wall position).

Table 6

Freq. (Hz)	Cut-off freq. (Hz)	Flare coeff. (in^{-1})	Area increase (% in^{-1})	Doubling dist. (in)
200	166	.155	17	4.48
250	208	.193	21	3.59
300	250	.233	26	2.97
350	292	.271	31	2.56
400	330	.307	36	2.26
450	375	.349	42	1.98
500	420	.391	48	1.77
550	458	.426	53	1.63
600	500	.465	59	1.49
700	580	.539	71	1.29
800	660	.614	85	1.13
900	750	.698	101	.993
1000	840	.781	118	.887
1100	920	.855	135	.810
1200	1000	.930	153	.745
1300	1083	1.01	175	.686
1400	1166	1.08	196	.642
1500	1250	1.163	218	.596
2000	1660	1.54	368	.450
2500	2080	1.93	590	.359

Table 6. Exponential constants for mid/top horn.

Table 10

Freq. (Hz)	3½	5	6½	8
200	30.9	26.3	22.9	20.3
250	22.5	18.8	16.1	14.0
300	17.1	14.0	11.8	10.0
350	13.6	10.9	8.98	7.46
400	11.1	8.78	7.07	5.73
450	9.09	7.05	5.55	
500	7.58	5.77	4.42	
550	6.51	4.84		
600	5.56			
700	4.24			
800	3.31			
900	2.58			

Table 10. Length of mid/top horn (in), free loading. Since the mouth perimeter equals 1.5 times the highest working wavelength, the tractrix cannot be used. Tractrix contours can however be incorporated if the mouth perimeter is reduced to one wavelength.

Table 3

Freq. (Hz)	Area (sq. ft)	Dia. (ft)	Sq. side (ft)	Rect. sides (ft)	
30	14.0	4.22	3.75	3.32	4.22
40	7.87	3.16	2.81	2.49	3.16
50	5.03	2.53	2.24	1.99	2.53
60	3.5	2.11	1.87	1.66	2.11
70	2.57	1.80	1.60	1.42	1.80
80	1.97	1.58	1.40	1.24	1.58
90	1.55	1.41	1.25	1.10	1.41
100	1.26	1.27	1.12	0.995	1.27
110	1.04	1.15	1.02	0.904	1.15
120	0.87	1.05	0.93	0.829	1.05

Table 3. Minimum mouth dimensions for bass horn (corner position).

Table 8

Freq. (Hz)	3½		5		6½		8		10	
	Ex	Tr	Ex	Tr	Ex	Tr	Ex	Tr	Ex	Tr
30	27.3	25.1	24.7	22.5	22.9	20.7	21.4	19.2	19.8	17.6
40	19.2	17.6	17.2	15.6	15.8	14.2	14.7	13.1	13.5	11.9
50	14.1	12.8	12.6	11.3	11.5	10.2	10.6	9.3	9.62	8.30
60	11.2	10.1	9.88	8.78	8.98	7.88	8.22	7.12	7.42	6.32
70	9.17	8.23	8.05	7.11	7.25	6.31	6.60	5.66	5.92	4.98
80	7.69	6.83	6.70	5.84	6.01	5.15	5.44	4.58	4.83	3.97
90	6.48	5.75	5.61	4.88	5.00	4.27	4.50	3.77	3.97	3.24
100	5.57	4.91	4.79	4.13	4.25	3.59	3.80	3.14	3.32	2.66
110	4.90	4.30	4.18	3.58	3.69	3.09	3.28	2.68	2.84	2.24
120	4.34	3.79	3.68	3.13	3.23	2.68	2.85	2.30	2.46	1.91

Table 8. Length of bass horn (ft) for different flare constants, wall position. Ex-exponential, Tr-tractrix. N.B. The tractrix lengths are approximate.

Table 4

Freq. (Hz)	Wave-length (in)	Dia. (in)	Area (sq. in)	Sq. side (in)	Rect. sides (in)	
200	67.5	32.2	815.4	28.6	25.3	32.2
250	54.0	25.8	522.9	22.3	20.3	25.8
300	45.0	21.5	365.1	19.1	16.9	21.5
350	38.57	18.4	265.9	16.3	14.5	18.4
400	33.75	16.1	203.6	14.3	12.6	16.1
450	30	14.3	160.6	12.7	11.3	14.3
500	27.0	12.9	130.7	11.4	10.1	12.9
550	24.55	11.7	107.5	10.4	9.2	11.7
600	22.5	10.7	89.9	9.5	8.4	10.7
700	19.28	9.2	66.5	8.2	7.2	9.2
800	16.88	8.1	51.5	7.2	6.3	8.1
900	15	7.2	40.7	6.4	5.6	7.2
1000	13.5	6.4	32.2	5.7	5.1	6.4
1100	12.27	5.9	27.3	5.2	4.6	5.9
1200	11.25	5.4	22.9	4.8	4.2	5.4
1300	10.38	4.9	18.8	4.3	3.9	4.9
1400	9.64	4.6	16.6	4.1	3.6	4.6
1500	9	4.3	14.5	3.8	3.4	4.3
2000	6.75	3.2	8.0	2.8	2.5	3.2
2500	5.40	2.6	5.3	2.3	2.0	2.6

Table 4. Minimum mouth dimensions for mid/top horn (free loading).

Table 9

Freq. (Hz)	3½		5		6½		8		10	
	Ex	Tr	Ex	Tr	Ex	Tr	Ex	Tr	Ex	Tr
30	24.8	22.6	22.2	20.0	20.4	18.2	18.9	16.7	17.3	15.1
40	17.3	15.7	15.3	13.7	13.9	12.3	12.8	11.2	11.6	10.0
50	12.6	11.3	11.1	9.8	9.98	8.66	9.08	7.76	8.12	6.80
60	9.95	8.85	8.64	7.54	7.73	6.63	6.97	5.87	6.17	5.07
70	8.10	7.16	6.96	6.02	6.18	5.24	5.53	4.59	4.83	3.89
80	6.75	5.89	5.75	4.89	5.07	4.21	4.50	3.64	3.89	3.03
90	5.65	4.92	4.78	4.05	4.17	3.44	3.67	2.94		
100	4.83	4.17	4.05	3.39	3.51	2.85				
110	4.22	3.62	3.51	2.91						
120	3.72	3.17								

Table 9. Length of brass horn (ft) for different flare constants, corner position. Ex-exponential, Tr-tractrix. N.B. The tractrix lengths are approximate.

minimum frequency and mouth dimensions for horns positioned in free air (4π solid radians) at a wall (π solid radians), and in a corner ($\pi/2$ solid radians). In table 1, the speed of sound has been taken as 1125 ft/sec, and the mouth perimeter as the wavelength. The mouth areas in tables 2 and 3 are equal to $\frac{1}{4}$ and $\frac{1}{8}$ respectively of the mouth area in free air, and the dimensions for the circular, square and rectangular mouths are derived from these areas. It is tempting to reduce the areas of the square and rectangular horns so as to give a perimeter equivalent to the wavelength (suitably scaled for wall or corner positioning) but this is not recommended. However, the shorter side of the rectangular horn has been derived in this way (i.e. a square horn with this side would have the appropriate perimeter).

After settling the mouth dimensions, the throat may be determined from the chosen loudspeaker unit. Table 7 gives suggested throat areas for five typical mean loudspeaker sizes. In some designs, the choice of loudspeaker will be influenced by considerations of overall size (the length of the horn is greatest for the smallest loudspeaker) and whether the loudspeaker is to perform as both bass and mid/top driver, using two separate horns on either side. Many loudspeakers will possess different dimensions, and in these cases table 7 will be of little value. The effective area (piston area) has been taken as 0.7 of the area derived from the mean (quoted) diameter, and the throat area as 0.3 of the effective area. Although there is obviously scope for experiment here, the quoted dimensions should give very acceptable results.

Having decided the throat and mouth areas, tables 8 and 9 give the overall lengths of horns with true exponential and tractrix contours for both wall and corner placing for horns with the five derived throat areas at each of the cut-off frequencies specified in table 1. The factor of 1.2 applied to the cut-off frequency in table 5 when calculating the flare coefficient is to ensure a fairly linear frequency relationship throughout the working range of the horn. The flare coefficient m is thus given by

$$m = (4\pi/c)(f/1.2)$$

where c is the speed of sound (1125ft/sec) and f is the lowest frequency to be reproduced.

The area increase is given by $(e^m - 1)\%$ and the doubling distance by $(\log_e 2)/m$ for each frequency. The length of the exponential horn is given by $(1/m)\ \log_e\ S_m/S_T$ for each specified set of areas, and the length of the tractrix horn will be $r_m(1 - \log_e 2)$ shorter than the true exponential, where S_m = mouth area, S_T = throat area, r_m = mouth radius.

N.B. The tractrix lengths given in tables 8 and 9 are approximations, being based on the fully developed tractrix referred to the flare cut-off frequency, whereas the mouth radius is referred to the lowest bass frequency to be reproduced.

Middle top horn design

Attention should now be directed to the middle and high frequency horns. The mouth perimeter should not be less than the wavelength of the lowest working frequency, and in practice a perimeter of 1.5 times the lowest working frequency has been found to give good results. Table 4 is based on this factor of 1.5, and gives the recommended minimum mouth dimensions for free air loading. It is safest to assume free air loading to apply at these higher frequencies, because diffraction and reflection effects at short wavelengths prevent true wall or corner loading from being achieved, and it is for this same reason that the perimeter has been specified at 1.5 times the wavelength of the lowest working frequency. The dimensions of square and rectangular horns have been derived in the same way as those in tables 2 and 3. The throat dimensions of middle and high frequency horns should match the drive unit directly, and may be taken as the mean diameter and area of the chosen loudspeaker, shown in table 7. Tables 6 and 10 give the flare constants and lengths of exponential horns assuming the throat and mouth dimensions of tables 7 and 4 respectively.

Integration of multiple horns

It has been emphasized that the radiation from the mouths of each pair of horns at their common crossover frequency should be in-phase. Assuming that the mouths of all the horns will lie in the same plane, the total length of each pair of horns should be compared with the multiples of half wavelengths of the crossover frequency set out in table 11. If the drive signals at both throats are in-phase (separate loudspeakers), the total length should be an even number of half-wavelengths; if the drive signals are out-of-phase (single speaker horn-loaded at both front and rear) the total length should be an odd number of half wavelengths. If necessary, small changes may be made to the crossover frequency (with subsequent re-design of the higher frequency horn) to ensure optimum conditions at crossover.

The complete design

The bass horn will generally be folded. Originally it was intended to provide a table giving the maximum permitted length of horn before folding should cease because the horn diameter has become equal to 0.6 times the lowest wavelength to be transmitted. However, examination has shown that at frequencies up to five times the bass cut-off frequency (i.e. 4 octaves bandwidth) this restriction does not apply to the corner-positioned horn (due to the small mouth dimensions) and with the wall-positioned horn the limitation lies between 92% and 95% of the full exponential length. It may therefore be assumed that provided the wall-positioned horn is not folded within the final 10% of its length, the problem of cross reflections will not arise.

Finally, the cavities at the throats of the lower frequency horns should be designed in accordance with the formula already given, remembering to allow for the loss of cavity volume due to the frame, magnet and cone assembly of the loudspeaker itself.

The design procedure laid down in this part has been applied to two different designs of horn to follow, and further examples of overall horn design are given in refs 34 to 37, and also in ref. 5.

Appendix

A variable bandpass active filter for feeding a 3 horn loudspeaker system (see Fig. 11):

Low-pass filter

Frequency (Hz)	R_1 (kΩ)	R_2 (kΩ)	C_1 (pF)	C_2 (pF)
200	59	59	20,000	10,000
1k	12	12	20,000	10,000
2k	59	59	2,000	1,000
10k	12	12	2,000	1,000
6k	59	59	680	330
30k	12	12	680	330

N.B. R_1 & R_2 to be realized as 12k in series with 47k log pots.

High-pass filter

Frequency (Hz)	R_3 (kΩ)	R_4 (kΩ)	C_3 (pF)	C_4 (pF)
25	28	57	160,000	160,000
100	7	14	160,000	160,000
250	28	57	16,000	16,000
1k	7	14	16,000	16,000
4k	28	57	1,000	1,000
16k	7	14	1,000	1,000

N.B. R_3 to be realized as 6.8k in series with 22k log pot. R_4 to be realized as 12k in series with 47k log pot.

All i.cs to be Signetics N5741V, etc. R_5 10k log, R_6 22k, R_7 100k.

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PROJECT

Radio astronomy as a school activity

by J. C. Codling,* F.R.A.S.

As readers of this journal will know, there have, in recent years, been many important changes at all levels in the teaching of science in our schools. These have included not only important changes in the curriculum but also in the way science is presented to pupils of all levels of ability.

Very briefly, curriculum changes have brought science, and physics in particular, more into line with the world outside the classroom, while the emphasis has shifted from teaching to learning. Pure blackboard and lecture demonstration methods have largely given way to pupil-based activities either individually or in small groups using an impressive array of modern apparatus. Topics which were once the preserve of "A" level and above are now introduced much lower down in the school. So now, it is not uncommon to see basic courses in electronics introduced in the first and second years, i.e. with 11- to 13-year-old children, while higher up in the school their colleagues often reach a remarkable level of ability and are encouraged to design and build interesting projects based on their earlier mastery of fundamentals. Their physics lessons are no longer complete in themselves because the children are actively encouraged to apply this knowledge to problems they will meet in the world of technology outside the classroom. Nowhere has this trend been more evident than in the field of electronics, which is now well established in physics syllabi from CSE level upwards. A recent series of articles in this journal by a distinguished colleague well illustrates the sort of advanced projects which are being successfully undertaken by schools up and down the country.[1]

It is against this background of change that the work described below was started in a Suffolk school and continues now with students undergoing a three-year course of teacher training.

The boys concerned with this project were already following a course in practical electronics as part of their physics work in the school. As they progressed from the simple experiments of the first and second years they became used to handling test equipment such as oscilloscopes, signal generators and valve voltmeters. At different stages of the course they constructed projects of increasing difficulty from simple logic circuits using relays or transistors to oscillators, model binary computers and amplifiers. Some of these have been described elsewhere.[2]

The school already had a flourishing astronomical group who made regular observations with a six-inch telescope and small home-constructed refractors. As part of their work they took photographs of the moon, of star trails and carried out a variety of astronomical measurements both at school and at home. It seemed an exciting idea to extend these to include a regular radio watch of the sun over the recent maximum period and try to relate the results to any optical activity observed on the disc. By choosing a frequency of 136MHz they could at the same time monitor the many American scientific satellites transmitting beacon and telemetry signals on this band. As we wished to record not only the more intense radio storms but also the continuous level of the quiet sun (of the order of 10^{-22}W(Hz m^{-1})$^{-2}$ of aerial power) we decided in spite of the added circuit complexity and the extra amount of setting up involved, a phase-switching interferometer would best serve our purpose (Fig. 1).

In this arrangement the signals are

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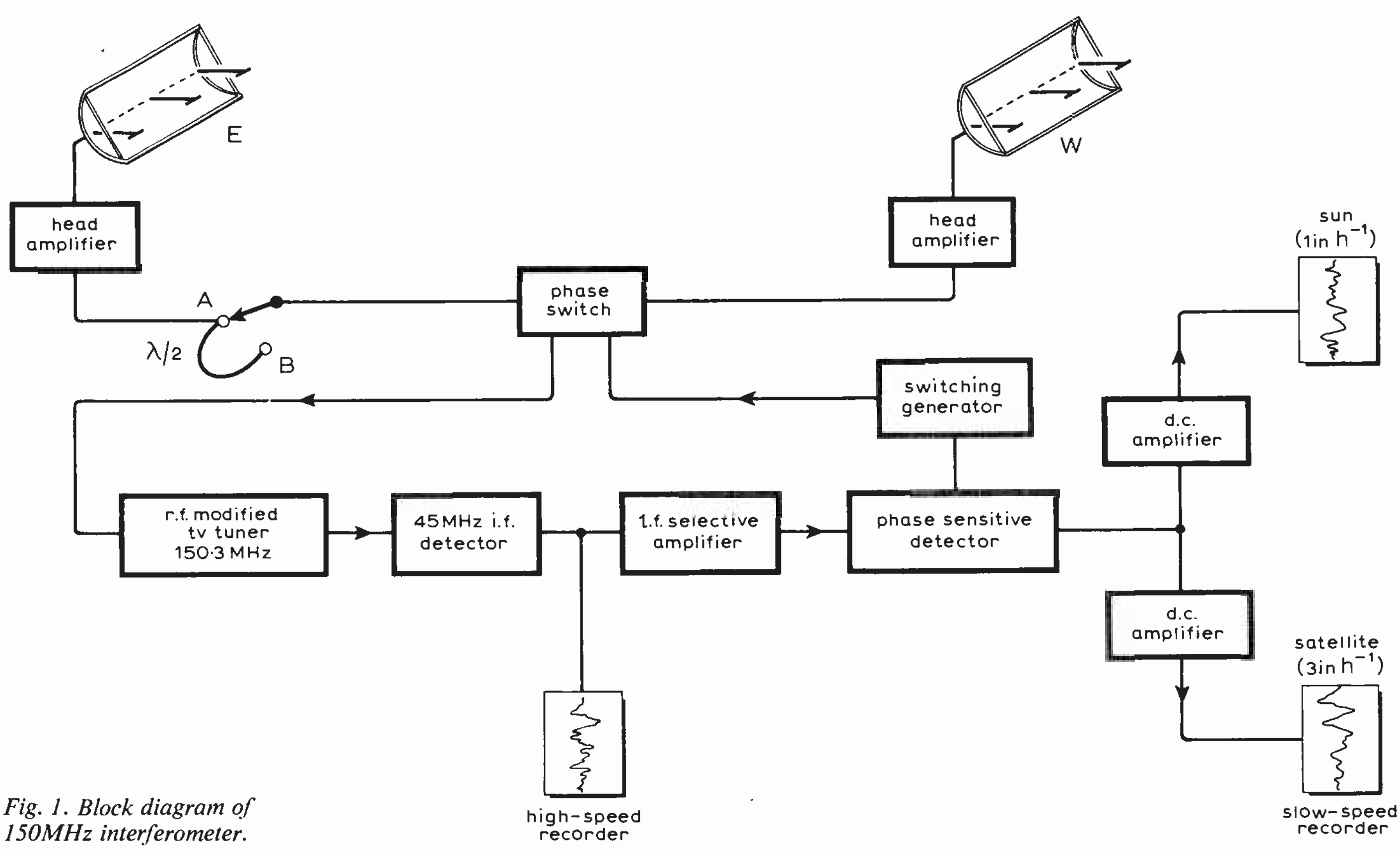

Fig. 1. Block diagram of 150MHz interferometer.

received by two aerials on an east–west baseline spaced an exact number of electrical wavelengths apart. The aerials can be altered in altitude to allow for the changing N–S swing of the sun during the year, but they are fixed in azimuth. The polar diagram of one aerial is shifted by half a lobe when an extra half wavelength of coaxial cable is switched into its feeder by a conventional multivibrator operating at a low frequency, in this instance, 600Hz. In position *A* of Fig. 2 the signals reach the aerials by equal paths, in position *B* all previous lobe maxima become minima and vice versa. If a signal source is on a fringe maximum at moment A, the aerial outputs will add and the detector output will be, say, positive. The next moment B they will cancel and the detector output will be zero. Noise is neglected in both cases.

$$\text{Output} = \frac{A}{(2S+N)} - \frac{B}{(O+N)} = 2S$$

When the source has moved half a fringe:

$$\text{Output} = \frac{A}{(O+N)} - \frac{B}{(2S+N)} = -2S$$

Here S is the signal from one aerial and N is the receiver noise. The fringe amplitude thus remains unchanged but reverses in sign as the phase of one aerial is reversed. By adding a $\lambda/2$ piece of coaxial cable to one of the aerial feeders the fringe pattern will be shifted so that peaks will occur where nulls used to be. By switching the loop in and out at a rapid rate the fringes scan back and forth between two adjacent regions of the sky. If one of these regions contains a local source like the sun, for one half cycle the receiver will see the source, whilst on the other half cycle it will not. So the interferometer will generate an alternating signal which is easily detected and amplified. A broad source like the Milky Way gives rise to little or no signal, since the receiver sees virtually the same intensity for both fringe positions. The lobe-switching interferometer is highly effective in picking out small sources from background interference and also reduces problems of receiver noise and stability.

The aerials

Ready-made Yagi aerials are expensive and not easily modified for other frequencies. Parabolas provide excellent reflectors giving full illumination and could be built by students at minimum cost. Accordingly the graph of $y=\frac{x^2}{72}$ was plotted and enlarged on the workshop floor so that the end formers could be bent to this shape. These were bolted to 12-ft-long galvanized pipes. The reflecting surface consisted of lengths of Post Office wire spaced at one-inch intervals—more than adequate for this frequency. The six folded dipoles, three for each aerial, were cut from aluminium strip supported at their earthy ends on angle iron. The dipoles were sited along the *latus rectum* of the reflector and fed by twin 300Ω feeders in parallel and one wavelength long (Fig. 3). In order to match the balanced aerials to the unbalanced input of the aerial amplifiers, a quarter wave balun was used and sealed in wax to protect it from the weather.

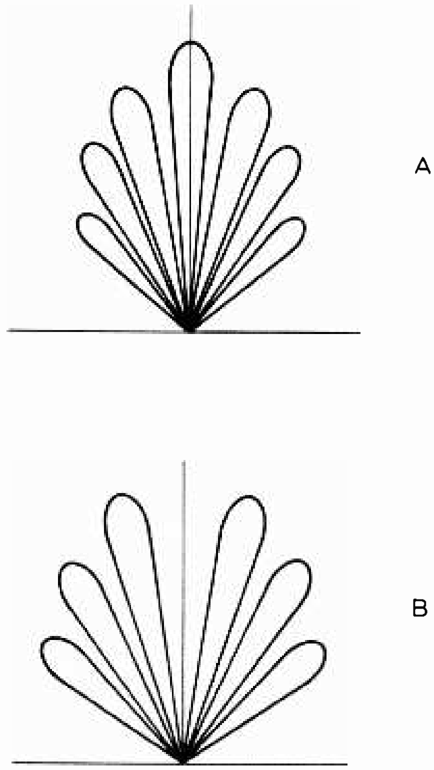

Fig. 2. Polar diagram of parabolic aerial shown with shifted lobes introduced by $\lambda/2$ addition of feeder cable.

Receiver components

Power supplies All d.c. power supplies are stabilized against mains fluctuations. These include h.t. stabilization for the valve sections of the receiver and low-voltage supplies of 14V for the f.e.t. converter and aerial head amplifiers—the latter fed up the coaxial feeders. To make fault-finding easier all voltages and currents are monitored by meters on the power supply panel. Alternating current for the heaters is supplied from a constant-voltage transformer.

Phase switch and switching generator (Fig. 4) The half wave loop in the phase switch and other stubs were cut to resonance by driving them with an oscillator at the operating frequency and cutting off small pieces at a time until a simple reflectometer showed the best forward/backward standing wave ratio. The half wavelength loop in the phase switch is switched in and out of the feeder of the east aerial by using square wave to block off two OA47 diodes connected between the feeder and the loop. The frequency and amplitude of the square wave was checked with an oscilloscope and the mark to space ratio adjusted for unity.

R.f. and i.f. units (Fig. 1) The r.f. unit is a current AB Electronics f.e.t. television tuner realigned for the 150–153MHz band and with its i.f. output increased to 45MHz. The i.f. strip is an ex-radar unit Type 7925 with a centre frequency of 45MHz and a band width of 5MHz. This is a more recent unit than the previous wartime i.f. strip which used EF50 valves, and after some modifications to the suppressor and bias circuits has proved reliable and free from faults over a long period of continuous use. After the diode detector the usual cathode follower feeds the valved low-frequency sections of the receiver.

Low-frequency sections From the cathode follower of the i.f. strip, the signal is passed to a selective amplifier tuned to the narrow pass band of the switching frequency. It was here that resistor and capacitor values had to be selected with some care using decade boxes whilst watching the output waveform on the oscilloscope. This output is applied to two EB91 diodes, each diode connected in series with its partner. The detector is synchronized to the frequency of the lobe switch by the other square wave output from the multivibrator. The output waveform at the anode cathode junction of one diode pair is shown on the oscilloscope in Fig. 5 and shows receiver noise contained within the square wave envelope.

The output of this phase-sensitive detector is fed via an integrating circuit of a 1MΩ resistor and suitable paper capacitors of values required to smooth out small impulsive interference, depending on the chart speed of the particular recording. It was found, for example, that with the slow excursion of the sun across the aerials at a chart speed of 1in/hr, a time constant of 1MΩ and 8μF was adequate.

When the telescope started recording solar noise, by far the most serious problem was interference from strong aircraft transmissions near the original operating frequency of 136MHz. Due to the exceptional sensitivity of the receiver and the wide bandwidth used, these signals frequently obliterated the trace due to the quiet sun. The problem was further aggravated because cross modulation by these signals was occurring through the original germanium transistors in the head amplifiers.

At this stage we decided to apply to the Royal Society Research in Schools Committee for a grant to purchase two high-gain f.e.t. head amplifiers. This proved to be a double blessing for not only did we obtain new head amplifiers but also the Royal Society appointed Professor Anthony Hewish, F.R.S., as our adviser. It is largely due to his interest and help that the project advanced beyond this stage. At his suggestion we also changed our operating frequency to 150–153MHz so that aircraft interference was greatly reduced. Although we lost contact with the scientific satellites on 136MHz we still occasionally record those operating near the amateur two-metre band.

Calibration The instrument is calibrated by allowing the Cassiopeia "A" radio source to drift across the aerials during the night and the maximum pen deflection (Fig. 6) is measured. The mean amplitude of the solar fringe pattern is measured at noon each day and, after conversion, for convenience to a logarithmic scale, is plotted on a monthly summary chart (Fig. 7) which also shows the level of the calibration source. Solar flares show as peaks on top of the interference fringes and are drawn on top of these with a scale to represent duration in minutes or hours. A much faster pen recorder is connected to the output of the i.f. detector to record details of these short-lived bursts. A more complete picture is seen if any optical activity on the sun's disc is recorded on the same time scale.

Solar activity 1968–1973

We have tried to keep a continuous radio watch on the sun over this, the 21st recorded solar cycle. From mid-1965 onwards, there was a rapid rise of active areas to a peak during 1969–1970. One of the most interesting observations has been the number of intense storms in the period 1970–1972, the last major one recorded being of exceptional intensity occurring during August 1972, after a relatively quiet July. From worldwide reports this gave rise to brilliant aurorae, severe interruption of microwave radio reception and a noticeable increase in solar wind recorded by Pioneer 9 at the beginning of August. A glance at the *Wireless World* h.f. predictions for August 1972 will confirm the many results of this storm. At present it looks as if the predicted minimum of 1973–1974 will be extended to 1975 or even 1976. Certainly, there have been two or three peaks of activity over the whole four years or so of the maxima. The most intense storm for years originating in a 100,000-mile-diameter group of spots was first detected by OSO7 on July 28, 1972. The 28, 21 and 14MHz amateur bands were subject to almost complete blackout. This was certainly the highest energy solar storm ever recorded.

A glance at the two summary charts for March/April 1972 and January/February 1970 (Fig. 6) will show the high levels of two of these storms which have been a characteristic of this late and prolonged maximum period. For comparison these peaks, often of days duration, should be compared to the level of the calibration source and that of the quiet sun—all on the vertical log scale. During the prolonged storm of October 1970 a second interferometer on 610MHz was brought into use, and although this receiver was handicapped by low collecting power of single Yagi aerials, the recorder indicated sufficient amplitude to confirm the activity on the v.h.f. band.

Looking forward to the next active sunspot period we should hope by then to compare results continuously on both v.h.f. and u.h.f. bands, together with some detail of shorter bursts with a faster speed recorder.

Looking back over the years since the project started it is difficult to assess the success of the enterprise since no current examination could possibly do this justice. There are, however, several interesting facts which emerge which those of us interested in education in its broadest sense would do well to note.

1. Most of the boys involved in this project have now gone on at different levels according to their ability to make their careers in the electronics industry, and a fair number with the GPO Engineering Branch. All these boys, including those who completed university courses success-

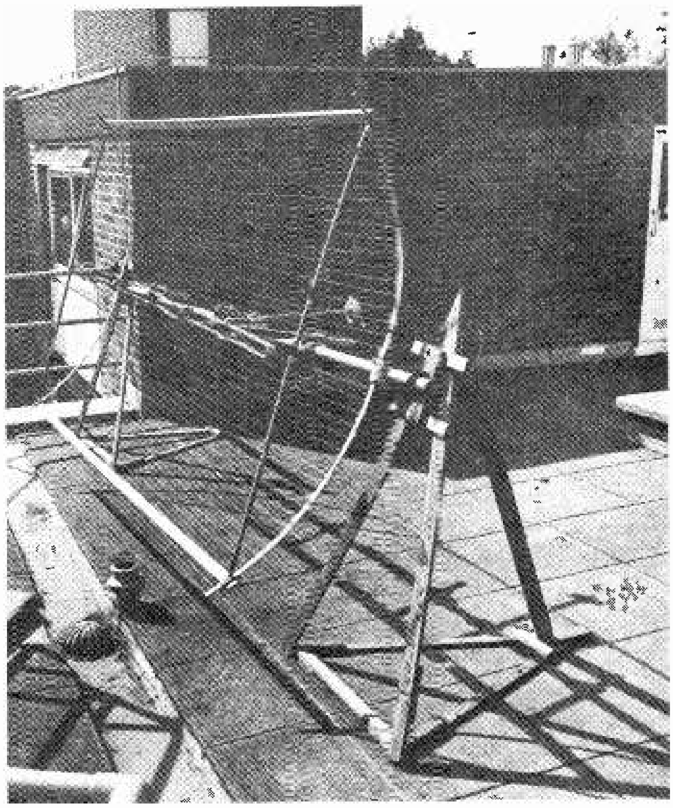

Fig. 3. East aerial showing the folded dipoles at the focus.

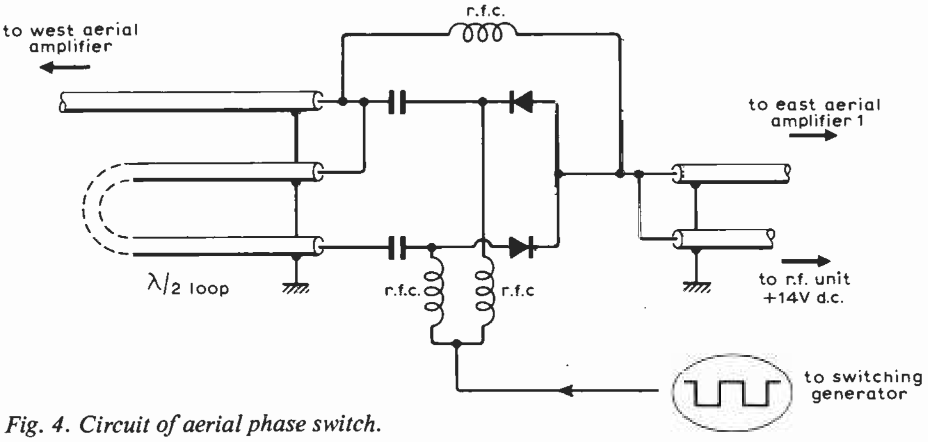

Fig. 4. Circuit of aerial phase switch.

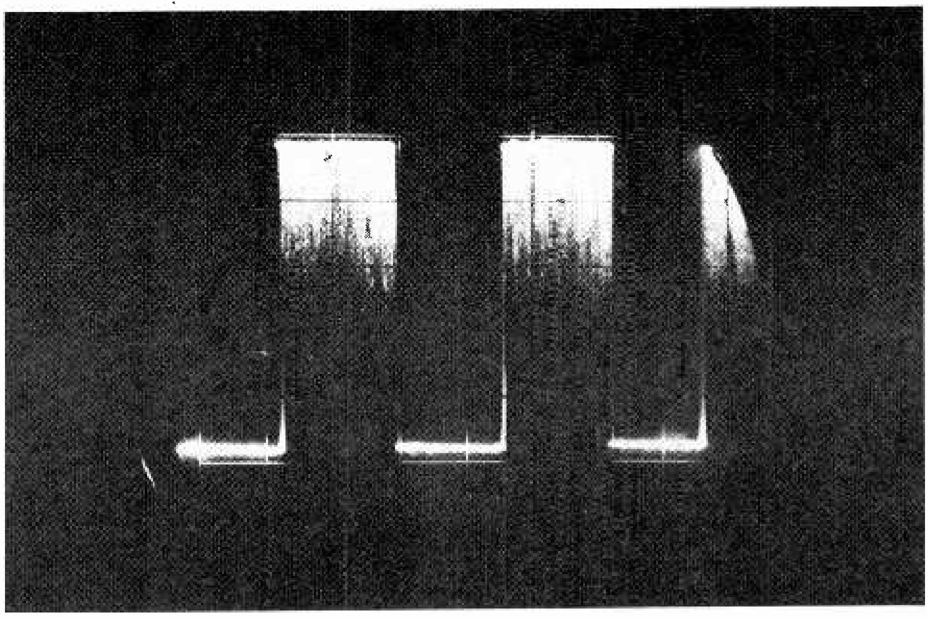

Fig. 5. Square wave enclosing received noise, at the anode-cathode junction of phase-sensitive detector.

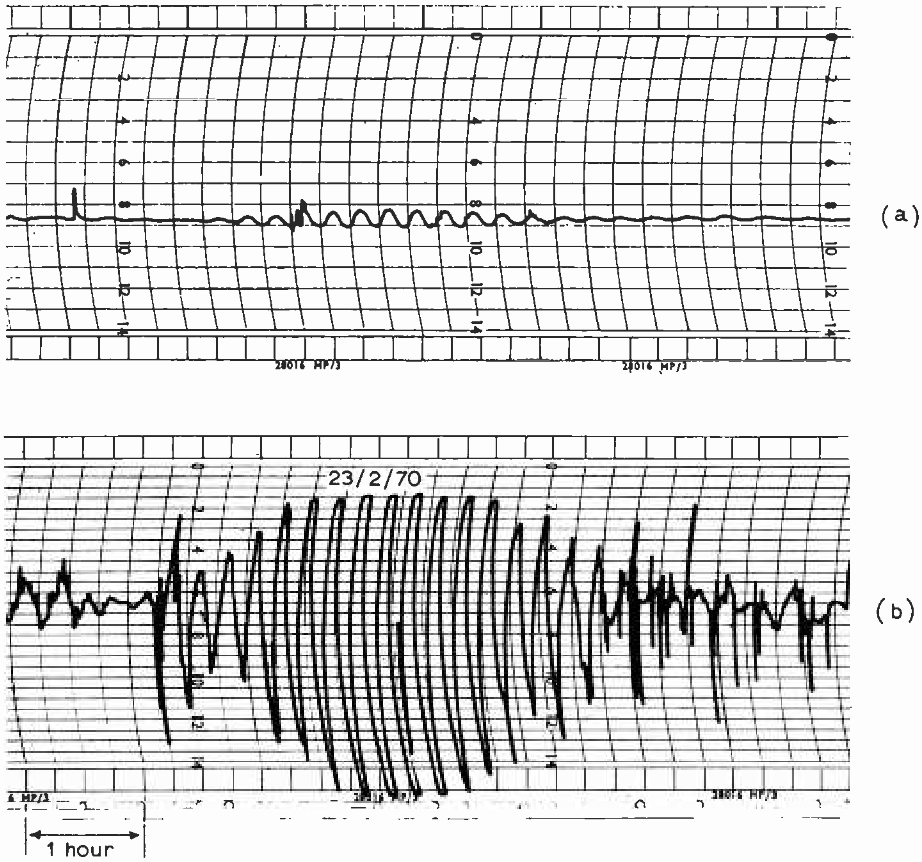

Fig. 6. (a) Pen recording at 1in/hr showing the noise from a quiet sun. (b) Recording at same chart speed showing a full-scale deflection obtained during a solar storm recorded in 1970.

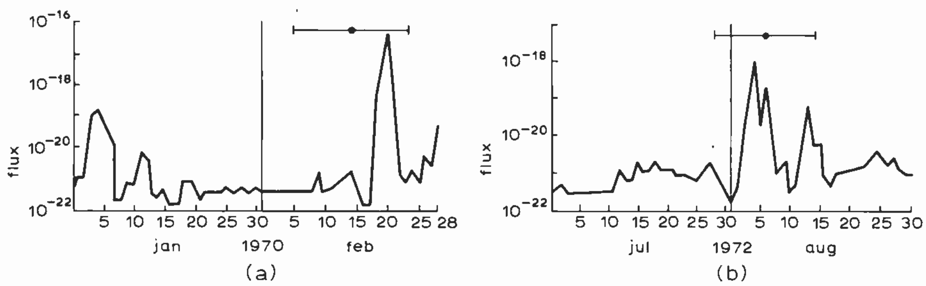

Fig. 7. (a) Summary chart for Jan./Feb. 1970. The horizontal line shows the passage of a major sunspot group. (b) Summary chart for Jan./Feb. 1970. The horizontal line shows a major storm from Aug. 1 to Aug. 10.

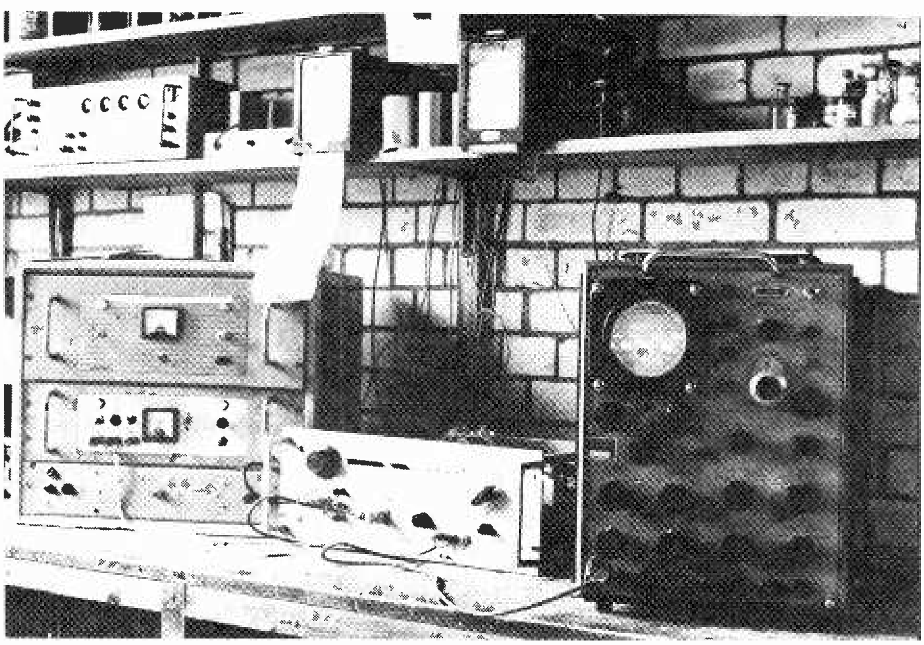

Fig. 8. Complete interferometer receiver and recording equipment.

fully, had failed the selection examination as 11-year-olds.

2. Reports of their success beyond "O" level, i.e. ONC, HNC and degree courses, have shown consistently that they not only did well in these examinations but in their practical work they showed a much broader grasp of the subject than the examinations themselves demanded.

3. Probably, most of all, they have learnt to apply branches of their school physics to the solution of problems, some of which presented considerable difficulties. They were certainly tremendously enthusiastic about the work and looked upon the many difficulties we encountered as problems which we could solve together, sometimes with help from interested people in the world of electronics outside the school. For these reasons, amongst others, I personally welcome the approach to science which the Schools Council Project Technology is now advocating at this level.

Finally, this enterprise could never have succeeded but for the generous help of the people and organizations listed below. Nowadays schools who wish to embark on such projects have a ready-made organization for liaison with the electronics industry. One of the conclusions of the Committee established by the Working Group on Scientific and Technological Manpower states, "There is almost universal goodwill in industry towards schools, there is a widespread desire among teachers for practical and improved contacts with industry at local level."[3] Long before this report was written, we had to make our own contacts not only locally but nationwide and everywhere we found such a desire to help that we wondered why this great pool of goodwill had not been used before.

Acknowledgments

The author would like to acknowledge the following without whose help this project would not have succeeded.

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The Directors, Solartron Ltd, Farnborough.

The Director, Sensitised Coatings Ltd.

Photography by Mr Peter Smith of the Audio-Visual Aids Department, Gipsy Hill College of Education.

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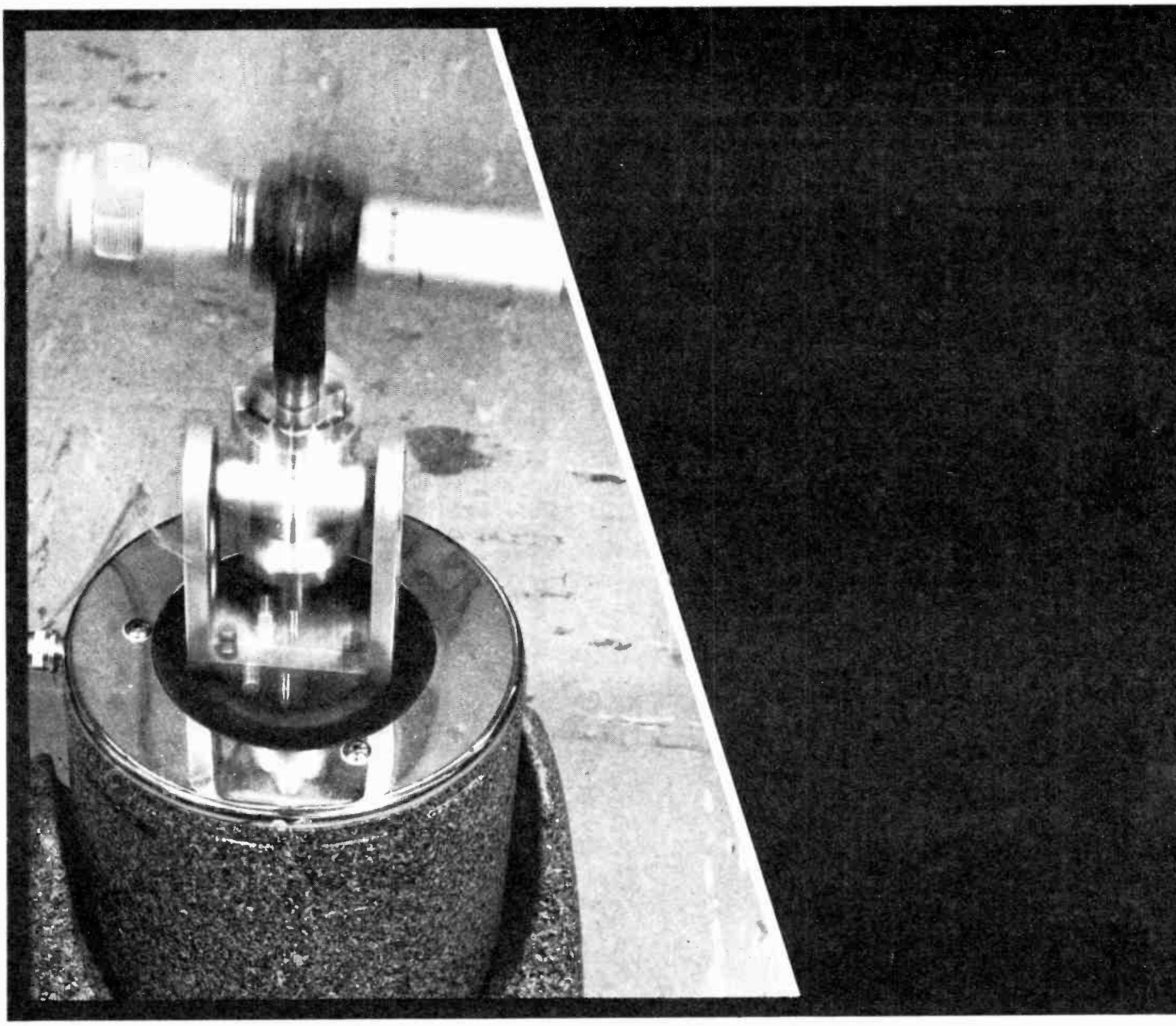
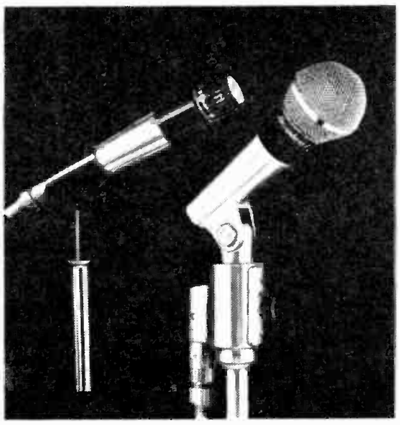




Electronic piano design

Part 3—tuning the touch-sensitive design, an m.o.s. master oscillator and other optional circuits.

by G. Cowie, B.Sc.

This simple and inexpensive design retains the touch-sensitive feature of string pianos, unlike most electronic keyboard instruments. The first article (vol. 80 no. 1459) described design concepts together with circuit and component details and the second part (vol. 80 no. 1460) gave constructional procedure. This final article includes circuits for suppressing "thump", hiss due to leakage and an m.o.s. master oscillator to simplify tuning.

When you have completed the wiring of the piano the remaining work is to commission and tune it. In a project of this complexity it is inevitable that a number of faults and wiring errors will occur and the purpose of the commissioning stage is to weed these out and make various adjustment.

Start by applying power and making the following voltage checks

supply busbars, 0V, +5V, −5V
collector busbar, about 0.5V
switch busbar (after R_{507}), 7 to 8V
damper busbar, about −0.4V
bias busbar, about +0.8V
output busbar, +0.4V.

Turn both potentiometers on the amplifier board to mid-position, and check that the pre-amp and amplifier outputs are about 0V before proceeding further.

Connect headphones or an audio amplifier to one of the output sockets. A hiss and probably some whistles will be audible but ignore this for the moment. If nothing is heard, check the output amplifier and preamplifier. Check that a note is heard when each key is struck, and that the pitches are more or less in the right order, bearing in mind that the oscillators are not tuned.

The system is organized in such a way that with a little thought any fault evident can be localized to one or two connecting lines, or a few components either in a letter-group or in a key circuit. Absence of signal from a key circuit will most likely be caused by absence of input signal, resulting from a reversed diode, or a misconnection at a divider or oscillator. Whistles, traceable by their pitch, will be caused by leaky transistors or bias connection faults, or damper faults. Faint notes will be caused by collector open-circuits. Open or bent key-switches will show up as faults. The sort of defects to look for are missing wires, missing links near i.cs, bad soldered joints, assembly mistakes, solder bridges, parts touching where they should not touch, tracks not cut. It may possibly be necessary to add power supply decoupling capacitors on the various circuit boards.

If the power supply uses a 9-volt transformer, R_{507} must be increased to about 18 ohms to drop the raw direct voltage to the 8V required for the switch busbar.

Check that each note ceases when its key is released, then short-circuit the sustain pedal socket and check that the notes now are sustained after the keys are released.

When all the circuits have been made to work, several finer adjustments can be made. Disconnect the positive-signal input of the summing preamplifier from 0V and extend it from the edge-connector with about 30in of flex wire. Solder the wire to the end of resistor R_{401} and then attach R_{401} to the 0-V busbar on the key circuit boards, in a position that gives minimum pick-up of unwanted signals. Run the positive signal lead alongside the output busbar as far as possible. It is important to arrange the 0-V lines carefully, to minimize stray signals. Connect a lead directly between the key circuits 0-V busbar and the preamplifier ground. Hiss should be inaudible while the instrument is being played.

If there is still too much background hiss,* then reduce the value of R_{501}, until the hiss is reduced to a low level. If the resistance is reduced too much there will be an undesirable effect whereby the keys refuse to work at all when pressed down very slowly.

If the damper action is felt to be too abrupt then the potential of the damper bus can be raised by connecting a resistance of a few hundred ohms in series with R_{502}, and connecting the base of Tr_{502} to the junction of the resistors.

If the action of any of the keys is noticeably different from that of the majority, the cause should be looked for and put right, otherwise it will be a permanent irritation when playing the instrument.

It is important to alter the light spring-

*If a hiss present while the piano is not being played is annoying, it can be eliminated with a "squelch" circuit, given later.

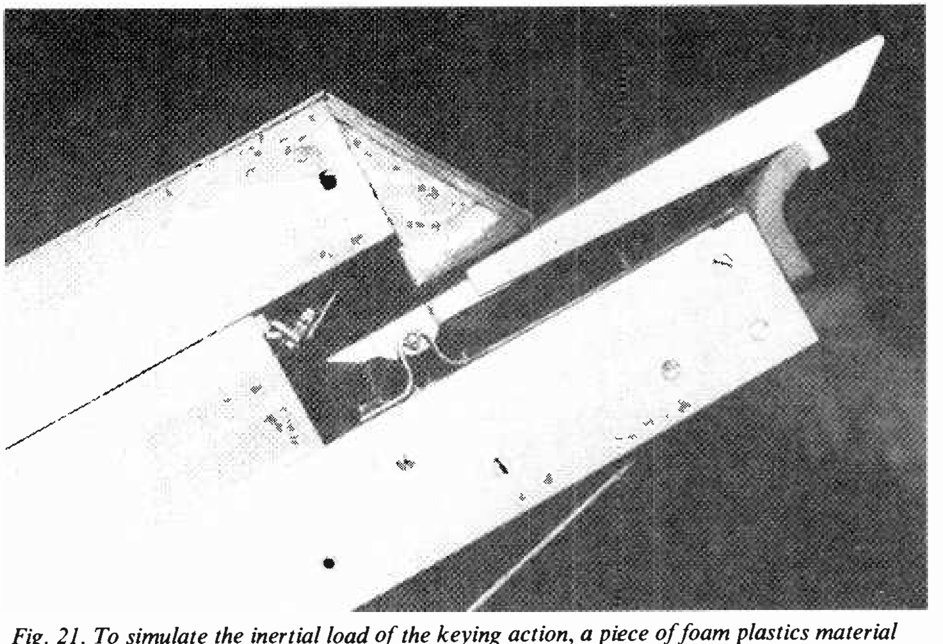


Fig. 21. To simulate the inertial load of the keying action, a piece of foam plastics material is inserted between the key undersides and the lower flange on the keyboard chassis.

loaded feel of the keys if the touch-sensitive action is to be satisfactory. The ideal arrangement would compromise 61 viscous dampers simulating inertial loads, but in the prototype a much simpler device was adopted which proved to give an acceptable result.

Cut a piece of flexible foam plastics material to dimensions of $2 \times \frac{3}{8} \times 33$in. If a piece 33-in long cannot be found then use shorter lengths. Push this into place between the white key undersides and the lower flange on the key chassis (see Figs 10 & 21). In this position the black keys will rub against the foam and the white keys will deform it so that a drag is felt on the keys. Key action will not be satisfactory unless this is done.

Tuning

The easiest and most satisfactory way of tuning the oscillators is to remove the oscillator board from the instrument and take it to a laboratory which has a suitable digital timer/counter and d.c. power supplies. The oscillators should be connected to a $\pm$5-V supply. They should be monitored at the op-amp output where a clean square wave is present. It is advisable to use an oscilloscope to look at the waveforms and see that all is well.

The oscillators can then be adjusted to the frequencies in Table 1 (part 1) by the tuning pots to an accuracy of ± 2 parts in 1000. If an adjustment is outside the span of the potentiometers it will be necessary to add padding resistors. Label the oscillators after they are set so that they can be wired up without confusion.

If you do not have access to the above equipment, either through work or friends, the oscillators must be tuned *in situ*, by ear. The person doing the tuning must have a musical ear and be equipped with an "A" tuning fork. The piano case must be open so that the tuning pots are accessible. Tune the A group of notes against the fork. Notes F are next tuned against the A; the interval should be a major third. Next tune C by means of the major chord F–A–C, and adjust F again if necessary. Use C to tune E, the interval being a major third, then tune G in the major chord C–E–G. Use G to tune B (major third) then tune D using the major chord G–B–D. This completes the white notes.

Tune E♭ using the chord F–A–C–E♭ and B♭ using the major chord E♭–G–B♭. Tune A♭ using the chord B♭–D–F–A♭ or the major third C–A♭. Tune F$^\#$ using the major third D–F$^\#$. Tune C$^\#$ using the major chord A–C$^\#$–E. You will probably need to go over the process several times. Fortunately the electronic piano is much easier to tune than a string piano, which has over two hundred adjustment points.

If you use a m.o.s top-octave synthesizer i.c., only one tuning adjustment will be necessary, and will take only a few minutes (see later).

Circuit options

On the key circuit boards (Fig. 18), remove the links between track 24, to which resistors R_2 are grounded, and track 23. Link the tracks by a silicon signal diode on each board, connecting the cathodes to track 23. This modification is based on work done after the prototype was completed, and if carried out should slightly improve the keying action at the "soft" end of the dynamic range.

The prototype is a basic instrument in that no attempt is made to modify the inherent tone of its working waveform, except by a single low-pass filter. It is purely by coincidence and the laws of physics that it sounds as much like a harpsichord as anything. If this tone is not acceptable then additional wave-shaping can be added fairly easily. There is room on the keying boards to fit a low-pass filter between D_1 and R_5. I fitted filters on the 16 lowest notes to take harshness out, with resistors of 10kΩ and capacitors of 20nF. More complex circuits could be built on a separate board, linked by a 61-way cableform.

A power amplifier could be fitted inside the case, but as this would need a separate power supply it does not seem worthwhile. Similarly, loudspeakers could be fitted in the case, but as fairly large speakers will be needed to reproduce the bass notes properly, and as the case is not designed as a loudspeaker enclosure, this is not recommended.

A tremolo circuit could easily be fitted after the preamplifier. It is not known whether vibrato can be applied to the oscillators successfully, and anyway this seems inappropriate.

The headphone amplifier could be replaced by an integrated circuit. The MFC 4000 is a cheap i.c. designed for the output stage of transistor portable radios.

A board containing twelve L–C oscillators could be made as a plug-in replacement, but as discussed in part 1, relaxation oscillators are preferred for several reasons.

Amplification

For low-power amplification, as for practising, almost any amplifier and speaker can be used provided that the speaker is of adequate size. A speaker of 8in diameter should give good results, bearing in mind that the bass notes have more fundamental than those of an acoustic piano. If high powers are wanted then it is essential to use heavy-duty speakers of the type used for electric guitars. The speakers should have a higher nominal rating than the amplifier otherwise the percussive piano waveform will probably damage them.

A standard volume control pedal may be bought and fitted between the piano and amplifier, and R_{403} preset to a suitable level.

M.O.S. master tone generator

The r.f. oscillator and AY-1-0212 master tone generator replace twelve oscillators (Fig. 22). The frequencies generated are within 0.1% of an equal-temperament scale, so the piano will work perfectly well without being tuned at all! It can easily be tuned against another instrument or a frequency counter if desired. It would be possible to

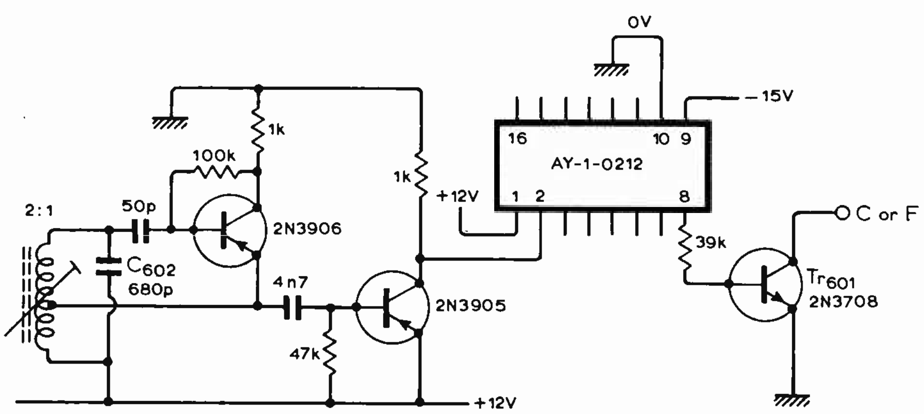


Fig. 22. This alternative tone generator, which can replace the twelve RC oscillators used in the original design, avoids conventional tuning procedures.

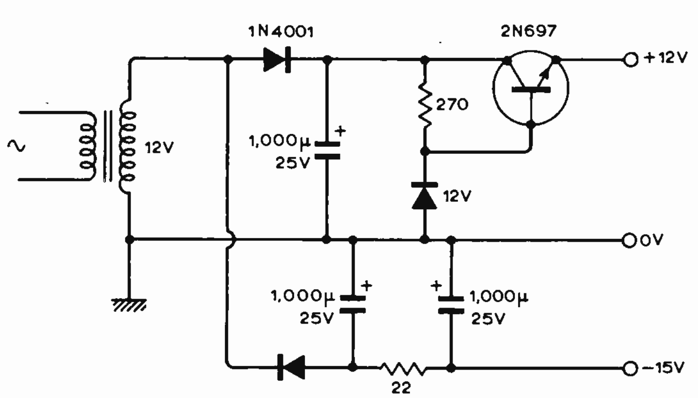


Fig. 23. Power unit to provide appropriate supplies for the m.o.s. tone generator also feeds the preamplifier and headphone amplifier. If the m.o.s. circuit is used, the −5V supply in Fig. 8 (part 1) can be omitted.

Parts for m.o.s. tone generator

AY-1-0212 i.c. from General Instrument Microcircuit Sales, 57 Mortimer Street, London W1N 7TD.
470-kHz i.f. transformer, 2:1 turns ratio, with ferrite core
2N3708—Tr_{601} (twelve)
2N3706
2N3905
Capacitors—50pF, 680pF (C_{602}), 4.7nF
Resistors—1k (two), 100k, 39kΩ (twelve)
16-pin d.i.l. socket

Power unit (Fig. 23)
12-V, 50-mA transformer
Capacitors—1000μF, 25V (three)
Resistors—270, 22Ω
1N47001 diodes (two)
BZY88-C12V zener diode
2N697 or BFY52 transistor

AY-1-0212 connections

1 V_{SS} +12V	9 V_{GG} −15V
2 in 500 or 334kHz	10 V_{DD} 0V
3 C# or F#	11 A# or D#
4 E or A	12 A or D
5 G or C	13 F# or B
6 G# or C#	14 F or A#
7 B or E	15 D# or G#
8 C or F	16 D or G

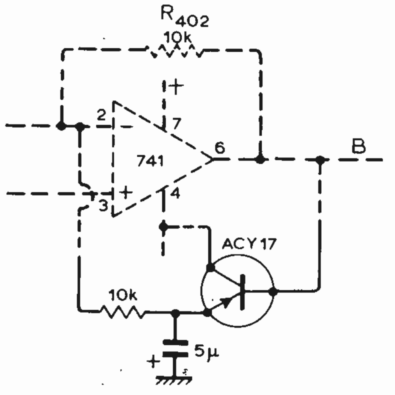


Fig. 24. Optional "anti-thump" circuit comprises three additional components to the circuit of Fig. 7.

arrange the circuit for rapid transposing; this is impracticable with twelve oscillator generators. It is still necessary to have twelve interface circuits to the t.t.l. dividers.

An extra power supply is necessary also. The circuit shown (Fig. 23) provides regulated +12V and smoothed unregulated −15V for the AY-1-0212. The −5V supply of the original piano design is omitted. The preamplifier and headphone amplifier should be powered from the +12V, −15V power supply.

A coil of the 470kHz, i.f. type, with a 2:1 turns ratio is needed. It may be necessary to change C_{602} to get the frequency into adjustment range of the ferrite screw core. The circuit will oscillate with any coil of about the right turns ratio.

The AY-1-0212 will stand a certain amount of abuse but should nevertheless be treated with care. It should be mounted in a 16-pin dual in-line socket. The one-off price is about £5.90. A Veroboard of 3×4in should give ample room for the oscillator, i.c. and the transistor/resistor array. It is advisable to bring the connections out at the edge of the board in scale order; the i.c. outputs are in a random order.

If high-frequency noise causes trouble on the lower octaves, additional power line filter capacitors should be fitted on the circuit board, or 1nF capacitors can be fitted at the Tr_{601} collectors or bases.

Squelch and anti-thump circuits

Some degree of "thump" will always be present where waveforms are not generated symmetrically about ground potential. Fig. 24 shows the anti-thump circuit now fitted in the prototype.

Hiss due to leakage though the reversed-biased diodes D_1 is very low, but can be completely eliminated by the "squelch" circuit of Fig. 25. Connect between points B-B in Fig. 7.

Correction. In the text on page 11 of part 1 (March issue) a line was omitted between lines 16 and 17. The missing line is "... that in the high state it acts as a current..." In Fig. 3 the annotations S_2 and S_3 should be transposed. In Fig. 18 of part 2 (key circuit board) diode D_2 should be reversed.
Parts kit. Elvins Electronics will supply a kit of parts for the piano design. Details from 12 Brett Road, London E8.

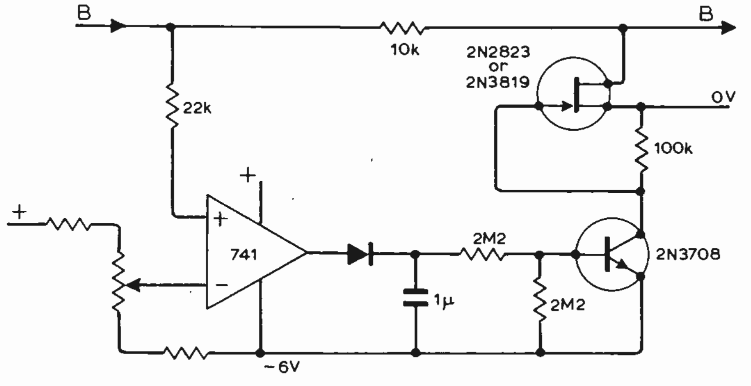
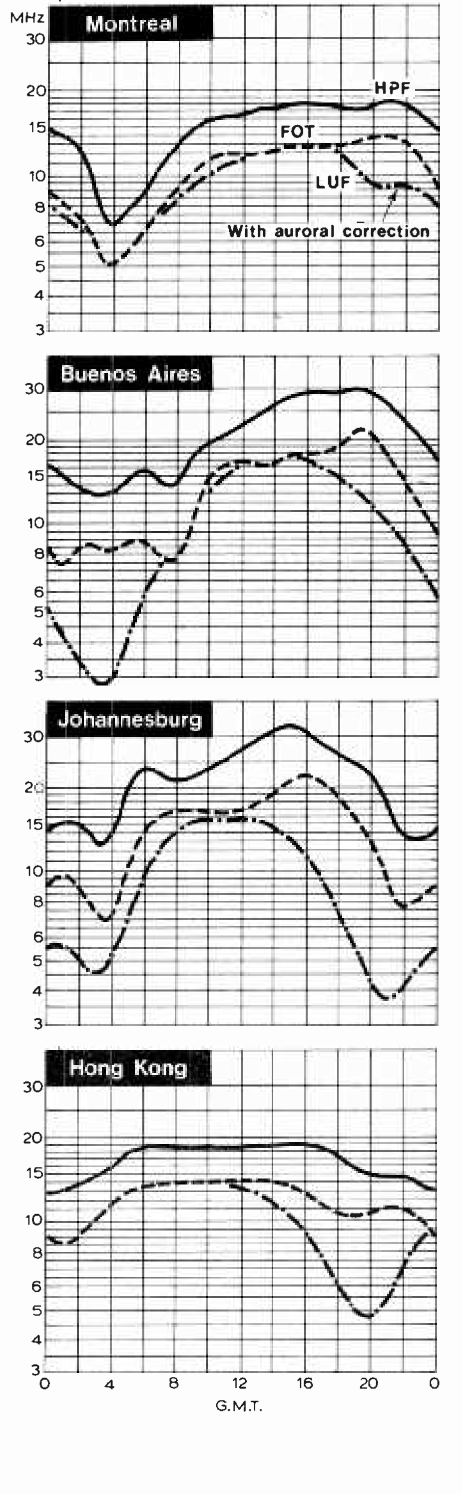


Fig. 25. Use this squelch circuit to eliminate "hiss" due to leakage currents that may be evident during standby. Suitable values for potential divider are 10kΩ and 5kΩ for the preset resistor.

H.F. Predictions for May

The charts are based on an ionospheric index of 8 giving FOT curves two or three MHz lower than those for May 1973 when the index was 40. Magnetic disturbances are likely on all days except between the 7th and 14th. This gloomy outlook should be brightened by sporadic-E propagation considerable modifying FOT curves on at least 20% of the days as follows: Hongkong peaking to 21MHz at 10GMT. Johannesburg rising to 22MHz at 09GMT and remaining so until 15GMT. Montreal maintaining 10MHz from 23 to 08GMT. Buenos Aires dip between 06 and 10GMT smoothed out.



World of Amateur Radio

10GHz to Guernsey

What is believed to be the first-ever amateur microwave contact between the Channel Islands and the mainland of England was effected at 1000GMT on Saturday, March 30. This was between Dr Dain Evans, G3RPE, operating portable at Prawle Point, south Devon, and Gordon Lean, G3WJG, operating as GC3WJG/P at Torteval, Guernsey, both on the 10GHz amateur band. The distance spanned was 111km from sites 100ft (Devon) and 250ft (Guernsey) above sea level. The transmitter used by G3RPE consisted of a 1W klystron and 3ft dish reflector; for GC3WJG a Gunn-diode oscillator provided 20mW of microwave power into a 4ft dish aerial. Further contacts were made at hourly intervals with the mainland signals received in Guernsey at least RS56, although there were times when signals from GC3WJG could not be heard in Devon; for the initial contact reports were RS59-plus at both ends.

The following day contacts on 10GHz were established between GC3WJG/P and A. R. Williams, G3KSU/P, at St Catherine's Point on the Isle of Wight from a site 750ft above sea level and where the equipment included a Gunn-diode oscillator providing 5mW output to a large horn aerial with a gain of 27dB. On Guernsey signals from this station varied from not readable up to RS56. The incoming signals at G3KSU/P were RS59 and at times the carrier/noise ratio varied from 18dB to as high as about 28dB. Path length is 161km. To assist the setting up of the microwave links, contact between the stations was made initially on 70MHz. It had been hoped to complete the triangle with contacts between Devon and the Isle of Wight but this was not possible in the time available.

On the other side of the world a new long-distance record for 2304MHz has been claimed by two Californian amateurs, W6FZJ and WA6HXW. With both stations operating from home locations and using "homebrew" equipment a 330-mile c.w. contact was made by means of tropo-scatter mode. Both stations used 6ft aerial dishes but W6FZJ had a power of only 5W compared with the 1kW input at WA6HXW.

Notes and news

The proposal to install a 144MHz f.m. repeater at the Crystal Palace (see March issue) has now been approved in principle by the Ministry and a licence has been applied for.

Contacts through the amateur satellite Oscar 6 are now being limited to the ascending orbits (afternoon and evenings) on Mondays, Thursdays and Saturdays in an effort to preserve battery life—hopefully until the launch of Oscar 7 later this year. Oscar 6 has already achieved an operational lifetime of 18 months, 50 per cent longer than the predicted lifetime of one year.

The International Amateur Radio Union has introduced new "five-band" and "six-band" categories of their "Worked All Continents" award with a view to promoting more uniform use of the h.f. bands for international communication. To qualify for these new versions of the popular WAC award contacts must have been made on or after January 1, 1974. While the original award is relatively easy to achieve using the 14 and 21MHz bands, a five-band or six-band award, for which two-way communication must be achieved with the six continental areas of the world on each band, represents no mean achievement.

The regular news and code-practice "broadcasts" from PAoAA in the Netherlands (see August, 1973, issue) on Friday evenings have been extended to "Top Band". PAoAA now transmits on 1827kHz, 3600kHz, 14·1MHz and 144·8MHz (changed from 145·14MHz) with news in English at 1915GMT, beginners' code practice at 1930GMT, advanced code practice at 2000GMT, r.t.t.y. news bulletin (45 baud) at 2030GMT and news in English again at 2115GMT. Proficiency tests at various Morse speeds are transmitted on the last Friday in each month at 2130GMT.

On the h.f. bands

Following a longish period of subdued "sunspot minimum" conditions on the h.f. bands, conditions perked up noticeably over the Easter holiday period with many Japanese and other Far Eastern signals on 21MHz and extremely strong North and South American signals in the evenings on 14MHz. Many amateurs are beginning to wonder if we shall soon reach the end of the present sunspot cycle; this would agree with forecasts made over a decade ago that mid-1974 might see the beginning of the next suspot cycle. On the other hand, the curious and still unexplained high level of sunspot activity throughout the summer of 1972 could mean that the old cycle still has some time to run. But once past the low point, a new cycle usually sees a fairly rapid rise in sunspot levels and consequent rise in usable frequencies to the benefit of users of 14, 21 and 28MHz.

Some amateurs can indeed claim to have experienced a considerable number of sunspot cycles. A recent QSL card from Robert Galea, 9H1E (one-time ZB1E and VP3E), mentions that he was first on the air as long ago as January, 1914. A personal reminder of passing years and sunspot cycles came when working VX1AW at St John's, Newfoundland, on Good Friday; it so happens that the very first long-distance contact ever made from G3VA was with VO1B, St John's, and that was 35 years ago on Good Friday 1939. I have to admit, however, to no longer using an 0-v-1 two-valve "straight" receiver and 10W transmitter as in 1939!

And 50 years ago (April/June, 1924) saw the biggest threat ever to British amateur operation (or "experimental" operation as it was then called) in the form of new licence conditions which stated that "Messages shall be transmitted only to stations in Great Britain or Northern Ireland which are actually co-operating in the licensee's experiments and shall relate solely to such experiments". It was this condition, which would have eliminated all casual and all international contacts, that caused *Wireless World* to offer to provide £500 to support the RSGB in a test case in the Courts. However, the authorities gradually gave way although they insisted that British amateurs should not use the general call "CQ" and this remained in force until 1946.

In brief

Callsigns in the sequence G4DAA are now being issued.... A meeting of the executive committee of the IARU Region 1 Division is to be held in The Hague from October 11 to 13.... Class-B type licences with a ZR prefix are being issued in South Africa for use on 144MHz and above to those who have passed all the conditions for the amateur licence except the Morse test.... Rosario Vollero, I8KRV, is the new president of the Italian amateur society ARI.... From the *Newsletter* of the Wirral Amateur Radio Society comes the following advice on successful low-power operation: "Stable transmitter, good operating technique, intelligent use of propagation, patience, perserverance, the courage to 'have a go' realizing that once you become an addict, you are 'hooked for life'." ... The Hull and District Amateur Radio Society is holding a mobile rally on Sunday, May 26, at the East Riding College of Agriculture, Bishop Burton on the A1079 York to Beverley road with talk-in stations on 1980kHz and 145MHz a.m. and 144·3MHz s.s.b. with a full programme of events (last year over 1,000 people attended).... The fifth Elvaston Castle Mobile Radio Rally is on Sunday, June 9, organized by the Nunsfield House Community Association amateur radio group. Elvaston Castle, near Derby, is on the B5010 some five miles south-east of Derby, just off the A6 and within easy access of the M1 (junction 24). The rally aims at providing a "family day out" of interest to the general public as well as to the radio amateur himself.... A meeting of the International Amateur Radio Club in Geneva will immediately follow the XIIIth Plenary Assembly of the CCIR, July 27 to 28, at the ITU headquarters building with a technical panel on "CCIR studies and the radio amateur".

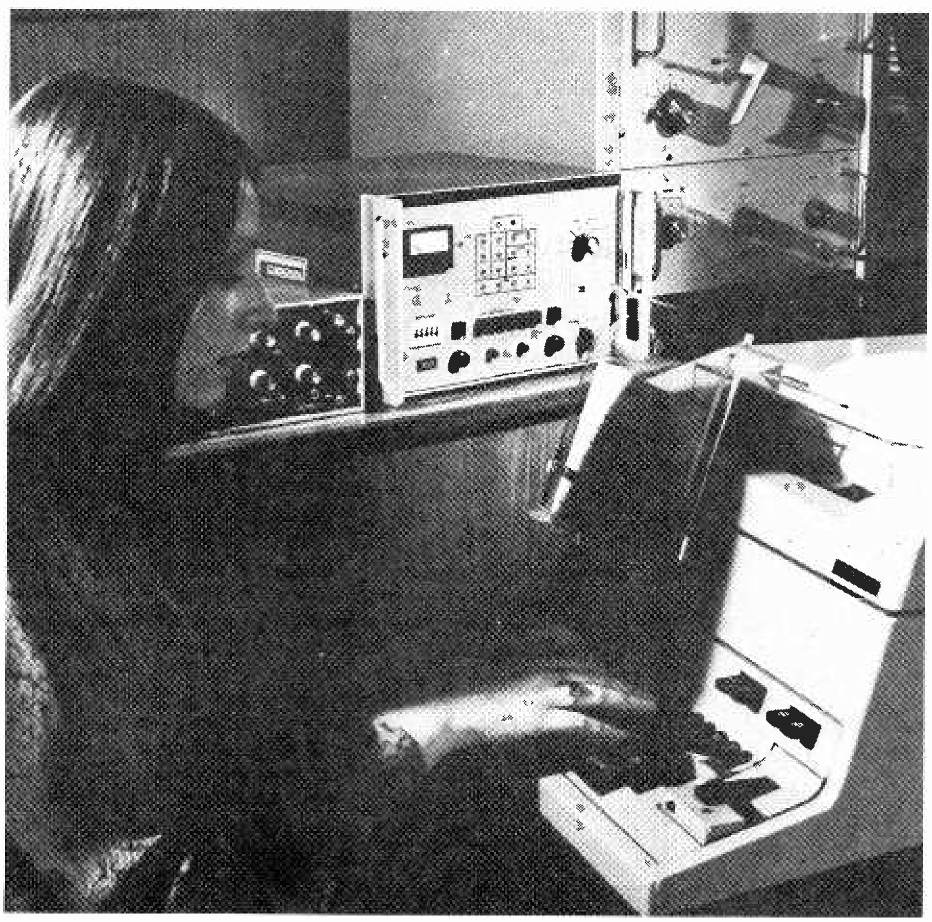
PAT HAWKER, G3VA

Communications 74

Radio & Data Communications

Exhibition and Conference
Brighton June 2–7

Encouraged by the success of Communications '72 held in 1972 the organizers are putting on a similar, but larger, conference and exhibition this year at the Metropole Convention Centre, Brighton, from June 4 to 7. Devoted to radio and data communications, it enjoys the full support of Government departments such as the DTI and the Ministry of Defence and of the industry's Electronic Engineering Association. The exhibition is a four-day event, embracing data, mobile radio, fixed radio and defence communications and has over 100 exhibitors. The conference call for papers attracted well over 100 papers from all parts of the world and 56 of these are to be read in a four-day, 14-session conference organized by *Electronics Weekly* and *Wireless World*. Six "inward missions" of senior users of radio and data communications equipment are being brought into the UK at a time to coincide with the event. These "missions" are sponsored by the EEA. For further information on the exhibition contact: ETV Cybernetics Ltd, BETA, 109 Kingsway, London WC2 6PU. For further information on the conference contact: Roger Woolnough, IPC Electrical-Electronic Press, Dorset House, Stamford Street, London SE1 9LU.



Marconi Spector automatic error correction unit

List of exhibitors

Airtech
Abbey Electronics
Antenna Specialists UK
Astro Communication Laboratory
Automation & Technical Services
Bantex
Barkway Electronics
J. Beam Engineering
Bell Telephone Manufacturing Co
Belling & Lee
Boyden Data Papers
British Aircraft Corporation
Burndept Electronics
Cable & Wireless
Campbell-Bruce Electronics
Cescom Electronics
Cole Electronics
Communication Accessories & Equipment
Computer & Systems Engineering
Cossor Electronics
Data & Control Equipment
Decca (KW Communications)
Dictaphone Company
Digital Systems
Dymar Electronics
Eddystone Radio
Electro-Acoustic Industries
Ever Ready Company (GB)
The Exchange Telegraph Co
Farnell Instruments
Ferranti Limited
Frederick Electronics
The GEC Electronic Tube Co
Goodacre & Davenport Semiconductors
Granger Associates
Gretag AG
Hatfield Instruments
Hayden Laboratories
HCD Research
The Home Office
Honeywell
International Aeradio
Interscan-dex
IPC Electrical & Electronic Press
Italtel SPA
ITT Creed
Knowles Electronics
Logica
Marconi Space & Defence Systems
Marconi Communications Systems
Marconi Instruments
MEL Equipment Company
Micro Computer Systems
Ministry of Defence
Ministry of Posts & Telecommunications
Motorola
Muirhead
Mullard
Multitone Electric Company
New Electronics
Panorama Radio Co
Plantronics
The Plessey Company
Post Office Telecommunications
Pyral (UK)

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Racal Electronics
Racal Communications
Racal BCC
Racal Mobilcal
Racal Antennas
Racal Amplivox Communications
S. G. Brown Communications
Racal Instruments
Racal Milgo
Racal Thermionic
Racal-Zonal
Rank Telecommunications
Rank Xerox (UK)
Redifon Telecommunications
REL Equipment & Components
RF Communications
RFL Electronics
Scientific Atlanta (UK)
Security Systems International
Solartron/Schlumberger
Standard Radio & Telefon AB
Data Equip. & Syst. Div. STC
STC Priv. Comms. Div.
Sperry Gyroscope Division
Storno
Tektronix (UK)
Teleprinter Equipment
Texas Instruments
Thomson-CSF
Transtel Communications
Trend Communications
Varta (GB)
Wandel & Goltermann (UK)
Watkins Johnson International
Wragby Plastics
Zellweger Uster

Racal transportable station including a solid-state 1kW transmitter (right), h.f. receiver and a radiotelephone terminal (centre)

The conference

June 4 is "data communications day" and has sessions on data communications, equipment design and mobile communications. A "highlight" paper is on the Post Office and its data customers—teleprocessing now and in the future.

June 5 is "mobile communications day" and has sessions on mobile communications, equipment design and maritime communications. A "highlight" paper is on computerized frequency assignment for the private land mobile services.

June 6 is "fixed communications day" and has sessions on fixed communications, equipment design and defence communications. A "highlight" paper is on tropospheric scatter.

June 7 is "defence communications day" and has sessions on defence communications (featuring the Clansman system), equipment design and instruments. A "highlight" paper is on electromagnetic compatibility—the army's outlook and the work of the army.

Letters to the Editor

Damping factor

More and more do we see damping factor incorrectly stated as the ratio of loudspeaker impedance to amplifiers internal (source) impedance. Figures quoted because of this assumption are often many hundred percent in error, errors arising largely because the source impedance of an amplifier is for very good reasons seldom resistive at low frequencies.

The method of measurement laid down by the British Standards Institution in BS 3860:1965 obviates these errors and should always be used if damping factor is to be quoted.

To the user, of course, damping factor is largely irrelevant because as soon as music is played via a moving coil loudspeaker the speech coil will warm up and change its resistance. The first four bars of Beethoven's fifth played at any reasonable level will change the loudspeaker damping by an amount greater than any variations between amplifier specifications.

The damping (in terms of circuit Q) of a moving-coil loudspeaker at resonance is approximated by

$$\frac{2\pi f M}{B^2 l^2}\left\{\frac{(R_E+R_G)^2+X_G{}^2}{R_E+R_G}\right\}$$

The relevant terms in the bracket are: R_E, d.c. resistance of speech coil (varying by 0.4% per degree centigrade); R_G, source resistance of amplifier; and X_G, source reactance of amplifier at loudspeaker resonant frequency.

P. J. Walker
The Acoustical Manufacturing Co. Ltd,
Huntingdon

Printed circuits kit

I have been following your recent correspondence on printed circuits with considerable interest and I wish to offer the following information in response to M. R. Yeo's letter "One-off printed circuit boards" (March 1974 issue).

For some time we have been marketing a printed circuit kit which was designed to provide the enthusiast, laboratories, educational establishments, etc., with a method of making low-cost, one-offs or prototypes to a reasonable degree of precision. The use of self-adhesive, paper-surfaced resist allows the user to draw, or trace, the desired pattern with any normal writing implement such as a pencil, ball-point, etc. A scalpel is used to cut and strip the unwanted resist. Chemicals are pre-packed for the convenience of the user who merely adds water, and the printed circuit board, for the etching process which can be observed as it proceeds.

J. H. Evans,
Keltronix Ltd,
15 Barra Street,
Glasgow G20 0AX,

Howl suppression

I agree with K. J. Young (Letters, March 1974) that, where there are one or two dominant peaks in the overall frequency response of a public address system, tunable rejection filters can be helpful in reducing acoustic feedback problems. Such equalization is often achieved nowadays by the incorporation of an octave-band or third-octave-band graphic equalizer.

However, one is still left with the inevitable response irregularity of the room itself, where adjacent peaks and dips are typically only a few hertz apart (Fig. 2 in my original article, *W.W.* July 1973, p.317). The smoothing of such a response is an impossible task for conventional filters, but the frequency shifter is able to overcome the ill-effects of such irregularity and effect a significant improvement in available gain prior to feedback.

I should be the last to deny that frequency shifting on music is a highly controversial subject. When I first designed and used the howl suppressor, it was solely with speech applications in mind; I expected the technique to be unacceptable for music. It was therefore with some surprise that I found the frequency shift usable for musical performances. The 5Hz beat, which, as I mentioned in the article, is sometimes audible on long continuous notes, is the only unusual effect. There are just one or two instruments, such as organ and electric guitar, where the beating is obvious, being heard as a sort of "stereo vibrato" between the original sound and the frequency-shifted version.

I found the absence of a beat in the majority of musical applications rather mystifying at first, but the answer was found to lie in the delay between direct and amplified sound. Virtually all public address systems exhibit such a delay, which occurs because of the difference in sound path lengths; in a well-designed system the direct sound is arranged to arrive at the listener first, exploiting the "Haas effect" to produce the correct apparent sound direction. To investigate the effect of time delays on beats, I tried mixing a music signal and its frequency-shifted version and feeding the signal to headphones. Strong 5Hz beats were audible on all types of music. When, however, an adjustable time delay was interposed in the frequency-shifted channel, a time difference of 3 ms was found to be sufficient to destroy coherence between the two signals on most types of music, thus eliminating beats.

Exceptions were found in the cases of organ and electric guitar, where even delays as long as 100 milliseconds did not destroy coherence, owing to the steady pitch and level of the notes produced. The beats produced on these instruments become very much less obvious if the frequency shift is reduced to 2.5Hz by doubling the values of capacitors C_2, C_3, and C_{10} in the oscillator circuit to 200nF. This change usually involves a slight loss (typically 2dB) in the amount of feedback reduction available, but it is worth trying if beats are audible.

I should be very interested to hear reports, whether favourable or otherwise, from any readers who have used the frequency shifter in a music amplification system.

M. Hartley Jones,
University of Manchester,
Institute of Science and Technology,
Manchester.

Current flow controversy

The letters by Messrs D. V. Ellis and C. H. Banthorpe in your December 1973 issue each has a final paragraph of such graceful compliment that it largely defuses what I might otherwise have said about what went before. Fortunately I feel I can confidently leave readers to draw their own conclusions on most of the arguments put forward, so that replying to them all in detail would be superfluous.

For example, if, as Mr Ellis suggests, my ideas on cathode rays are freakish and absurd, how is it that since those ideas were introduced into *Foundations of Wireless (and Electronics)* 22 years ago about 100,000 copies have been bought, and (many of them being in public and college libraries) the number of readers must be considerably greater, yet not a single one of them has pointed out the difficulties arising from use of the conventional direction of current flow in connection with that subject or with any other in that or any other of my works, but on the contrary people continue in large numbers to vote with their purses right up to the present day?

One thing I have ascertained from Mr Ellis's second letter is that he advocates reversing the current-flow convention but *not* the polarity conventions. So he does have to teach that his current flows from negative to positive, i.e., from a deficit to a surplus, presumably on the principle that "to him that hath shall be given and from him that hath not shall be taken away even that which he hath"—another paradox, but not one applicable to electric circuits. And yet by some logic that escapes me he reconciles this with water flow! This, in addition to teaching that the rules in the textbooks mean the opposite of what they say, and the arrows in device symbols are there to show the direction the current does *not* flow! And yet in August he found unacceptable an imaginary situation in which a horse described as black had to be taken as white!

Mr Banthorpe seems not to know what "the positive direction of current" means. May I try to enlighten him? The actual direction of current (conventional or electronic) from A to B in a complicated circuit may not be known; in fact, that may be what is to be found. So let us agree to call current from A to B (say) positive. Then if our calculations result in a positive value of current in that branch it does indeed flow from A to B. A negative value means it flows from B to A.

May I reiterate that "the direction of current flow" cannot be established consistently on a basis of physical facts, since an electric current can be constituted by physical movements in either or both directions. So it is a convention; and whichever of the two possible ones is adopted students and others will have to accept that some current carriers will move "against" the current. (In spite of what Mr Ellis says, the existence of negative ions does not get rid of this awkward fact.) If we could start from scratch we in electronics would almost certainly vote for the direction of electron flow, but Mr Smethurst has wisely reminded us that we are not the only pebbles on the beach of science. The important thing is that everyone should use the same conventions.

For about a century and a half there has been an accepted convention among British railwaymen that trains going in the general direction of London are referred to as "up" trains and those going in the opposite direction are "down" trains. If signalmen in cabins where this convention is manifestly absurd, because the track thereabouts goes uphill in the "down" direction, decided to take the "sensible" view and report as "down" all trains they saw going downhill, confusion in British Rail would be as great as during a work-to-rule. Much less confusing, when nobody can be literally right all the time, to stick to the convention that has been in use for so long. So it is, surely, with current.

"Cathode Ray"

Soldering-iron leakage

I was interested to read the letter from Mr Sproxton of Home Radio in your March issue. As far as I know only one soldering-iron manufacturer makes an issue of leakage currents but, I suspect, misguidedly.

The point really is that to solder semiconductor devices safely it is necessary to ensure that no voltage appears on the bit of the iron. Provided that the iron is fitted with a three-core flex which in turn is properly connected to a three-pin plug, then the bit must always be at earth potential, and it would take a very large leakage current indeed to make it otherwise. If the earth connection is not used, then even the smallest leakage current will cause a possibly damaging potential to build up on the bit.

Incidentally, nearly all temperature-controlled irons also produce switching transients which can damage the more delicate (and expensive) devices since they use mechanical or thyristor switching techniques. It was for this reason that we developed the special transistor switching circuit for our variable temperature ETC/1 system.

C. P. Adamson,
Light Soldering Developments Ltd,
Croydon,
Surrey.

Active filter crossover networks

Mr Read's article "Active filter crossover networks" (December) raised interesting ideas, which could prove very fruitful to audio experimenters. Indeed, I intend to experiment with such networks when student finances permit. However, I was astonished to read "Peak powers of 20W occurred in all the three bands". Could the author possibly enlarge as to how he measured these peak powers, and under what circumstances?

D. J. Bradshaw,
University College,
Oxford.

The author replies:

In answer to Mr Bradshaw's query regarding amplifier power requirements the following details of tests and observations made when setting up the 2 × 3-way arrangement described in my article may be helpful.

With the three KEF units (types B139 for l.f., B110 for m.f. and T27 for h.f.) installed in the transmission-line enclosure each speaker input signal was monitored by display on a storage oscilloscope during repeated runs of the same test programme comprising music from full orchestra, choir and solo female singer. The storage oscilloscope persistence control was set so that the decay time was of the same order as the test programme duration; the brightness control was at a suitably low setting to avoid "overloading" the phosphor during that period. In this way, the three filter outputs were (sequentially) displayed to indicate and record:

(1) Instantaneous peak power. Voltage amplitude was here considered proportional to *instantaneous* power; because of the change of load impedance with frequemcy. However, such an assumption was valid only for the intended purpose of comparative estimate.

(2) Integrated peak power. The differing trace brightness at various voltage levels showed the proportion of programme time spent at these levels and hence, taking the brightest level in each instance, the average peak power during the programme run. Again, this test is more concerned with intelligent observation than measurement—the human eye is a poor judge of brightness difference even by direct comparison and is still worse if it has to "remember" a previous

image. But, as the results show, the observed differences were sufficiently large to justify the conclusions reached.

The results were:

(a) The highest peak voltages (instantaneous powers) were those handled by the B139 (l.f. unit), being about 6dB more than for the B110 mid-range speaker.

(b) The integrated peak power was obviously much larger for the B110 unit —say 75% of the total compared to 20% for the B139.

(c) The T27 tweeter received the least amount of energy during the programme —in fact, the estimated figure for integrated peak power was only a few percent. But, and this is of prime importance, the input to this unit included short-duration peaks of nearly the same amplitude as the maximum recorded for the B110. Hence it was concluded that the *instantaneous* power requirement here was similar to that for the mid-range units.

Further tests were done using the same technique but for an input of typical "pop" music. As might be expected with the heavy bass component normal in this type of music, the results indicated a shift in power distribution between the m.f. and l.f. speakers such that their "integrated-power" percentage figures were more or less equal. In all other respects there was little difference as compared with the previous test.

I hope that above serves to show why the amplifiers feeding h.f. units required the full 20-watt capability and also why the output-stage heat sinks in both "l.f." and "m.f." amplifiers were chosen to be of the same size as the circuit boards themselves ($3\frac{1}{2}$in $\times$ $4\frac{1}{2}$in) whereas those for the "h.f." amplifiers were made smaller.

Finally, two other points should perhaps be mentioned. First, to obtain an overall level response (according to measurement in an anechoic chamber) the gain of amplifiers driving the l.f. units was made 5dB greater than for the other amplifiers. Secondly, considering the wide variation in speaker characteristic impedance, at some frequencies it is obviously the available supply voltage (and hence the maximum possible voltage swing) which sets the limit on amplifier output rather than its power handling capability.

D. C. Read

Fast printed circuit etching

I was appalled to read Mr Langvad's letter in the December 1973 issue of your magazine and fervently hope that my comments may prevent the occurrence of a very serious accident. Your correspondent recommends that printed circuits be etched with a mixture of hydrochloric acid and hydrogen peroxide. Although he issues a fairly gentle warning about the use of these chemicals, I would like to emphasize that the two are very vicious substances indeed, and hydrogen peroxide at the suggested concentration in particular is very, very hazardous to handle. The use of these should only be permitted in a laboratory and not in any amateur's workshop. Your correspondent may also be unaware that the result of the reaction between hydrogen peroxide and hydrochloric acid, as shown in the following overall equation

$$H_2O_2 + 2HCl \rightarrow 2H_2O + Cl_2$$

is chlorine gas, which, as everyone knows, is a very toxic gas.

E. I. Szabó,
Ottawa,
Canada.

Radio and TV museum

As part of educational technology, I am attempting to build a small museum of radio and television equipment to show the change in components and design philosophy since the inception of radio.

I would be most appreciative of any suitable equipment, however small, or technical literature, for the period 1900 to 1930. I must make it plain that the above would be in the form of a gift, as I have no finance for this project.

C. Matthews,
School of Engineering Science,
University of Edinburgh,
King's Buildings,
Mayfield Road,
Edinburgh EH9 3JL.

Valve amplifiers

Recently a "Williamson" amplifier fell into my hands, displaying the fault of falling gain over a period of hours of operation. (The older hands may remember that the Williamson design was first published in 1947 and modified in 1949—I, personally, wasn't born then!) On examination I discovered two major faults: (1) a cracked wire in the negative feedback meant that there was no negative feedback; and (2) a short-circuited decoupling capacitor was preventing half the output stages from functioning.

Yet, despite the faults, the amplifier was producing quite acceptable results. It makes one wonder if we were a little hasty in abandoning valves so absolutely.

D. J. Bradshaw,
University College,
Oxford.

"Recording by ear"

I was rather amused to read of the efforts of the scientists at the Battelle Institute (December, News of the Month). During 1963 I constructed an intercom system for use between the rider and passenger of a motor-cycle combination. As those with two- or three-wheel experience will know, high noise levels are prevalent. However, communication was secured as follows. Mounted in the toe of the side-car was a 7 $\times$ 4 elliptical loudspeaker driven by a 2-watt amplifier. The passenger spoke into a hand-held noise-cancelling microphone which was permanently live. This arrangement gave useful sidetone with no howl. The rider for his part listened through a miniature earphone let into the earflap of his crash helmet. This, however, pressed snugly against the ear, and doubled as a microphone operated by a push-button on the handlebars. Bystanders might be seen giving anxious and startled looks as a loud male voice apparently issued from the female resident of the sidecar.

A. Puffett,
Stevington,
Beds.

Calculator I.C.

I read with interest your article on the GIM C500 calculator chip in the March issue. I am in the process of designing and building a more ambitious calculator using this chip. Additional features are:

20 fixed functions (pi, reciprocals, %, metric conversion, etc.)
Automatic squaring and square root.
1 non-calculating store.
1-inch-high home-made display.
Left and right shift on decimal point.

The point of this letter is to air a criticism that all the above would have been far simpler if the manufacturers had provided a b.c.d. output instead of seven-segment. After all one can buy (quite cheaply) a chip to convert from b.c.d. to seven segment, but not the reverse.

Messrs GIM have expressed the wish that by releasing the C500 at a competitive price it would encourage its use in fields other than calculators, but the above remarks place limitations on interfacing with other logic. The m.o.s. inputs and outputs can be overcome with suitable circuitry.

A. M. Coppin,
Feltham,
Middlesex.

Return to c/s?

I am sure you will find your new feature Project very rewarding, especially as it will have the backing and experience of *Wireless World* behind it. Writing as a teacher of long experience, could I make one observation which I think would improve the physics masters' lot quite considerably?

Ever since the introduction of the term "hertz" instead of "cycles per second" there has been uncertainty as to its meaning. I noticed some hesitation and difficulty by lecturers on two occasions while giving the Christmas lectures, and on another occasion a member of the BBC television "Tomorrow's World" team deliberately used the old-fashioned "cycles per second" as it expressed what he wanted to say.

After all, Heinrich Hertz was investigating electromagnetic waves radiated through space, and if the term "hertz" were confined to this, then cycles per second could be applied to sound-wave frequencies. In fact, I would suggest that all wave frequencies below 20kHz, including the 50Hz mains, should revert to its more meaningful description.

G. A. Cozens,
Bartley,
Southampton.

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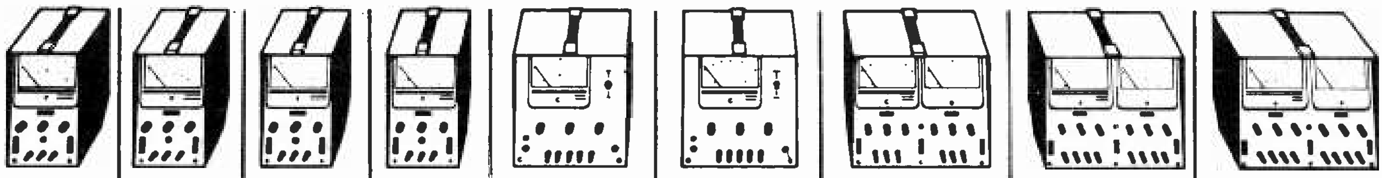

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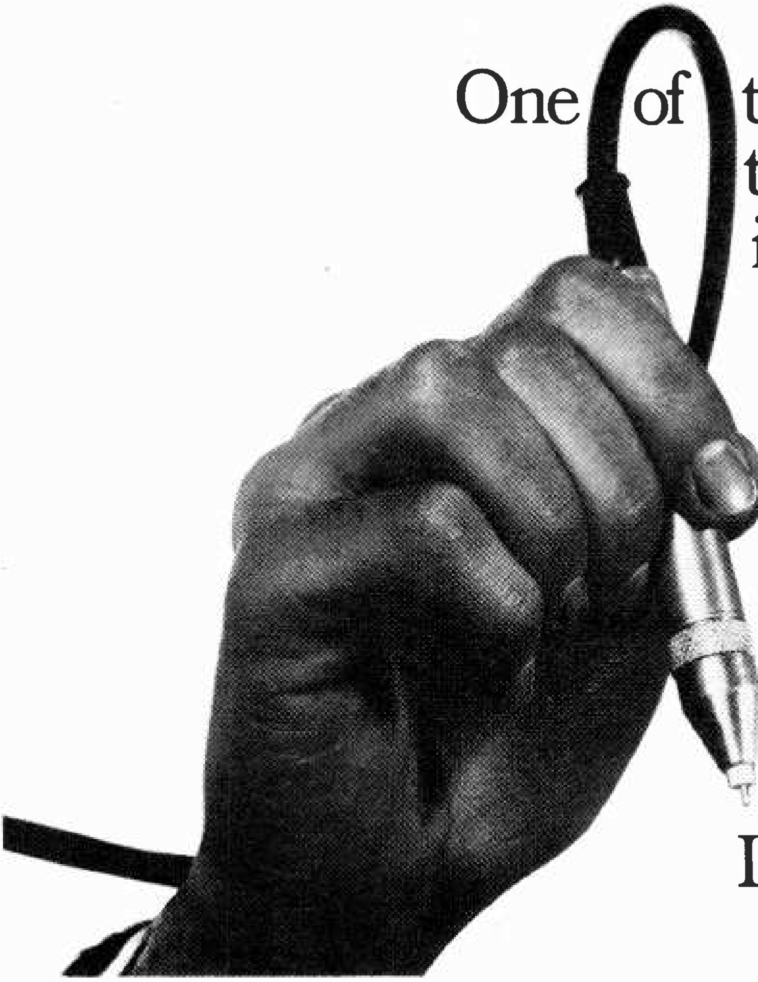

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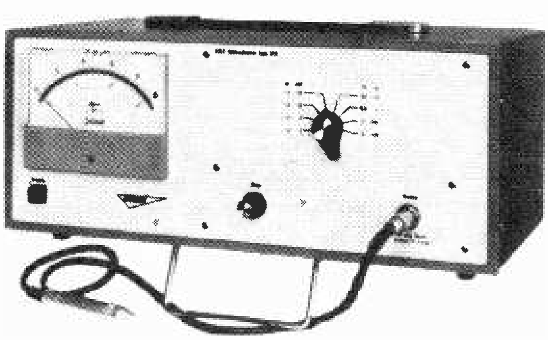

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Realm of microwaves

8—Lenses and radomes

by M. W. Hosking, M.Sc.
British Aircraft Corporation, Stevenage

From the last two articles it should be apparent that the most usual antenna function is to direct as much radiated energy as possible within a specified beamwidth. The efficiency with which this can be achieved depends on how closely the radiation from the antenna system approximates to a plane wavefront; that is, a constant phase across the aperture. An obvious and good example of this is the paraboloid reflector which converts the generally spherical wavefront of the primary feed to a plane-wavefront radiated beam. Such a situation implies equal electrical path lengths for all rays from the feed to the aperture plane and this can also be achieved by a microwave lens.

Microwave lens design can be approached along similar lines to those in optics but, because certain lens dimensions are comparable to the wavelength, diffraction effects cannot always be ignored. These lenses fall conveniently into three categories, although not every type of lens is discussed within each category.

Firstly, there is the uniform dielectric type of lens constructed from some solid material and behaving in much the same way as its optical counterpart. Secondly, there is the artificial dielectric lens wherein, as the name implies, an effective dielectric constant is produced by means other than the bulk property of a material. Thirdly, the non-uniform dielectric lens of which the dielectric constant is not, in fact, constant throughout the lens, but varies with distance in some prescribed manner.

Dielectric lens

Bringing back memories of school physics, the design of solid dielectric lenses can be based on the methods of geometrical optics. Analogous to the optical transparency is the dielectric loss tangent of the lens so for microwaves there is a much wider choice of materials. The lens does not have to be optically transparent and, being the same order of size in thickness as the wavelength, the overall transmission loss is low. However, when the mechanical, environmental and fabrication requirements are taken into account, the range of suitable materials is reduced; those most generally applicable being plastics such as the polyolefins, polystyrene and p.t.f.e.

Refractive index is one of the main design parameters, but microwave materials are characterized by their dielectric constant. There is, however, a direct relationship between the two. Refractive index is defined as the ratio of the speed of light or electromagnetic propagation in free space to that in material; that is, $n = c/v$. These speeds can be expressed in terms of the relative and absolute permeability and permittivity as

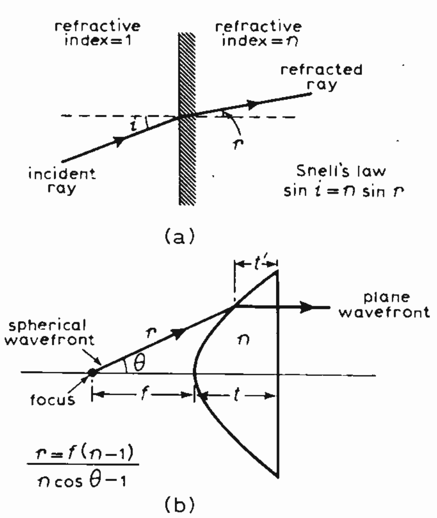


Fig. 1. Refraction of a plane wave at a dielectric interface (a). A point source, spherical wavefront can be converted to a plane wavefront by a suitably curved surface (b). In this case the contour can be hyperbolic or elliptical depending on whether n is greater or less than unity.

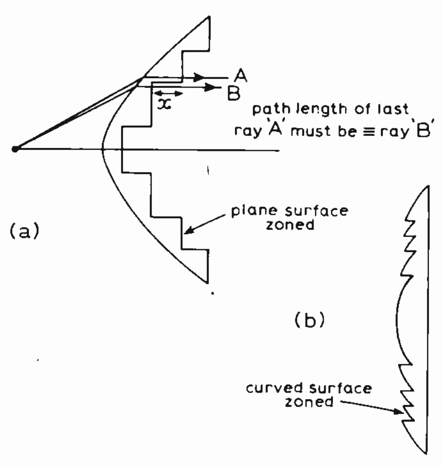


Fig. 2. Zoning the microwave lens saves weight, although at a sacrifice in bandwidth for the solid lens.

$c^2 = 1/\mu_o\varepsilon_o$ and $v^2 = 1/\mu_o\mu_r\varepsilon_o\varepsilon_r$. Manipulation of these relationships shows that $n = \sqrt{\varepsilon_r}$ for the case when $\mu_r = 1$. A word of caution here in that n is not necessarily the same as the optical refractive index, because the dielectric constant may vary with frequency between the microwave and optical bands.

Another important characteristic of the uniform lens is that Snell's law is obeyed so that $\sin i = n \sin r$ using the notation of Fig. 1(a). This makes ray-path tracing easier and simplifies equations for the lens surfaces; which brings us to Fig. 1(b). The requirement of the lens shown is to convert the spherical wavefront from a source at the focus into a transmitted plane wavefront. For this to happen, all of the ray-paths into and out of the lens must be equal electrically and defining one surface of the lens as plane, the problem is to find the equation for the other one. From the geometry shown, this means that $r+nt'$ must equal $f+nt$, or $r-f = n(t-t')$. The term $(t-t')$ can be expressed as $(r\cos\theta)-f$ resulting in the surface equation

$$r = \frac{f(n-1)}{(n\cos\theta)-1}.$$

For values of refractive index greater than unity this is the equation of a hyperbola of eccentricity n. So a simple microwave lens might be made from, say, polystyrene having a microwave refractive index of 1.6 and would be plano-convex in shape with the convex surface being a hyperbola facing the incident radiation.

If such a lens were to have an appreciable diameter, then the thickness would be large and the weight would consequently be high: both undesirable features. It is, however, possible to remove material from the lens in a controlled fashion and to drastically reduce the weight; the process being termed zoning, Fig. 2 showing end result. By "controlled" is meant removing a section of the lens such that the last ray, so to speak, in the dielectric, A of Fig. 2(a), differs in path length from the adjacent ray B in the air-gap left by a whole number of 2π phase changes. In this way the phase relationship between all rays is maintained at the correct value and, electrically, the lens does not know that pieces have been removed. The price paid is a reduction in bandwidth due to the frequency-sensitive nature of the steps, together with a reduction in aperture efficiency due to a diffraction at the edges of each step.

Although the dielectric lens antenna holds promise of greater ease of beam scanning by just moving the feed, it is up against severe competition from the reflector antenna and the phased array and is not nearly so widely used. Possibly its main application is as a phase corrector for microwave horns. The horn itself was reviewed in an earlier article and it can readily be appreciated that, due to the changing path length within the horn, there can be considerable phase change across the aperture causing inefficient radiation. By placing a lens in the aperture, the efficiency can be raised from something like 50 to about 80% together with a reduction in spill-over and back radiation.

Artificial dielectrics

It is possible to calculate, with varying degrees of success, the dielectric constant of a material from a knowledge of its molecular structure. In general, this means the determination of a quantity called polarizability, which is a measure of the ease with which an applied electric field can induce a directional charge in each atom. Normally, each molecule with its atoms and orbiting electrons has no preferential charge on it and is electrically neutral. But when brought under the influence of an electric field, some electron re-positioning occurs, producing a preferential alignment of charge in the same direction as the field—the dielectric becomes polarized.

Polarization also occurs in metallic conductors due to an applied electric field re-positioning surface charge and has led to a class of artificial dielectrics wherein metallic particles of various shapes are used to simulate the molecules and so form what is really a large-scale model of a molecular structure. Knowing the shape of the particles, their polarizability, and hence dielectric constant, can be fairly simply calculated (compared with an atomic structure) from an electrostatic approach.

Things are not that simple in practice, due largely to variations in particle size and shape and in uniformity of distribution. The particles can be of a variety of shapes: spheres, discs or flakes, filaments and strips being commonly used, with cross-sectional dimensions typically lying between 0.05 and 0.01 of a wavelength. Dielectric constant depends on the particle shape used and whether the particles have a preferred orientation. Spheres, for example, place an upper limit of about 1.6 ($n = 1.27$) on the dielectric constant, but being symmetrical this does not vary with the direction of propagation through the material. A disc on the other hand allows any value (theoretically) to be obtained, provided that both the electric and magnetic fields are tangential to the disc's surface. This means that the dielectric constant becomes a function of direction, to say nothing of alignment problems in producing the material itself. Whichever shape is selected, the particles themselves must be supported in some way and distributed as evenly as possible. The most popular supporting medium is polystyrene or polyurethene foams as these are light, easy to produce and have a very low refractive index.

Having selected the particle shape and distribution to give a particular refractive index, together with the binding medium the lens design can proceed as for the solid dielectric. The main advantage of this type of artificial dielectric is its low density, resulting in significant weight saving and not only in lens design. The material can also be used for radomes (see later). Possibly the largest problem facing its use is that of obtaining a uniform and repeatable dispersion of the metallic particles within the supporting medium.

There is another, widely-used method of creating an artificial dielectric constant which makes use of the guiding properties of parallel metal plates. A stack of such plates is shown in Fig. 3(a) with an incident electric field parallel to the plate surface. Under these conditions, the plates will support a waveguide mode, the wavelength of which then becomes governed by the plate spacing. It may be recalled from an earlier part of this series that the guide wavelength can be expressed as $1/\lambda_g^2 = (1/\lambda_o^2)-(1/4a^2)$ where the quantity $2a$ represents a cut-off wavelength above which energy will not propagate in the guide. The refractive index, $n = c/v$, which is the same as $n = \lambda_o/\lambda_g$, as the frequency remains constant. Therefore, by using the above expression for waveguide wavelength, a refractive index for the parallel plate system can be written as $n = [1-(\lambda_o/2a)^2]^{\frac{1}{2}}$. Some limitations are put on this expression as the spacing, a, must be greater than $\lambda_o/2$ to remain above cut-off and must be less than λ_o to avoid risking the propagation of the next-order waveguide mode.

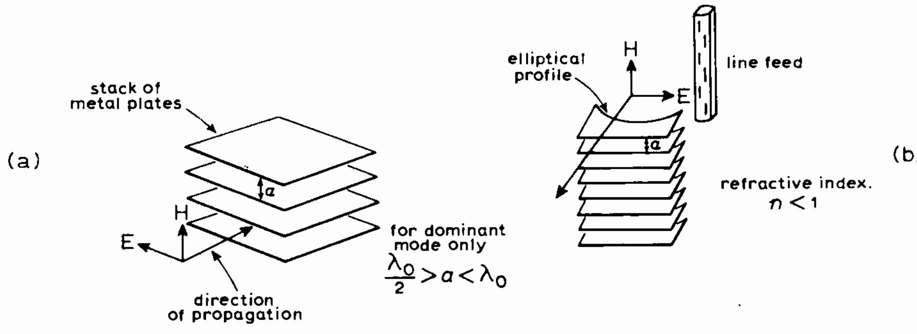


Fig. 3. Equivalent dielectric constant of less than unity can be produced by constraining the wave to pass through metal plates (a). By shaping the plate surface (b), a further type of microwave lens can be produced.

An interesting feature of this type of structure is that the refractive index is less than unity, implying that the velocity within the guide is greater than that of light. However, the overall velocity within any substance can be considered as the geometric mean of two velocities. One being that at which signal energy is carried, called group velocity and which cannot exceed c, and the other called phase velocity, which describes the movement of the phase front and which can be greater than c. For a non-dispersive medium the two are equal, but that is not the case here and v is the phase velocity.

We thus have another artificial dielectric with an equivalent refractive index and, in similar fashion to the solid dielectric case, wish to find the profile of one surface to produce a lens. The first equation can be used again, but with $n<1$ is re-written $r = f(1-n)/(n\cos\theta)-1$ which is now the equation of an ellipse. Thus, a metal plate lens might appear something like Fig. 3(b) in general profile.

Many other types of lens are possible and the methods of producing artificial refractive indices and lenticular effects are many and varied, although often having little practical application. Consequently, there is little to be gained in reviewing these further; rather the intention has been to introduce to the reader the concept of a microwave lens and to highlight differences in physical form between it and the more familiar optical counterpart. Anyone interested in delving further into the subject could obtain the basic groundwork.* There is one other lens from the category of non-uniform dielectrics which is well worth mentioning; partly because of its novelty and partly because it is the most widely used of all microwave lenses.

The Luneberg lens

This was first propounded in a treatise on optics but proved impractical to construct at those wavelengths. The idea is to produce a lens that will focus energy from a point on one side to a point on the other, with particular attention paid to the limiting case where one of these points is on the surface of the lens and the other point is at infinity. In other words, to derive another spherical to plane wave-front convertor. The lens itself is a sphere having the general ray geometry shown in Fig. 4(a) wherein radiation from a point-source feed on the surface follows elliptical ray paths through the lens and, if all of these ray paths can be made electrically equivalent, emerges as a plane wavefront. A fairly complicated mathematical analysis of this lens shows that to provide the necessary phase variations within the lens, the dielectric constant must vary with the distance from the centre of the lens, r, in the simple fashion given by: $\varepsilon_r(r) = 2-(r/r_o)^2$. In other words, the refractive index must vary continuously from unity at the lens surface ($r = r_o$) to $\sqrt{2}$ ($r = 0$) at the lens' centre.

When one gets down to constructing the Luneberg lens such a variation is not really practicable, so an equivalent approach

*From "Microwave Lenses" by J. Brown, Methuen 1953.

must be found. One which gives exceedingly good results and also permits a simple manufacturing process is to divide the lens into a series of hemispherical shells as in Fig. 5. Each shell has a definite dielectric constant, but different from its neighbour and so the variation of the last equation is achieved in step fashion instead of continuously. Provided the thickness of each shell is chosen so that the phase errors are not cumulative, the lens performs very well.

Because of its symmetry, the Luneberg lens is capable of scanning a beam in all directions and without distortion by just moving the feed. Its widest use, however, is as a radar reflector wherein the feed is replaced by a metal cap as shown in Fig. 4(b) onto which an incident plane wavefront is focused and then reflected back again in the same direction. Such reflectors are used in enhancing the radar return from small airborne targets, calibrating radar systems and acting as marker buoys.

Radomes

This topic is lumped together with that of the lens because, to my mind, the two have many similarities. Both are constructed from dielectric materials, either solid or artificial, both strive for maximum power transmission, and both involve the same basic design problem of an incident electromagnetic field at a dielectric air interface. Often a "tail-end Charlie" in system design and perhaps in receipt of less fundamental design attention than other components, the radome is nonetheless a vital part of radar and communication systems.

The radome is an unwanted extra in the majority of systems and it would always be an advantage, electrically, to do without it. This is seldom possible, as the prime function of the radome is to provide weather protection for the microwave and electronic equipment beneath it. Also, in the case of aircraft and missiles, the radome must form a part of the aerodynamic profile and therefore has to contend with the harsher set of environmental conditions which this imposes. Thus, the radome designer must be a fairly versatile character as he must produce

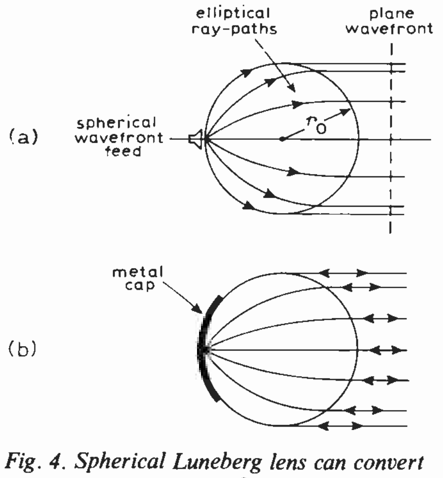


Fig. 4. Spherical Luneberg lens can convert a point source on its surface to a plane radiated wavefront by suitable radial grading of its refractive index (a). By placing a metal cap on the surface the lens can be converted into an efficient reflector (b).

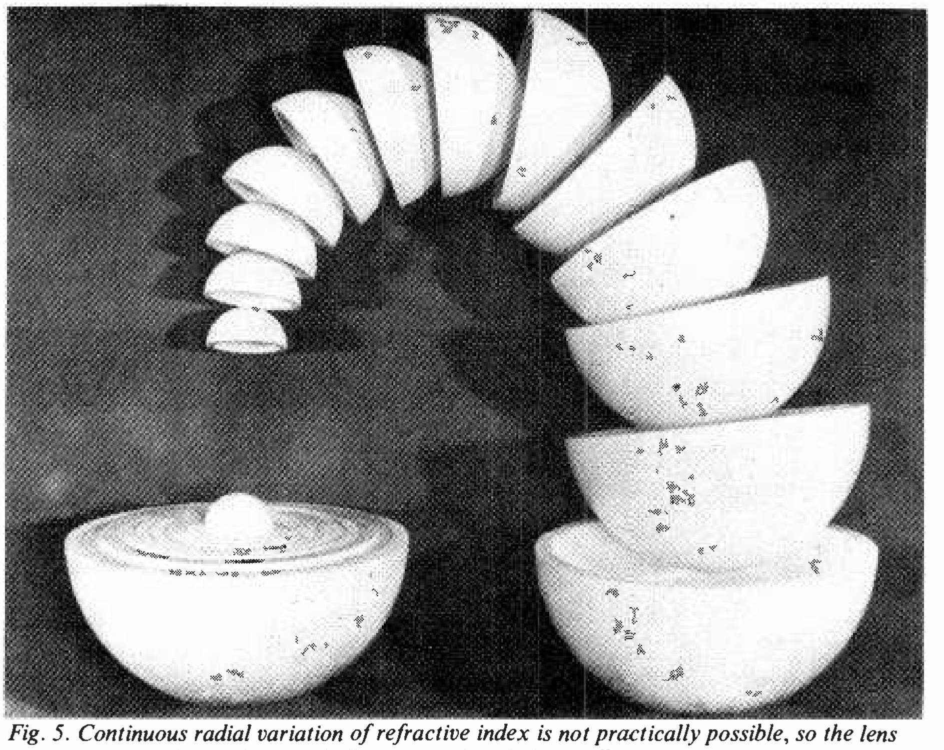


Fig. 5. Continuous radial variation of refractive index is not practically possible, so the lens is constructed of hemispherical shells, each with a slightly different refractive index.

an equipment cover that is electrically invisible, will withstand rain, snow, ice and extremes of temperature, is mechanically strong and is often aerodynamically profiled. Needless to say, these diverse requirements are not mutually compatible.

It is not reasonable to try and cover here the mechanical and environmental side, except to highlight major points, as this is really a materials technology problem. On the electrical design, however, radomes can be divided into fairly definite categories according to their method of construction and the design itself boils down to that of proper phasing of the reflections which occur at the various material boundaries.

Suppose a radome consists of a sheet of some plastics material of thickness d and dielectric constant ε_r. A wave travelling along in free space will see the dielectric as an abrupt change in the characteristic impedance of its environment. The net result will be a reflection of some power at the interface with an amplitude depending on ε_r and having a maximum possible value of $R = (\varepsilon_r - 1)^2/(\varepsilon_r + 1)^2$.

In addition, the phase of this reflected wave will be opposite to that of the incoming radiation. Having traversed the sheet, the wave now meets another impedance change as it emerges back into free space and this gives rise to a second reflected wave, equal in amplitude to the first but without the phase change. In summation, there will thus be two reflected waves emerging from our plastic sheet, one from the front surface and one from the back and, depending on the phase relationship between them (remember that one wave has traversed the panel twice), they will form a resultant. Such a resultant wave, by interfering with the incident radiation, will cause a further loss in the transmission performance of the radome and it is here that the radome designer steps in.

Fig. 6(a) shows how, for normal incidence, the power transmission of a dielectric sheet varies with its thickness, the features to note being the periodic nature of the curves and the existence of optimum values of d/λ_o. These optimum values to give maximum power transmission occur when the two reflected waves from the radome combine in such a way that their resultant is zero. In other words, one must be π radians out of phase with the other. Bearing in mind that because of the nature of the impedance change (high to low) the reflection from the front surface is 180° out of phase with the incident wave, the condition for cancellation is that the second wave should travel

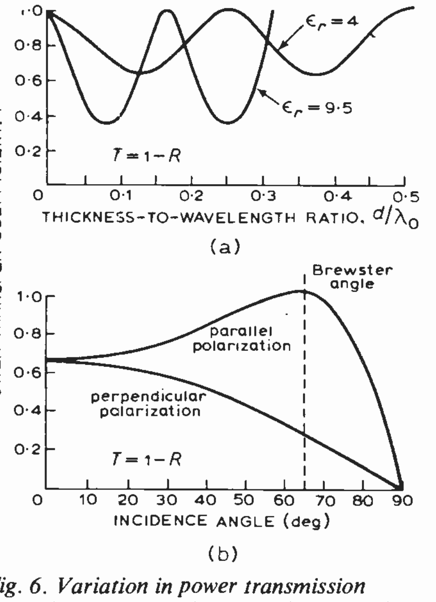


Fig. 6. Variation in power transmission through a dielectric sheet as a function of thickness for normal incidence (a). Transmission properties are different for perpendicular and parallel polarizations, that for perpendicular always being worst (b).

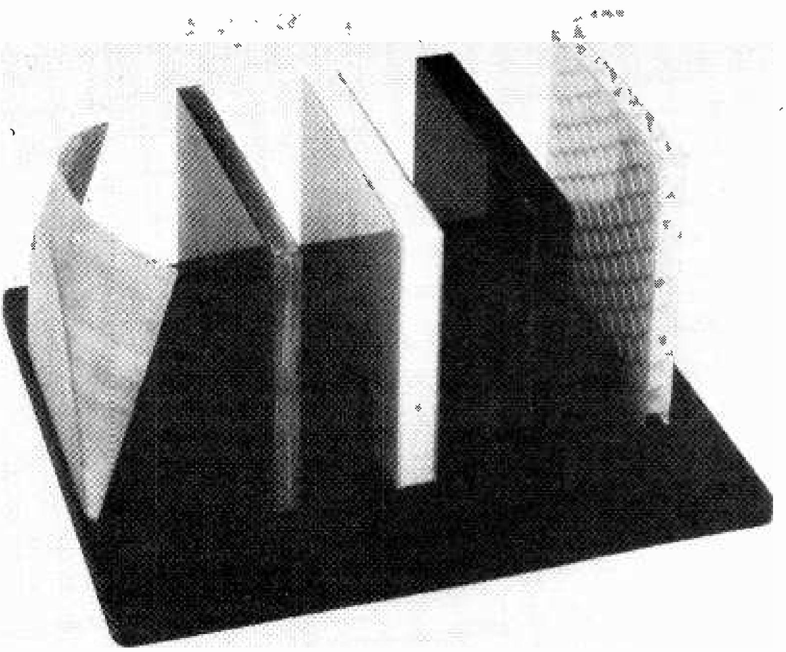


Fig. 7. Main types of radome construction are, from left to right: thin skin, half-wave and three A-sandwiches with different cores.

multiples of 2π radians before combining with the first. As 2π radians corresponds to one wavelength, the radome should therefore be a half-wavelength thick. This means the wavelength within dielectric; i.e. $\lambda_o/\sqrt{\varepsilon_r}$.

This feature of a dielectric sheet gives one of the main radome classifications: the half-wave type which finds application at frequencies generally above X-band (above about 10GHz). While many dielectrics are convenient for manufacture, the most popular material by far is fibreglass/resin laminate. Its loss tangent may leave something to be desired at about 0.01, but this is made up for by ease of fabrication, good weathering properties and great strength. With a dielectric constant of four, a fibreglass, half-wave radome designed to operate at 15GHz would thus be a nominal 0.5 cm thick.

A second radome type, really a limiting case of the half-wave, is the thin-skin radome which, as its name implies, has a thickness small compared with the wavelength. Generally, this means less than $\lambda_o/20$ and Fig. 6(a) shows that, for a fibreglass laminate, 85% power transmission is still achieved at this upper limit. Glass-fibre is still a commonly used material for the thin-skin radome but, when circumstance permits, relatively cheap radomes in polyolefin or polystyrene types of plastic can be made using vacuum forming. Example of a thin-skin and a half-wave radome are shown in the two left-hand items of Fig. 7.

The three other samples shown in this figure are from a third main type of radome: the sandwich. In this case, they are of an A-sandwich which consists of two high-dielectric constant thin skins and a low-dielectric constant core. There is also a less-used B-sandwich in which the core is of higher dielectric constant than the skins and a C-sandwich which is really a double A-sandwich. The main reason for going to a structure such as the A-sandwich is that of weight saving, at the same time maintaining good strength and rigidity. Electrically, the idea is to arrange the spacing of the two skins so that the reflection from the front skin cancels out the one from the rear. For this to happen, a 180° phase difference must exist, which means that the skins must be $\lambda/4$ (in the core material) apart. If the difference between this situation and the half-wave radome is not at first apparent, remember that the sandwich reflections arise at two high/low impedance interfaces whereas those of the half-wave come from a high/low and low/high transformation.

Construction-wise, the outer skins of the A-sandwich are usually of fibreglass and the core can be made from a number of low-density, low ε_r materials. The left-hand and centre sandwiches of Fig. 7 have cores of polyurethane foam and the end one uses a honeycomb or resin-impregnated fibreglass. Typical dielectric constants range from 1.1 to 1.2.

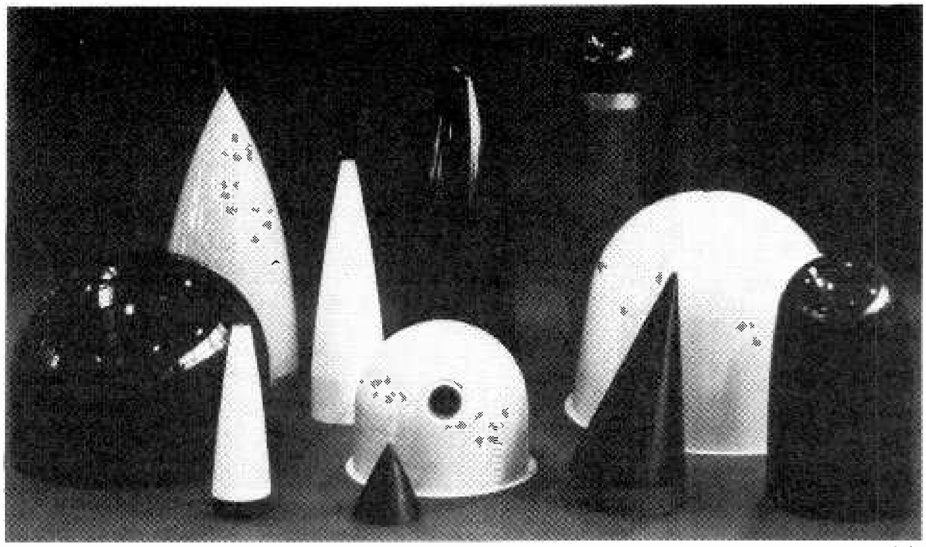
So far, the transmission properties of radome materials have been maintained with radiation incident only normal to the surface, but in practice angles of incidence as high as 80° can be encountered. The design situation then becomes much more complicated because the transmission coefficient varies both with incidence angle and polarization of the E-field vector. Before looking at this in more detail, it is necessary to define what is meant by E-field polarization. If this page represents the radome surface, then it is possible to define a plane of incidence formed by the normal to the page and a line indicating the direction of the incident wave. There are then two polarizations: vertical when the E-vector is perpendicular to the plane and parallel polarization when the E-vector is parallel to the plane. The transmission properties are different for each type. This difference is marked and is shown in Fig. 6(b) for fibreglass sheet of $\varepsilon_r = 4$. At normal incidence, the power transmission is limited by the reflection coefficient of the last equation giving $T = 0.64$. As the incidence increases, the transmission coefficient for perpendicular polarization steadily decreases to zero for 90° incidence, while that for parallel polarization increases and eventually reaches 100% transmission.

The incidence angle at which this occurs is the Brewster angle and is equal to $\tan^{-1}\sqrt{\varepsilon_r}$. Having passed this angle, the transmission falls off rapidly to zero at 90°. Over the whole range of incidence angles, the transmission of parallel polarization is always better than that for perpendicular which makes it much more difficult to design the more streamlined type of radome having a wide range of incidence angles. This is particularly so for the case of the sandwich radome as its transmission properties are more susceptible to changes in incidence angle than are those of the half-wave type. Fig. 8(a) shows a sample of aircraft and missile radomes of thin-skin, half-wave and sandwich construction where it can be seen that the designs range from the relatively straightforward, normal incidence, hemispherical radomes to types having a very high fineness. An advanced half-wave radome, both production-wise and design-wise, is the Concorde radome shown in Fig. 8(b). It is made from epoxy resin fibreglass, is 11ft high and has a slightly elliptical cross-section. Fig. 8(c) shows an example of a large A-sandwich radome 14ft diameter for a ship-borne radar.

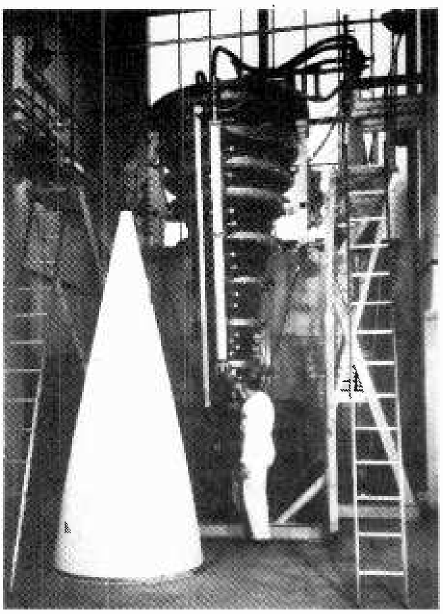
Because of the imperfect transmission properties and the way in which these vary with incidence and polarization, the placing of a radome over an antenna system gives rise to various types of performance degradation which it is the designer's job to minimize. One of these is the straightforward reduction of radiated power due to the mismatch reflections from the radome wall and the attenuation in passing through the lossy dielectric medium. Usually, these losses can be kept to around 0.5dB.

Another effect, generally called boresight error, causes the radiated beam to point in a slightly different direction from that of the antenna. The cause is diffraction effects at the radome and the amount of error is largely dependent upon the variation in phase across the radome surface. Depending on the method of construction, the boresight error is generally less than 20 minutes of arc, which may not sound much but can be most important to certain types of radar: missile homing systems, for example. Once again, due to phase variations, the radome can distort the antenna pattern, usually manifesting itself as a broadening of the beam and an increase in sidelobe level.

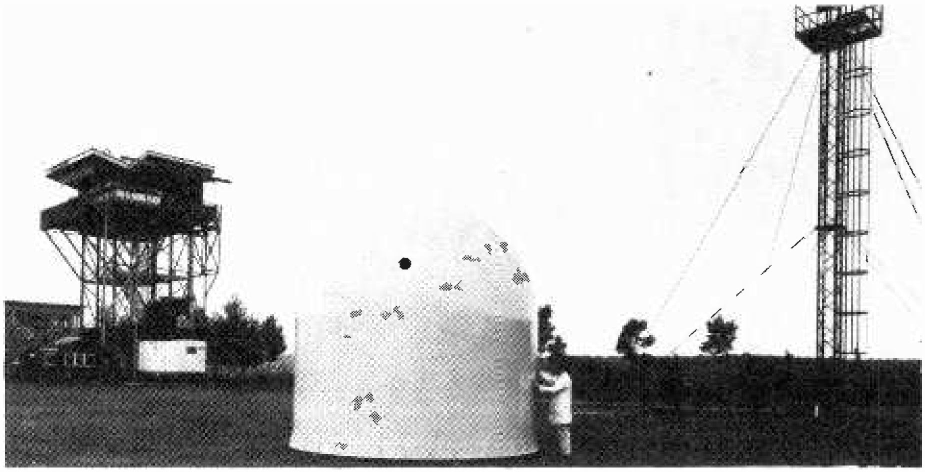
Although the main types of radome have been reviewed here there are, needless to say, many variations. The core of the A-sandwich, for example, could be made of lightweight artificial dielectric of the same ε_r as the skins, thereby forming the less polarization-sensitive half-wave radome but at a much-reduced weight. Thickness and weight can again be saved by embedding wires in thin radome skins to produce lumped inductive or capacitive elements instead of the distributed transmission path through the normal radome. When one



(a)



(b)



(c)

Fig. 8. Aircraft and missile radomes of different methods of construction illustrate the wide range of radome shapes (a). Half-wave Concorde radome and part of its 3½-ton mould (b) and a large A-sandwich radome (c).

adds to these electrical design considerations the severe environmental and mechanical requirements such as imposed by most aircraft and missile systems, the design of a radome becomes a most interesting topic involving many areas of technology.

Scottish search for gravity waves

For the last few years the detection of "gravity waves" from outer space has been claimed by the American physicist J. Weber. Gravity waves are bursts of gravitational energy which are expected to be emitted when a star is swallowed by a "black hole". Gravity waves travel at the speed of light and are detectable by measuring the movement produced when they traverse a freely suspended mass. (Piezoelectric transducers convert the movements into voltages which are then amplified and recorded.)

Weber detects about one short-duration (less than 500 milliseconds) gravitational "event" per day. This has presented astronomers with a problem. If each "event" marks the destruction of a star at the centre of our galaxy, and the process has been going on indefinitely at the same rate, then the entire galaxy should have been consumed long ago. This is one reason why other attempts to check on Weber's measurements are being made.

The detection problem is difficult because the incoming gravity waves are weak, and apt to be obscured by local noise. This noise may be caused by external (seismic) vibrations or by internal temperature effects (thermal vibrations). Seismic effects are excluded by using two detectors, spaced well apart, and correlating their outputs. Thermal noise has to be combated by signal-processing techniques.

An improved type of detector is in use at Glasgow University. In this, each freely-suspended mass (a 300kg aluminium bar) is divided into two equal parts, with the piezoelectric transducers between them, acting as mechanical couplers. The transducers detect relative movements of the two half-bars. This arrangement is much more sensitive than the earlier ones in which transducers were fixed to the surface of the suspended mass.

Thermal noise sets the detector-mass vibrating on its resonant frequency of about 1kHz. The arrival of a signal impulse from outside interferes with this resonance signal, producing an increase, decrease, or phase shift. Any such modulation of the output requires the existence of other frequencies. If the natural resonance signal is eliminated by a notch filter, the true incoming signals can be distinguished.

In the Glasgow apparatus the outputs of the six stacks of piezoelectric transducers at each detector are pre-amplified by f.e.t. amplifiers and filtered by a broad bandpass filter centred on the fundamental resonance frequency of the detector mass. The fundamental output frequency is eliminated by a passive *LCR* bridged-T notch filter.

The two detectors are separated by 50 metres. Their outputs are applied to coincidence circuitry and then recorded in various forms. So far, "events" have been recorded very infrequently in comparison with Weber's results, though there is still a possibility that Weber may have detected events of much larger duration than the short (a few milliseconds) events predicted and searched for at Glasgow.

A problem of measurement

Rectifier-meter readings with distorted waveforms

by Thomas Roddam

At an exhibition last season, or maybe it was the season before, I was surprised, and then alarmed, to find quoted for a piece of equipment two figures which seemed incompatible. The alarm came when the chief engineer of the company concerned said he could see nothing wrong with them. The equipment was, if you are sitting on the edge of your chair with excitement, a sine wave power source. I have forgotten the exact numbers, but typically they were 10% distortion and an output voltage constant to within 2%. Readers who remember the old engine-driven aircraft generator with its carbon-pile regulator will also remember that the most certain way of burning out the valve heaters in flight was to set up the carbon-pile regulator using an average-reading voltmeter.

For much of the time most of us are content to use a rectifier meter, which reads, i.e. responds to, the average voltage but is calibrated to indicate the root-mean-square voltage of a pure sinewave giving the same meter reading. To what extent should we turn away from this easy and inexpensive practice now that our power supplies may no longer have the same purity of waveform as that supplied by the Generating Board?

Until twenty years ago there was no question about it. The one really critical voltage inside a piece of equipment was the valve heater voltage. If the heaters were too hot, the life was shortened: if they were too cold, some circuits, though none of mine, just would not work. Looking back more critically, however, we did accept quite wide variations by modern standards. The 12.6 volt line of a wide range of valves was a 12-volt battery, and no one expected that to be closer than $\pm 10\%$.

Technically it is not difficult to measure r.m.s. voltage, although the simple measuring techniques all have flaws. The old and tried method was the use of a thermocouple, calibrated in my young days against d.c. for each measurement or group of measurements. Accident-prone and slow, I do not regret that we no longer see this. Thermistor circuits are also slow, and I suspect that they are temperature dependent. Then there are tricks, using a number of diodes to build up the parabolic characteristic in a set of arcs.

I used this method a long time ago in a psophometer but I am not sure how good it is over a wide temperature range. More recently all kinds of clever devices have come into use. A Hall multiplier will produce V^2, and one can also do the multiplication by using length and amplitude modulation of a sampling train of pulses. In fact you can buy an expensive box of tricks.

Is this refinement necessary? How much does it really mean? In this article I propose to look at the error caused by distortion and on some of the other factors which are involved.

In order to make life easy, because, as I have never failed to preach, any examination of principles should not allow a passion for generality to complicate the argument, I shall examine only the effect of the third harmonic. As this is usually the main source of error, we do not lose much by this limitation. It is often, though not always, the predominating harmonic in an imperfect power supply. We therefore take a supply waveform

$$\sin\theta + h\sin(3\theta+\phi)$$

where h is the fraction of harmonic; θ is ωt; and ϕ the phase of the harmonic, which is very important.

We need to consider the value of the function over the range from $\theta = 0$ to $\theta = \pi$, a half cycle, since we are dealing with only odd terms. The average value is quite simply given by

$$V_{AV} = \frac{1}{\pi}\int_0^\pi \sin\theta + h\sin(3\theta+\phi)\,d\theta$$

$$= \frac{-1}{\pi}\left[\cos\theta + \frac{h}{3}\cos(3\theta+\phi)\right]_0^\pi$$

$$= -\frac{1}{\pi}\left(-2 + \frac{2h}{3}\cos\phi\right)$$

$$= \frac{2}{\pi}\left(1 - \frac{h}{3}\cos\phi\right)$$

The value of $\cos\phi$ may be anything from -1 to $+1$.

For the r.m.s. value we can do some rather more complicated mathematics. However, the whole point of using r.m.s. measurement is that it adds up the component powers, and the result is that

$$V_{rms} = 0.707\,(1+h^2)^{\frac{1}{2}}$$

or, if h is reasonably small,

$$V_{rms} = 0.707\,(1+h/2)$$

The factors $2/\pi$ and 0.707 are always wrapped up inside the measuring device, and so we see that a true r.m.s. meter will be reading $(1+h/2)$ when an average-sensing meter reads something between $(1+h/3)$ and $(1-h/3)$. It is very convenient to look at this for a waveform with 6% distortion. The r.m.s. meter indicates 1.03, while the other meter may read anything from 0.98 to 1.02. Thus the average-sensing meter may be giving an indication which is 5% low for a distortion of 6%. If the distortion were 12%, the error could be as much as 10%.

If we were to consider the fifth harmonic we should get a term of the form $1-(h/5)\cos\phi$), which is not so bad, and similar forms for the higher harmonics.

It is this analysis which is used to justify the demand for testing the power supply with a meter which reads the r.m.s. voltage. It also gives us a rather easy way of checking our simple r.m.s. indicating systems. Let us put the fundamental at 50Hz. We add to this a small amount, 10 or 20%, of nearly third harmonic, 151Hz. A true r.m.s. meter will give a steady reading, but since the effect of the small frequency difference is to change ϕ continuously, an average-reading meter will show the beats quite clearly.

We have seen that with an impure sinewave there is a real error in using the average value in place of the r.m.s. value. Is this of great significance in practice? A first thought is that a disadvantage of the average indication is that if the power factor of the load is varied, with the actual constituent voltages held constant, there will be a change in relative phase of the harmonic and thus a change in meter reading. I do not believe that this matters at all. The sort of load which has a significant linear phase angle is a motor, or some similar type of inductive device. We are talking, then, of current-operated systems, and the very effect which produces the deviation of the power factor from unity also reduces the flow of harmonic current. The literature is by no means agreed on the effect of even square waves on motors and my own limited experience suggests that a waveform containing no third harmonic but some 20% of fifth harmonic, together with higher harmonics, actually reduces the motor losses.

I am inclined to discount the valve heater problem. The designers of valve equipment rarely expected the precision of supply which we all seem to take for granted nowadays. In any event, they are working at constant power factor, and a once-for-all correction is all that would be needed if they were to become seriously concerned.

A good deal of the 50Hz power we put into equipment is transformed and smartly turned into d.c. Here we really do run into some very interesting problems with the sinewave inverters which are the main alternative source of supply. When we wish to produce a sinewave under conditions of the highest efficiency, and once the power gets up into hundreds of watts we will not be in business unless the efficiency is high, we must adopt methods which have ideally 100% efficiency. Do not be misled by the "stay in business". Even if it is just a unit you rig up to keep the heating pump running off a car battery during the next power strike, you still need to eke out your limited number of ampere-hours. So any power conversion unit from d.c. to a.c. must operate in the switching mode.

I had thought that there were two basic alternatives at this point, but I find that this is not so. Or perhaps more correctly, the two alternatives are not what one imagines.

The most usual form of switching inverter produces a square wave output. This contains 33% third harmonic, 20% fifth harmonic, and so on. We do not wish to feed these harmonics through to the load. We therefore require two sub-systems. One must reflect the harmonic energy back into the inverter, while the other converts the harmonic energy back into d.c. and stores it for re-use. A small amount of energy may be used to set up special current and voltage conditions, the commutation process involved in making thyristors switch off. There is a rule about the filter and storage element which I think goes back to work by Belevitch on switching modulators: the reactive components of the two sub-systems must be of opposite signs. In the commonest form this means that the output filter has a series inductor and there is a large capacitor to accept the reflected energy.

The most economical way of regulating the output voltage of such an inverter is to maintain all the devices switched off for part of each half-cycle. This also has a very useful effect on the harmonics. If the current only flows for $\frac{2}{3}$ of the time, the third harmonic is zero. This, then, is the form of the basic a.c. input to the filter: $+V$, 0, $-V$, 0, $+V$ and so on. Diodes, one might call them flywheel diodes, come into operation during the 0 period, maintaining the interchange of energy between the filter and the storage element which is needed to avoid wasting harmonic energy.

Notice that this is a three level system. It can be generated by binary logic elements, but only if a branch is taken off the chain and brought back in what I call push-push, though I imagine the mathematicians have a classy name for it.

When I want to slow down my motor car, nowhere in particular, I let it free-wheel to rest. So I go forward, coast, or reverse: a three-level logic system. An aircraft landing on a runway simply cannot free-wheel, and the brake shoes, or whatever they have, cannot get rid of all that energy. The answer is reverse thrust. We could have modified our square wave for regulation purposes by producing the waveform shown in Fig. 2. I have put in the reference square wave to show how at the beginning and end of each half cycle there is a reverse push. But this, you will see, is only a two-state logic system. We always have either V or $-V$, never an intermediate zero. Of course the filter con-

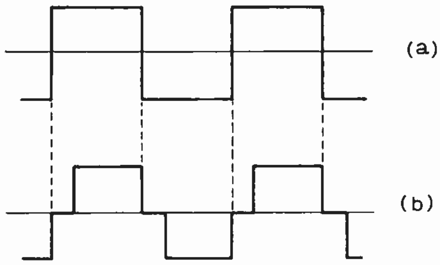


Fig. 1. The square wave (a) is modified to the three-level logic waveform (b) for the purpose of voltage regulation.

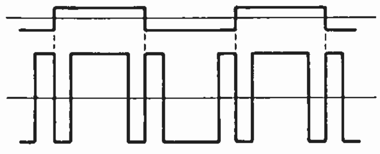


Fig. 2. Another way of regulating a square wave.

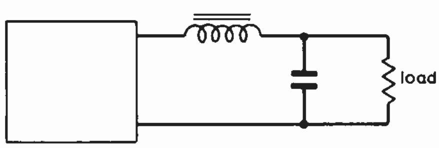


Fig. 3. The essentials of the filter.

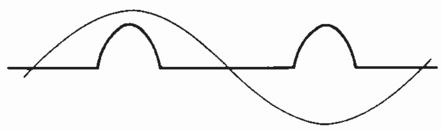


Fig. 4. Typical current waveform in rectifier capacitance circuit.

tinues to refuse all this harmonic energy and may not be prepared to pass it back through the device which is switched on. The flywheel diodes are still needed.

It is clear that in modifying the waveform we have introduced some new, higher, harmonics. I think it is also clear that if the short up-down section lasts for $\frac{1}{3}$ of half a cycle it is too fast to produce third harmonic, and averages out to the zero of Fig. 1(b) which gave zero third harmonic. Do the mathematics, but do not write and tell me I am wrong. The point is that something like that happens, even if the pulses are not 30 degrees.

We can add more reversals and if we time them correctly we can get rid of successively increasing harmonics. I am not going to draw any waveforms, but one way of getting just the pattern we want is an old, and I fear a long-lost friend, the class-D amplifier. All that we have done is to restrict the signal in our class-D system to a single frequency, and state that the switching frequency is to be a multiple of the signal frequency.

The essential difference between the systems really arises from the circuit detail. It would be possible to produce a three-level logic type of waveform with the many switching operations needed to synthesize a sinewave free from all low harmonics, but it is not the economical solution. The two classes of system remain distinct from one another.

The essential job of an ideal filter is to store the unwanted energy until it can be dispatched back to the source. It can do no other, for the ideal filter has no dissipative elements, and what it cannot send back to the source it must send on to the load. The energy storage capability must be measured in terms of storing the lowest unwanted frequency for half a cycle. It is this feature which makes the practical difference between the simple waveform of Fig. 1(b) and the very complicated one of the class-D amplifier. There is a world of difference between having to reject the third harmonic and having to reject the thirtieth.

We can represent the filter in the simple form of Fig. 3. We can have additional half sections added on before the load, and we can indulge ourselves in frequency and impedance transformations until square root signs come out of our ears. None of this will alter the fact that if most of the work of cleaning up the waveform is to be done by the filter, the inductance will be biggish, whereas if we use a lot of clever switching operations the inductance will be smallish.

Now we consider that rather common load, the rectifier and capacitor. The sort of current demand this makes is shown in Fig. 4. Before the rectifier the pulses of current are alternating. Their duration depends on the ratio of source resistance to load and the value I have chosen, which gives about 0.85 times the peak input voltage, makes the pulses last about 60 degrees. The load, in fact, is demanding third harmonic.

It is at this point that the two techniques of power generation, the square wave and filter, and the waveform synthesis type, behave quite differently. If we have a filter which is designed to stop third harmonic it will also refuse to supply it. The waveform across the load will have its top clipped off, and any connection between the r.m.s. voltage and the peak voltage will be purely coincidental.

With the synthesis type of generator this does not happen. Something much more alarming does, though. I have not got the Schade results handy, but you will remember that with this type of supply unit you must always check the rectifier peak current. Well, the rectifier peak current, some 3–5 times the load current, is also, after allowing for the transformation, the device peak current. You will need some 500W of device capability to get 100W of d.c. supplies in the load. That small inductor just will not help to make life easier.

Of course, you will never discover this.

In exploring the problem of mobile and stand-by power supply measurement I have not really expressed any conclusions. Discussions over the years have led to two simple rules, however. The first is that the higher the professional qualifications the less dogmatic the opinion on this matter tends to be. The second is that absolute certainty is expressed by people who have one, and only one, system to sell.

I suspect that there are already readers who are licking their pencils in preparation for a letter to the editor demolishing all my ideas. Remember, as you write, that once you hand one of these units over to a user you have no control at all over the mixture of loads he will connect to it. And even if you know now, what is he going to use in the future?

New Products

Thick-film networks

Sprague now offer standardized single in-line networks similar to the dual in-line range. All resistors are rated at $\frac{1}{8}$ watt and are available with a standard $\pm5\%$ tolerance or up to $\pm1\%$ on special order. Type 216C Metanet s.i.l. resistor networks for signal and data processing applications are also available especially designed for calculators, electronic clocks and gas-discharge displays. Type 206C Multi-Comp s.i.l. resistor capacitor networks are also intended for use with gas-discharge displays and for interfacing between m.o.s. logic and display drivers. Resistor ratings up to 40V are available with a typical temperature coefficient of ±500p.p.m./°C, while the ceramic chip capacitors are rated at 200V over the temperature range -55 to $+70$°C. Sprague Electric (UK) Ltd, 159 High Street, Yiewsley, West Drayton, Middx.
WW306 for further details

Cermet film resistors

A new cermet film resistor from Allen-Bradley measures 0·25in long and 0·09in in diameter. The resistor, type CC, is available over the range 10 ohms to 1 megohm (E96 preferred values only) at $\pm1\%$ selection tolerance and is rated at $\frac{1}{4}$ watt at 70°C, or $\frac{1}{8}$ watt at 125°C with a temperature coefficient of ±100p.p.m./°C. The resistor is suitable for automatic insertion and can be supplied bandoliered. Allen-Bradley Electronics Ltd, Bede Industrial Estate, Jarrow, County Durham NE32 3EN.
WW304 for further details

Precision potentiometers

Beckman Instruments Ltd have introduced two single-turn precision potentiometers. Model 3371 is $1\frac{5}{16}$in diameter; model 6671 is 2in diameter. Both models feature a new conductive plastics resistance element providing stability, fine independent linearity and immunity to adverse environmental conditions. Power ratings are 1W at 65°C for model 3371 and 8W at 70°C for model 6671. The output smoothness is 0·1% maximum for both types. In addition to model 6671's bushing-mount type, a servo-mount version is available in model 6673. Beckman Instruments Ltd, Queensgate, Glenrothes, Fife.
WW303 for further details

Continuous wire-wrapping tool

Vero Electronics are now offering a continuous wire-wrapping tool manufactured by the OK Machine & Tool Corporation. The model AW-8LS is a rugged, pistol grip, bare wire-strapping tool which is designed to make wire-wrapped continuous connections of gas-tight quality. The bare wire feeding through the tool permits interconnection of as many terminals as needed. The tool, which weighs $19\frac{1}{2}$oz, will accommodate wire sizes a.w.g. 22 and a.w.g. 24 and comes complete with a two-metre length of flexible plastic air hose. Vero Electronics Ltd, Industrial Estate, Chandler's Ford, Eastleigh, Hants.
WW301 for further details

Splash-proof panel indicator lamps

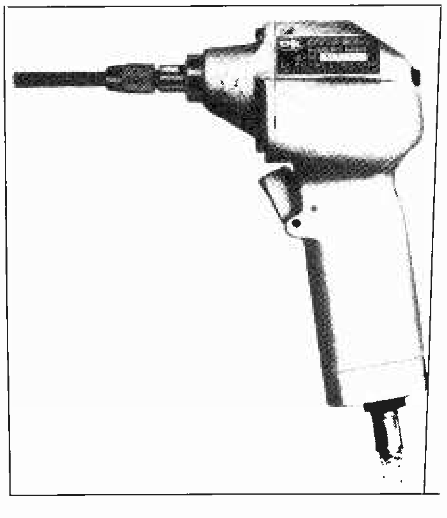
A range of splash-proof panel indicator lamps manufactured by Sloan AG of Switzerland, is available exclusively from Walmore Electronics Ltd. The lamps will withstand pressures of up to 5kg/cm² in both fresh and sea water. The lampholders, which are called the 867, can be supplied with a variety of interchangeable nickel-plated brass lens caps in either fully or partially shrouded styles with an anodized or a black finish. The four basic lens cap styles are supplied fitted with 11·6mm-diameter nylon lenses in one of six colours (blue, green, amber, red, white and clear). The body of the lampholder measures 30·1mm long (including contacts) by 13mm in diameter. The lampholders cost 92p each or 72p each for 1000+. Walmore Electronics Ltd, 11–15 Betterton Street, Drury Lane, London WC2H 9BS.
WW302 for further details

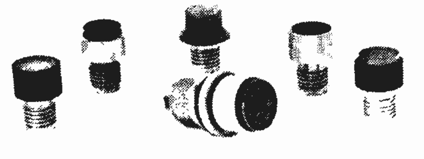
Travelling wave tube amplifiers

EMI-Varian have introduced a new range of 17in rack-mounted travelling wave tube amplifiers (t.w.ts) suitable for laboratory and production test applications. Frequencies from 1–18GHz are covered by only three amplifiers, saving capital expense. Standard frequency ranges are 1–4GHz, 4–12GHz and 12–18GHz. Power levels of 1, 2, 5, 10 and 20 watts are available for each frequency range. Each t.w.t. has 115V and 220V power supply tappings and protective circuitry including warm-up time delay, helix overload cut-out and overheating cut-out. The new range of t.w.ts has a.m. and p.m. noise levels of 50dB below carrier and spurious non-harmonic noise levels are 80dB below carrier. EMI-Varian Ltd, Blyth Road, Hayes, Middlesex.
WW310 for further details

Microwave panoramic frequency analysers

The 8011 series of panoramic frequency analysers are now available from Telonic. These instruments which cover the range 0·5–30GHz enable rapid analysis of spurious products of microwave signals. Using a swept y.i.g. filter no cross modulation products or spurious signals are produced. Full tuning range of the instruments, e.g. 1–18GHz, can be covered in one sweep and controls give a choice of start/stop or centre frequency setting. The dynamic


WW 301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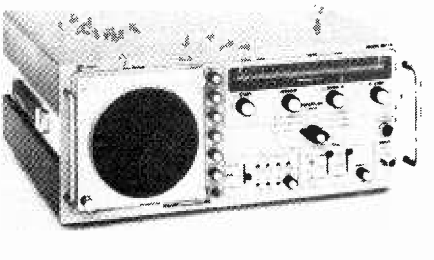
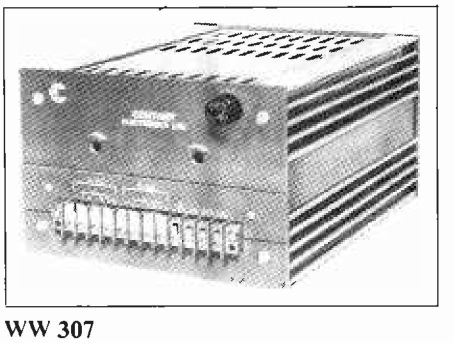

WW 309


WW 307

range of 55dB is displayed in either log or linear modes on the 5in display tube. The flat response of ±2dB over most of the tuning range enables accurate power measurements to be taken. Options available enable the y.i.g. filter to be used as an independent r.f. filter with input and output on the front panel of the analyser. Also available is a four-digit l.e.d. read-out of the centre frequency. The tuning ranges for the models are 1–18GHz (8011B), 1–20GHz (8011C), 3–30GHz (8011) and 0·5–5GHz (8011L). Telonic Industries UK, The Summit, 2 Castle Hill Terrace, Maidenhead, Berks.
WW309 for further details

Impulse counters

A range of impulse counters, manufactured by Hopt GmbH, are now available in the UK from Radiatron Components. Two basic types make up the ZR range, the ZR3 and ZR4; both count up to 25 impulses per second d.c. or ten impulses per second a.c., displaying three, four, five and six digits. Push-button reset facilities are available on the three- and four-digit versions and all types can be rear stud or panel mounted. The ZR6 series are six-digit instruments, panel or socket mounting, and incorporate either electrical or mechanical reset options. Counting speeds up to 50 impulses per second can be achieved with a wide range of operating voltages. Additional features include elapsed-time counting functions, multi-group mounting facilities, key reset, magnified numerals, lamp and dummy modules and a step-down ratio unit. For higher speed applications a modular predetermining electronic counter with a solid-state display can be supplied. Radiatron Components Ltd, 76 Crown Road, Twickenham, Middlesex.
WW308 for further details

Twin-output modular power supplies

Two new units, designated GPT200 and GPT500, are twin-output supplies that are complementary to Coutant's existing single-output GP range. They are both contained in standard metalwork and offer the same principal specifications: line regulation 0·01% + 1mV for ± 10% mains fluctuation, 0·03% +3mV zero to full load, ripple less than 1·5mV peak-to-peak, re-entrant auto-resetting overload protection, optional overvoltage protection and an operating temperature range of 0–50°C. The 125 × 125 × 240mm GPT200 offers twin outputs of 2A at 12–15V and the GPT500 offers two 5A outputs at 12–15V in a 190 × 125 × 240mm case. Prices of the two new power supplies are £40 for the GPT200 and £58 for the GPT500. Coutant Electronics Ltd, 3 Trafford Road, Reading RG1 8JR.
WW307 for futher details

Speaker matrix

Beyer Dynamic (GB) Ltd have recently introduced a four-channel synthesizer for use with loudspeakers or headphones. Up to three pairs of quadraphonic headphones may be connected to the unit, alternatively up to three stereo headphones may be used.

Headphone outputs are connected to separate three-contact jack sockets for the front and rear channels of each quadraphonic headphone. A changeover switch selects either loudspeakers or headphones, with the speakers being muted when headphones are connected.

The unit is designed to work into the following load impedances: loudspeakers, 4–16Ω; four-channel headphones, 150–300Ω and stereo headphones, 25Ω upwards. Power handling capacity is 60W/channel and the price is £20·23 plus VAT Beyer Dynamic (GB) Ltd, 1 Clair Road, Haywards Heath, Sussex RH16 3DP.
WW 316 for further details

Illuminated push switches

From Walmore Electronics Ltd comes a range of illuminated push switches manufactured by Sloan AG of Switzerland.

They are available in on-off and momentary contact arrangements containing gold-plated silver, single-pole changeover contacts, brought out to either a printed circuit board or solder pin connections. The lamps can be either T1 base incandescent lamps, current rated from 20–60mA at 5–28V or alternatively T1 based l.e.ds can be used. Several bezel types are available and five lens colours.

The switches are rated for a maximum current of 1A and a maximum resistive load of 100W. Voltage limitations are 110V a.c. and 30V d.c. Price in small quantities is about £3·14 each falling to £2·56 each for quantities between 100 and 999. Walmore Electronics Ltd, 11–15 Betterton Street, Drury Lane, London WC2H 9BS.
WW315 for further details

Clip contact adaptor

A perennial problem in any electronic laboratory is the connection of electronic equipment to the mains supply on a temporary basis without using a plug. A solution offered by Rendar, called "Insta-power", makes such connections possible from a 13A socket to loads of up to 1kW.

Looking rather like a conventional "unbreakable" 13A plug top, the interior contains three spring clips for retaining the wire ends and 5A fusing. Access to the interior is only obtained by unplugging the unit thus rendering the unit totally safe when open.

With a case moulded in flame-retardant glass-filled nylon, the clip jaws have moulded coloured push tabs to open them for connection and are marked L, E and N. The cable entry will accept up to 0·4in dia. cables, clamping being achieved by the cover and its screw fixings. Price £2. Rendar Instruments Ltd, Victoria Road, Burgess Hill, Sussex RH15 9LE.
WW314 for further details

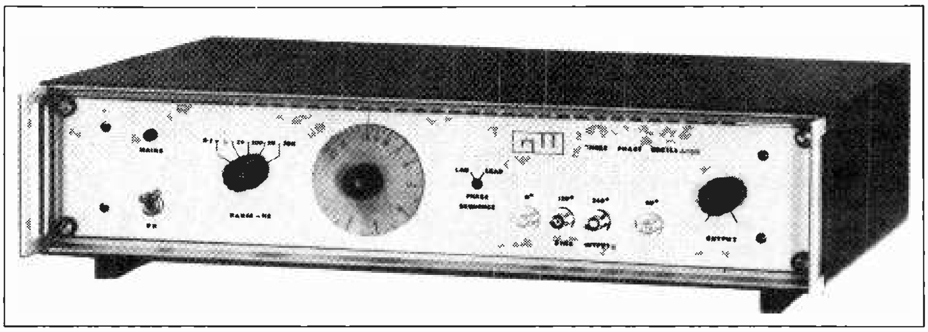
Two- and three-phase oscillator

This device, produced by Gearing and Watson (Electronics) Ltd, provides the source for two- or three-phase power to be generated over the frequency range 0·2Hz–20kHz.

Designed to be used in conjunction with suitable power amplifiers, available from the same company, from 75W to several kilowatts can be produced.

A phase sequence switch is provided to reverse phase rotation and four outputs,

WW 308



WW 312

0°, 90°, 120° and 240° are provided on both front and rear panels. The 90° quadrature output can be used for two-phase systems, for "Scott" connected three-phase systems and for reference purposes. The oscillator output is 1V r.m.s. with a maximum error between phases of 5° and a distortion of less than 1%. Gearing & Watson (Electronics) Ltd, Birch Close, Eastbourne, Sussex BN23 6PE.
WW312 for further details

Wide-band differential d.c. amplifiers

A new range of wide-band differential d.c. amplifiers is available from Datron Marketing Ltd. Called the 700 series, the range is based on a single common design which is offered with a wide range of options, resulting in a total of 510 different configurations within the range. The standard housing for all configurations is a 5·25in high × 1·4in wide rack-mounting module. All models have their own internal power supply for operation on 105/220V, 50/400Hz. There are six fixed, switch-selectable or computer-controlled gains available, from 0 to 1000, with a 0·01% gain accuracy and 0·003%/°C gain stability. Common-mode voltage is given as ±100V d.c. or ±300V d.c. or peak a.c. to 400Hz, according to option. The common-mode rejection is 126dB with a bandwidth of 100kHz and linearity ±0·005% f.s. Datron Marketing Ltd, Meteor Close, Norwich Airport Industrial Estate, Norwich NOR 17B.
WW300 for further details

3½-digit multimeter

D. A. Pitman have recently released details of a 3½-digit, bi-polar, portable multimeter from DigiTec. The d.c. ranges extend from 199·9mV, full scale, to 1000V, full scale, with an accuracy of 0·1% of reading. The a.c. ranges extend from 1·999V, full scale, to 500V, full scale, with an accuracy of 0·5% of reading. Resistances from 199·9Ω to 19·99MΩ can be measured with an accuracy of 0·5% of reading, test lead resistance being balanced out using a front panel control.

All functions are selected by push-button switches and ranges by rotary switch. An l.e.d. display is used which blanks out leaving only the decimal point illuminated when overranging occurs. Price £127. D. A. Pitman Ltd, Jessamy Road, Weybridge, Surrey.
WW311 for further details

Small power bench supplies

Intended for use where space is at a premium, the Datoda units are available from Lawtronics. The unit is 6 × 3 × 2½in and is available in two forms. One provides fixed output levels (Type VB1), the other has a switched output range of 5, 6, 9, 12 and 15V. Current and thermal overload protection is provided with a full load regulation of 10mV at 1A. The VB1 is priced at £11·50 and the VB2 at £16, in small quantities. Lawtronics, 139 High Street, Edenbridge, Kent TN8 5AX.
WW320 for further details

Solid State Devices

The names of suppliers of devices in this section are given in abbreviation after each entry and in full at the end of the section.

Avalanche photodiode

Epitaxial silicon photodiode type S30506 is a high-speed, light-sensitive detector with a circular photoactive area of approximately 0·5mm diameter. Internal current gain is obtained by reverse biasing the detector near to the avalanche breakdown voltage which improves sensitivity to weak light signals. A short decay time for the output current, 90%–10% in 6ns, after illumination with near infra-red radiation at modulation frequencies up to 100MHz is claimed.
WW350 for further details EMI

High-voltage rectifiers

A range of high-voltage silicon rectifier assemblies has been manufactured by Semtech. The KV-PAC PLUS series has a rating of 1 amp as a half-wave rectifier and 2 amps in a bridge circuit with a one-cycle surge current capability of 50 amps at 55°C. Peak inverse voltages are 5 to 15kV at 55°C and the reverse current at p.i.v. is 1·0μA at 25°C.
WW351 for further details Bourns

High-speed r.a.ms

Fairchild has added two new high-speed e.c.l. random access memories to its 10,000 series of integrated circuits. The new memories, F10410 and F10415, complement the previously announced F10405 r.a.m. The 10410 is organized as 256 × 1 bits with typical access time of less than 20 nanoseconds. The F10415 organized as 1024 × 1 bits has typical address times of less than 45 ns. Both memories have inputs and outputs at standard 10k e.c.l. levels and outputs drive standard 50-ohm line loads.
WW352 for further details Fairchild

Cascade amplifiers

The WJ-A5 and WJ-A7 type, 5–500MHz cascadable amplifiers are now available from Watkins-Johnson. The amplifiers exhibit a flat frequency response, temperature stability and are unconditionally stable for any source and load conditions. The WJ-A5 and WJ-A7 are guaranteed over the temperature ranges −54 to +100°C and −54 to +71°C respectively. The amplifiers are supplied in four-pin TO-8 packages and have a typical performance of 14·5dB gain with a gain flatness of ±3dB and a noise figure of 4dB (WJ-A5), 5dB (WJ-A7). Output power is +9dBm (A5) and +14dBm (A7), phase linearity ±1·0° from 10–500MHz, power supply range 8–20V d.c. (A5), 15–24V d.c. (A7).
Watkins-Johnson
WW354 for further details

Multi-port register file

Motorola have added the MC10143 8 × 2 multi-port register file to their MECL 10,000 series. This device, which falls into the l.s.i. class, is capable of simultaneously reading two bits while writing another bit. The access time is typically 10ns or 5ns from clock to data out. The MC10143 employs two sets of eight latches for data storage and is fully compatible with all other members of the MECL 10,000 and MECL 3 series.
WW353 for further details Motorola

Sample and hold op-amp

A monolithic sample-and-hold op-amp has been introduced by Harris Semiconductor. Designated the HA-2425, the device has a d.t.l./t.t.l. compatible control input, 2MHz bandwith, 50ns aperture time and a slew rate of 5Vμs. The HA02425, which is available in a 14-pin dual-in-line package, operates from 0 to 75°C and has a slew rate to droop rate ratio of 5 × 10^6. Internal design consists of a high-performance op-amp with its output in series with an analogue switch providing low leakage current (1nA max). The switch is then buffered with a m.o.s.f.e.t. input unity-gain amplifier.
WW355 for further details GDS

21-stage counter using c.m.o.s.

A low-voltage c.m.o.s. 21-stage counter has been introduced by RCA. The device, designated TA6152, is a timing circuit designed for use in digital equipment where low dissipation or operation in the 1·1–6V range is required. Quiescent dissipation is 0·5μW (typical) at V_{DD}=1·5V; 2·5μW (typical) at V_{DD}=5V; operating dissipation is 75μW (typical) at V_{DD}=1·5V and f=1MHz. The TA6152 consists of 21 negative edge counter stages, two inverter output drivers and input inverters for use in a crystal oscillator. The device is supplied in a 16-lead dual-in-line ceramic package and samples will be available in June/July.
WW356 for further details RCA

Suppliers

EMI Electronics and Industrial Operations, Blyth Road, Hayes, Middx.
Bourns (Trimpot) Ltd, Hodford House, 17/27 High Street, Hounslow, Middx.
Fairchild Semiconductor Ltd, Kingmaker House, Station Road, Barnet, Herts.
Motorola Semiconductor Ltd, York House, Empire Way, Wembley, Middx.
Watkins-Johnson, Shirley Avenue, Windsor, Berks.
GDS Marketing Ltd, Michaelmas House, Salt Hill, Bath Road, Slough, Bucks.
RCA Ltd, Solid State Europe, Sunbury-on-Thames, Middx.

Audio Products

A selection of new equipment seen at the concurrent Sonex 74 and Hi Fi 74 exhibitions

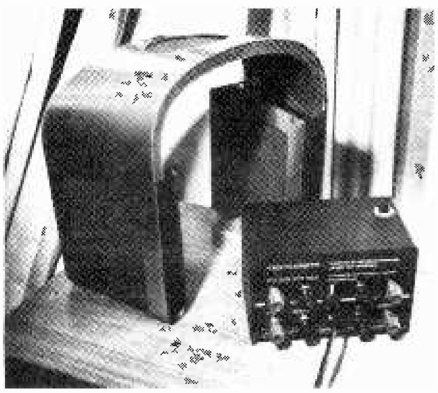
Electrostatic headphones

Perhaps the most remarkable sight in the Sonex exhibition were the Jecklin Float headphones. Manufactured by a Swiss company and appearing by courtesy of the Lustraphone stand, these units were being displayed in an effort to gauge public reaction prior to launching the product in the UK.

The electrostatic elements were large and rectangular in shape, reminiscent of a design published by *Wireless World* in November 1971. Of doublet design, the Jecklin units radiate both towards the ear and outwards and the fit of the headband is intentionally loose.

The headband and holder for the drive units is moulded from a single piece of plastic in a silver metal sheen and lined with polyurethane foam. A power supply in a black rectangular metal box is used to polarize the electrostatic elements and also provides a connecting point for loudspeakers. Designed to be driven by amplifiers capable of accepting 8-Ω loads, the Jecklin float headphones have not yet been priced. Belcaire Trading, 59 Cheriton High Street, Folkestone, Kent.

WW360 for further details



WW 360

Mini monitor loudspeaker

Several high-quality bookshelf speakers are now produced from various sources and in fact this seems to be the end of the market where most improvements are being made, a reflection made more apparent by the introduction of the new Rogers LS3/3A monitor loudspeaker. This measures only $7\frac{1}{4} \times 6\frac{1}{2} \times 11\frac{3}{4}$in and weighs $9\frac{1}{2}$lb. The speaker is necessarily inefficient but is ideal for monitoring or domestic purposes where space is lacking and high power output is not required. Two drive units are used in a sealed enclosure—a 4in bass driver with a doped Bextrene cone and a $\frac{3}{4}$in unit. Both units are selected to meet a BBC standard. Cross-over frequency is 3kHz. Response extends from 60Hz to 20kHz ±4dB. Price is around £60. Rogers Developments (Electronics) Ltd, 4 Barmeston Road, London SE6 3BN.

WW361 for further details

WW 361

New series of speakers

The Quasar loudspeakers QS1, QS2 and QS3 comprise the new range from Eagle International. These should be followed by the introduction of a deck, cartridge, amplifiers and tuners under the Quasar name. Minimization of distortion has included consideration in the reduction of Doppler distortion in conjunction with J. Moir & Associates.

The main specifications of the largest and highest performance loudspeaker (QS1) in the Quasar range are:

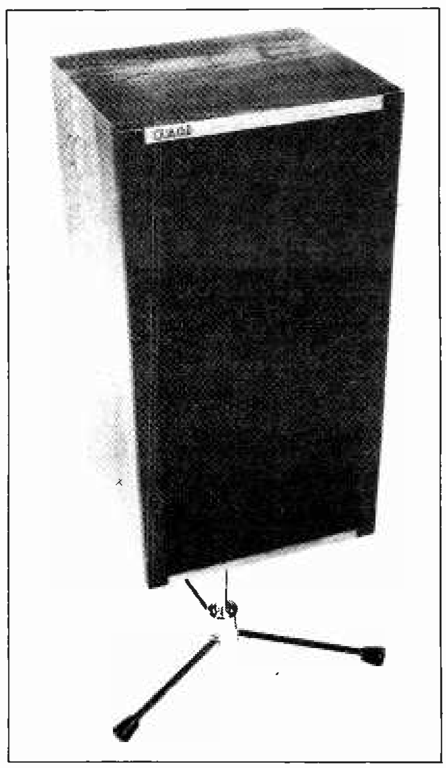
Dimensions	$11\frac{1}{2} \times 15\frac{1}{2} \times 26$in
Frequency response	45Hz to 20kHz ± 3dB
Impedance	8ohm
Nominal power capacity	50W continuous
Drive units	12in, 4in, 2in and 1·5in
Harmonic distortion	100Hz 0·7%, 1kHz 0·16% both for 90dB at 1m
Doppler distortion	0·007% for 90dB at 1m, with input at 100Hz and 3kHz simultaneously
Price (inc. VAT)	£92·40

Quasar Division Precision Centre, Heather Park Drive, Wembley, Middx HA0 1SU.

WW362 for further details

Denon amplifiers

Denon-brand hi-fi products, now imported from Nippon Columbia by Johnson's of Hendon, include two integrated ampli-



WW 362

fiers, a stereo tuner, pick-up arm and direct-drive turntable (see separate item). Amplifier PMA350Z has an output power of 28 watts per channel at 0.1% distortion and power bandwidth 10Hz to 40kHz (−1dB, 0.1% distortion). Type PMA500 delivers 40 watts per channel at 0.1% distortion and power bandwidth of 5Hz to 75kHz (−3dB). Intermodulation distortion is quoted as 0.06% at −3dB of rated output.

PMA350Z preamplifier section has a sensitivity of 2mV (pickup inputs) and a maximum input level of 100mV at 1kHz. Signal-to-noise ratio is 62dB (pick-up inputs) with input short-circuited. Harmonic distortion is 0.08% at rated output. Filters at 9kHZ and 40Hz have slopes of 12dB per octave. PMA-500 preamplifier has an harmonic distortion of 0.05% rated output and a 65dB s/n ratio (pickup inputs). Both have muting, tone, dubbing, tape monitor and loudness controls. In addition, the 500 has a microphone input mixing facility. RIAA equalization accuracy is ± 0.5dB. Johnson's of Hendon Ltd, Radlett Road, Colney Street, St Albans, Herts.

WW363 for further details

SQ/RM decoder-amplifier

The new Trio KSQ-400 is a quadraphonic decoder with rear-channel amplifier and costing about £70. Phase shift circuitry, having a phase-frequency response 90 ± 10° from 25Hz to 18kHz, is switchable to provide SQ and RM decoding. Amplifier gives 15 watts (1kHz) in both channels for 4-ohm loads with 0.6% harmonic distortion at rated output and 0.2% at −3dB. B. H. Morris & Co, Trio House, The Hyde, London NW9 6JP.

WW364 for further details

British electronic turntable

As well as a restyled version of the RD11 turntable, Ariston Audio Ltd will be marketing a two-speed electronically-governed turntable with variable speed control. With wow and flutter of 0.04% weighted r.m.s., it will cost around £136. The RD11 itself has a redesigned main bearing and the makers claim an unmeasurable rumble and hum level. The 24-pole synchronous motor drives the 9½lb table through a non-stretch belt. Ariston Audio Ltd, P.O. Box 13, Irvine, Ayrshire KA12 8JL.

WW365 for further details

ERA amplifier

Models 5770 and 5750 are new French stereo amplifiers with output powers of 40 and 24 watts per channel respectively. A power bandwidth of 30Hz to 30kHz is quoted for the ST50 together with harmonic distortion at maximum output of 0.5%. (Full details of the 5770 were not available at the time of going to press.) A stereo tuner will be marketed shortly. Current products mainly centre around a 48-pole synchronous motor fitted to three turntables each with different pickup arms, but all with a quoted 0.04% wow and flutter (pk-pk) and a rumble level of −73dB DIN weighted. De Banks Electronics Ltd, Market House, High Street, Tring, Herts.

WW366 for further details

Professional cassette recorder

Although Jonathan Fallowfield did not have a stand at either Sonex or the High Fidelity Exhibition at Heathrow, two of their latest imports were in evidence on several stands at Sonex. These were the new and remarkable cassette machines from the Nakamichi stable. The model 1000 is intended for professional use at the very professional price of £695 inc. VAT. It would seem that an effort has been made, in designing this recorder, to include just about every feature of advanced design ever seen on other recorders, plus one or two new ones.

The deck mechanics are solenoid operated and contain memory rewind facilities and dual capstan drive. Three magnetic heads are provided, thus optimizing the requirements of record and replay gap. The replay head is wrapped around one of the pinch wheels and fits in the same cassette entry. It is therefore extremely small and requires precise alignment and high-quality cassettes to ensure reliable performance. The electronics incorporate both Dolby B and the Philips d.n.l. together with a record amplifier limiter.

Finally, as if that were not enough, there is a unique arrangement for checking the azimuth of the record head. Using a blank cassette, a test tone is recorded from an internal oscillator and the replayed signal sampled by a phase sensitive switch. Adjustment of the head is by a knurled knob and is continued until two indicator lamps flicker alternately. Jonathan Fallowfield Ltd, Strathcona Road, North Wembley London HA9 8QL.

WW367 for further details

Capacitor cartridge

As well as showing a new CD-4 demodulator and four-channel amplifier, Toshiba announced the UK marketing of the electret capacitor cartridge, type C401S. By relying on the variation of capacitance between cantilever and two fixed electrodes, attachment of electrodes or magnets to the cantilever is avoided. Relying merely on such a small capacitor size and variation would result in poor signal-to-noise ratio so Toshiba have used an electret electrode with a charge equivalent to several hundred volts, together with built-in i.c. preamplifiers. Power for the i.c. is provided by an additional lead in the screened pickup wire. The cartridge provides 40mV (at 5cm/s and 1kHz) which is then equalized by a special amplifier, SZ-200, giving an output level of 200mV and a distortion of 0·1% at ten times rated output. Amplitude response extends to 35kHz and is virtually flat over the whole audible range, and Toshiba claim an excellent phase response that is especially appropriate for playing matrixed records. Price of cartridge and equalizer is £70.

A version of the cartridge that extends amplitude response to 50kHz is fitted in the SR-510 direct-drive turntable and pickup arm. It includes the Toshiba "extend" stylus. Wow and flutter of this deck is given as 0·03% with a signal-to-noise ratio of 60dB. Toshiba (UK) Ltd, Great South West Rd, Feltham, Middx.

WW368 for further details

Turntable with servo control

An interesting method of detecting platter speed is employed by the Denon DP 3700F direct drive turntable. The inner rim of the platter has a magnetic coating on which 1,000 pulses are recorded at accurately determined intervals. As the turntable rotates, the pulse signals are detected by a magnetic head. Comparison of the signal voltage thus generated with a reference voltage indicates any speed error. Any difference is instantly detected to produce a differential voltage which regulates the motor servo control. Wow and flutter is less than 0·03% (weighted r.m.s.) and signal-to-noise ratio is better than 60dB. Final speed is attained in half a revolution. Johnsons of Hendon Ltd, Radlett Road, Colney Street, St Albans, Herts AL2 2EA.

WW369 for further details

Amplifier with overload indicator

An amplifier with two unusual facilities was introduced at the show by Cambridge Audio. The P60 provides separate pre-amplifier volume and power amplifier level controls to cope with varying levels of input so that the capabilities of the power amplifier can be used to the full. Coupled with this is an l.e.d. overload indicator which doubles as a power on-off light. The l.e.d. flashes whenever either of the two power amplifiers is overloaded.

Main specifications for the P60 are:

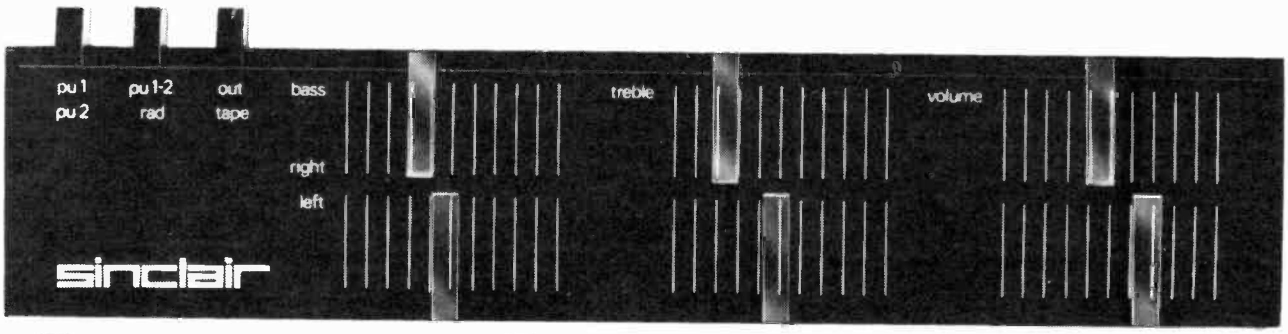
Power output	30W continuous into 8Ω at 1kHz
Amplitude response	25Hz to 25kHz ±0·5dB
Harmonic distortion	less than 0·5% at 1kHz
Intermod. distortion	less than 0·1% at any level ($f_1$60Hz, $f_2$7kHz, amplitude ratio 4:1)
Signal-to-noise ratios	better than 60dB pickup, 70dB tuner (unaffected by volume setting)
Input overload capacity	50dB
Dimensions	16½ × 9⅝ × 2in
Price (inc. VAT)	£130·90.

Cambridge Audio Ltd, The River Mill, St Ives, Huntingdon PE17 4EP.

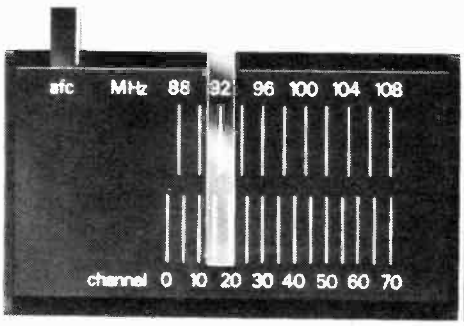
WW370 for further details

Sinclair Project 80

exciting

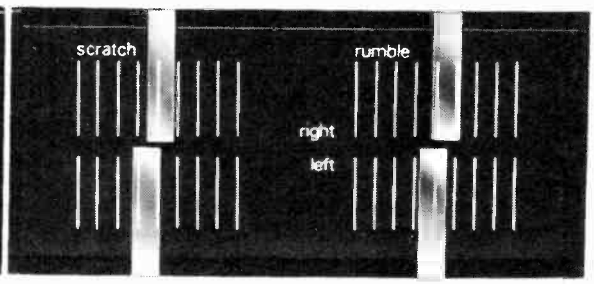


Stereo 80 pre-amplifier/control unit



Project 80 tuner

Stereo decoder



Project 80 Active Filter Unit (AFU)

only $\frac{3}{4}$'' deep x 2'' high

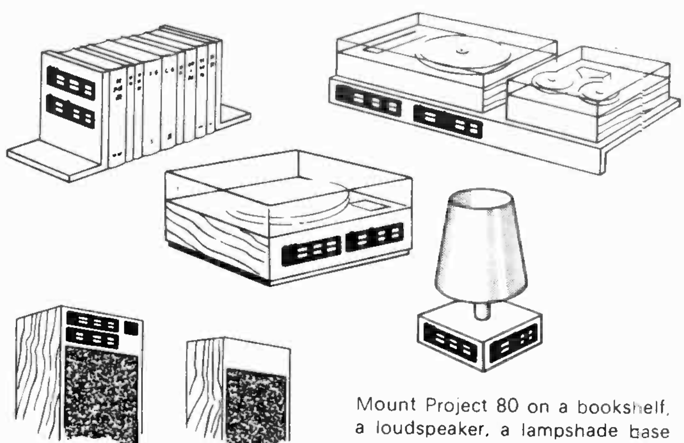
Living with hi-fi takes on new meaning with Sinclair Project 80. The electronics of these revolutionary new modules are all contained within elegantly designed matching cases no more than three-quarters of an inch deep. They are designed for mounting on any appropriate flat surface by means of 6BA bolts extending from the rear of each module and which pass through suitably drilled holes. Connections are taken away out of sight in a similar manner. The possibilities opened up by Project 80 are endless – superb hi-fi systems can be installed in ways hitherto only dreamed about and never before made practical. No more cutting out and shaping to put modules in position. A few holes drilled with the aid of templates supplied and the job is done. Now you need never again be faced with problems of keeping the hi-fi from clashing with carefully thought-out furnishing schemes. (That will surely please wives!) Slider controls have been introduced in place of knobs and all modules in the range incorporate new up-dated circuitry with emphasis on performance standards and built-in protection against overload and shorting. The aim was to re-think modular construction completely – to make it infinitely more versatile, even simpler and more reliable – the result – Project 80 – another triumph for Sinclair, and the most exciting construction modules ever.

the slimmest, most elegant hi-fi modules ever made

Typical Project 80 applications

System	The Units to use	Units cost
Simple battery record player	Z.40	£5·45 +54p V.A.T.
Mains powered record player	Z.40, PZ.5	£10·43 +£1.04 V.A.T.
30W. RMS continuous sine wave stereo amp.	2 × Z.40s, Stereo 80; PZ.6	£30·83 +£3.08 V.A.T.
50W (8 Ω) RMS continuous sine wave de luxe stereo amp.	2 × Z.60s, Stereo 80; PZ.8	£33·83 +£3.38 V.A.T.
Indoor P.A.	Z.60, PZ.8	£14·93 +£1.49 V.A.T.

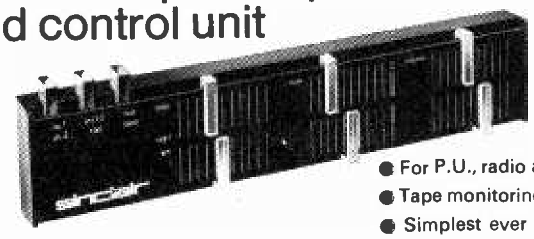
Project 80 FM tuner, decoder, and A.F.U. may be added as required



Mount Project 80 on a bookshelf, a loudspeaker, a lampshade base a false wall with two Q.16 loudspeakers . . . almost anywhere.

new thinking in modular hi-fi

Stereo 80 pre-amplifier and control unit



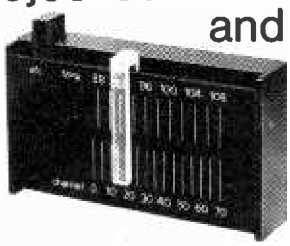
- For P.U., radio and tape
- Tape monitoring switch
- Simplest ever fixing

Each channel has its own separate tone and volume controls operated by sliders, enabling ideal environmental matching to be obtained. A virtual earth input stage forms part of the up-dated circuitry that ensures the finest possible quality from all signal sources. Generous overload margins are allowed on all inputs. Clear instructions with template are supplied.

TECHNICAL SPECIFICATIONS
Size – 260 × 50 × 20mm (10¼ × 2 × ¾ins)
Finish – Black with white indicators and transparent sliders
Inputs – Magnetic pick-up 3mV RIAA corrected; Ceramic pick-up 300mV
Radio 300mV; Tape 30mV
Signal/noise ratio – 60dB
Frequency range – 20Hz to 15KHz ± 1dB: 10Hz to 25KHz ± 3dB
Power requirements – 20 to 35 volts
Outputs – 100mV + AB monitoring for tape
Controls – Press button for tape radio and P.U. Sliders for volume.
bass (+ 12dB to – 14dB at 100Hz) treble (+ 11dB to – 12dB at 10KHz)

R.R.P. £11.95 +£1·19 V.A.T.

Project 80 FM tuner and stereo decoder



- Twin dual varicap tuning: 4 pole ceramic filter: switchable A.F.C.
- On the decoder, solid state stereo indicating beacon.

Making the Project 80 F.M. tuner and decoder available separately gives a wider choice of systems and saves money where stereo reception may not be required. The tuner is a triumph of electronic design and assures excellent performance. The decoder gives a 40dB channel separation with 150mV output per channel. Both units may be used with other than Project 80 systems.

TECHNICAL SPECIFICATIONS OF TUNER
Size – 85 × 50 × 20mm (3½ × 2 × ¾ins)
Tuning range – 87·5 to 108 MHz
Detector – I.C. balanced coincidence for good A.M. rejection
One I.C. equal to 26 transistors
Distortion – 0·2% at 1 KHz for 30% modulation
4 pole ceramic filter in I.F. section
Aerial impedance – 75 Ω or 240-300 Ω
Sensitivity – 4 microvolts for 30dB quieting
Output – 300 mV for 30% modulation
Power requirements – 23 to 33 volts

R.R.P. £11.95 +£1·19 V.A.T.

DECODER
Size – 47 × 50 × 20mm (1⅞ × 2 × ¾ins)
One 19 transistor I.C.

R.R.P. £7.45 +0·74 V.A.T.

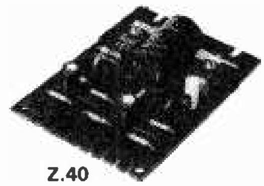
Guarantee

If, within 3 months of purchasing any product direct from us, you are dissatisfied with it, your money will be refunded on production of receipt of payment. Many Sinclair appointed stockists also offer this guarantee. Should any defect arise in normal use, we will service it without charge. For damage arising from mis-use a charge (typically £1·00) will be made.

sinclair

Sinclair Radionics Ltd. London Road, St. Ives, Huntingdon PE17 4HJ
Telephone St. Ives (0480) 64646

Z.40 & Z.60 power amplifiers totally short-circuit proof



Z.40

Z.60

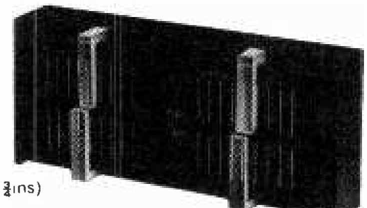
Intended for use in Project 80 installations, these modules readily adapt to an even wider range of applications. Both incorporate built-in protection against short circuiting and risk of damage from mis-use is greatly reduced.

Z.40 TECHNICAL SPECIFICATIONS
Size – 55 × 80 × 20mm (2¼ × 3¼ × ¾ins) 9 transistors
Input sensitivity – 100mV
Output – 15 watts RMS continuous into 8 Ω (35v)
Frequency response – 10Hz – 100KHz ± 1dB
Signal/noise ratio – 64dB
Distortion – at 10 watts into 8 Ω less than 0·1%
Power requirements – 12 to 35 volts

Z.60 TECHNICAL SPECIFICATIONS
Size – 55 × 98 × 15mm (2¼ × 3¾ × ¾ins) 12 transistors
Input sensitivity – 100-250mV
Output – 25 watts RMS continuous into 8 Ω (45V).
Distortion – typically 0·03%
Frequency response – 10Hz to more than 200KHz ± 1dB
Signal/noise ratio – better than 70dB
Built-in protection against transient overload and short circuiting
Load impedance – 4 Ω min; max. safe on open circuit

Z.40 R.R.P. **£5.45** + 0·54 V.A.T.; **Z.60** R.R.P. **£6.95** + 0·69p V.A.T.

Project 80 active filter unit



Makes a highly desirable part of any worthwhile system where inputs may be from record, radio or tape. As with Stereo 80, separate controls applied to each channel make it easier to obtain ideal stereo balance.

TECHNICAL SPECIFICATIONS
Size – 108 × 50 × 20mm (4¼ × 2 × ¾ins)
Voltage gain – minus 0·2dB
Frequency response – 36Hz to 22KHz controls minimum
Distortion – at 1KHz – 0·03% using 30V supply
HF cut off (scratch) – 22KHz to 5·5KHz, 12dB/oct. slope
L.F. cut off (rumble) – 28dB at 20Hz, 9dB/oct. slope

- For scratch and rumble control
- Transistorised active circuitry

R.R.P. £6.95 +0·69 V.A.T.

Power supply units

PZ.8

Stabilised. Re-entrant current limiting makes damage from overload or even direct shorting impossible. Normal working voltage (adjustable) 45V.

R.R.P. £7·98 + 0·79p V.A.T.
Without mains transformer

PZ.5 30V unstabilised
R.R.P. £4·98 + 0·49p V.A.T.

PZ.6 35V. stabilised
R.R.P. £7·98 + 0·79p V.A.T.

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for which I enclose Cash/Cheque for £ ______ including V.A.T.

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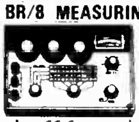
WW—099 FOR FURTHER DETAILS

WW—100 FOR FURTHER DETAILS

LASKYS

Also see previous page

TRANSISTORISED L.C.R. A.C. BR/8 MEASURING BRIDGE



A new portable bridge offering excellent range and accuracy at low cost. Resistance: 6 ranges: 0.1 ohm-11.1 megohm ± 1% Inductance: 6 ranges: 1 microhenry-111 henries ± 2% Capacity: 6 ranges: 10pf-1110 mfd ± 2% Turns Ratio: 6 ranges: 1:1/1000-1:11100 ± 1% Bridge Voltage at 1,000cps. Operated from 9-volt battery. 100 microamp meter indication. Size 7⅞" x 5" x 2"

OUR PRICE £25.00 P&P 25p

TE16A TRANSISTORISED SIGNAL GENERATOR

5 ranges, 400kHz to 30 MHz. An inexpensive instrument for the handy-man. Operates on 9V battery. Wide easy to read scale. 800kHz modulation. Size: 149 x 149 x 92mm. Complete with instructions and leads.

OUR PRICE £8.97 P&P 25p

MODEL TE20 RF SIGNAL GENERATOR

Six bands. 120kHz—260MHz. Dual output RF terminals. Separate variable audio output. Accuracy ± 2%. Audio output to 8V. Power requirements: 105—125V, 220—240V AC. Size: 193 x 265 x 150mm. Complete with test leads etc.

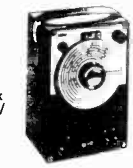
OUR PRICE £17.50 P&P 40p

TE-20D RF SIGNAL GENERATOR

Accurate wide range signal generator covering 120 kHz-500 MHz on 6 bands. Directly calibrated. Variable R.F. attenuator audio output. Xtal socket for calibration. 220/240V a.c. Brand new with instructions. Size 140mm x 215mm x 170mm

OUR PRICE £17.50 P&P 30p

ARF 300 AF/RF SIGNAL GENERATOR



All transistorised compact fully portable. AF sine-wave 18Hz to 220 kHz. AF square wave 18Hz to 100k Hz. Output Square/Sine wave 10V. P-P RF 100kHz to 200MHz. Output 1V maximum. 220/240V AC operation. Complete with instructions and leads.

OUR PRICE £29.95 P&P 50p

MODEL MG100 SINE SQUARE WAVE AUDIO GENERATOR

Range 19-220,000Hz Sine Wave 19—100,000 Hz Square Wave. Output Sine or Square wave 10v. P. to P. Size 180 x 90 x 90mm. Operation 220/240v. A.C.

OUR PRICE £19.95 P&P 37p

MCA220 Automatic Voltage Stabiliser

Input 88—125V AC or 176—250V AC. Output 120V AC or 240V AC. 200V/A rating. P&P 50p

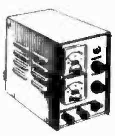
OUR PRICE £11.97

PS100B Regulated POWER SUPPLY UNIT

Solid state. Output 6, 9 or 12V DC up to 3 Amp. Meter to monitor current. Input 220/240V AC. Size: 100 x 82 x 159mm.

OUR PRICE £11.97 P&P 25p

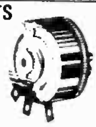
PS200 Regulated POWER SUPPLY UNIT



Solid state. Variable output 5—20V DC up to 2 Amp. Independent meters to monitor voltage and current. Output 220/240V AC. Size: 190 x 136 x 98mm.

OUR PRICE £19.95 P&P25p

POWER RHEOSTATS



High quality ceramic construction. Windings embedded in vitreous enamel. Heavy duty brush wiper. Continuous rating. Wide range available ex-stock. Single hole fixing. ¼" diameter shafts. Bulk quantities available.

25 WATT 10/25/50/100/250/500/1000/2500 Ohms **£1.15** P&P 10p

50 WATT 10/25/50/100/250/500/1000/2500/5000 Ohms. **£1.62** P&P 10p

100 WATT 1/5/10/25/50/100/250/500/1000/2500 Ohms **£2.34** P&P 15p

AUTO TRANSFORMERS

0/115/250V. Step up or step down. Fully shrouded.

80 WATTS	£2.75	P&P 18p
150 WATTS	£3.50	P&P 18p
300 WATTS	£4.50	P&P 23p
500 WATTS	£6.95	P&P 33p
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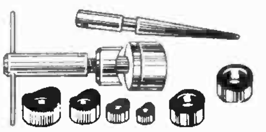
1500 WATTS	£12.50	P&P 43p
2250 WATTS	£20.95	P&P 50p
5000 WATTS	£44.95	P&P £1

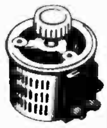
CP110 CHASSIS PUNCH SET



Carefully machined top grade steel. Contains 1/2", 5/8", 3/4", 1" and 1 1/8" punches complete with gripper and accessories.

OUR PRICE £3.00 P&P 40p

YAMABISHI VARIABLE VOLTAGE TRANSFORMERS



Excellent quality at low cost. Input: 230V 50/60Hz. Output 0—260V.

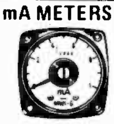
MODEL S260 BENCH MOUNTING

		P&P
1A	£10.50	30p
2.5A	£12.00	35p
5A	£17.50	37p
8A	£30.35	50p
10A	£33.75	75p
12A	£29.50	75p
20A	£85.00	125p
25A	£95.00	130p
40A	£120.00	150p

MODEL S260B PANEL MOUNTING

1A	£10.00	30p
2.5A	£12.00	35p

240° Wide Angle 1mA METERS



MW 1—6 60x60mm

£6.50 P&P 15p

MW 1—8 80x80mm

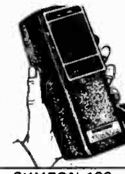
£6.90 P&P 15p

BV05 Vernier TUNING DIAL

App. 7:1 ratio planetary drive vernier dial. Log scale 0—180 degrees. Blank scales 1—5. Dial size 128 x 76mm. Overall size 190 x 117 x 41mm. deep including knob and coupling. ¼" diam. shaft

OUR PRICE £1.62 P&P 15p

WALKIE TALKIES



SKYFON 100mW

OUR PRICE £24.95 per pair

P302 Two Channel 300mW

OUR PRICE £52.50 per pair

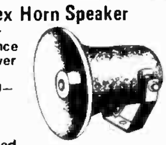
P1003 Three Channel 1 Watt

OUR PRICE £71.25 per pair

P&P 50p per pair

NB. Licence required for use in UK

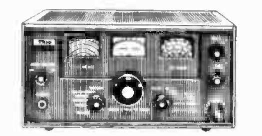
RUH6 Reflex Horn Speaker



Built-in driver unit. Impedence 16 ohms. Power rating 10W. Response 380—7000Hz. Size app. 6" x 6". Weather and shock protected.

OUR PRICE £4.97 P&P 30p

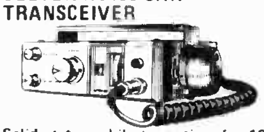
TRIO 9R59DS RECEIVER



Four bands covering 550kHz to 30 MHz continuous and electrical bandspread on 10, 15, 20, 40,and 80 mtrs. 8 valve plus 7 diode circuit. 4 to 8 ohm output and phone jack. SSB—CW, ANL, variable BFO. S Meter and separate band spread dial. IF frequency 445kHz, audio output 1½ watt. Variable RF and AF gain controls. 115/250V AC, with instructions.

Our Price £42.50 CARR. PAID

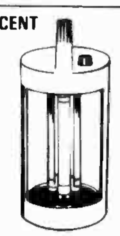
BELTEK W5400 CAR TRANSCEIVER



Solid state mobile transceiver for 12 volt DC neg. Transmits and receives on any 12 of 28 channels between 144 and 146MHz. Power output 10W and 1W switchable. Controls: On/off/volume, squelch and channel selector. Internal 3" speaker. Complete with dynamic mic. PTT switch, three sets of crystals for 144.48, 144.6 and 145MHz, mounting bracket and instructions. Size: 150 x 70 x 220mm.

OUR PRICE £75.00 P&P 50p

HITACHI FLUORESCENT LANTERN L1901



A portable battery operated lantern ideal for home, motoring, camping etc. Approx. 10" tall. Provides brilliant light from 9 1.5v batteries (not supplied).

OUR PRICE £7.90

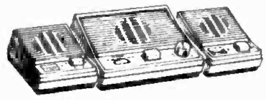
P&P 25p.

DT55G DIGITAL CLOCK MECHANISM

Features 24 hour alarm setting, on/off and auto alarm 'sleep' switch. Illuminated rotary dial with hours, minutes and seconds. Automatically turns off radio, TV, light etc. and with auto-switching will turn on again when required. 240V AC operation. Switch rating 250V—3 Amp.

OUR PRICE £5.95 P&P 30p

KE630 3 Station INTERCOM



Master and two sub-stations. Can be used on desk or wall mounted. Complete with cable and batteries.

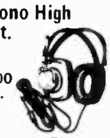
OUR PRICE £5.25 P&P 50p

LH02S STEREO HEADPHONES

Light weight headphones with padded ear pieces. 4/16 ohms 20—20,000Hz. Complete with 6' lead and plug.

OUR PRICE £1.97 P&P 30p

TE1018 Deluxe Mono High Impedence Headset.



Sensitive magnetic headset with soft ear pads. Impedence 2,600 ohms (600 ohms DC). Frequency response: 200—4,000Hz.

OUR PRICE £2.25 P&P 30p

DH02S STEREO HEADPHONES

Wonderful value and excellent performance combined. Adjustable head band. Impedence 8 ohms. 20—12,000Hz. Complete with lead and plug.

OUR PRICE £2.50 P&P 30p

TE1035 Stereo HEADPHONES

Low cost with excellent response. Foam rubber earcups. Adjustable headband. 8 ohms impedence. Frequency response 25Hz—18kHz. Complete with cable and stereo jack plug.

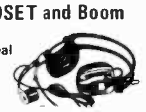
OUR PRICE £2.60 P&P 30p

SH8DV MONO/STEREO HEADPHONES

Volume control for each channel. 4/16 ohms impedence. Frequency response 20Hz—18kHz. Complete with 10ft. coiled lead and jack plug.

OUR PRICE £4.97 P&P 30p

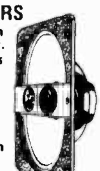
BH001 HEADSET and Boom Microphone



Moving coil. Ideal for language teaching, communications etc. Headphone impedence 16 ohms. Microphone impedence 200 ohms.

OUR PRICE £5.95 P&P 30p

EMI LOUDSPEAKERS



Model 350 13 x 8" with single tweeter/crossover. 20—20,000Hz. 15 watts RMS. Available 8 or 15 ohms.

OUR PRICE £7.50 each P&P 37p

Model 450 13 x 8" with twin tweeter/crossover. 55—13,000Hz. 8 watts RMS. Available 8 or 15 ohms

OUR PRICE £3.62 each P&P 25p

SPECIAL PURCHASE LIMITED QUANTITY! Tannoy 12" DR/8 Bass Speakers

8 ohms. 30 watt. Heavy duty, ideal for Hi-Fi P.A. Group.

OUR PRICE £12.50.

P&P 50p.

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All kits are complete with comprehensive easy to follow instructions and covered by full guarantee.

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AF310 Mono amplifier	£5.91
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AT25 Window wiper robot	£5.82
AT30 Photo cell switch unit	£5.70
AT50 400W triac light dimmer/speed control	£4.80
AT56 2,200W triac light dimmer/speed control	£6.90
AT60 1 channel light control	£7.80
AT65 3 channel light control	£14.55
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GP310 Stereo pre-amplifier for use with 2 x AF310	£21.27
GP312 Circuit board	£11.45
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HF61 Diode detector	£3.32
HF65 FM transmitter	£2.70
HF75 FM receiver	£2.87
HF310 FM tuner	£15.81
HF325 Deluxe FM tuner	£24.12
HF330 Decoder (HF310/325)	£9.96
HF380 lw/vhf aerial amplifier	£4.94
HF395 broadband aerial amp.	£1.77
LF380 Quadraphonic device	£11.36
M160 Multi-vibrator	£1.71
M191 VU Meter	£4.55
M192 Stereo balance meter	£4.97
M1302 Transistor tester	£8.45
NT10 Stabilised power supply 100mA, 9V	£6.15
NT300 Stabilised p. supply	£12.51
NT305 Voltage converter	£4.50
NT315 Power supply 240V AC to4,5/15V DC, 500mA	£9.57

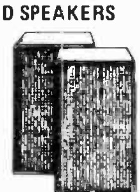
Amateur Electronics by Josty-Kit, the professional book for the amateur—covers the subject from basic principals to advanced electronic techniques. Complete with circuit board for AE1 to AE10.

OUR PRICE £3.30 (No VAT)

P&P 25p plus VAT.

AE1 100mW output stage	£1.50
AE2 Pre-amplifier	£1.15
AE3 Diode receiver	£1.82
AE4 Flasher	99p
AE5 Astable multi-vibrator	95p
AE6 Monostable multi-vibrator	93p
AE7 RC generator	97p
AE8 Bass filter	90p
AE9 Treble filter	90p
AE10 CCIR filter	90p

SPECIAL BARGAIN !! STEREOSOUND SPEAKERS



Matched pair of stereo bookshelf speakers. Deluxe teak veneered finish. Size: 368 x 229 x 190mm. 8 ohms. 8 watts RMS, 16 watts peak. Complete with Din lead.

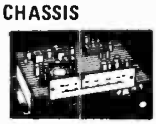
OUR PRICE £12.95 P&P 50p

SPECIAL BARGAIN! FERGUSON 3406 HI-FI SPEAKERS

High quality 2 way speaker systems. 25 Watts. 4—8 ohms. 40Hz—18kHz. Size: 560 x 340 x 255mm. approx. Wood grain finish with black fronts.

OUR PRICE £26.95 PR. P&P £1

FM TUNER CHASSIS



6 transistor high quality tuner. Size only 153 x 101 x 63mm 3 IF stages. Double tuned discriminator. Ample output to feed most amplifiers. Operates on 9V battery. Covers 88—108MHz. Ready built, ready for use. Fantastic value for money.

OUR PRICE £5.95 P&P 20p

Model A1018 FM TUNER

6 transistor high quality unit—3 IF stages and double tuned discriminator. For use with most amplifiers. Covers 88—108MHz. Powered by 9V battery.

OUR PRICE £13.50 P&P 30p

Stereo multiplex adapter £5.95 extra.

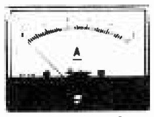
ALL PRICES EXCLUDE VAT

SEW CLEAR PLASTIC PANEL METERS

USED EXTENSIVELY BY INDUSTRY, GOVERNMENT DEPARTMENTS, EDUCATIONAL AUTHORITIES ETC.

Over 200 ranges in stock—other ranges to order. Quantity discounts available. Send for fully illustrated brochure.

CLEAR PLASTIC MODEL SD640
Size: 85 x 64mm



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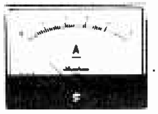
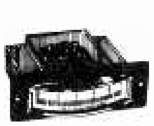
100uA	£3.75
200uA	£3.70
500uA	£3.65
50-0-50uA	£3.75
100-0-100uA	£3.70
1mA	£3.65
5mA	£3.65
10mA	£3.65
50mA	£3.65
100mA	£3.65
500mA	£3.65
1A DC	£3.65
5A DC	£3.65
10A DC	£3.65
5V DC	£3.65
10V DC	£3.65
20V DC	£3.65
50V DC	£3.65
300V DC	£3.65
15V AC	£3.75
300V AC	£3.75
VU Meter	£3.90

CLEAR PLASTIC MODEL SW100
Size: 100 x 80mm



50uA	£4.60
100uA	£4.50
500uA	£4.30
50-0-50uA	£4.50
100-0-100uA	£4.45
1mA	£4.30
1A DC	£4.30
5A DC	£4.30
20V DC	£4.30
50V DC	£4.30
300V DC	£4.30
150V AC	£4.45
300V AC	£4.45
VU Meter	£4.90

EDGWISE MODEL PE70
Size: 90 x 34mm



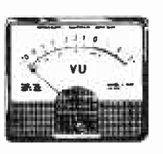
50uA	£4.15
100uA	£4.10
200uA	£4.05
500uA	£3.90
50-0-50uA	£4.10
100-0-100uA	£4.05
1mA	£3.85
300V AC	£3.95
VU Meter	£4.30

MODEL ED107 EDUCATIONAL METER
Size: 100 x 90 x 150mm including terminals

A range of high quality moving coil instruments ideal for school experiments and other bench applications. 3" mirror scale. The meter movement is easily accessible to demonstrate internal working.

50uA	£8.50
100uA	£7.90
50-0-50uA	£7.90
1mA	£7.60
1-0-1mA	£7.60
1A DC	£7.60
5A DC	£7.60
5V DC	£7.60
10V DC	£7.60
15V DC	£7.60
20V DC	£7.60
50V DC	£7.60
300V DC	£7.60
500mA/5A DC	£8.60
5V/50V DC	£8.60
5V/15V DC	£8.60
1/5A DC	£8.60
1A/15A DC	£8.60

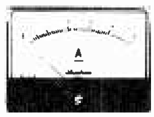
CLEAR PLASTIC MODEL MR 85P
Size: 120 x 110mm



50uA	£5.45
100uA	£5.40
200uA	£5.35
500uA	£5.25
50-0-50uA	£5.40
100-0-100uA	£5.35
500-0-500uA	£5.20
1mA	£5.20
1-0-1mA	£5.20
5mA	£5.20
10mA	£5.20
50mA	£5.20
100mA	£5.20
500mA	£5.20
1A DC	£5.20
5A DC	£5.20
15A DC	£5.20
30A DC	£5.40
10V DC	£5.20
20V DC	£5.20
50V DC	£5.20
150V DC	£5.20
300V DC	£5.20
15V AC	£5.30
300V AC	£5.30
S Meter 1mA	£5.20
VU Meter	£5.55
1A AC	* £5.20
5A AC	* £5.20
10A AC	* £5.20
20A AC	* £5.20
30A AC	* £5.20

*Items with asterisk are Moving Iron type, all others are Moving Coil

CLEAR PLASTIC MODEL SD830
Size: 110 x 83mm



50uA	£4.30
100uA	£4.25
200uA	£4.20
500uA	£4.15
50-0-50uA	£4.25
100-0-100uA	£4.20
1mA	£4.10
5mA	£4.10
10mA	£4.10
50mA	£4.10
100mA	£4.10
500mA	£4.10
1A DC	£4.10
5A DC	£4.10
10A DC	£4.10
5V DC	£4.10
10V DC	£4.10
20V DC	£4.10
50V DC	£4.10
300V DC	£4.10
15V AC	£4.20
300V AC	£4.20
VU Meter	£4.40

CLEAR PLASTIC MODEL MR 45P
Size: 50 x 50mm

50uA	£3.20
100uA	£3.15
200uA	£3.10
500uA	£3.00
50-0-50uA	£3.15
100-0-100uA	£3.10
500-0-500uA	£2.95
1mA	£2.95
5mA	£2.95
10mA	£2.95
50mA	£2.95
100mA	£2.95
500mA	£2.95
1A DC	£2.95
5A DC	£2.95
10V DC	£2.95
20V DC	£2.95
50V DC	£2.95
300V DC	£2.95
15V AC	£3.05
300V AC	£3.05
S Meter 1mA	£2.95
VU Meter	£3.40
1A AC	* £2.95
5A AC	* £2.95
10A AC	* £2.95
20A AC	* £2.95
30A AC	* £2.95

CLEAR PLASTIC MDDEL MR 38P
Size: 42 x 42mm

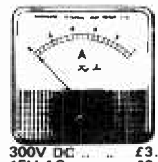
50uA	£3.10
100uA	£3.05
200uA	£3.00
500uA	£2.85
50-0-50uA	£3.05
100-0-100uA	£3.00
500-0-500uA	£2.80
1mA	£2.80
1-0-1mA	£2.80
2mA	£2.80
5mA	£2.80
10mA	£2.80
20mA	£2.80
50mA	£2.80
100mA	£2.80
150mA	£2.80
200mA	£2.80
300mA	£2.80
500mA	£2.80
750mA	£.280
1A DC	£2.80
2A DC	£2.80
5A DC	£2.80
10A DC	£2.80
3V DC	£2.80
10V DC	£2.80
15V DC	£2.80
20V DC	£2.80
50V DC	£2.80
100V DC	£2.80
150V DC	£2.80
300V DC	£2.85
500V DC	£2.85
750V DC	£2.90
15V AC	£2.90
50V AC	£2.90
150V AC	£2.90
300V AC	£2.90
500V AC	£3.00
S Meter 1mA	£2.80
VU Meter	£3.20

CLEAR PLASTIC MODEL SD460
Size: 59 x 46mm

50uA	£3.50
100uA	£3.45
200uA	£3.40
500uA	£3.35
50-0-50uA	£3.45
100-0-100uA	£3.40
1mA	£3.30
5mA	£3.30
10mA	£3.30
50mA	£3.30
100mA	£3.30
500mA	£3.30
1A DC	£3.30
5A DC	£3.30
10A DC	£3.30
5V DC	£3.30
10V DC	£3.30
20V DC	£3.30
50V DC	£3.30
300V DC	£3.30
15V AC	£3.45
300V AC	£3.45
VU Meter	£3.65

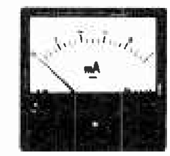
POSTAGE & PACKING 15p

CLEAR PLASTIC MODEL MR 65P
Size: 86 x 78mm



50uA	£3.95
100uA	£3.85
200uA	£3.80
500uA	£3.75
50-0-50uA	£3.85
100-0-100uA	£3.80
500-0-500uA	£3.70
1mA	£3.70
1-0-1mA	£3.70
5mA	£3.70
10mA	£3.70
50mA	£3.70
100mA	£3.70
500mA	£3.70
1A DC	£3.70
5A DC	£3.70
10A DC	£3.70
15A DC	£3.70
20A DC	£3.80
30A DC	£3.85
50A DC	£4.05
5V DC	£3.70
10V DC	£3.70
15V DC	£3.70
20V DC	£3.70
50V DC	£3.70
150V DC	£3.70
300V DC	£3.70
15V AC	£3.80
50V AC	£3.80
150V AC	£3.80
300V AC	£3.90
500V AC	£3.80
S Meter 1mA	£4.10
VU Meter	£3.70
1A AC	* £3.70
5A AC	* £3.70
10A AC	* £3.70
20A AC	* £3.70
30A AC	* £3.70
50mA AC	* £3.70
100mA AC	* £3.70
200mA AC	* £3.70
500mA AC	* £3.70

BAKELITE MODEL S80 Enlarged Window
Size: 80 x 80mm



50uA	£4.50
100uA	£4.45
500uA	£4.20
50-0-50uA	£4.45
100-0-100uA	£4.40
1mA	£4.20
1A DC	£4.20
5A DC	£4.20
20V DC	£4.20
50V DC	£4.20
300V DC	£4.20
300V AC	£4.30
VU Meter	£4.70

CLEAR PLASTIC MODEL MR 52P
Size: 60 x 60mm

50uA	£3.70
100uA	£3.50
500uA	£3.35
50-0-50uA	£3.50
100-0-100uA	£3.45
1mA	£3.30
5mA	£3.30
10mA	£3.30
50mA	£3.30
100mA	£3.30
500mA	£3.30
1A DC	£3.30
5A DC	£3.30
10V DC	£3.30
20V DC	£3.30
50V DC	£3.30
300V DC	£3.30
15V AC	£3.40
300V AC	£3.40
S Meter 1mA	£3.30
VU Meter	£3.80
1A AC	* £3.30
5A AC	* £3.30
10A AC	* £3.30
20A AC	* £3.30
30A AC	* £3.30

BAKELITE MODEL MR 65 Size: 80 x 80mm

25uA	£5.25
50uA	£4.00
100uA	£3.95
500uA	£3.65
50-0-50uA	£3.95
100-0-100uA	£3.90
500-0-500uA	£3.60
1mA	£3.60
1-0-1mA	£3.60
5mA	£3.60
10mA	£3.60
50mA	£3.60
100mA	£3.60
500mA	£3.60
1A DC	£3.60
2A DC	£3.60
5A DC	£3.60
10A DC	£3.60
15A DC	£3.60
30A DC	£3.60
50A DC	£3.80
5V DC	£3.60
10V DC	£3.60
15V DC	£3.60
20V DC	£3.60
50V DC	£3.60
150V DC	£3.60
300V DC	£3.60
30V AC	* £3.60
50V AC	* £3.60
150V AC	* £3.60
300V AC	* £3.60
500V AC	* £3.60
VU Meter	£4.10
1A AC	* £3.60
5A AC	* £3.60
10A AC	* £3.60
20A AC	* £3.60
30A AC	* £3 60
50A AC	* £3.60
500mA AC	* £3.60
50mV DC	£3 75
100mV DC	£3.75

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Project 805........................... £26.95
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PZ6 Power Supply.................. £7.98
PZ8 Power Supply.................. £7.98
Transformer for PZ8............. £4.05

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2 x Z40/Stereo 80/PZ6.......... £27.75
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C120	£2.73	£5.17	£12.24

AUDIOTRONIC CrO2 CASSETTES

TYPE	5	10	25
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CR90	£5.32	£10.46	£25.22

AUDIOTRONIC 8 TRACK CARTRIDGES

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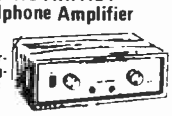
80M	£1.15	£5.40	£10.25

P&P Cassettes 3p, Cartridges 5p each OVER 10 of either POST FREE!

AUDIOTRONIC AHA101 Stereo Headphone Amplifier



All silicon, transistor amplifier operates from magnetic, ceramic or tuner inputs with twin stereo headphone outputs and separate volume controls for each channel. Operates from 9V battery. INPUTS: 5mV and 100mV. OUTPUT: 50mV per channel.

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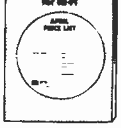

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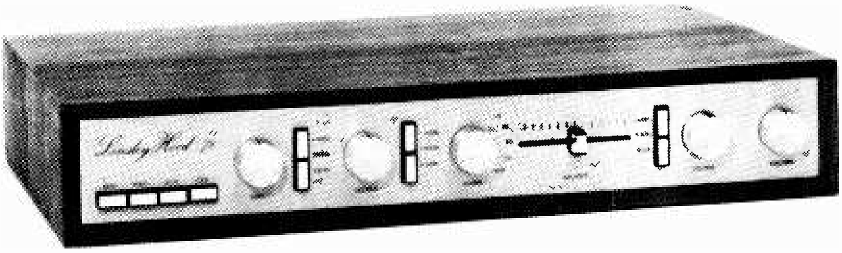

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£62.40 POST FREE (U.K.)

Full circuit description in handbook

Pack		Price
1	Fibre glass printed circuit board for power amp.	£0.85
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6	Set of low noise resistors, capacitors, pre-sets for pre-amp.	£2.70
7	Set of low noise, high gain semiconductors for pre-amp.	£2.40
8	Set of potentiometers (including mains switch).	£2.05
9	Set of 4 push button switches, rotary mode switch.	£3.70
10	Toroidal transformer complete with magnetic screen/housing primary: 0-117-234 V, secondaries: 33-0-33 V 24-0-24 V.	£9.15
11	Fibre glass printed circuit board for power supply.	£0.65
12	Set of resistors, capacitors, secondary fuses, semiconductors for power supply.	£3.50
13	Set of miscellaneous parts including DIN skts, mains input skt, fuse holder, interconnecting cable, control knobs	£4.25
14	Set of metalwork parts including silk screen printed fascia panel and all brackets, fixing parts, etc.	£6.30
15	Handbook.	£0.30
16	Teak cabinet.	£7.35

2 each of packs 1-7 inclusive are required for complete stereo system.

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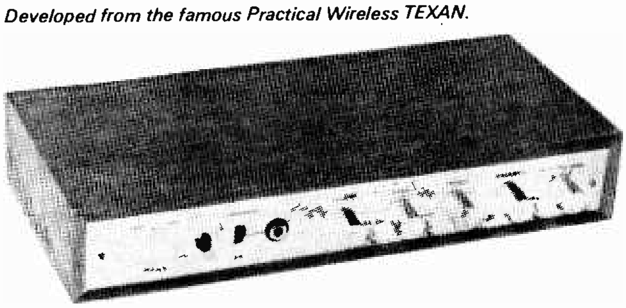
★ WITH TOROIDAL TRANSFORMER
★ 20 WATTS PER CHANNEL

Developed from the famous Practical Wireless TEXAN.



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2N699	0.25	2N4058	0.12	BC214L	0.14	MPSA66	0.40	TIP33A	1.00
2N1613	0.20	2N4062	0.11	BCY72	0.13	MPSU05	0.60	TIP34A	1.50
2N1711	0.25	2N4302	0.60	BD529	0.85	MPSU55	0.70	TIP41A	0.74
2N2926G	0.10	2N5087	0.42	BD530	0.85	SN72721P	0.58	TIP42A	0.90
2N3053	0.15	2N5210	0.54	BDY56	1.60	SN72748P	0.58	TIP3055	0.60
2N3055	0.45	2N5457	0.45	BF257	0.40	TIP29A	0.50	IB08T20	0.50
2N3442	1.20	2N5459	0.45	BF259	0.47	TIP30A	0.60	IB40K20	1.40
2N3702	0.11	2N5830	0.30	BFR39	0.25	TIP29C	0.71	IN914	0.07
2N3703	0.10	40361	0.40	BFR79	0.25	TIP30C	0.78	IN916	0.07
2N3704	0.10	40362	0.45	BFY50	0.20	TIP31A	0.60	IS920	0.10
2N3705	0.10	BC107	0.10	BFY51	0.20	TIP32A	0.70	5B05	1.20
2N3706	0.09	BC108	0.10	BFY52	0.20				
2N3707	0.10	BC109	0.10	MJ481	1.20				
2N3708	0.07	BC125	0.15	MJ491	1.30				
2N3709	0.09	BC126	0.15	MJE521	0.60				
2N3710	0.09	BC182K	0.10	MPSA05	0.30				
2N3711	0.09	BC212K	0.12	MPSA12	0.55				
2N3819	0.23	BC182L	0.10	MPSA14	0.35				
2N3904	0.17	BC184L	0.11	MPSA55	0.35				
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Pk. 2 Resistors, capacitors, pots	£2.15
Pk. 3 Semiconductor set	£5.60
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Pk. 1 F/Glass PCB	£0.70
Pk. 2 Resistors, capacitors, pots	£2.40
Pk. 3 Semiconductor set	£3.35
60V REGULATED POWER SUPPLY	
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Pk. 3 Semiconductor set	£3.10
BAILEY-BURROWS PRE-AMP	
Pk. 1 F/Glass PCB	£1.60
Pk. 2 Resistors, capacitors, pre-sets, transistors	£4.95
Pk. 3R Rotary potentiometer set	£1.60

For further details on the above and other designs including 100W amplifier and Stuart Tape Recorder write for FREE LIST.

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Designed to house Bailey, Blomley or Linsley-Hood Class AB amplifiers with simple or regulated power supplies and Bailey Burrows pre-amp. Options of standard or hum reducing toroidal mains transformer. Also rotary control version. Details in price list.

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KEMPSTON HARDWICK
BEDFORD

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CALLERS WELCOME
MON.-SAT. 9 a.m.-5 p.m.

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RESISTORS

½W Iskra high stability carbon film—very low noise—capless construction. ⅓W Mullard CR25 carbon film—very small body size 7·5 x 2·5 mm. ¼W 2% ELECTROSIL TR5.

Power watts	Tolerance	Range	Values available	Price 1–99	100+
½	5%	4·7Ω–2·2MΩ	E24	1p	0·9p
½	10%	3·3MΩ–10MΩ	E12	1p	0·9p
¼	2%	10Ω–1MΩ	E24	3·5p	3p
⅓	10%	1Ω–3·9Ω	E12	1p	0·9p
⅓	5%	4·7Ω–1MΩ	E12	1p	0·9p
4	10%	1Ω–10Ω	E12	6p	5·5p

Quantity price applies for any selection. Ignore fractions on total order.

DEVELOPMENT PACK

0·5 watt 5% Iskra resistors 5 off each value 4·7Ω to 1MΩ.
E12 pack 325 resistors **£2·40.** E24 pack 650 resistors **£4·70.**

POTENTIOMETERS

Carbon track 5kΩ to 2MΩ, log or linear (log ¼W, lin ½W).
Single, **12p.** Dual gang (stereo), **40p.** Single D.P. switch, **24p.**

SKELETON PRESET POTENTIOMETERS

Linear: 100, 250, 500Ω and decades to 5MΩ. Horizontal or vertical P.C. mounting (0·1 matrix).
Sub-miniature 0·1W, **5p** each. Miniature 0·25W, **7p** each.

TRANSISTORS

AC107	15p	AF126	20p	BF115	25p	OC42	12p	2N3707	12p
AC126	12p	AF139	32p	BF173	20p	OC44	12p	2N3708	10p
AC127	15p	AF178	32p	BF177	28p	OC45	12p	2N3709	11p
AC128	15p	AF180	40p	BF178	32p	OC70	12p	2N3710	11p
AC131	12p	AF181	40p	BF179	32p	OC71	12p	2N3711	11p
AC132	12p	BC107	12p	BF180	32p	OC72	12p	2N3819	32p
AC176	15p	BC108	12p	BF181	32p	OC81	12p	2N4062	12p
AC187	22p	BC109	12p	BF194	14p	OC82D	12p	2N4286	20p
AC188	22p	BC147	12p	BF195	14p	2N2646	60p	2N4289	20p
AD140	50p	BC148	12p	BF197	15p	2N2904	20p	40360	35p
AD149	45p	BC149	12p	BF200	32p	2N2926	10p	40361	35p
AD161	33p	BC157	14p	BF750	20p	2N3054	58p	40362	40p
AD162	36p	BC158	14p	BF751	20p	2N3055	60p	40408	40p
AF114	20p	BC159	14p	BF752	20p	2N3702	13p	ZTX108	15p
AF115	20p	BC187	22p	BU105	225p	2N3703	12p	ZTX300	15p
AF116	20p	BD131	75p	OC26	45p	2N3704	13p	ZTX302	20p
AF117	20p	BD132	75p	OC28	50p	2N3705	12p	ZTX500	15p
AF118	38p	BD133	75p	OC35	50p	2N3706	11p	ZTX503	20p

ZENER DIODES

400mW 5% 3·3V to 30V, **12p.**

WIRE WOUND POTS

3W, 10, 25, 50Ω and decades to 100kΩ, **45p.**

DIODES

RECTIFIER

BY127	1250V	1A	12p
IN4001	50V	1A	7p
IN4002	100V	1A	8p
IN4004	400V	1A	8p
IN4006	800V	1A	10p
IN4007	1000V	1A	12p

SIGNAL

OA85	7p
OA90	5p
OA91	5p
OA202	7p
IN4148	5p
BA114	8p

BRUSHED ALUMINIUM PANELS

12in x 6in, **25p;** 12in x 2½in, **10p;** 9in x 2in, **7p**

SLIDER POTENTIOMETERS

86mm x 9mm x 16mm, length of track 59mm.
DUAL GANG, 10K + 10K etc. log. or lin. **60p.**
KNOB FOR ABOVE, **12p.**
FRONT PANEL, **65p.**
18 Gauge panel 12in x 4in with slots cut for use with slider pots. Grey or matt black finish complete with fixings for 4 pots.

THERMISTORS

VA 1055S 15p
VA 1066S 15p
VA 1077 .... 15p
R 53 .... £1·35

THYRISTORS

2N5060 50V 0·8A	65p
2N5064 200V 0·8A	80p
106F 50V 4A	55p
106D 400V 4A	80p

MULLARD POLYESTER CAPACITORS C296 SERIES

400V: 0·001µF, 0·0015µF, 0·0022µF, 0·0033µF, 0·0047µF, **2½p.** 0·0068µF, 0·01µF, 0·015µF, 0·022µF, 0·033µF, **3p.** 0·047µF, 0·068µF, 0·1µF, **4p.** 0·15µF, **6p.** 0·22µF, **7½p.** 0·33µF, **11p.** 0·47µF, **13p.**
160V: 0·01µF, 0·015µF, 0·022µF, 0·033µF, 0·047µF, 0·068µF, **3p.** 0·1µF, **3½p.** 0·15µF, **4½p.** 0·22µF, **5p.** 0·33µF, **6p.** 0·47µF, **7½p.** 0·68µF, **11p.** 1·0µF, **13p.**

MULLARD POLYESTER CAPACITORS C280 SERIES

250V P.C. mounting: 0·01µF, 0·015µF, 0·022µF, **3p.** 0·033µF, 0·047µF, 0·068µF, **3½p.** 0·1µF, **4p.** 0·15µF, 0·22µF, **5p.** 0·33µF, **6½p.** 0·47µF, **8½p.** 0·68µF, **11p.** 1·0µF, **13p.** 1·5µF, **20p.** 2·2µF, **24p.**

MYLAR FILM CAPACITORS 100V

0·001µF, 0·002µF, 0·005µF, 0·01µF, 0·02µF, **2½p.** 0·04µF, 0·05µF, 0·068µF, 0·1µF, **3½p.**

CERAMIC DISC CAPACITORS

100pF to 10,000pF, **2p** each.

ELECTROLYTIC CAPACITORS—MULLARD O15/6/7

(µF/v) 1/63, 1·5/63, 2·2/63, 3·3/63, 4·7/63, 6·8/40, 6·8/63, 10/25, 10/63, 15/16, 15/40, 15/63, 22/10, 22/25, 22/63, 33/6·3, 33/16, 33/40, 47/4, 47/10, 47/25, 47/40, 68/6·3, 68/16, 100/4, 100/10, 100/25, 150/6·3, 150/16, 220/4, 220/6·3, 220/16, 330/4, **6p.** 47/63, 100/40, 150/25, 220/25, 330/10, 470/6·3, **7p.** 68/63, 150/40, 220/40, 330/16, 1000/4, **10p.** 470/10, 680/6·3, **11p.** 100/63, 150/63, 220/63, 1000/10, **12p.** 470/25, 680/16, 1500/6·3, **13p.** 470/40, 680/25, 1000/16, 1500/10, 2200/6·3, **18p.** 330/63, 680/40, 1000/25, 1500/16, 2200/10, 3300/6·3, 4700/4, **21p.**

SOLID TANTALUM BEAD CAPACITORS 12p

0·1µF 35V	2·2µF 35V	22µF 16V
0·22µF 35V	4·7µF 35V	33µF 10V
0·47µF 35V	6·8µF 25V	47µF 6·3V
1·0µF 35V	10µF 25V	100µF 3V

VEROBOARD

	0·1	0·15
2½ x 3¾	22p	16p
2½ x 5	24p	24p
3¾ x 3¾	24p	24p
3¾ x 5	27p	27p
17 x 2½	75p	57½p
17 x 3¾	100p	78p
17 x 5 (plain)	—	82p
17 x 3¾ (plain)	—	60p
17 x 2½ (plain)	—	42p
2½ x 5 (plain)	—	12p
2½ x 3¾ (plain)	—	11p
Pin insertion tool	52p	52p
Spot face cutter	42p	42p
Pkt. 50 pins	20p	20p

JACK PLUGS AND SOCKETS

Standard screened	28p	2·5mm insulated	12p
Standard insulated	18p	3·5mm insulated	12p
Stereo screened	40p	3·5mm screened	18p
Standard socket	20p	2·5mm socket	11p
Stereo socket	30p	3·5mm socket	11p

D.I.N. PLUGS AND SOCKETS

2 pin, 3 pin, 5 pin 180°, 5 pin 240°, 6 pin, 7 pin
Plug 12p. Socket 8p.
4 way screened cable, **25p/metre.**
6 way screened cable, **30p/metre.**

BATTERY ELIMINATOR £1·50

9V mains power supply. Same size as PP9 battery.

LARGE (CAN) ELECTROLYTICS

1600µF 64V 74p	2500µF 64V 80p	4500µF 16V 50p
2500µF 40V 74p	2800µF 100V £3·20	4500µF 25V £1·68
2500µF 50V 58p	3200µF 16V 50p	5000µF 50V £1·10

HIGH VOLTAGE TUBULAR CAPACITORS—1,000 VOLT

0·01µF 10p	0·047µF 13p	0·22µF 20p
0·022µF 12p	0·1µF 13p	0·47µF 22p

POLYSTYRENE CAPACITORS 160V 2½%

10pF to 1,000pF E12 Series Values, **4p** each.

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The GDI is the world's first semiconductor that can convert a concentration of gas or smoke into an electrical signal. The sensor decreases its electrical resistance when it absorbs deoxidizing or combustible gases such as hydrogen, carbon monoxide, methane, propane, alcohol, North Sea gas, as well as carbon-dust containing air or smoke. This decrease is usually large enough to be utilized without amplification. Full details and circuits are supplied with each detector.
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Draw the planned circuit on to a copper laminate board with the P.C. Pen, allow to dry, and immerse the board in the etchant. On removal the circuit remains in high relief.

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Model 320 LOGIC PROBE

* Wrong polarity and overload protectors provided
* Detection of the peak value of input waveform
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* Up to 12 MHz

For use in detecting TTL, DTL flip flop and other pulse circuits

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£13·95

This NEW, versatile **De Luxe 4-Station Transistorised Intercom (1 Master and 3 Subs)** for desk or wall mounting can solve your communication problems instantly. Effective range 300ft. Call/talk/listen from **Master** to **Subs** and **Subs** to **Master.** With Selector switch. Ideally suitable for office, shop, home or surgery. Adaptable for Mains. Complete with three 66ft. connecting wires and accessories. On/Off switch volume control. P. & P. 47p.

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TEKTRONIX 536 Oscilloscope with T & CA plug-ins **£295.**

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Carriage £1·50

AMERICAN SWEEP GENERATOR type 452. Covers from 5 to 100 MHZ. Has built in display and 101 DB Push Button RF Attenuator in one DB steps, plus Calibrated Marker Generator covering 5 to 100 MHZ continuous. American Government Contract, so quality is high. Supplied for 240V 50 HZ operation with plugs and leads. Size 13½ × 9½ × 19in. Price **£70** each. Carriage £1·50.

AMERICAN SWEEP GENERATOR type TRM 3 15 to 400 MHZ. **£300.**

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12″ LONG PERSISTANCE TUBES

Ideal for SSTV; educational purposes. Type 12DP7A. Connections, voltages etc. Brand New Boxed **£7·50** each including carriage and VAT.

SPECIAL 40 MHZ SCOPE SOLARTRON CD1212 ONLY £50. Has to be a snag. There is—no plug—in Y amps available.
TB-100 nanosecs per cm. to 5 secs. per cm. in 24 calibrated ranges. 20 nanosecs per cm. with times 5 expansion. 5″ flat faced tube. Trace locator. 0-2 microsec. signal delay. Built in calibrator. 1 KHZ square wave. 200 micro volts to 100 volts in 18 calibrated ranges. Tube sensitivity 3 V/CM MAIN FRAM Y AMP boosts this to better than 200mV per cm. at 40 MHZ. 240V. 50 HZ input. Complete with full manual including plug-in circuits. Come and see one working or Carriage £1·50.

***STILL at £42·50**
Solartron CD 711S.2 Double Beam Oscilloscope DC—9 mc/s; 3 mv/cm; trigger delay; crystal calibrator; 4″ flat faced tube. In good working condition. Carr. £1·50.

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MARCONI VVM TF1041A £22·50.

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SLOPED CASES size 9 × 7in. with 8in. slope, 15in. long, in Hammer Grey. Brand New boxed **£1.** Packing and postage 37p.

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Ideal **EXTENSION** Telephones with standard GPO type dial, bell and lead coding. **£1·75** ea. P. & P. 25p.

All telephones complete with bell and dial.

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COLVERN 3 watt. Brand new, 25; 50k all at **13p** ea.

MORGANITE Special Brand new, 2·5; 10; 100; 250; 500K; 1 in. sealed, **17p** ea.

BERCO 2½ Watt. Brand new, 5; 10; 50; 250; ohms; 1; 2·5; 10; 25; 50K at **15p** ea.

STANDARD 2 meg. log pots. Current type **15p** ea.

INSTRUMENT 3 in. Colvern 5 ohm **35p** ea.; 50k and 100K **50p** ea.

BOURNS TRIMPOT POTENTIOMETERS. 20; 50; 100; 200; 500 ohms; 1; 2; 2·5; 5; 10; 25K at **35p** ea. ALL BRAND NEW.

RELIANCE P.C.B. mounting: 270; 470; 500 ohms; 10K at **35p** ea. ALL BRAND NEW.

ALMA precision resistors 200K; 400K; 497K; 998K; 1 meg—0·1% **27p** ea.; 3·25k, 5·6k, 13k-0·1% **20p** ea.

CAPACITORS. Brand New. 10,000mfd 50V 60p ea. P & P 15p.

RELAYS

Varley VP4 Plastic covers 4 pole c/o. 15K—**33p** ea.

CARPENTERS polarised Single pole c/o 20 and 65 ohm coil as new **37p** each. 14 ohm coil **33p** each. 45 ohm coil **33p** each.

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Gard/Parm/Part. 450-400-0-400-450. 180 MA. 2 x 6·3v. **£3** ea.

Neptune Series. Multi 6·3 volts to give 48V at 3·5 amps etc. **£3·50** incl. P. & P.

Large quantity LT, HT, EHT transformers and chokes.

Vast quantity of good quality components
—NO PASSING TRADE—so we offer
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£1 WORTH OF 'UFS'. Six Brand New capacitors all between 15V and 100V. Total capacitance not less than 7,000mfd. P. & P. 45p.

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POTS 10 different values. Brand new. **50p.** P. & P. 17p.

COMPONENT PACK consisting of 5 pots various values, 250 resistors ½ and ¼ watt etc., many high stabs. All brand new. Fine value at **50p** per pack. P. & P. 27p.

DELIVERED TO YOUR DOOR 1 cwt. of Electronic Scrap chassis, boards, etc. No Rubbish. FOR ONLY **£3·50.** N. Ireland **£2** extra.

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BECKMAN MODEL A. Ten turn po complete with dial. 100k 3% Tol 0·25%—only **£1·13** ea.
Also 450K 0·5% with dial **£2·13** ea.

ELECTROSTATIC VOLTMETERS from 0–300 Volts to 0–10KV. S.A.E. with your requirements.

FIBRE GLASS PRINTED CIRCUIT BOARD. Brand new. Single sided up to 2½″ wide × 15″ ½p per sq. in. Larger pieces 1p per sq. in. Double sided. Any size 1p per sq. in. Postage 10p per order.

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0·05mfd	2·5kv	**50p** ea.	0·01mfd	5kv	**40p** ea.
0·05mfd	8kv	**50p** ea.	0·01mfd	10kv	**50p** ea.
0·1 mfd	4kv	**35p** ea.			

DUBILIER 0·1mfd 5 KV; 0·1mfd 7·5 KV; 0·25mfd 7·5 KV; 0·5mfd 5 KV all at **50p** ea. P. & P. 15p.

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From As New to well used condition. Price from **£275** (Main frame).

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P.O.A.

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Standard Mains Input. **£2·75** each.
P. & P. 25p.

MAKE YOUR SINGLE BEAM SCOPE INTO A DOUBLE WITH OUR NEW LOW PRICED SOLID STATE SWITCH. 2 HZ to 8 MHZ. Hook up a 9 volt battery and connect to your scope and have two traces for ONLY **£5·50.** P. & P. 25p.
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20HZ to 200KHZ SINE AND SQUARE WAVE GENERATOR

In four ranges. Wien bridge oscillator thermistor stabilised. Separate independent sine and square wave amplitude controls. 3V max sine, 6V max square outputs. Completely assembled P.C. Board, ready to use. 9 to 12V supply required. **£7·85** each. P & P 25p. Sine Wave only **£5·85** each. P & P 25p.

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12V to 1·5 KV 2MA. Size 1½ x 2½ x 4in. Multi tapped secondary and output level control makes possible large range of voltage and current output combinations without modification. Very flexible unit at **£2·95** each. P. & P. 25p.

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5 MHZ to 150 MHZ (Useful harmonics up to 1·5 GMZ) up to 15 MHZ sweep width. Only 3 controls, preset RF level, sweep width and frequency. Ideal for 10·7 or TV IF alignment, filters, receivers. Can be used with any general purpose scope. Full instructions supplied. Connect 6·3V AC and use within minutes of receiving.
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Unless stated—please add £1·50 carriage to all units.

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VERY IMPORTANT. ONLY branded I.C's are to the FULL manufacturers specifications. ALL others are not. Henry's sell *only* branded Integrated Circuits . . . From **TEXAS . . . I.T.T. . . . FAIRCHILD . . . SIGNETICS.** So why buy alternatives or under spec. devices when you can purchase the genuine article from us—ex stock . . . need we say more!

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SN7413N	0·30	0·27	0·25	SN7489N	4·32	4·32	3·78	SN74165N	2·01	2·01	1·76
SN7414N	0·72	0·72	0·63	SN7490N	0·75	0·70	0·63	SN74166N	2·16	2·16	1·89
SN7416N	0·30	0·27	0·25	SN7491AN	1·10	1·00	0·90	SN74167N	4·10	4·10	3·59
SN7417N	0·30	0·27	0·25	SN7492N	0·75	0·70	0·63	SN74170N	2·88	2·88	2·52
SN7420N	0·20	0·18	0·16	SN7493N	0·75	0·70	0·63	SN74172N	5·70	5·78	5·64
SN7422N	0·28	0·28	0·25	SN7494N	0·85	0·80	0·75	SN74173N	1·60	1·66	1·45
SN7422AN	0·38	0·38	0·33	SN7495N	0·85	0·80	0·75	SN74174N	1·80	1·80	1·57
SN7423N	0·37	0·34	0·32	SN7496N	1·00	0·90	0·83	SN74175N	1·29	1·29	1·13
SN7425N	0·37	0·37	0·32	SN74100N	2·16	1·89	1·89	SN74176N	1·44	1·44	1·26
SN7427N	0·37	0·37	0·32	SN74104N	0·60	0·53	0·45	SN74177N	1·44	1·44	1·26
SN7428N	0·43	0·43	0·37	SN74105N	0·60	0·53	0·45	SN74180N	1·44	1·44	1·26
SN7430N	0·20	0·18	0·16	SN74107N	0·51	0·51	0·45	SN74181N	5·18	5·18	4·53
SN7432N	0·37	0·37	0·32	SN74110N	0·57	0·57	0·50	SN74182N	1·44	1·44	1·26
SN7433N	0·43	0·43	0·38	SN74111N	0·86	0·86	0·75	SN74184N	2·16	2·16	1·89
SN7433AN	0·57	0·57	0·50	SN74116N	2·18	2·16	1·89	SN74185AN	2·16	2·16	1·89
SN7437N	0·43	0·43	0·37	SN74118N	1·00	0·90	0·83	SN74188N	6·48	6·48	5·67
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SN7441AN	0·85	0·78	0·73	SN74122N	0·80	0·80	0·70	SN74193N	2·30	2·30	2·01
SN7442N	0·85	0·78	0·73	SN74123N	1·44	1·44	1·26	SN74194N	1·72	1·72	1·51
SN7443N	1·50	1·27	1·13	SN74125N	0·69	0·69	0·60	SN74195N	1·44	1·44	1·26
SN7444N	1·50	1·27	1·13	SN74126N	0·60	0·69	0·60	SN74196N	1·58	1·58	1·38
SN7445N	2·16	2·16	1·89	SN74132N	0·72	0·72	0·63	SN74197N	1·58	1·58	1·38
SN7446N	2·16	2·16	1·89	SN74136N	0·63	0·63	0·55	SN74198N	3·16	3·16	2·77
SN7447AN	1·80	1·80	1·57					SN74199N	2·88	2·88	2·52

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ASY27	30p	BFX88	22p	NKT217	45p	ORP60	45p	2N2160	60p	40250	45p
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BC108	15p	BFY90	75p	OA200	8p	TIP30A	58p	2N3055	45p	40486	75p
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3 AMP RANGE

Type	P.I.V.	1-11 Price Each
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SC35D	400v	90p
SC35E	500v	£1·20

6 AMP RANGE

SC40A	100v	90p
SC40B	200v	95p
SC40D	400v	£1·20
SC40E	500v	£1·50

10 AMP RANGE

SC45A	100v	£1·05
SC45B	200v	£1·15
SC45D	400v	£1·45
SC45E	500v	£1·85

15 AMP RANGE

SC50A	100v	£1·45
SC50B	200v	£1·65
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TRIACS Additional Types

40430	TRIAC (T066)	85p
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3 Amp T048

15 Amp T048

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Type	P.I.V.	1-11
ONE AMP (T05) P.I.V.		
CRS 1/05AF	50v	30p
CRS 1/10AF	100v	30p
CRS 1/20AF	200v	35p
CRS 1/40AF	400v	45p
CRS 1/60AF	600v	55p
THREE AMP (T048)		
CRS 3/05AF	50v	40p
CRS 3/10AF	100v	40p
CRS 3/20AF	200v	45p
CRS 3/40AF	400v	55p
CRS 3/60AF	600v	65p
FIVE AMP		
CRS 5/400	400v	90p
SEVEN AMP (T048)		
CRS 7/100	100v	60p
CRS 7/200	200v	67p
CRS 7/400	400v	85p
CRS 7/600	600v	95p
SIXTEEN AMP (T048)		
CRS 16/100	100v	70p
CRS 16/200	200v	75p
CRS 16/400	400v	85p
CRS 16/600	600v	£1·10

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605	Power supply for 115	5·31
610	Power supply for 120	5·31
615	Power supply for 2 x 120	6·64
230	AM/FM aerial amplifier	3·29
240	Auto packing light	6·90
275	Mic. preamplifier	6·98
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575S	Sq. wave generator 20Hz-20Khz	19·77
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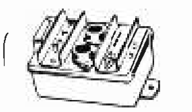
465	Quartz XTAL checker	9·90
220	Signal injector	2·30
390	Vox	15·50
432	Testakit	19·30
670	Buffer Battery Charger	6·55
885	Capacitive Contact Alarm	6·25
850	Electronic Keyer	18·75
820	Electronic Digital Clock	58·50



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B025/05	50 PIV	16p
B025/10	100 PIV	18p

¼ x ¼ x ¼" dia.

½ AMP 1-11 Pricing

Type	P.I.V.	Price ea.
B05/05	50v	20p
B05/10	100v	22p
B05/20	200v	23p
B05/40	400v	25p
B05/60	600v	27p

⅜H x ⅜L x $\frac{3}{16}$" dia.

1 AMP P.I.V.

B1/05	50v	25p
B1/10	100v	25p
B1/20	200v	28p
B1/60	600v	30p

⅜H x ⅜L x $\frac{3}{16}$" dia.

1 AMP P.I.V.

W005	50v	29p
W01	100v	30p
W02	200v	32p
W06	600v	35p

⅜ x ⅜" Tubular

2 AMPS P.I.V.

B2/05	50v	35p
B2/10	100v	40p
B2/20	200v	45p
B2/60	600v	50p
B2/100	1000v	55p

⅜H x ⅜L x $\frac{3}{16}$" dia.

4 AMPS P.I.V.

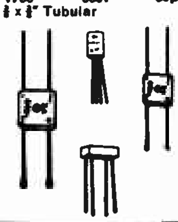
B4/100	100v	55p
B4/200	200v	59p
B4/400	400v	65p
B4/600	600v	75p
B4/800	600v	£1·00

⅜H x ⅜L x $\frac{3}{16}$" dia.

6 AMPS P.I.V.

B6/05	50v	65p
B6/10	100v	70p
B6/20	200v	80p
B6/40	400v	90p
B6/6x0	600v	£1·00

⅜H x ⅜L x $\frac{3}{16}$" dia.



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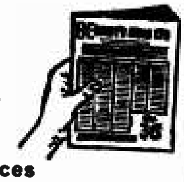

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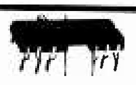

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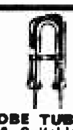

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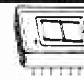

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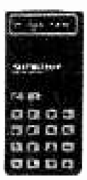

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20 + 20WATT IC STEREO AMPLIFIER
As featured by *Practical Wireless* 1972

Now built and used by thousands of satisfied customers. Features slim design overall size in cabinet 15¼" x 2¾" x 6¾" 6-IC's, 10 transistors, stabilisers Gardners low field transformer. Fibre Glass PC Panel, complete chassis work. Now available built and tested as well as in kit form. HIGH QUALITY AND STABILITY ARE PREDOMINATE FEATURES—DEVELOPED BY TEXAS ENGINEERS FOR PERFORMANCE, RELIABILITY ANDEASE OF CONSTRUCTION FACILITIES.

On/off switch indicator, headphones socket, separate treble, bass, volume and balance controls, scratch and rumble filters, mono/stereo switch, input selector: Mag. P.U., Radio Tuner, Aux. Can be altered for Mic., Tape, Tape-head, etc. Constructional details Ref. No. 21 30p. Distributed by Henry's throughout UK.

FREE — Teak cabinet with complete kit.

Kit Price £28·50 (+VAT+50p carr/packing) or built and tested £35·00 (+VAT+50p carr/packing), as illustrated.

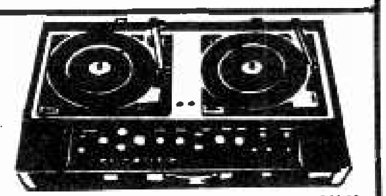
BUILD THE NEW HENELEC STEREO FM TUNER

A completely new high stability stereo FM tuner. Features variable capacity diode tuning, stabiliser power supply, IC Decoder, high gain low noise. IF stages, LED indicators. Tuning meter, AFC, easy to construct and use. Mains operated. Slim modern design with fibre glass PC, teak cabinet etc. Available as a kit to build or ready built. Overall size 8" x 2¾"×6¾". Produced to give high performance with a realistic price. (Parts list and constructional details Ref. No. 5 30p.) Henry's are sole distributors UK and Europe.

Kit price £21·00 (+VAT)
OR BUILT AND TESTED £24·95 (+VAT)

EARN YOURSELF EASY MONEY, WITH PORTABLE DISCO EQUIPMENT

DISCO MINI A complete portable disco, fitted mixer/preamp, 2 decks all facilities	£98·50
As above but with Slider Controls	£118·50
100 watt amplifier for above	£49·50
SDLS100 100 watt mixer/amplifier with slider controls	£80·00
R50 50 watt mixer/amplifier	£40·50
R100 100 watt mixer/amplifier	£57·50
DISCO AMP 100 watt mixer/amplifier	£73·00
NORTHCOURT	
400, 40 watt Mixer Amplifier	£37·50
800, 80 watt Mixer Amplifier	£45·00
DISCO MIXER/PREAMPLIFIERS (OP for up to 6-100 watt amplifiers)	
SDLI (rotary controls)	£40·50
SDLII (slider controls)	£58·50
DISCO VOX (slider controls) the complete disco preamp	£72·00
DJ100 100 watt power amplifier for above	£49·50
DJ30L Mk II 3 channel 3kw sound to light	£38·00
DJ30L Mk III Slider Controls	£45·50
DJ DISCLITE As 30L/II +Variable speed flashes	£54·00

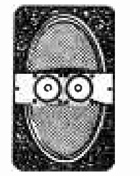


Carlsbro Reverberation Unit	£44·00
Disco anti-feedback microphone	£11·95
Colt 150 watt liquid wheel projector	£23·50
150 watt QI liquid wheel projector	£50·00
150 watt QI cassette wheel projector	£50·00
Spare Effects and Liquid cassettes large range of patterns	£6·00
6in. Liquid wheels £5·50. Various Cassettes	£6·00
Mini spot bank fitted 3 lamps	£12·95
Auto Trilite (mini with flashers)	£17·00
Bubblemaker with 1 gall. Liquid	£22·50

Mixer/Misc/Speakers/Lighting UK's largest range. FREE stock list ref. No. 18 on request. AKG/RESLO/DJ/CARLSBRO/EAGLE Mics, Stands, Mixers, Cabinets, Chassis and complete Speaker Systems, Megaphones, Turntables, Public Address Components.

LOW COST HI-FI SPEAKERS

SPECIAL OFFER
EMI 13" x 8"—full range speakers (post 20p each or 30p pair)
*150TC—8 ohms Twin Cone 10 watt £2·20 each or £4·00 pair.
*450 10 watt C/o Twin Tweeters 3, 8 or 15 ohms £3·85 each.
EW 15 watt 8 ohms C/o Tweeter £5·25 each. or £7.40 per pair.
350 20 watt C/o Tweeters 8 or 15 ohms £7·80 ea.
* Polished wood cabinet £4·00 post 35p.

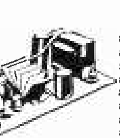


SPEAKER KITS (carr. etc. 35p)

20-2	8"	30 watt	£24·50 pair
20-3	8"	40 watt	£35·95 pair
LINTON 2		20 watt	£18·30 pair
GLENDALE 3		30 watt	£32·95 pair
DOVEDALE 3		50 watt	£51·50 pair
KEF KK2			£55·00 pair
KEF KK3			£78·00 pair

MINIATURE AMPLIFIERS

AMPLIFIERS (carr. etc. 20p).



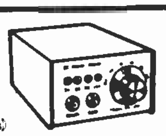
4-300, 0·3 watt 9 volt	£1·75
104, 1 watt 9 volt	£3·10
304, 3 watt 9 volt	£3·95
555, 3 watt 12 volt	£4·10
E1208, 5 watt 12 volt	£5·10
608, 10 watt 24 volt	£4·95
410, 10 watt 28 volt	£4·95
E1206, 30 watt 45 volt	£9·75
E1210, 2½ + 2½ watts 12 volt	£7·75
RE500, 5 watt IC mains operated Amplifier with controls	£8·30
SAC14, 7 + 7 watt Stereo with controls	£11·75
SAC13, 15 + 15 watt Stereo with controls	£14·95
PROJECT 605 KIT	£19·95
PROJECT 805	£28·95
SP40-5 2Z40/Stereo 80/P25	£25·00
SP40-6 2Z40/Stereo 80/P26	£27·75
SP60 2Z60/Stereo 80/P28	£36·45

FIBRE OPTICS

0·01 diam. Mono Filament £1·50 per 25 metre reel.
0·13 diam. 64 Fibres Sheathed. £1·00 per metre.
SPRAYS 15mm. diam. Mares Tails. £9·50

POWER SUPPLIES FOR EVERY PURPOSE

(All cased unless stated chassis)



470C 6/7½/9 volt 300 MA (includes Multi-Adaptor for Tape Recorders, etc.)	£2·15 post 20p
Car Lighter Voltage Adaptors 300mA (State voltage 6v, 7½v, 9v)	£1·95 ea. post 25p
SC202 3/6/7½/9 volt 400mA	£3·65 carr. 30p
HC244R Stabilised version	£4·00 carr. 30p
P500 9 volt 500mA	£3·20 post 20p
P11 24 volt 500mA (chassis)	£2·90 post 20p
P15 26/28 volt 1 amp (chassis)	£2·90 post 20p
P1080 12v 1 amp (chassis)	£4·50 post 20p
P1081 45v 0·9 amp (chassis)	£7·50 post 20p
P12 4½-12 volt 0·4-1 amp	£7·15 post 30p
SE101A 3/6/9/12 volt 1 amp (Stab.)	£12·50 post 25p
RP164 6/7½/9/12 1 amp (Stab.)	£12·95 post 30p

TEST EQUIPMENT MULTIMETERS

(carr. etc. 30p)

ITI-2	20K/V Slimline	£5·95
	20K/Volt Slimline deluxe with case	£6·75
TLH33D	2K/Volt Robust with case	£7·50
U437	10K/Volt Steel case. AC up to 40KHz	£4·95
U4324	20K/Volt with AC current ranges	£8·00
AF105	50K/Volt	£11·95
U4313	20K/Volt AC current. Steel case	£10·50
U4341	Plus Built in transistor tester	£10·50
Model 500	30K/Volt	£9·95

OTHER EQUIPMENT

SE250B	Pocket Signal injector	2·10 carr. 15p
SE500	Pocket Signal Tracer	1·70 carr. 15p
TE15	Grid Dip meter 440kHz-280mHz	15·00 carr. 30p
TE40	AC Millivoltmeter 1·2mHz	18·95 carr. 35p
TE65	28 Range valve voltmeter	19·95 carr. 40p
TE20D	120kHz-500mHz RF Generator	17·95 carr. 40p
TE22D	20Hz-200kHz Audio Generator	18·95 carr. 40p
SE350A	Deluxe Signal Tracer	12·50 carr. 20p
SE400	Volts/ohms/R-C sub./RF field/RF gen.	14·75 carr. 20p

NEW SINCLAIR PROJECT 80

Stereo Pre-Amplifier	£11·95
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2Z60 25 watt Amplifier	£8·95
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PZ6 Mod. (S Tab) 1 on 2 Z40	£7·98
PZ8 Mod. (S Tab) 1 on 2 Z60	£7·00
TRANSFORMER FOR PZ8	£3·95
NEW FM TUNER	£11·95
STEREO DECODER	£7·45

All items post paid.

NEW REVOLUTIONARY SUPER TESTER 680R
The complete testing system

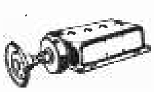
Volts AC=11 ranges from 2V to 2500V
Volts DC=13 ranges from 100mV to 2KV
Amp DC=12 ranges from 500A to 10A
Amp AC=10 ranges from 200µA to 5A
Ohms=6 ranges from one tenth of Ohm to 100MΩ
Reactance=1 range from 0 to 10MΩ
Capacity=6 ranges from 0 to 500pF and from 0 to 0·5µF and from 0 to 50·000pF
Frequency=2 ranges from 0 to 500Hz and from 0 to 5000Hz
Output Voltage=9 ranges 10V to 2500V
Decibels=10 ranges from −24 to +70dB

PRICE **£18.50**

ACCESSORIES

Transistor tester	11·00
Electronic voltmeter	18·00
Ampclamp	11·95
Temperature probe	11·95
Guass meter	11·95
Signal Injector	5·95
Phase Sequence	5·95
EHT Probe	5·95
Shunts 25/50/100A	4·50

SPECIAL PURCHASES



UHF TV TUNERS CHANNELS 21 TO 64
Brand new transistorised geared tuners for 625 line Receiver IF output. £2·50 post 20p.

GARRARD BATTERY TAPE DECK

GARRARD 2 speed 9 volt tape decks. Fitted record/play and oscillator/Erase heads. Wind and rewind controls. Takes up to 4" spools. Brand new complete with head circuits. £9·50 carr. 30p.

TOP QUALITY SLIDER CONTROLS

60mm stroke high quality controls complete with knobs (post, etc., 15p any quantity).
Singles Log and Lin 5K, 10K, 22K, 50K, 100K, 250K, 500K, 1 Meg. 45p each.
Ganged Log and Lin 10K, 22K, 50K, 100K, 250K, 85p each. (Quantity discounts available.) Complete with knobs.

MARRIOT TAPE HEADS

4 TRACK MONO or 2 TRACK STEREO. '17' High impedance £2·50. '18' Medium impedance £2·50. '36' £5·00. R730/E73 2 track mono Record/Erase, low imp. 75p pair. Erase Heads for '17', '18' and '36' £1·00. '63' 2 track mono Hi imp, £1·75. '43' Erase Head for '63' 75p. (Post etc., 15p any quantity.)

EXCLUSIVE DECCA KELLY SPEAKERS

12 watt speaker Tweeter systems. 8in. Bass/Midrobe and Melinex Domed HF radiator plus crossover £12·50 per pair of systems (carr./pkg. 40p) or built into veneered cabinets, size 18×12×6½in. £19·50 pair (carr. £1).

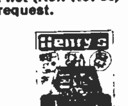
Electronics Supplies

Specialists in electronics for more than 30 years. Trade and industry supplies—every type of component and equipment.

TRANSISTORS/ SEMICONDUCTORS

U.K.'s largest range for every application. Small quantity discounts. Also Trade, Export and industrial enquiries invited. Latest stock list (Ref. No. 36) includes valves on request.

HI-FI TAPE EQUIPMENT



U.K.'s largest range with discount and demonstrations for callers. Latest stock lists on request (Ref. No. 17) Phone 01-402-4736 for Barclay/Access Card Direct orders and latest prices.

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Due to rapid price changes, shortages of paper and raw materials, all prices in the existing catalogues no longer apply. Call or phone for latest prices. A new catalogue will be available for Aug./Sept. 1974.

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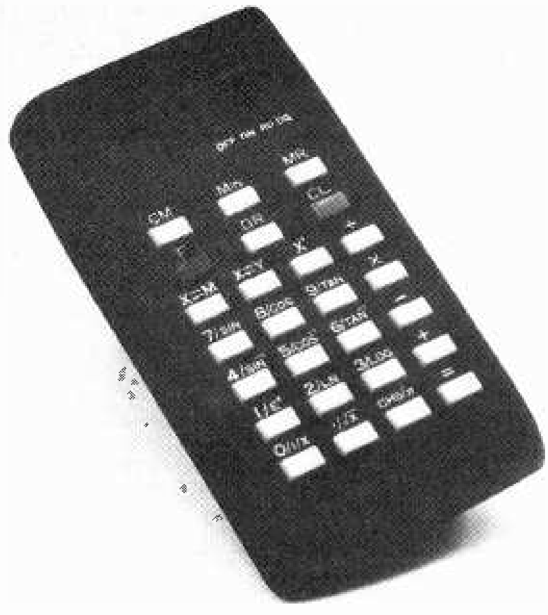
Hi-Fi – Tape Equipment Discount Stock List Free at all stores

Samplebest Ltd 'for the amateur electronics engineer'



FULL SCIENTIFIC CALCULATOR

OUR PRICE £88·50 (Inc: VAT, P&P)

7-day trial offer—Money-back guarantee

This fully portable scientific calculator is on special offer for a limited period. The QI 1015 is a fully proven calculator with the following functions:

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*4 standard (+, −, ×, ÷) *Chain operation
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*The interchange of X and Y register (X ⇄ Y)
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*Sine (Sin) *Cosine (Cos) *Tangent (Tan)
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*Arc tangent (Tan $^{-1}$)
*Exponential Function (E^x)
*Natural logarithm (LN) *Log (Log)
*Reciprocal ($^1/_x$) *Square root ($\sqrt{X}$)
*Power (X^y) . . . . *Pi (π)
*Trig facility of answers in radian or degrees

General
Display: 9-digit light emitting diodes. **Capacity**: 8 digits for all factors and results in operation. **Decimal Point**: Full floating system. **Negative Numbers**: True value indication with minus sign at ninth digit. **Overflow and Error Indicator**: sign at ninth digit, indicating the result of operation is over 8 digits, or the argument of operation is out of range. **Function Mode Indicator**: · (decimal point) at ninth digit indicating the scientific function mode is activated. **Battery—low indicator**: sign at ninth digit. **Operating Temperature**: 0°C–40°C. **Power Supply**: 4 × 1.5 volt batteries (SP7); 6 volt AC adaptor. **Power Consumption**: DC 0.30 watts. **Size**: 145mm × 77mm × 32.5mm. **Weight**: 207 grms. (7.29 ozs) with batteries.

SB

CHEQUES SHOULD BE MADE PAYABLE TO
SAMPLEBEST LTD.
ALLOW 7/10 days for delivery

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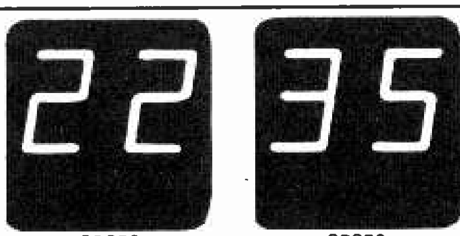
WW—123 FOR FURTHER DETAILS



SR352 SP352

MK50250N—NEW MOSTEK ALARM CLOCK IC .... **£6·00 + VAT = £6·60**
24hr format—Alarm—Snooze—Multiplexed 4- to 6-digit display—etc. This is a high performance clock IC from Mostek Corporation at a break-through price.

BUILD AN ATTRACTIVE DIGITAL ALARM CLOCK WITH RADIO TURN-ON
A kit of all parts except case and switches for a digital alarm clock with radio turn-on using the MK50250N and highly attractive SP352 .55″ displays (see above). The kits include: Building instructions, MK50250N, SP352 displays, all semiconductors, resistors and capacitors, radio turn-on relay, miniature loudspeaker for alarm, soldercon pins for IC socket, main PCB and digit mounting PCB. Both PCBs have been designed so that constructors of the 4-digit clock may easily expand their unit to 6 digits at a later date.
4-digit kit .... **£26·00 + VAT = £28·60**
6-digit kit .... **£31·40 + VAT = £34·54**

Send for free information on low-cost kits using the MK50250N with LEDs, Minitrons, etc. For details of the SP352 and other Beckman Displays available from us, see our WW April or PE June ads or send for free information.

CT5001 4-FUNCTION CALCULATOR IC .... **£5·00 + VAT = £5·50**
We have designed an exciting low-cost calculator for the amateur constructor using this device—send for free information.

SLA7.33″ RED LED DIGITAL DISPLAYS plug-in replacements for DL707
Pack of 4: 4 × £1·70 .... **£6·80 + VAT = £7·48**
Pack of 6: 6 × £1·70 .... **£10·20 + VAT = £11·22**

MM5316N ALARM CLOCK IC .... **£15·00 + VAT = £16·50**
RCA TA8055T LIQUID CRYSTAL DISPLAY (Note: Extended delivery)
.... **£11·60 + VAT = £12·76**
Transmissive 4-digit clock-format, similar to AN4132; supplied with socket.
MM5316N + TA8055T (Extended delivery)
together, ONLY .... **£21·00 + VAT = £23·10**
PCB for P.E. Digital Clock with RCA L–C .... **£1·50 + VAT = £1·65**
N.B. CONSTRUCTORS OF THE P.E. DIGITAL CLOCK. With minor modifications an RCA Liquid Crystal may be substituted for the Siemens Liquid Crystal, and RCA L–Cs bought from us will include clear instructions on how this may be done.

Data supplied with all devices. Also available separately at 10p per device
NO P&P CHARGE for UK orders. Overseas p&p 50p.

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WW—124 FOR FURTHER DETAILS

MAGNA

The FORGESTONE 400

a high quality colour television receiver.

A complete and up-to-the-minute Electronic Kit*
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- Full technical construction manual
- Thick film resistor units
- Glass epoxy printed circuit panels
- Fully isolated power supply
- Each module kit available separately
- LT supply regulator

*less cabinet, which can be manufactured yourself from normal DIY sources.

Send for further details of the Forgestone 400 . . . the quality kit for the constructor of today.

Forgestone Components

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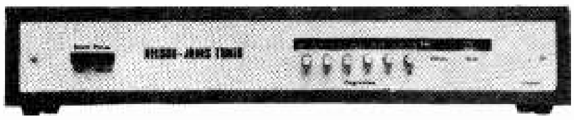
THE NEW NELSON-JONES FM TUNER



PUSH-BUTTON VARICAP DIODE TUNING (6 Position)

('WW' JUNE '73)

Exclusive Designer Approved Kits

What are the important features to look for in an FM tuner kit? Naturally it must have an attractive appearance when built, but it must also embody the latest and best in circuit design such as:—

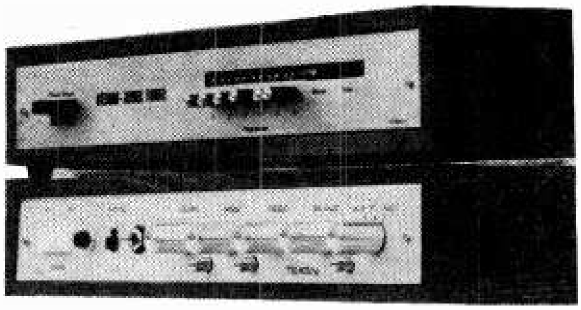
MOSFET Front end for excellent cross modulation performance and low noise.
3 GANG Tuning for high selectivity
VARICAP tuning diodes in back to back configuation fo low distortion.
CERAMIC IF filters for defined IF response.
INTEGRATED circuit IF amplifiers for reliability and excellent limiting/AM rejection.
PHASE LOCKED Stereo decoder with Stereo mute, see below.
LED fine tuning indicators.
PUSH BUTTON tuning (with AFC disable) over the whole FM band.
IC STABILISED and S/C protected power supply.
CABINET veneered inside and out.

The Nelson-Jones Tuner has **all** of these features and many more, and more importantly the design is fully **proven** not just with a few prototypes but with many thousands of working tuners spread across the world.

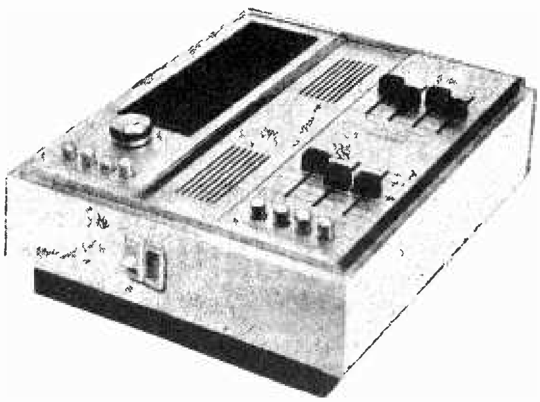
Type Specn: 20 dB quieting 0.75uV. Image rejection —70dB.I.F. Rejection —85 dB

Basic tuner module prices start as low as **£10·79**, with **complete** kits starting at **£23·95** (mono) + PP 50p. and of course all components are available separately.
Our low cost **alignment service** is available to customers without access to a signal generator. Please send large SAE for our latest price lists which detail all of the many options and special low prices for complete kits. All our other products remain available.
PORTUS AND HAYWOOD PHASE LOCKED DECODER (W.W. Sept. '70). Still the lowest distortion P.L. decoder available. THD typically 0.05% (at Nelson-Jones Tuner O/P level)! Supplied complete with Red LED.
Price **£5.50** when bought with a **complete** N-J tuner kit or **£7.68** if bought separately (P.P. 19p.)
PLEASE NOTE. Existing tuners are readily convertible and kits/parts are available for this purpose.

TEXAN AMPLIFIER. We have designed the tuner case and metalwork to match the Texan amplifier (see photograph). Complete designer approved Texan kits are available at **£28·50** plus p.p 50p including Teak Sleeve.



Available Shortly: Varicap tuner using Mullard LP1186 module—no alignment required. Image Rejection —40dB. I.F. Rejection —65dB.



THE RONDO QUADRAPHONIC SYSTEM (20 WATTS/CHANNEL)

Complete designer approved kits for this outstanding Quadraphonic Sound System ('P.E.' Sep. '73, etc.) with the following features:—

- ★ SWITCHING FACILITIES AND MODULES FOR SQ, QS AND CD4.
- ★ COMPLETE LOUDSPEAKER ENCLOSURE DESIGN.
- ★ INDIVIDUAL KITS MAY BE INCORPORATED IN EXISTING EQUIPMENT.
- ★ LOW COST, FULLY ENGINEERED, INTEGRAL DESIGN.
- ★ COMPLETE LOUDSPEAKER SYSTEMS AVAILABLE.
- ★ MODULAR BUILT IN-AM/FM RADIO.
- ★ KITS AVAILABLE AS PUBLISHED—SEE BELOW.

CBS SQ* MATRIX DECODER *TM CBS INC.	Complete Kit	£8·00	Post Free Incl. CBS Licence Fee	VAT Extra
PREAMPLIFIER BOARD	Complete Kit	£3·00	Post Free	VAT Extra
MASTER VOL./TONE/BALANCE BOARD	Complete Kit	£8·50	Post Free	VAT Extra
POWER AMP. BOARD AND HEATSINK STEREO PAIR	Complete Kit per Board	£7·50	Post Free	VAT Extra
POWER SUPPLY BOARD	Complete	£5·00	Post Free	VAT Extra
MAIN SMOOTHING CAPACITORS (TWO REQD)	Per Pair	£1·50	Post Free	VAT Extra
MAINS TRANSFORMER	Complete Kit	£6·25	Post Free	VAT Extra
CHASSIS—PUNCHED and DRILLED WITH SCREENS	Complete Kit	£3·25	Post Free	VAT Extra
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HARDWARE PACK		£2·00	Post Free	VAT Extra
CONTROL SECTION FACIA		£3·50	Post Free	VAT Extra

THE COMPLETE P.E. RONDO SYSTEM IS AVAILABLE AS PUBLISHED. *PLEASE PHONE OR WRITE FOR FULL DETAILS*

Access

You can order these goods by Telephone on Access. Simply quote your Access Number.

OPTO-DEVICES

Panel mounting LED's.

RED	1-9	29p	10-24	23p
GREEN	1-9	59p	10-24	49p

7 Seg LED's
0·325" RH Dec Point.
Common Anode 1-4 £2·00; 5-24 £1·80.
Common Cathode 1-4 £2·00; 5-24 £1·80.
7447 Dec Driver £1·30 (C.A.)

V.A.T. Please add V.A.T. at 10% to all prices for U.K. orders.

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Special Offer!!!—From Stock—New—Boxed—AND 60% Discount!

MULLARD ELECTROLYTIC CAPACITORS

071 and 072 Series

Type No.	Working Voltage Vdc.	Capacitance µF	Max. Ripple Current at 50°C	Weight	Price
071 14472	10	4700	2·5 amps	1oz	15p
071 14682	10	6800	4 amps	1oz	17p
071 15332	16	3300	2·4 amps	1oz	15p
071 15472	16	4700	3·9 amps	1oz	17p
071 15682	16	6800	5·8 amps	1½oz	22p
071 14113	10	11000 + 11000	10·6 amps	3oz	37p
072 14173	10	16500 + 16500	13·4 amps	4oz	49p
072 15752	16	7500 + 7500	10·5 amps	3oz	37p
072 15113	16	11000 + 11000	13·8 amps	4½oz	49p
072 16502	25	5000 + 5000	9·6 amps	3½oz	37p
072 16752	25	7500 + 7500	12·6 amps	4½oz	49p
071 18681	63	680	2·1 amps	1oz	15p

106 and 107 Series

106 14153	10	15000	7 amps	4oz	57p
106 17103	40	10000	12 amps	7½oz	94p
107 10222	100	2200	10 amps	5½oz	74p

Type No.	Voltage	Capacitance	Weight	Price
102 15163	16	16000	8oz	20p
104 90003	20	39000	16oz	30p
102 16802	25	8000	7oz	25p
104 90001	45	20000	16oz	50p

A discount of 10% may be deducted from above prices on lots of 100 of any one type.

Please calculate the weight of your order and include appropriate postage.

Not over	Ordinary Parcels
1½lb	20p
2lb	22p
4lb	27p
6lb	32p
8lb	37p
10lb	42p
14lb	52p
18lb	62p
22lb	72p

SMALL ELECTROLYTICS

Ref. No.	Capacity	Voltage	Price
H8/2	2·2µf	25v	4p
H8/2A	3·3µf	25v	4p
H8/3	3µf	50v	4p
H8/3A	4µf	50v	4p
H8/4	4·7µf	25v	4p
H8/4A	5µf	64v	4p
H8/5	5µf	10v	4p
H8/5A	5µf	150v	4p
H8/6A	10µf	10v	4p
H8/7	10µf	70v	4p
H8/8	16µf	35v	4p
H8/8A	16µf	16v	4p
H8/9	20µf	6v	2p
H8/9A	20µf	70v	4p
H8/10	22µf	50v	4p
H8/10A	22µf	100v	4p
H8/11	25µf	12v	4p
H8/12	32µf	15v	4p
H8/12A	30µf	10v	4p
H8/13A	32µf	50v	4p
H8/14	40µf	25v	5p
H8/14A	40µf	16v	4p
H8/15	47µf	50v	4p
H8/15A	40µf	35v	4p
H7/1	50µf	6v	3p
H7/1A	50µf	10v	4p
H7/2A	64µf	2·5v	2p

Ref. No.	Capacity	Voltage	Price
H7/3A	64µf	25v	4p
H7/4	64µf	15v	4p
H7/4A	64µf	35v	5p
H7/5	80µf	16v	4p
H7/7	100µf	25v	4p
H7/8	125µf	16v	5p
H7/8A	100µf	35v	6p
H7/9	100µf	63v	6p
H7/9A	125µf	4v	4p
H7/10	125µf	25v	6p
H7/10A	160µf	2·5v	3p
H7/11	160µf	25v	6p
H7/11A	150µf	16v	5p
H7/13A	200µf	25v	8p
H7/14	220µf	50v	10p
H7/15	220µf	25v	5p
H7/15A	220µf	35v	10p
H6/1A	250µf	4v	3p
H6/3A	320µf	2·5v	3p
H6/4	320µf	10v	4p
H6/4A	330µf	16v	5p
H6/5	330µf	25v	10p
H6/5A	330µf	35v	15p
H6/8	470µf	25v	10p
H6/8A	470µf	35v	20p
H6/9A	400µf	40v	20p
H6/13A	1000µf	25v	16p

RECTIFIERS 1N4007 1200 peak volts, 30 amps peak current, 1 amp mean current. 100 for £7·50, 1,000 £50.

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TO3-NPN DIFFUSED SILICON PLANAR EPITAXIAL.
VCBO COLLECTOR TO BASE—80 VOLTS.
VCEO COLLECTOR TO EMITTER—60 VOLTS.
VEBO EMITTER TO BASE—5 VOLTS.
20 WATTS—2 AMPS—30 MHz. FEATURES HIGH CURRENT GAIN OVER WIDE RANGE OF COLLECTOR CURRENT

25p! ONLY

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An aerosol spray providing a convenient means of producing any number of copies of a printed circuit both simply and quickly.

Method: Spray copper laminate board with light sensitive spray. Cover with transparent film upon which circuit has been drawn. Expose to light. (No need to use ultra-violet.) Spray with developer, rinse and etch in normal manner.

Light sensitive aerosol spray .. .. £1·00 plus
Developer and Etchant .. .. 50p postage
Copper-clad Fibre-glass Board—50p sq. ft. (max. 3′ × 4′)

NEWER THAN NEW!!!

Fibre Glass Board pre-treated with light-sensitive lacquer enabling you to produce prototype printed circuits within five minutes.

75mm × 100mm 33p
150mm × 100mm 66p
150mm × 200mm .. .. .. £1·32
250mm × 200mm .. .. .. £2·20

SILICON P.N.P.

Type	*Voltage*	*Frequency*	*Price*
BCY 71	45	200 MHz	12p
BFS 92	100	70 MHz	20p
BFS 95	40	70 MHz	17p
BFX 12	25	210 MHz	10p
2N 2906	60	200 MHz	15p
2N 3702	40	100 MHz	11p
2N 3703	50	100 MHz	12p

SILICON N.P.N.

BC 108	30	150 MHz	10p
BC 109	30	150 MHz	10p
BF 179	225	125 MHz	40p
BF 180	30	625 MHz	25p
BFW 58	80	80 MHz	15p
BFX 43	30	500 MHz	20p
BFX 86	40	50 MHz	17p
BFY 53	30	50 MHz	10p
2N 697	60	40 MHz	12p
2N 709	15	900 MHz	30p
2N 718	60	60 MHz	12p
2N 753	25	250 MHz	12p
2N 744	20	300 MHz	12p
2N 1613	75	60 MHz	17p
2N 2220	60	250 MHz	15p

SILICON N.P.N.

Type	*Voltage*	*Frequency*	*Price*
2N 3053	60	100 MHz	17p
2N 3707	30		12p
2N 5179	20	900 MHz	40p

GERMANIUM P.N.P.

ACY 44	50	1 MHz	10p
ADY 26	80	75 watts	£1
AF 124	20	75 MHz	20p
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ASY 32	25	5 MHz	10p
ASZ 21	15	450 MHz	20p
GET 113	32		10p
GET 120	32	2 watts	10p
OC 123	50	1 MHz	10p
OCP 70	Light-sensitive		20p
2N 1307	30	10 MHz	15p
2N 1309	30	15 MHz	15p
2N 443	60	150 watts	£1

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BFR 64	40	1,200 MHz	£1
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BLY 218	36	1,200 MHz	£2
2N 709	15	800 MHz	15p
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CL 8300	Gunn effect oscillator	9·4 GHz	£40
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CL 8390	ditto	11·5 GHz	£10
CL 8430	ditto	9·35 GHz	£40
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CL 8470	ditto	9·35 GHz	£40
BXY 27	Varacter Diode. "S" Band. Cut-off	70 GHz	£1
BXY 28	Varacter Diode. Cut-off	100 GHz	£1
BXY 32	Frequency Multiplier. "X" Band	150 GHz	£1
BXY 35A/C	ditto	25 GHz	£1
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BXY 37C/D	ditto	100 GHz	£1
BXY 38C/E	ditto	120 GHz	£1
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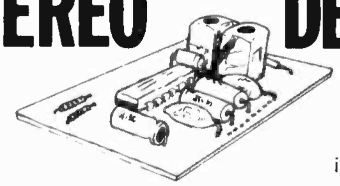

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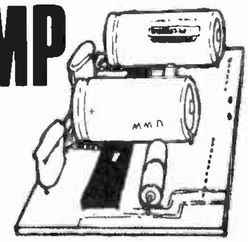
A ready built unit ready for connection to the I.F. stages of existing F.M. Radio or Tuner. A tell-tale light can be connected. The unit is a small printed circuit, no further adjustment necessary. A L.E.D. is recommended as the indicating light, suitable device available from us at 36½p. Instructions included.

3 W R.M.S. I.C. AMP



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On P.C. Board with all components or 2 on one board for £2.86. Order Code I.C.A. 1/S.
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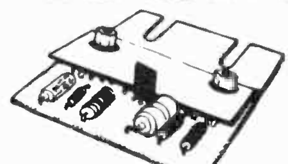

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These matchbox size amplifiers have an exceptionally good tone and quality for the price. They are only 2¼" x 1¾". The 5W amp will run from a 12V car battery making it very suitable for portable voice reinforcement such as public functions. Two amplifiers are ideal for stereo. Complete connection details and treble, bass, volume and balance control circuit diagrams are supplied with each unit. Discounts are available for quantity orders. More details on request. **Cheapest in the U.K. Built and tested.**

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Pri 120/240V Sec 120/240V Centre Tapped & Screened

Ref. No.	VA (Watts)	Weight lb oz	Size cm.	£	P & P p
07	20	1 8	7·0× 7·0× 6·0	2·55	30
149	60	3 12	9·9× 7·7× 8·6	3·79	36
150	100	5 8	9·9× 8·9× 8·6	4·17	52
151	200	8 0	12·1× 9·3×10·2	7·09	52
152	250	13 12	12·1×11·8×10·2	9·25	67
153	350	15 0	14·0×10·8×11·8	12·32	82
154	500	19 8	14·0×13·4×11·8	17·87	*
155	750	29 0	17·2×14·0×14·0	24·31	*
156	1000	38 0	17·2×16·6×14·0	29·87	*
158	2000	60 0	21·6×15·3×18·1	49·25	*
159	3000	85 0	23·5×17·8×19·7	76·53	*
160	6000	78 0	35·0×20·4×29·3	125·89	*

AUTO TRANSFORMERS

Ref. No.	VA (Watts)	Weight lb oz	Size cm.	Auto Taps	£	P & P p
113	20	1 0	5·8× 5·1× 4·5	0-115-210-240	1·34	22
4	75	2 4	7·0× 6·7 ×6·1	0-115-210-240	2·64	36
4	150	3 4	8·9× 7·7× 7·7	0-115-200-220-240	3·18	36
66	300	6 4	9·9× 9·6× 8·6	,, ,,	6·19	52
67	500	12 8	12·1×11·2×10·2	,, ,,	9·20	67
84	1000	19 8	14·0×13·4×14·3	,, ,,	16·71	82
93	1500	30 4	14·0×15·9×14·3	,, ,,	24·19	*
95	2000	32 0	17·2×16·6×14·0	,, ,,	31·57	*
73	3000	40 0	21·6×13·4×18·1	,, ,,	39·17	*

CASED AUTO TRANSFORMERS
115V 500VA cased transformer, with mains lead and two 115V outlet sockets, £9·49. P & P 67p. A 20 Watt version. £2·02. P & P 22p.

LOW VOLTAGE TRANSFORMERS

PRIMARY 200-250 VOLTS 12 AND/OR 24 VOLT RANGE

Ref. No.	Amps. 12V	Amps. 24V	Weight lb oz	Size cm.	Secondary Windings	£	P & P p
111	0·5	0·25	8	4·8× 2·9× 3·5	0-12V at 0·25A×2	1·34	22
213	1·0	0·5	1 4	6·1× 5·8× 4·8	0-12V at 0·5A×2	1·58	22
71	2	1	1 12	7·0× 6·4× 6·1	0-12V at 1A×2	2·09	22
18	4	2	2 12	8·3× 7·7× 7·0	0-12V at 2A×2	2·95	36
70	6	3	3 8	8·9× 8·0× 7·7	0-12V at 3A×2	3·52	42
108	8	4	5 8	9·9× 8·9× 8·6	0-12V at 4A×2	3·96	52
72	10	5	6 4	9·9× 9·6× 8·6	0-12V at 5A×2	4·67	52
116	12	6	6 12	9·9×10·2×8·6	0-12V at 5A×2	5·61	52
17	16	8	8 12	12·1× 9·9×10·2	0-12V at 8A×2	7·22	52
115	20	10	18 8	14·0× 9·6×11·8	0-12V at 10A×2	9·20	67
187	30	15	15 8	14·0×12·1×11·8	0-12V at 15A×2	16·94	82
226	60	30	32 0	17·2×15·3×14·0	0-12V at 30A×2	31·28	*

30 VOLT RANGE

Ref No.	Amps.	Weight lb oz	Size cm.	Secondary Taps	£	P & P p
112	0·5	1 4	6·1× 5·8× 4·3	0-12-15-20-24-30V	1·56	22
79	1·0	2 4	7·0× 6·7× 6·1	,, ,,	2·11	36
3	2·0	3 4	8·9× 7·7× 7·7	,, ,,	3·18	36
20	3·0	4 8	9·9× 8·3× 8·5	,, ,,	3·96	42
21	4·0	6 4	9·9× 9·6× 8·5	,, ,,	4·67	52
51	5·0	6 12	12·1× 8·6×10·2	,, ,,	5·83	52
117	6·0	8 0	12·1× 9·3×10·2	,, ,,	6·94	52
88	8·0	12 0	12·1×11·8×10·2	,, ,,	9·00	67
89	10·0	13 12	14·0×10·2×11·8	,, ,,	11·36	67

50 VOLT RANGE

Ref. No.	Amps.	Weight lb oz	Size cm.	Secondary Taps	£	P & P p
102	0·5	1 12	7·0× 6·4× 6 1	0-19-25-33-40-50V	2·09	30
103	1·0	2 12	8·3× 7·4× 7 0	,, ,,	3·08	36
104	2·0	5 8	9·9× 8·9× 8·6	,, ,,	4·26	42
105	3·0	6 12	9·9×10·2× 8·6	,, ,,	5·79	52
106	4·0	10 0	12·1×10·5×10·2	,, ,,	7·69	52
107	6·0	12 0	14·0×10·2×11·8	,, ,,	11·38	67
118	8·0	18 0	14·0×12·7×11·8	,, ,,	12·40	97
119	10·0	25 0	17·2×12·7×14·0	,, ,,	18·62	*

60 VOLT RANGE

Ref. No.	Amps.	Weight lb oz	Size cm.	Secondary Taps	£	P & P p
124	0·5	2 4	7·0× 6·7× 6·1	0-24-30-40-48-60V	2·12	36
126	1·0	3 4	8·9× 7·7× 7·7	,, ,,	2·97	36
127	2·0	6 4	9·9× 9·6× 8·6	,, ,,	4·67	42
125	3·0	8 12	12·1× 9·9×10·2	,, ,,	7·11	52
123	4·0	13 12	12·1×11·8×10·2	,, ,,	9·20	67
40	5·0	12 00	14·0×10·2×11·8	,, ,,	10·83	67
120	6·0	15 8	14·0×12·1×11·8	,, ,,	13·35	82
121	8·0	25 00	14·0×14·7×11·8	,, ,,	15·01	*
122	10·0	25 0	17·2×12·7×14·0	,, ,,	22·10	*
189	12·0	29 00	17·2×14·0×14·0	,, ,,	24·74	*

MINIATURE TRANSFORMERS WITH SCREENS

Ref. No.	MA	Weight lb oz	Size cm.	VOLTS	£	P & P p
238	200	2	2·8×2·6×2·0	3-0-3	1·44	10
212	1A 1A	1 4	6·1×5·8×4·8	0-6 0-6	1·67	22
13	100	4	3·9×2·6×2·9	9-0-9	1·23	10
235	330, 330	4	4·8×2·9×3·5	0-9, 0-9	1·67	10
207	500, 500	1 00	6·1×5·4×4·8	0-8-9, 0-8-9	2·23	22
208	1A, 1A	1 12	7·0×6·4×6·1	0-8-9, 0-8-9	3·00	30
236	200, 200	4	4·8×2·9×3·5	0-15, 0-15	1·67	10
214	300, 300	1 4	6·1×5·8×4·8	0-20, 0-20	1·76	22
221	700 (D.C.)	1 8	7·0×6·1×6·1	20-12-0-12-20	1·55	30
206	1A, 1A	2 12	8·3×7·7×7·0	0-15-20, 0-15-20	4·05	38
203	500, 500	2 4	8·3×7·0×7·0	0-15-27, 0-15-27	3·10	38
204	1A, 1A	3 4	8·9×7·7×7·7	0-15-27, 0-15-27	3·15	38

BATTERY CHARGER TYPES
PRIMARY 200-250 VOLT (Secondary 2V, 6V, 12V)

Ref. No.	Amps.	Weight lb oz	Size cm.		£	P & P p
45	1·5	1 8	7·0× 6·1× 6·1	Please note, these units do not include rectifiers	1·61	30
5	4·0	3 4	8·9× 7·7× 7·7		2·93	42
86	6·0	6 4	9·9× 9·6× 8·6		4·40	52
146	8·0	6 12	9·9×10·2× 8·6		5·02	52
50	12·5	12 0	14·0×10·2×11·8		7·53	67

*Carriage via B.R.S.

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I.C.s

Here too a wide range of TTL types are shown, together with linear and special purpose types. Over 60 circuit and connection diagrams as well as much other useful information is included.

MINITRON DIGITAL INDICATORS

3015F Seven segment filament, compatible with standard logic modules. 0–9 and decimal point: 9mm characters in 16 lead DIL. **£1·20**
Suitable BCD decoder driver 7447 **£1·15**
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CAPACITORS

POLYESTER C.280

Radial leads for P.C.B. mounting. Working voltage 250V d.c.
0·01, 0·015, 0·022, 0·033, 0·047 ea. **3p**
0·068, 0·1, 0·15 ea. **4p**
0·22, **5p**; 0·33, **7p**; 0·47, **8p**; 0·68, **11p**; 1·0, **14p**; 1·5, **21p**; 2·2, **24p**

TANTALUM BEAD

0·1, 0·22, 0·47, 1·0 mF/35V ea. **13p**
2·2/16V, 2·2/35V, 4·7/16V, 10/6·3V ea. **13p**
4·7/35V, 10/16V, 22/6·3V ea. **16p**
10/25V, 22/16V, 47/6·3V, 100/3V ea. **18p**

POLYCARBONATE

Type B32540 Working Voltage—250V d.c.
Values in mF: 0·0047; 0·0068; 0·0082; 0·1; 0·012; 0·015 ea. **3p**
0·018; 0·022; 0·027; 0·033; 0·039; 0·047; 0·056; 0·068; 0·082; 0·1 ea. **4p**

Working voltage 100V d.c.
0.1; 0.12; 0.15 4p; 0.18 5p; 0.22 **6p**
0.27 7p; 0.33 8p; 0.39; 0.47 **9p**
0.56 12p; 0.68 **13p**

SILVERED MICA

Working voltage 500V d.c.
Values in pFs—2·2 to 820 in 32 stages ea. **6p**
1000, 1500 **7p**; 1800 **8p**; 2200 **10p**; 2700, 3600 **12p**; 4700, 5000 **15p**; 6800 **20p**; 8200, 10.000 **25p**

CERAMIC DISC

1000pF/500, 2000/500, 5000/500, 0·01mF/50, 0·02mF/50, 0·1mF/3—each **2p**; 0·05mF/50V—**3p**

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Decades of 10, 22 and 47 only available in ranges above.
Skeleton Carbon Presets Type PR, horizontal or vertical **6p** each.

SLIDER

Linear or log. 4·7K to 1 meg. in all popular values ea. **30p**
Escutcheon plates, black, white or light grey ea. **10p**
Control knobs, blk/wht/red/yel/grn/blue/dk. grey/lt grey ea. **7p**

JACKS AND PLUGS

SOCKETS

2 circuit unswitched S1/SS **12p**
2 circuit 2 break contacts S1/BB **15p**
3 circuit unswitched (Not GPO) S3/SSS **17p**
3 circuit with 3 break contacts S3/BBB **20p**
2 circuit with chrome nut and black/white/red/green or grey unswitched S5/SS **16p**
with 2 break contacts S5/BB **20p**
Miniature 3.5mm 2 circuit, (black) 2 break contacts S6/BB **9p**

PLUGS

2 circuit screened top entry P1 **24p**
side entry SEP1 **36p**
Line socket mono 231 **40p**
Line socket stereo 244 **45p**
3 circuit unscreened, black/grey/white P4 **46p**
2 circuit, unscreened, black/white/red/black/green/grey P2 **18p**
3 circuit screen top entry P3 **53p**
side entry SEP3 **55p**
Miniature 3·5mm 2 circuit screened P5 **13p**
Miniature 3·5mm 2 circuit unscreened various colours P6 **10p**

INSULATED SCREW TERMINALS

In moulded polypropylene, with nickel plate on brass. With insulating set, washers, tag and nuts, 15A/250V In black/brown/red/yellow/green/blue/grey/white. Type TP.1 ea. **14p**

DIN CONNECTORS

2 way loudspeaker	**Socket 10p**	**Plug 12p**
3 way audio	**Socket 10p**	**Plug 12p**
5 way audio 180°	**Socket 12p**	**Plug 15p**
5 way audio 240°	**Socket 12p**	**Plug 15p**
6 way audio	**Socket 13p**	**Plug 15p**

RESISTORS

Code	*Watts*	*Ohms*	*1 to 9*	*10 to 99*	*100 up* (see note below)
C	1/3	4·7–470K	**1·3**	**1·1**	**0·9** nett
C	1/2	4·7–10M	**1·3**	**1·1**	**0·9** nett
C	3/4	4·7–10M	**1·5**	**1·2**	**0·9** nett
C	1	4·7–10M	**3·2**	**2·5**	**1·9** nett
MO	1/2	10–1M	**4**	**3·3**	**2·3** nett
WW	1	0·22–3·9Ω	**9**	**9**	**8**
WW	3	1–10K	**7**	**7**	**6**
WW	7	1–10K	**9**	**9**	**8**

Codes:
C = carbon film, high stability, low noise.
MO = metal oxide, Electrosil TR5, ultra low noise.
WW = wire wound, Plessey.
Values: All E12 except C $\frac{1}{3}$W, C $\frac{3}{4}$W, and MO $\frac{1}{2}$W.
E12: 10, 12, 15, 18, 22, 27, 33, 39, 47, 56, 68, 82 and their decades.
E24: as E12 plus 11, 13, 16, 20, 24, 30, 36, 43, 51, 62, 75, 91 and their decades.
Tolerances:
5% except WW 10% ±0·05Ω below 10Ω and MO $\frac{1}{2}$W 2%.
Prices are in pence each for quantities of the same ohmic value and power rating. NOT mixed values. (Ignore fractions of one penny on total value of resistor order.) Prices for 100 up in units of 100 only.

ZENER DIODES

Full range **E24** values: 400mW: 2·7V to 36V, **14p** each: 1W: 6·8V to 82V, **21p** each: 1·5W: 4·7V to 75V, **48p** each. Clip to increase 1·5W rating to 3 watts (type 266F). **5p.**
20W 7·5V to 75V **69p** each

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Copper clad 0·1 matrix—2·5 × 3·75 ins. **27p**; 3·75 × 3·75 ins.—**30p**; 2·5 × 5 ins.—**30p**; 3·75 × 5 ins.—**33p**. Copper clad 0·15 in. matrix 2·5 × 3·75 ins.—**20p**; 3·75 × 3·75 ins.—**30p**; 2·5 × 5 ins.—**30p**; 3·75 × 5 ins.—**36p**.
Vero spot face cutter (any matrix) **43p**.
0·040 pins (for 0·1 matrix) per 100—**35p**.
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CATALOGUE 7

SECOND PRINTING

112 pages, thousands of items, illustrations, diagrams, much useful technical information. The 2nd printing of this catalogue has been updated as much as possible on prices. It still costs only 25p post free and still includes a refund voucher for 25p for spending when ordering goods list value £5 or more.

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Many types including:
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Type 6WI Extruded aluminium 1° C/W, undrilled **60p**
drilled 2 × T03 **78p**

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Unsurpassed for "breadboard work" can be used indefinitely without deterioration. Components just push into plug holes and connect automatically. Slot for control panel. 70 holes **£1·98**

T-DEC

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6 ft strip **66p**
25 mtr. reel **£7·15**

ELECTROLYTIC CAPACITORS

Axial Lead

qF	3V	6·3V	10V	16V	25V	40V	63V	100V
0·47	—	—	—	—	—	—	**11p**	**8p**
1·0	—	—	—	—	—	**11p**	—	**8p**
2·2	—	—	—	—	**11p**	—	**8p**	**9p**
4·7	—	—	—	**11p**	—	**8p**	**9p**	**8p**
10	—	—	—	—	**8p**	**9p**	**8p**	**8p**
22	—	—	**8p**	—	**9p**	**8p**	**8p**	**10p**
47	**8p**	—	**9p**	**8p**	**8p**	**8p**	**10p**	**13p**
100	**9p**	**8p**	**8p**	**8p**	**9p**	**10p**	**12p**	**19p**
220	**8p**	**8p**	**9p**	**10p**	**10p**	**11p**	**17p**	**28p**
470	**9p**	**10p**	**10p**	**11p**	**13p**	**17p**	**24p**	**45p**
1.000	**11p**	**13p**	**13p**	**17p**	**20p**	**25p**	**41p**	—
2.200	**15p**	**18p**	**23p**	**26p**	**37p**	**41p**	—	—
4.700	**26p**	**30p**	**39p**	**44p**	**58p**	—	—	—
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BD107 (SNPN)	11·5w	64	100	63p
2N711B/2G106 (SPNP)	150mw	18	120/150 Tot. Sw. Time 275 NS	43p
2N985 (GPNP)	300mw	15	Tot. Sw. Time 115 NS	95p
2N1304 (GPNP)	150mw	30	6	15p
2N1309 (GPNP)	150mw	30	15	30p
2N1046 (GPNP)	50w	100	20	£2·50
2N1146A (GPNP)	90w	70	15	45p
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2N1547 (G)	106w	100	0·35	75p
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Type	Price	Type	Price	Type	Price
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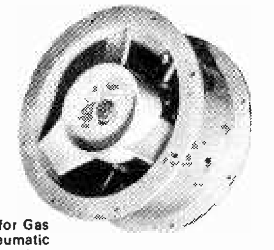

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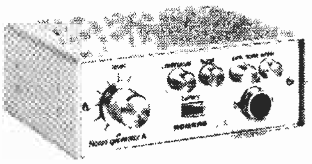

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BC109C	16p	BFX87	30p	OA70	12p	TIP31B	75p	2N1305	25p	2N4059	12p
BC147	12p	BFX88	30p	OA81	10p	TIP32B	85p	2N1306	25p	2N4060	12p
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BC159	14p	BFY53	25p	OA210	35p	TIP29C	75p	2N1711	25p	2N4288	15p
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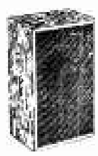

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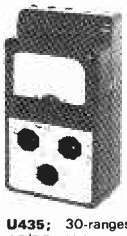

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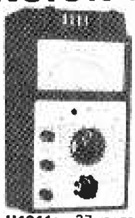

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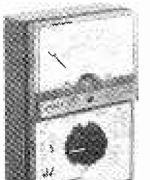

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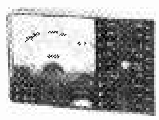

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BC116	0·20
BC117	0·20
BC125	0·22
BC126	0·20
BC132	0·15
BC134	0·20
BC135	0·15
BC136	0·20
BC137	0·20
BC138	0·20
BC142	0·30
BC143	0·35
BC147B	0·13

Type	Price (£)
BC148	0·12
BC149	0·14
BC152	0·25
BC153	0·20
BC154	0·18
BC157	0·15
BC158	0·13
BC159	0·15
BC167B	0·15
BC168B	0·13
BC169C	0·13
BC170	0·15
BC171	0·15
BC172	0·14
BC173	0·20
BC176	0·16
BC177	0·20
BC178	0·20
BC179	0·20
BC182L	0·11
BC183	0·11
BC183L	0·11
BC184L	0·13
BC186	0·25
BC187	0·25
BC212L	0·12
BC213L	0·12
BC214L	0·15
BC261	0·28
BC263	0·25
BC300	0·58
BC303	0·60
BC308	0·62
BC309	0·15
BC360	0·95
BC433	0·36
BD115	0·65
BD123	0·98
BD124	0·80
BD131	0·45
BD132	0·50
BD135	0·40
BD136	0·46
BD137	0·48
BD138	0·50
BD139	0·55
BD140	0·62
BD234	0·75
BDX32	2·55
BDY18	1·78
BDY20	0·99
BF115	0·20
BF121	0·25
BF123	0·28

Type	Price (£)
BF125	0·25
BF127	0·30
BF158	0·25
BF159	0·27
BF160	0·22
BF161	0·45
BF163	0·45
BF167	0·25
BF173	0·25
BF177	0·30
BF178	0·33
BF179	0·33
BF180	0·35
BF181	0·33
BF183	0·44
BF184	0·26
BF185	0·26
BF194	0·15
BF195	0·15
BF196	0·15
BF197	0·17
BF198	0·20
BF199	0·25
BF200	0·35
BF222	1·08
BF240	0·20
BF241	0·20
BF244	0·18
BF256	0·45
BF257	0·49
BF258	0·66
BF259	0·93
BF263	0·70
BF337	0·35
BF596	0·70
BFT43	0·55
BFW10	0·55
BFX29	0·30
BFX30	0·35
BFX84	0·25
BFX85	0·26
BFX88	0·24
BFY50	0·25
BFY51	0·23
BFY52	0·23
BFY90	0·70
BPX25	1·65
BPX29	1·60
BPX52	1·75
BRY39	0·40
BSY54	0·50
BSY56	0·80
BT106	0·99
BU105/02	1·95
BU108	3·25
BU126	1·93
BU204	1·98

Type	Price (£)
BU205	1·98
BU207	3·00
BU208	3·15
BU209	2·55
CRS1/40	0·45
ME6001	0·16
ME6002	0·17
ME8001	0·18
MJE340	0·68
MJE341	0·72
MJE370	0·65
MJE520	0·85
MJE521	0·95
MJE2955	1·20
MJE3055	0·74
MPF102	0·40
OC28	0·65
OC36	0·55
OC44	0·15
OC45	0·15
OC70	0·15
OC71	0·15
OC72	0·15
OC75	0·25
OC81	0·25
OC81D	0·30
OC139	0·28
OC170	0·25
OC171	0·30
ON236A	0·65
R2008B	2·05
R2010B	2·10
TIP31A	0·65
TIP32A	0·67
TIS43	0·30
2N706	0·12
2N706A	0·15
2N916	0·20
2N918	0·42
2N1304	0·21
2N1305	0·21
2N2646	0·53
2N2904	0·22
2N2904A	0·26
2N2905	0·72
2N2926G	0·13
2N2926Y	0·12
2N3019	0·75
2N3053	0·21
2N3054	0·55
2N3055	0·60
2N3391A	0·23
2N3706	0·10
2N3771	1·70
2N3772	1·90
2N3773	2·90
2N3790	4·15

Type	Price (£)
2N3794	0·20
2N3819	0·35
2N3823	1·45
2N3904	0·16
2N3905	0·18
2N3906	0·15
2N4036	0·52
2N4046	0·35
2N4289	0·20
2N4291	0·18
2N4292	0·20
2N5296	0·37
2N5298	0·38
2N5457	0·30
2N5458	0·35
2N6027	0·65

DIODES

Type	Price (£)
AA119	0·09
AA129	0·20
AAZ13	0·30
BA102	0·25
BA110U	0·30
BA115	0·12
BA145	0·17
BA148	0·17
BA154	0·13
BA155	0·16
BA156	0·15
BA157	0·25
BAX13	0·06
BAX16	0·07
BB105B	0·45

Type	Price (£)
BB105G	0·35
BR100	0·50
BY100	0·15
BY126	0·16
BY127	0·17
BY133	0·23
OA47	0·07
OA81	0·10
OA90	0·08
OA91	0·07
OA95	0·07
OA200	0·10
IN914	0·07
IN4148	0·05
IN4448	0·10
IS44	0·07

RECTIFIERS

Type	Price (£)
IN4001	0·05
IN4002	0·06
IN4003	0·07
IN4004	0·08
IN4005	0·09
IN4006	0·11
IN4007	0·14
IN5400	0·15
IN5401	0·17
IN5402	0·20
IN5403	0·22
IN5404	0·25
IN5405	0·27
IN5406	0·30

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12p each	18p each
3·0V—33V	3·3V—100V

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MINIATURE BRIDGE RECTIFIERS

PIV	2A	4A	6A
50V	0·35	0·38	0·43
100V	0·38	0·43	0·49
200V	0·41	0·48	0·60
400V	0·45	0·60	0·71

INTEGRATED CIRCUITS

Type	Price (£)
CA3065	1·90
MC1310P	2·94
MC1351P	0·75
MC1358PQ	1·80
MC3051P	0·58
TAA300	1·46
TAA320	0·94
TAA350	1·54
TAA450	1·85
TAA570	1·39
TAA630Q	3·29
TAA700	3·30
TAA840	1·64
TAD100	1·42
TBA240A	0·88
TBA480Q	1·24
TBA520Q	2·72
TBA530	1·98
TBA530Q	1·98

Type	Price (£)
TBA540	2·20
TBA540Q	2·21
TBA550Q	3·29
TBA560C	2·71
TBA570	1·17
TBA673	1·80
TBA700	1·90
TBA720Q	2·20
TBA750Q	1·54
TBA800	1·75
TBA920Q	3·29
TBA990	3·29
TBA990Q	3·29
TCA270Q	3·30
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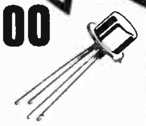

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90 Watt	26½p	24½p	22p
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3A	24-30-36v	10	£9·00	60p
3B	24-30-36v	5	£7·50	50p
3C	24-30-36v	2	£3·50	40p
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4B	12-20-24v	10	£7·50	60p
4C	12-20-24v	5	£4·95	40p
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5B	3-12-18v	10	£6·95	60p
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Fully shrouded, terminal block connections. Pri. 220-240v. Screen tap. Sec. 30-25-0-25-30v., 2 amps. £4·75, carr. 40p. Heavy duty type 36-25-0-25-36v. 5 amps. £9·75, carr. 50p.

STEP DOWN 240/110v AUTO TRANSFORMERS
3000 watts. Built into steel case with two American 2 pin grounded socket outlets. Carry handle. 6 ft. mains lead. **£29·50,** carr. £2. Without case and fittings **£22·00,** carr. £1·50.
Other Types Available. 80-1500 watts, fully shrouded, with American socket outlet and 6 ft. mains lead. Let us know your requirements.

PARMEKO HT TRANSFORMERS
110v Pri. only. 50 Hz. Sec. 475-0-475v 150 m/a 350-0-350v 274 m/a. 6·3v CT 3·2a 6·3v CT 1·6a 6·3v 0·3a twice. Potted type. **£4·50** carr. £1. 6·3v 11a 1·4 kv. pk. wkg. 6·3v 0·3a 7 kv. pk wkg **£2·50** carr 50p. 530-0-530v 330 m/a 6·5 6a **£4·50** carr. £1.

GARDNER HT TRANSFORMERS
Pri. 110-220-240v. Sec. tapped 470-490v 350 m/a. Open frame. Table top connections **£4·50** carr. 75p
Pri. 230v. Sec. 450-0-450v 200 m/a **£3·50** carr. 75p.
AC Industries. Pri. 110-220-240v. Sec. 250v 80 m/a and 15v 1·2a and 6·3v 4·5a **£2·00** p.p. 40p. Atlas Transformer Co. Pri. 110-210-230-240v. Sec. 230v 200 m/a and 6·3v 7a **£3·00** p.p. 40p.

H.T. TRANSFORMERS by Famous Manufacturers. All Primaries 220-240v. Type 1 350-0-350v. 200 M/A, 6·4 6A, 5v. 3A potted, **£4·00,** carr. 50p. Type 2, 630-0-630v. 105 M/A, 5v. 4A, 5v. 2A, potted **£3·50,** carr. 50p. Type 3, 1875v. 60 M/A, 4·2kv wkg. and 500v. 31 M/A, potted, **£4·50** carr. 50p. Type 4, 890-710-0-710-890v. 120 M/A open frame terminal block connections, **£2·75,** post 40p. Type 5, 150-165v. 4 amps. open frame terminal block connections, **£4·00,** carr. 75p. Type 6, 450-0-450v. 150 M/A, 6·3v. 2·8A, 6·3v. 1·4A, 6·3v. 1·2A, **£4·00,** carr. 50p. Type 7, 250v. 60 M/A, 15v. 1·2A, 6·3v. 4·5A, **£2·00,** carr. 35p. Type 8, 230v. 200 M/A, 6·3v. 7A, potted, **£2·50,** carr. 50p. Type 9, 350v. 150 M/A 6·3v. 4A, 6·3v. 2A, **£2·00,** post 40p.

GRESHAM 'C' CORE 10H 350 M/A
£3·50 carr. 50p. Potted type 10H 300 m/a **£3·00** carr. 50p. 9 H 500 m/a 5 kv DC wkg **£6·50** carr. £1.00.

PLEASE ADD 10% VAT TO ALL ORDERS INC. CARR.

L.T. TRANSFORMERS FRACTION OF MAKERS PRICE ALL PRIMARIES 220-240v
PARMEKO Potted types No 1 tapped 24-30-32v. 2a. **£2·25** p.p. 35p No. 2 24v. 1a. and 12·6v. 0·7a. and 6·3v. 0·5a. **£2·25** p.p. 35p. No. 3 Sec. tapped 9-10v. 0·42a. and 6·3v. 3·5a. 6·3v. 1·5a. **£1·50** p.p. 40p. No. 4 Pri. 115-230v. Sec. 6·6v. 6a. twice and 5v. 6a. **£4·00** carr 75p.

G.E.C. Open frame. Terminal Block Connections Primaries 220-240v. No. 1 Sec. Tapped 51-61 65-67-69v. 10a. **£7·50** carr £1. No. 2. Sec 58 63-69-74v 3a. and 6v. 3a. **£3·50** p.p. 50p. No. 3 3 separate windings 3v. 1·8a. 9v. 1·8a. 27v. 1·8a. and 17-0-17v. 250 m/a **£2·25** p.p. 25p.

GARDNERS. C core No. 1 Sec. 36v. 350 m/a **£1·00** p.p 25p. No. 2 Sec. tapped 2·5-6v. In ½v. steps. 1·5a. and 13v. 300 m/a **£1·00** p.p. 25p. No. 3 12·6v. 2·5a. and HT winding 290v. 350 m/a open frame table top connections **£3·00** p.p. 50p. No. 4 Sec. 50v. 1a. and 10v. 1·2a. open frame table top connections **£2·25** p.p. 25p. No. 5 Sec. 90-0-90v. 100 m/a 'C' core **£1·50** p.p. 25p. No. 6 Sec. tapped 5-10-20v 2·5a. and 1-2-3-4v. 2·5a. Potted type **£3·00** p.p. 35p.

GRESHAM. Type 1 16·3v. 1a. twice 10v. 1a. twice. 22·5-25-28v. 5a. 26v. 2·5a. 23v. 1a,. 6·3v. 2a. 145-0-145v. 200 m/a 'C' core **£4·95,** carr 75p. Type 2 38v. 4a. 20v. 4a. 40v. 7a. 29v. 2a. 30v. 2·6a. 26v. 3·8a. 51v. 200 m/a. All separate windings, 'C' core **£8·50,** carr. £1. Type 3 25v. 2a. twice, 16v. 4a. twice, 25v. 5a. 31v. 7a., all separate windings, open frame table top connection, **£8·50,** carr. £1. Type 4 tapped 30-31v. 4a. **£2·75,** post 35p. Type 5 17v. 2a. twice, open frame type, **£1·75,** post 30p.

12 volt 2 amp TRANSFORMER enclosed in metal case. Size 5×4½×3 ins. with fitted input and output fuses. On/off switch. Output sockets and 4 ft. 240v. mains lead. **£2·75** p.p. 35p.

LEMARK Pri. 240v. Sec. 40v. 6a. 5-0-5v 2a. 5-0-5v. ½a. Open frame design. **£4·50** carr. 75p. Pri. 240v. 16-0-16v. 2·5a. 24v. 630 m/a twice. 24v. 65 m/a and 115v. 2a. auto tap on primary. Open frame table top connections **£3·50** carr. 50p Pri. 240v. Sec. 20-0-20 ½a. 5-0-5 2a. **£1·75** carr 35p. All above transformers have a screen winding.

BORDON SOLENOIDS
12v. DC. ⅛in. Pull. Size 1in. dia., length 2in. **50p,** post 10p. Reg. **20Ω**

BENSONS SOLENOIDS
AC 240v 25% duty. Approx 2 ins. ½ in. pull. Size 2×1½ × 1ins. Res. 350Ω 75p p.p. 10p. Similar to 12v DC Type above.

NEW-THE HIGH DEPENDABILITY POWER SUPPLY. ByJOHNSTEED
In a single unit. Choice of 12v. DC. at 4a. 24v. DC at 2a. or simultaneously, 12v. and 24v. DC. Each with total drain of 50 watts. Basic unit **£8·25** p.p. 45p. Encased with switch, fuse, pilot light, mains cord, output connector. **£13·75** p.p. 50p.

STC RELAYS
Type 250XCE 2500 ohm 2 H.D. CO contacts set to pull in at 22v. with base and cover. **60p,** post. 5p.

KEYSWITCH KMK1 AC. 230v. One 5 amp. change over contact. **45p,** post. 10p.

AUTO TRANSFORMERS
Partridge. Tapped 0-220-230-240-250v. 500 watts unshrouded table top connections **£2·50** carr. 40p. Lemark tapped 0-240 115v. 500 watts unshrouded table top connections **£5·00** carr. 60p 300 watts **£3·50.**

LIMIT SHADED POLE MOTORS
AC 110-240v 50Hz 1500 RPM Double end spindle. Length 1ins. and ⅜ ins. **£1·25** p.p. 25p overall size 3×2½×3½ ins

GRESHAM MULTI TAPPED L.T. TRANSFORMERS
Pri. 110-220-240v. Sec. 21-22-23-27-28-30v 10a and 23-24-26v 2·5a. Twice and 15-16-18v 5a and 15-16-18v 5a and 25-0-25v 50 m/a three times. C. core type. Table top connections **£10·00** carr. £1.

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PEN RECORDERS

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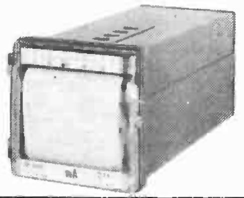
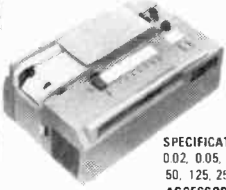


MINIATURE PEN RECORDER

Provides permanent record of DC currents up to 1mA. Eminently suitable for use where space is limited. Separate time marker pen provided. Chart width 80mm. Chart length 40ft. Chart speeds: Slow 20-60-180 mm/hour. Fast 600-1800-5400 mm/hour. Dimensions 120x120x285mm. Weight 7.7 lbs. (3.5 Kg). Price complete with accessories

£39.00

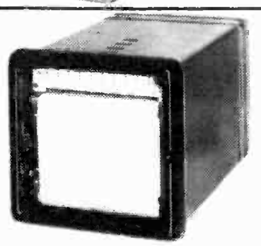


NEW HIGH SPEED PEN RECORDERS 3 MODELS AVAILABLE:

SINGLE CHANNEL **£180** : THREE CHANNEL **£310** : FIVE CHANNEL **£420**

Frequency range DC to 100Hz. Recording presented in curvilinear coordinates by means of ink on paper. Built-in solid state amplifier (one per channel) provides 8 calibrated sensitivity steps. Two marker pens are provided; one of these can be connected to internal time marker oscillator providing 1 second pulses. This pen can also be used as a process marker to mark a desired event on the chart. Second marker pen can be used as 'zero' (reference) line marker or as another event marker. Full range of chart speeds is immediately available by means of push button control.

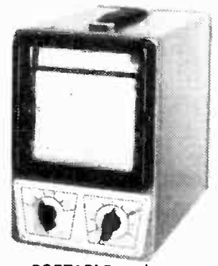
SPECIFICATION. Basic error 4%. Frequency response from DC to 100Hz, 2 db. Calibrated sensitivity V/cm: 0.02, 0.05, 0.1, 0.2, 0.5, 1, 2, 5. Width of each recording channel 40mm. Chart speeds mm/sec: 1, 2, 5, 10, 25, 50, 125, 250. Internal calibrating voltage: 40mV. Chart length: 50 meters. Voltage: 220/250. **COMPLEMENT OF ACCESSORIES AVAILABLE.**



10 CHANNEL EVENT RECORDER

Designed for recording sequences of up to ten different operations, e.g. sequence of machine tool operation, switching sequences, etc. Record is presented in the form of square "pulses". When energised, pen moves by approximately 4mm. to the right of zero line. Response time 100 milliseconds. Chart width 110mm. Chart length 50ft. Inv. capacity 72 hours. Chart speeds 20-60-180-600-1800-5400 mm/hour. Size 160x160x255mm. Weight 9 lbs. Price complete with accessories

£52.00



PORTABLE AC/DC RECORDING VOLTAMMETER

Fitted with separate zero-marking pen. Accuracy 1.5% DC, 2.5% AC. Measurements ranges — AC and DC: 5-15-150-250-500mA 1.5-5 Amps 5-15-50-150-250-500V. DC only 150mV. Frequency range 45 to 1000 c/s. Chart width 100mm. Chart speeds 20-60-180-600-1800-5400 mm/hour. Weight 22 lbs. Price complete with accessories

£78.00

SINGLE PEN RECORDER

TYPE 230

A most versatile pen recorder producing a trace on a curvilinear 3 in. strip chart. Two synchronous speeds: 1 in. and 6 in. per hour. Fitted with high and low alarm contacts operated by the moving coil. Basic movement 1mA DC coil resistance 400 ohms. Fitted with rectifier to allow operation on AC effective coil impedance at 50Hz. 1800 ohms.

Power supply required: 230V 50Hz.
Applications: Ideal for recording relatively slow changing phenomena such as:
Temperature: Gas or Liquid Flow Rates, Sound Levels, Speed variations, Power Demand, Rainfall, humidity, etc.

PRICE £25.00

Clockwork version also available £29.50

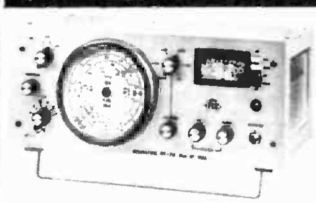
MINIATURISED STRIP CHART RECORDER

Indicates the magnitude of applied currents or voltages by a continuous distortion-free line on pressure sensitive paper. Moving coil movement, scale calibrated 0-1 milliamp d.c. internal resistance 100 ohms. Chart drive motor 240V 50Hz. Chart speed 1" per hour. Complete with handbook.

Price £25.00

TES EQUIPMENT

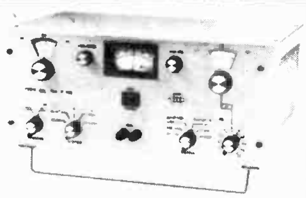
OBTAINABLE ONLY FROM ELECTRONIC BROKERS. SEND READER'S CARD FOR FREE CATALOGUE OF TEST EQUIPMENT (WW 118)



AM-FM GENERATOR Type AF 1065

Permits fast and accurate calibration of modern radio receivers. Suitable for calibration and testing in the laboratory. AM frequency range: from 140 KHz to 46 MHz in 6 ranges expended range 430–530 KHz. FM frequency range: 9.5–12 MHz; 85–110 MHz. Frequency accuracy: better than 1%. RF output voltage: adjustable from 0.1 μV to 0.1V. Output impedance: 75 Ohm constant. Modulation: AM; FM; AM + FM. Amplitude modulation: 400 Hz: from 0–50% adjust. Frequency modulation: 1000 Hz adjust. Deviation from 0 – +/– 50 KHz. External modulation: AM; FM: from 30 Hz to 15 KHz.

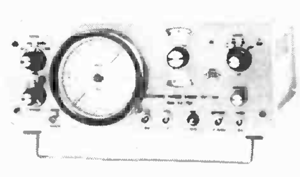
£259·00



RCL BRIDGE Type P 966

For measurement of RCL and capacitor dissipation factor and inductors figure of merit Q. Consists of a system of switchable bridges, a 1 KHz generator, and a sensitive tuned detector. Particularly suitable for testing of small production batches and selection of component parameters.
Measurement ranges:
Resistance: from 0.1 Ohm to 11 MOhm.
Capacitance: from 1 pF to 1100 μF.
Inductance: from 10 μH to 1100 H.
Accuracy: +/– 1%. Dissipation factor D: from 1.10^{-3} to 50. Quality Factor Q: from 0.02 to 1000. Internal oscillator: 1 KHz.

£245·00

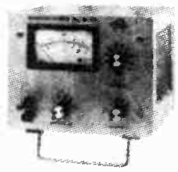


TV SWEEP MARKER GENERATOR Type VU 167

Suitable for alignment of tuned circuits in television sets. Incorporates a sweep generator, a market generator and a crystal-controlled oscillator operating at 5.5 MHz. Sweep frequency range 1–30 MHz. 170–260 MHz Fund. 470–780 MHz Harmonic. Marker frequency range 2–266 MHz. 480–800 MHz.

£259·00

Many other models available Send for list



OUTPUT POWER METER TYPE M J 964.

This instrument basically consists of a transistorized amplifier voltmeter which measures the voltage across a specified load. It is provided with 40 load values ranging from 2.5Ohm to 20K Ohm. As the loads are purely resistive, their value keeps constant with varying frequency. A special negative feedback loop allows a nearly linear scale to be obtained. No damages to the instrument result from errors in presetting the load values or the power ranges.

Power measuring range (in 4 ranges)	from 1mW to 10 W
Level measuring range Ref. 1mW	from – 3 dB to + 40 dB
Frequency range	from 20 Hz to 50KHz
Accuracy	Within 0.5 dB
Load input resistances	40 Values
Resistances accuracy	better than 5%
Instrument Calibration	R.M.S.

£129·00

ADD 10% VAT TO ALL PRICES

Carriage and packing charge extra on all items, unless otherwise stated.

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THESE ACCESSORIES CAN BE USED IN CONJUNCTION WITH THE SUPERTESTER 680R. ALSO IN MANY CASES WITH POPULAR MAKES OF TEST METERS.

Amperclamp

For measuring a.c. currents from 250mA to 500 amps. **£11.95**

Signal Injector

Producing 1KHz and 500 KHz signals for circuit testing. **£5.95**

Transistor Tester

For transistors and diodes. **£11.00.**

Gauss Meter

For measuring magnetic field strengths. **£11.95**

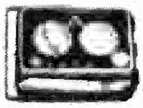
Phase Sequence Indicator

To indicate the phase sequence of a 3 phase supply. **£5.95.**

Temperature Probe

Covering the range −50 to +200°C **£11.95**

Electronic Voltmeter

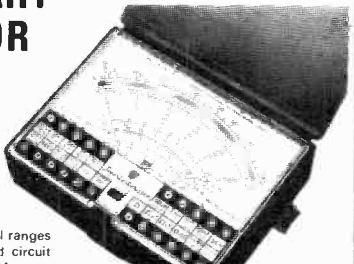


Input resistance of 11Mohms for d.c. and 1.6Mohms shunted by 10pF for a.c. **£18.00**

OTHER ACCESSORIES AVAILABLE

SHUNTS D.C. 25, 50 and 100 amps. **£4.50** each.
CURRENT TRANSFORMERS A.C. 25 and 100 amps. **£7.00** each.
E.H.T. PROBE Extends D.C. voltage to 25,000v. **£5.95.**

THE REVOLUTIONARY SUPERTESTER 680R



FOUR INTERNATIONAL PATENTS — SENSITIVITY 20,000 Ohms per Volt
10 FIELDS OF MEASUREMENT AND 80 RANGES. ACCURACY 1% in D.C. 2% in A.C.
OUTSTANDING FEATURES:
20.000 Ohm per Volt sensitivity ● Fully screened against external magnetic fields ● Scale width and small case dimensions (128 x 95 x 32mm) ● Accuracy and stability (1% in D.C., 2% in A.C.) of indicated reading ● Simplicity and ease of use and readability ● Full ranges of accessories ● 1000 times overload ● Printed circuit board is removable without de-soldering ● More ranges than any other meter. VOLTS A.C. = 11 ranges: 2-10-50-250-1000-2500. Volts and **4-20-100-500 and 2000 Volts**. VOLTS D.C. = 13 ranges: 100mV-2V-10-50-200-500-1000 Volts **200 mV-4V-20-100-400 and 2000 Volts** AMP D.C. = 12 ranges: 50μA-500μA-5 mA-50 mA-500 mA-50 Amp and **100μA-1 mA-10 mA-100 mA-1 Amp and 10 Amp.** AMP. A.C. = 10 ranges: 250μA-2.5mA-25mA-250mA-2.5Amp and **500μA-5mA-50 mA-500 mA-5 Amp.** OHMS REACTANCE = 6 ranges: **x1-x10-x100-x1000-x0.000 and Low Ohms.** DETECTOR = 1 range: from 0 to 10 Megaohms. FREQUENCY = 2 ranges; from 0 to 500 and from 0 to 5000 Hz V. OUTPUT VOLTAGE = 9 ranges: 10-50-250-1000-2500 V and **20-100-500-2000 Volts.** DECIBELS = 10 ranges: from −24 to +70 db. CAPACITY = 6 ranges: from 0 to 50,000 and from 0 to 500.000 pF using the mains and from 0 to 20, from 0 to 200, from 0 to 2,000 and from 0 to 20.000 Micro farad using the incorporated 3 Volts battery.
Bold figures indicate depress button.

£18·50 with shockproof case

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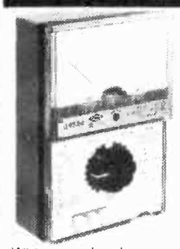
METERS PROBES, ETC.

FANTASTIC VALUE

AC/DC MULTI-METER



With taut band suspension movement. Sensitivity 20,000 ohms per volt on DC and 4,000 ohms per volt on AC.
Technical Data:
0.06-0.6-6-60-600mA-3 Amps DC. 0.3-3-30-300mA-3 Amps AC. 0.6-1.2-3-12-30-60-120-600 DC. 1200 Volts. 3-6-15-60-150-1300-600-900 Volts AC. 45 to 20,000 Hz.
500Ω. 5-50-500kΩ resistance. Decibel range −10 to +12dB Accuracy (% of F.S.D.):—DC and resistance measurements +2.5. Price with test leads, and storage case **£8.00 POST FREE**

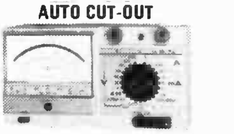
AMPERTEST 690 NEW CLAMP TYPE AMMETER

With unique self-locking meter system retains reading until released, enabling engineer to obtain accurate results after testing inaccessible places etc.

Designed for use in one hand, measures without breaking the circuit. It has six current ranges from 3A to 600A f.s.d. with the first division at 100 mA. a 10-to-1 current rransformer supplied with the instrument provides ranges from 300mA to 60A f.s.d. with the first division at 10mA. Two a.c. voltage ranges of 250V and 600V f.s.d. are provided.

£39.50 POST FREE
inc. leather case

MULTIMETER WITH FULLY AUTO CUT-OUT



With taut suspension movement and full coverage of AC and DC current and voltage ranges. The instrument incorporates all facilities needed for field and laboratory measurements. Knife edge pointer and 86mm long mirror scale allow the high inherent accuracy of the instrument to be utilized in full. The movements and circuits are fully protected by transistorized triggering circuit.
Scale length: 86mm D.C current ranges: 50μA, 0.5, 1, 5, 10, 50, 250mA 1, 5 Amps. A.C. current ranges: 0.25, 0.5, 1, 5, 10, 50, 250mA, 1, 5 Amps. D.C. voltage ranges: 100mV, 0.5, 2.5, 10, 25, 50, 100, 250, 500, 1000V. A.C. voltage ranges: 0.5, 2.5, 10, 25, 50, 100, 250, 500, 1000V. Transmission level: −5 to +10db. Resistance ranges 0.5, 200; mid-scale reading 13 10Ω–3kΩ; mid-scale reading 200Ω, 100Ω, 30kΩ; mid-scale reading 2000Ω, 1kΩ–300kΩ mid-scale reading 20kΩ. Accuracy, % of F.S.D.: D.C. ranges — 1.5 A.C. ranges — 2.5. Sensitivity: D.C. ranges, 20,000Ω/V. A.C. ranges, 4,000Ω/V for all ranges except 2.5V and 10V. 1000Ω/V for 10V range 200Ω/V for 2.5V range. Batteries required: 2 dry cells 1.5V for automatic cut-out. 1 dry cell 1.5V for resistance range. Overall dimensions: 210 x 115 x 90mm in carrying case, complete with test leads.

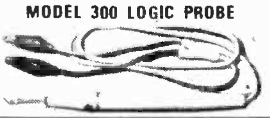
POST FREE £15·00

UNIQUE MULTI-METER/SIGNAL GENERATOR

Taut suspension movement. Simple multimeter combined with audio/I.F. Test Oscillator providing AC and DC Voltage ranges. D.C. current ranges and resistance ranges, 1kHz and 465kHz oscillator output makes the instruments suitable for general tuning of receivers etc.
Scale length: 65mm. D.C voltage ranges: 0.5, 2.5, 10, 50, 250, 500, 1000V. A.C. voltage ranges: 2.5, 10, 15, 250, 500, 1000V. D.C. current ranges: 0.05, 0.5, 5, 50, 500mA.
Sensitivity: 20.000Ω/V. Resistance ranges: 5–1000Ω mid-scale reading 50Ω 50Ω 10k: mid-scale reading 500Ω. 500Ω–100kΩ; mid-scale reading 5kΩ 5kΩ–1mΩ mid-scale reading 50kΩ.
Accuracy: 5% of F.S.D. Internal battery: 3V dry cell.
Oscillator output: 1kHz squarewave. 465kHz sinewave modulated by 1kHz squarewave signal. Output voltage: 1V minimum.
Overall dimensions: 160 x 97 x 40mm. in carrying case, complete with test leads.

£7·00 POST FREE

MODEL 300 LOGIC PROBE



A compact easy-to-operate logic probe. As a light-emitting diode is used the unit actuates with low power. It does not affect the circuit under test because of high input impedance. Up to as high a frequency as 12 MHz.
POST FREE £5.50

ADD 10% VAT TO ALL PRICES
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Canada calls Mult £1 Million

Contract signed against international competition.

The Multitone Electric Company Limited have announced that their Canadian subsidiary, Multitone Electronics Limited of Toronto, have signed a contract with Bell Canada—one of the largest users of mobile communications equipment in Canada. This contract, worth approximately £1 million, is for digital selectively called communications receivers and digital base station equipment. The contract has been won against considerable international competition.

Most sophisticated equipment of its type in the world.

The equipment will form part of an area-wide paging system, believed to be the largest and most sophisticated in use anywhere in the world, operating throughout Ontario and Quebec. About 60 transmitters are co-ordinated throughout the system by two central computers which store incoming calls, automatically decide which transmitters are to be used for each outgoing call and access the correct transmitters over the public telephone system.

British technology to the fore

The Multitone group Research and Development facility in London was responsible for the design of the receivers and the associated digital equipment. Their unique expertise in designing low power-consumption RF circuitry, allied with high packaging density and rugged mechanical design has made possible the high performance receivers required by this contract. In fact, the whole package weighs only 5 ounces, including batteries and occupies a volume of 7 cubic inches.

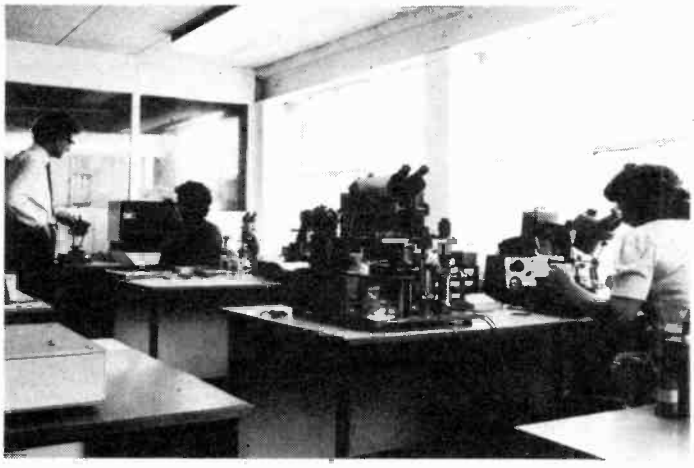
Design Philosophy

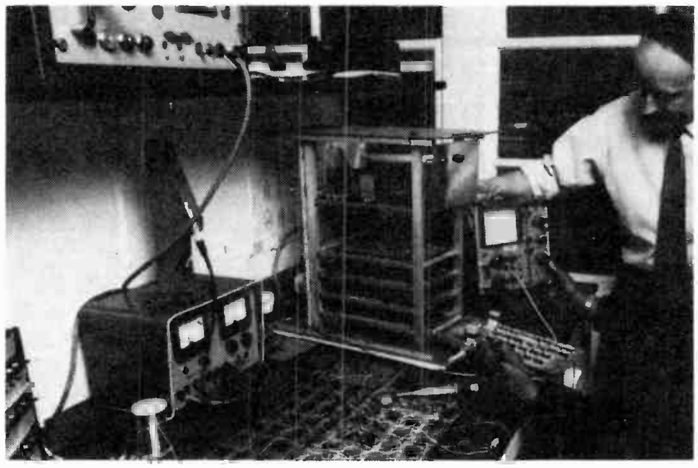
The receiver section consists of an internal antenna, and a double conversion high performance communications receiver operating in the 150 MHz band with 25 kHz channelling. Particular care has been taken to minimize spurious responses so that the performance is unaffected by interference in a crowded urban radiocommunications environment. C-MOS technology is used to achieve the complex decoding and internal timing requirements with a minimum of power consumption. Battery power is also conserved by a system whereby the power supply is only switched on for short periods, during which time the receiver senses whether a signal is present or not. If it is, the receiver locks on until the signal ceases.

High Speed—High Integrity

The address code has been developed by Multitone specifically for selective calling purposes. It combines the high traffic rate of up to 4 calls per second with virtually complete freedom from false calling. In addition to addressing the individual receivers, the code contains additional data which allows the receiver to pass up to eight messages to the user to indicate, for example, the urgency or the origin of the call. Also the code permits the calling of receivers in groups in addition to their being called individually.

one to the sound of





Bell's intentions

In the Bell system, the code is generated by special code converter units designed by Multitone. They convert incoming data from the computer terminal to the receiver address code. These code converters form a part of the existing transmitter controllers, which in turn pass the address code to the transmitters. These controllers also receive data regarding the transmitter operating status for transmission back to the terminal.

Plans for the future

The British headquarters of Multitone are naturally delighted with the success, but a spokesman for the company expressed the view that this would only generate more pressure in terms of research and development. "As an expanding company, our attitude is one of ensuring that we are always one step ahead. Naturally, this makes demands on our manpower resources, and doubtless with the confidence which has been shown in our products we shall be looking for more people to join us and apply their expertise to what is an ever-increasing market."

From the Managing Director

Reaffirming the point, I. H. Karten, Managing Director of Multitone Electric Company, stated, "The wide-area paging market opens up broad new horizons for our company both in sales growth and product sophistication. Multitone will bring to the wide-area market, products which will extend to this field the leadership we have already established world-wide in on-site applications."

Prospects

All in all, it looks very much as though people, particularly engineers, will be warmly welcomed at Multitone.
The world-wide explosion of the radio paging market and the universal acceptance of this form of data transmission as a prime communications aid is leading to unique technical developments. This is a new field waiting to be exploited both by those who enjoy the challenge of innovation, and those who find satisfaction in master-minding a well designed product into large scale production.

A NEW TECHNOLOGY

Today a new technology is being developed. From small beginnings has come the possibility of real personal communications—not communications with vehicles or buildings, but directly with people.
Radio Selective Calling and Paging are being applied to a vast number of communication problems—for Public Safety, Business Efficiency, Hospital Administration etc. etc.
To develop the potential of this new activity we need engineers with a flair for innovation, engineers with a flair for project administration, engineers whose experience has brought them into close contact with radiocommunications.
Some of the tools of the trade which are making these developments possible are:

- ★ **High performance radio receiver/transmitter design**
- ★ **Frequencies from HF to UHF**
- ★ **Custom integrated circuit design**
- ★ **C/MOS technology**
- ★ **Thick film development**
- ★ **Ultra high density packaging**
- ★ **High speed data transmission**

If you have experience of the design or development of radio receivers, radio transmitters, or digital circuits why not get in touch with us?
Salaries are good, ranging from £2000 to £4000+, and so are the prospects, because Multitone is an expanding international group of companies—British owned.
If you would like more information just ring our R & D manager—Peter Coles—on an informal basis.

Multitone Electric Co. Ltd.
10-28 Underwood Street, London N1 7JT. Tel: 01-253 7611

3756

APPOINTMENTS VACANT

DISPLAYED APPOINTMENTS VACANT: £11·88 per single col. inch.
LINE advertisements (run-on): 66p per line (approx. 7 words), minimum two lines.
BOX NUMBERS: 30p extra. (Replies should be addressed to the Box number in the advertisement, c/o Wireless World, Dorset House, Stamford Street, London, S.E.1. 9LU.)
PHONE: Allan Petters on 01-261 8508
Classified Advertisement Rates are currently zero rated for the purpose of VAT

Advertisements accepted up to 12 noon Tuesday, June 3rd for the June issue subject to space being available.

DOLBY SYSTEM

Noise Reduction in Recording and Communications

Dolby Laboratories manufacture professional noise reduction equipment which has been accepted by all major recording companies in the world. The same techniques have been applied to consumer products which are being built in several countries by licensees, and are now widely available.
We have vacancies in the engineering department for talented engineers to continue research and development in these fields. The department is expanding but is still small (a dozen people) in an organization of 100. We are situated in a modern building south of the river with excellent communications to the centre of London and main railway stations.

**Project Engineer
Professional Products
£3,000–£4,000**

This position is suited to an engineer inclined towards professional audio. He will work on the design of new products aimed at the recording, broadcasting and communications industry using appropriate Dolby system noise reduction techniques. He should be capable of and interested in following his design through to prototype models and later of advising the production department throughout the life of the product.
The ideal candidate will probably be about 25–35 with an honours degree in engineering or physics, and with experience in some of the areas mentioned above, together with a personal interest in music and quality sound reproduction.

**Project Engineer
Licensed Product
Evaluation
£2,500–£3,000**

The rapid increase in licensees (now over 40) of the Dolby B-type consumer noise reduction system has resulted in a corresponding increase in our liaison activities.
Part of the continuing licensing programme involves evaluation of a wide variety of consumer products incorporating our circuit, and we are looking for an engineer to be part of the team which performs these evaluations. He will be responsible for planning and executing the testing programme, which requires some familiarity with the design and construction of consumer products. He will be 25–35 and have a degree, together with experience of and a high level of interest in quality tape recording and sound reproduction.

Write with brief details in the first instance or telephone

David Robinson, Chief Engineer
Dolby Laboratories Inc, 346 Clapham Road, London SW9. Telephone: 01-720 1111

Dolby and the Double-D symbol are trade marks of Dolby Laboratories Inc

3720

Customer Engineers

As one of the largest and most successful computer manufacturers, we place particular importance on the maintenance of a high level of customer service. Our equipment is among the most advanced in the world today. Highly sophisticated hardware used by top companies and organisations in commerce, industry, science and government.

Our Customer Service organisation is, therefore, immensely important to us if we are to maintain the high standards we have set ourselves over the years, during which we have pioneered much of the advanced technology in use today throughout the industry.

We're looking for Customer Engineers to carry out, to a high professional standard, all electronic and electro-mechanical work concerned with installation, modification, refurbishing, preventive and remedial maintenance on Sperry Univac equipment in the UK.

We require men with a knowledge of electronic or mechanical fault-finding techniques. In addition to technical competence, essential requirements are a pleasant personality and the ability to maintain a good relationship with customers. Full product training will be given.

To Engineers looking for the best in salaries, vacancies exist in most parts of the country. Conditions and fringe benefits are what you would expect when you join a company within the international Sperry Rand organisation. Future career prospects in the computer field are excellent.

For vacancies in London or the South write with full personal and career details to Personnel Manager, Ref. WW, Sperry Univac, Univac House, 160 Euston Road, London NW1. Telephone 01-387 0911. For vacancies in the Midlands and North write with full personal and career details to Personnel Manager, Ref. WW, Sperry Univac, Lynnfield House, Church Street, Altrincham, Cheshire. Telephone 061-928 7731.

SPERRY UNIVAC

PROFIT FROM EXPERIENCE

13733

SIEMENS

We are Siemens Limited, the UK company of the Worlds most diversified electronic and electrical engineering organisation. We are expanding rapidly and urgently require

Customer Service Engineers for Scientific Instruments

To work on analytical x-ray equipment, electron miscroscopes and chromatographs. Ideally applicants will be educated to HNC level in electronics or physics, but sufficient relevant experience would be favourably considered. If necessary training will be given to the successful candidates. This is a unique position in a large well established multi-national concern. Excellent salary and fringe benefits. Vacancies are based in London and Glasgow, interviews can be arranged at either centre. If you are interested and feel you have the experience and necessary qualifications then write or phone for an application form to Roger Kingsley, Personnel Manager, Siemens Limited, Great West House, Great West Road, Brentford TW8 9DG, Middlesex. Telephone 01-568 8281 Ext. 34

(3680

HAYDEN LABORATORIES LIMITED

exclusive U.K. agents for NAGRA tape recorders and SENNHEISER microphones.

A vacancy has arisen in our London Service Department for an engineer to carry out servicing work on the above products. We are seeking an enthusiastic and conscientious worker with a good understanding of microphones and tape recorders and a standard of workmanship consistent with the quality and reputation of these products.

Good working conditions. Four weeks' annual holiday. Holiday arrangements will be honoured for this summer. Salary by negotiation. Interviews in London. *Please apply in writing to*

Managing Director, **HAYDEN LABORATORIES LTD.,** Hayden House, 17 Chesham Road, Amersham, Buckinghamshire

(3748

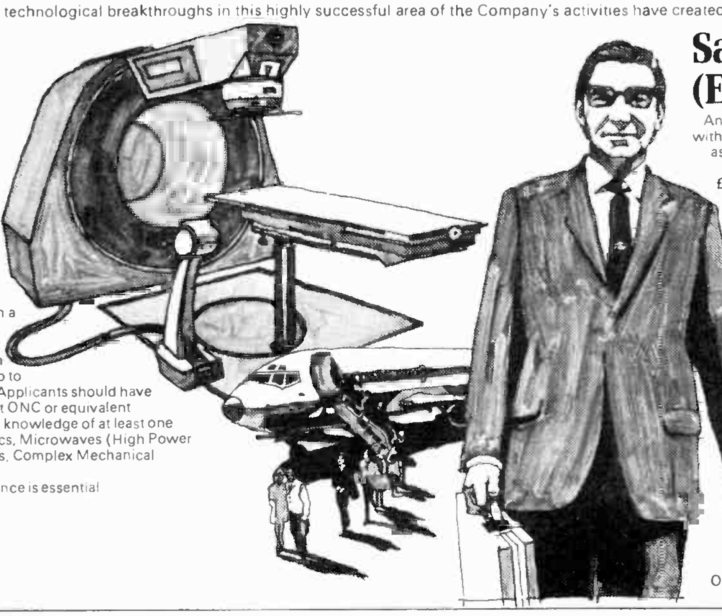
THE M.E.L SL75

One of the most advanced Linear Accelerators for world users

The M.E.L. Equipment Company Limited situated at Crawley, Sussex, is that part of the Philips Group involved in the development, manufacture and marketing of professional electronic equipment.

The SL75 series is the latest of a long line of medical Linear Accelerators which have been used for the treatment of cancer in hospitals throughout the world for over twenty years.

Further technological breakthroughs in this highly successful area of the Company's activities have created the following opportunities.



Technical Support Engineers

They will be required to work with a team based at Crawley, on the installation and technical support of the accelerator equipment both at home and abroad. Periods of up to 3 months will be spent overseas. Applicants should have a technical qualification to at least ONC or equivalent and it is desirable that they have a knowledge of at least one of the following: Radiation Physics, Microwaves (High Power Radar), High Vacuum Techniques, Complex Mechanical Assemblies.

Semi Conductor Circuitry experience is essential

Sales Support Engineer (Export)

An experienced Sales Support Engineer is required to assist with the promotion of export sales of Linear Accelerators and associated peripheral equipment to medical, industrial and scientific customers overseas with values of between £100,000 and £300,000. He will give specialist advice on the product to the National Sales Organisations of the International Philips Group.

In view of the type of equipment and the markets concerned, a degree in Science and experience in electronic, scientific and electro-medical markets would be strong assets but the Company is predominantly seeking an engineer with experience of sales and export marketing.

Applicants must be prepared to spend up to a total of six months a year overseas, mostly in short periods but with occasional trips up to two months.

The Company offers attractive salaries and fringe benefits for these positions including at least four weeks holiday a year and assistance towards moving to Sussex if required.

MEL

Initially, applicants should write or telephone for an application form to:– Mr. M. A. Burns, Personnel Officer (DT/109), The M.E.L. Equipment Co., Ltd., Manor Royal, Crawley, Sussex. Tel: Crawley 28787.

(3723

Installation Engineering with IAL
up to £3,000
Worldwide Travel

The chance for advancement is open to ENGINEERS AND TECHNICIANS looking for a UK based job with worldwide travel opportunities.

As a member of our new installation team you may have your first job in Singapore or it could be in Dubai for IAL's contracts are in all parts of the world. For the most part your trips will be of around one month's duration but some may be extended depending on job requirement and complexity.

We have positions for ENGINEERS to head the teams whose experience covers the installation and commissioning of FDM in the VHF, UHF, and SHF spectra and/or radar and sophisticated ground based aeronautical navigational equipment.

There are also interesting positions available for TECHNICIANS who will supervise projects. Here we require experience in the installation and commissioning of single channel radio equipment in the HF and VHF spectras and with radio and telephone line communications equipment generally. A maintenance background in these areas would be useful.

The positions offer real job responsibility and satisfaction, generous overseas allowances will be paid. Other benefits include membership of a sound contributory pension and life insurance scheme and opportunities for holiday air travel at nominal rates worldwide.

Please apply by phoning or writing to Mr Rodney Radcliffe, Personnel Officer (Ref: IE/WW), International Aeradio Limited, Aeradio House, Hayes Road, Southall, Middlesex. Tel: 01-574 2411.

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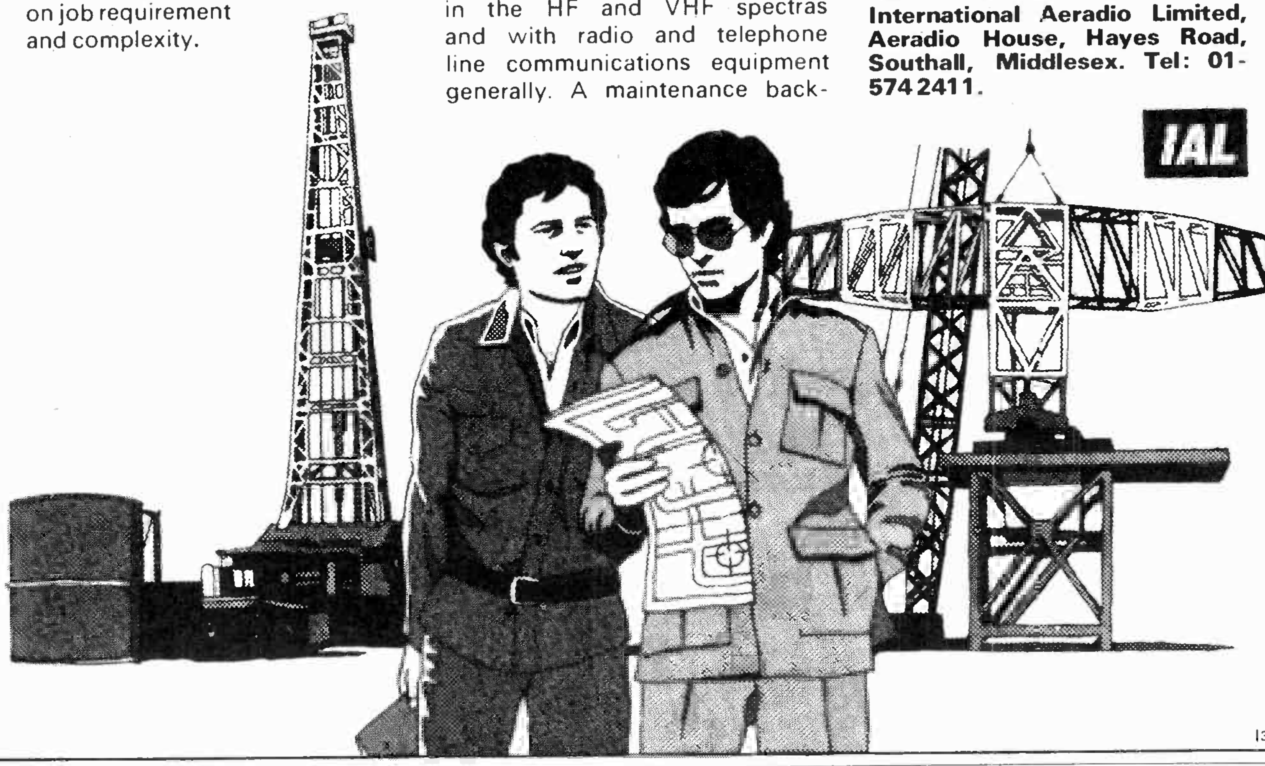


13694

SONY®
A Career with Sony

A unique opportunity to join a world-famous Company, renowned for its product Quality and Reliability.
We are looking for 6 young men aged 16–17 years, educated to between CSE Grade 4 and "O" level standard, preferably with Maths and Physics to become

Apprentice Bench Service Engineers

The four-year Apprenticeship, which leads to City and Guilds Certificate, commences in September with a 13-week full-time course at Kingston College (Surrey).
For full details of a Career with SONY telephone or write to: **The Personnel Officer, SONY (UK) LIMITED. Pyrene House, Staines Rd. West, Sunbury on Thames, Middx. Telephone: Sunbury 87644.**

13743

Electronics Engineers

Do something completely different-become a Lecturer.

We are looking for several Electronics Engineers whom we can train to teach the practicalities of computer servicing.

You will be based at our training centre in Letchworth, Herts – the largest of its kind in Europe. Here, you will be given a comprehensive grounding in computer technology in general and ICL equipment in particular. You will also be taught how to teach and therefore be thoroughly prepared to train Engineers to the point where they will be capable of maintaining computers at the optimum operational specification.

Ideally, you will have an HNC or Forces' training in electronic engineering. Any experience in digital electronics or computers, while not essential, will be useful.

We'll start you as an Assistant Lecturer on a salary between £2200 and £2756. You'll be encouraged and expected to progress to the position of Senior Lecturer which carries a salary of up to £3840. Relocation expenses will be considered where appropriate.

For an application form, write to A E Turner, quoting reference WW at International Computers Limited, 85/91 Upper Richmond Road, Putney, London SW15 2TE.

International Computers ICL
think computers-think ICL

[3681

ELECTRONICS TECHNICIAN

required to join a small team dealing with most aspects of medical electronics including safety, calibration, purchase, design and modifications.

The technician appointed will be expected to gain experience by working in various hospitals in South and Central Liverpool.

Salary scale will be on the Medical Physics Technician Grade III (£719 £2,211).

Applicants should have O.N.C. C & G Certificates or equivalent and have experience in electronics.

Application forms and job description obtainable from the District Administrator, 80 Rodney Street, Liverpool, L1 9AP, to be returned by the 4th June 1974.

[3737

RADIO OFFICERS

Do you have PMG I, PMG II, MPT 2 years operating experience?

Possession of one of these qualifies you for consideration for a Radio Officer post with composite signals organisation.

On satisfactory completion of a 7month specialist training course, successful applicants are paid on a scale rising to £3,096 pa; commencing salary according to age—25 years and over £2,245 pa. During training salary also by age, 25 years and over £1,724 pa with free accommodation.

The future holds good opportunities for established status, service overseas and promotion.

Training courses commence at intervals throughout the year. Earliest possible application advised.

Applications only from British-born UK residents up to 35 years of age (40 years if exceptionally well qualified) will be considered.

Full details from:

**Recruitment Officer,
Government Communications Headquarters,
Room A/1105, Priors Road, Oakley,
Cheltenham, Glos GL52 5AJ
Telephone Cheltenham 21491 Ext 2270**

[92

RAILWAY SIGNAL ENGINEER

required by a firm of Consulting Engineers on the South Coast.

Applicants should be graduates and members of the Institution of Railway Signal Engineers and have had experience in a responsible position of the design and execution of modern railway signalling systems, train describers and automatic routing systems. Experience of signalling under 25kV a.c. traction conditions is desirable.

Duties would include the preparation of signalling and train description specifications from outline drafts, preparation of signalling schemes, analysis of tenders and technical supervision of signalling works.

Salary will be according to qualifications and experience.

Applications should be addressed to the Personnel Manager, Messrs. Preece Cardew & Rider, Paston House, 165-167 Preston Road, Brighton, BN1 6AF, Sussex, quoting reference: GET/Pers/3080.

[3689

OPPORTUNITIES FOR ELECTRONIC TECHNICIANS IN SOUTH AFRICA

Uitenhage Municipality requires the services of a qualified electronic technician to work in the Test Section of the Electricity Department. Applicants should preferably be in possession of a H.N.C. and have had experience in digital supervisory systems as related to a distribution authority.

Uitenhage is situated 30 km from Port Elizabeth in the Cape Province and has an excellent climate which is conducive to the many outdoor amenities provided.

Benefits of employment include pension and medical schemes, housing loans at a reduced interest rate, annual bonus, six weeks annual leave and assisted passage and removal expenses for the successful applicant and family. It is expected the salary will be up to R6,498.00 per annum (R1=£0.61).

Applicants shall, in the first instance, write to Mertz & McLellan, Carrier House, Warwick Row, London, SW1E 5EN, giving age, marital status, qualifications and a career resume. Interviews will be held in London during June/July.

[3703

BIAS ELECTRONICS LTD.

have recently moved to larger premises and to meet the demand for our internationally acclaimed professional tape recorders require

TEST ENGINEERS

with experience on high quality audio and tape recording equipment;

JUNIOR TEST ENGINEERS

with plenty of enthusiasm and the desire to gain experience in professional audio;

ELECTRONIC WIRE MEN/ASSEMBLERS

capable of working to high standards and with the opportunity to progress to test and inspection.

Take this opportunity to join a dynamic expanding company where you will be regarded as one of the team and not just a number. Good rates of pay and profit sharing scheme.

For further information write or phone

BIAS ELECTRONICS LTD.
572 KINGSTON ROAD
LONDON, SW20 8DR
01-540 8808 or 01-540 9818

[3700

School leavers-
learn while you earn at Pye Telecom

You could train for a professional career, gain help in obtaining further qualifications – and earn good money at the same time. Pye Telecom is part of the Pye Group, leading manufacturers in the electronics industry. Joining will bring you extensive opportunity stemming from Pye Telecom's vigorous growth. You can start as either of the following:

Student Engineer

'A' level Maths and Physics plus 3 'O' levels including English, or ONC/OND with credits, are essentials. You will embark on a 'thin sandwich' course (6 months' practical experience at Pye Telecom, Cambridge, alternating with 6 months at a college of your choice,) which will lead to a B.Sc, or HND in Electronic Engineering. After qualifying your career path could include Design Engineering, Systems Engineering, Production Engineering or Junior Management. If necessary, lodgings will be found for you during periods spent at Cambridge.

Trainee Technician

Entry qualifications: 'O' level English, Maths, Physics, plus another science-based subject, preferably Engineering Drawing, or alternatively good equivalent CSE passes. A 4-year practical training course will combine with day release to take ONC/HNC or City & Guilds Telecommunications Technicians courses. You could become a Test Engineer, Production Engineer, Production Planner, Draughtsman, Engineering Laboratory Technician or Service Engineer. There are some opportunities to progress as a Student Engineer, and take a degree.

For further information and your application form please write immediately to Mrs. Rowan Turnbull, Training Officer,

Pye Telecommunications Ltd
Newmarket Road. Cambridge. CB5 8PD.
Tel: Cambridge 61222

A member of the Pye of Cambridge Group

[3715

GLASGOW COLLEGE OF TECHNOLOGY

DEGREE in ELECTRICAL AND ELECTRONIC ENGINEERING by PART-TIME STUDY

Applications are invited from holders of a good H.N.C. in Electrical or Electronic Engineering to enrol for the course:

B.Sc. in Electrical Engineering (CNAA)

This four-year part-time degree course is the first of its type to be offered in Scotland, and a start is proposed for August 1974.
Full details and application form from:

The Academic Registrar,
Glasgow College of Technology,
North Hanover Place, Glasgow, G40BA.

The College is only a few minutes walk from the City Centre and Queen Street Station giving easy access from the West of Scotland and Edinburgh.

[3744

Grow with Pye as a development engineer

We at Pye Audio Products are making a whole new range of sophisticated audio products, at our modern Stevenage plant, including car radios, radiograms and stereo equipment. We now have an interesting and rewarding opportunity for a Development Engineer.

Because of the continual demand for our equipment, and therefore expansion of our product range, we need someone to work in our laboratory, who is capable of self-motivation and possesses the ability to work on a complete project with the minimum of supervision.

Ideally the person we are looking for will be qualified to a minimum of HNC in Electronic Engineering and have experience in design techniques for R.F. (A.M. and V.H.F. stereo reception) and A.F. (powers up to 20 watts) applications, as applied to equipments for domestic markets. He will be dealing mainly in equipment for large volume production with costs playing an important part of the approach to a project.

Salary level and benefits are commensurate with a major company serving an international market. Are YOU looking for a position with good prospects and opportunity for career development? Come and grow with PYE.

Write briefly to: Gillian Charter, Pye Limited, Audio Products Division, Caxton Way, Stevenage or telephone for an application form: Stevenage 50241.

Pye Limited

Pye Audio Products, Caxton Way, Stevenage.
Tel: Stevenage 50241

A Member of the Pye of Cambridge Group

[3736

crown agents

CONTRACTS ENGINEERS— RADIO COMMUNICATIONS

required by the CROWN AGENTS for their London (Westminster) Office.

Candidates should preferably have had five year's experience as a Contracts Engineer in one or more of the areas of communications detailed below and possess ONC or equivalent in an appropriate discipline. Practical experience of the equipment desirable.

(a) Sound Navigational Aids (Radar, ILS, VOR/DME, etc)
(b) HF, VHF, UHF Communication Equipment.
(c) Microwave Equipment and Systems.

The duties include the checking of specifications, preparation of tender documents, technical and commercial correspondence connected with contracts, the evaluation of tenders and the placing of contracts. Candidates must be prepared to undertake occasional visits to works and to overseas principals.

Commencing salary according to age, qualifications and experience up to £2,557 rising to £2,891. Non-contributory pension scheme.

Write for further details and application form to the CROWN AGENTS, 4 Millbank, London SW1P 3JD stating brief details of qualifications and experience and quoting reference number MIS/OFFICE VI (RADIO COMM) WF

[3727

The **AGRICULTURAL RESEARCH COUNCIL** require a

SCIENTIFIC OFFICER

in the Electronics Section of their LETCOMBE LABORATORY.

Duties will involve the repair and routine maintenance of a variety of laboratory instruments, in particular equipment for the measurement of radioactive tracers used in the research programme, and also assisting with the development of new equipment. The Laboratory is well equipped with both manual and automated modern instruments.

Minimum qualifications: HNC, Pass degree or equivalent in Electronics or Applied Physics.

Salary Scale £1,435-£2,329 according to qualifications and experience. Superannuation Scheme with a non-pensionable allowance to offset contributions. Application forms and further particulars may be obtained from the Secretary, ref: 1/74, Agricultural Research Council, Letcombe Laboratory, Wantage, OX12 9JT. The closing date for application is 12 June 1974.

[3716

UNIVERSITY COLLEGE CARDIFF

Applications are invited for the following post:

TECHNICIAN GRADE 3 (ELECTRONICS)

for C.C.T.V. and Audio Studio in the Centre for Educational Technology.

Salary range: £1,650-£1,920. Duties include maintenance and operation of T.V., Audio and Projection Equipment: qualification standard O.N.C. or equivalent; interest in photography and Hi-Fi desirable. Duties to commence as soon as possible. Closing date for applications is one week from insert.

Applications, together with the names and addresses of two referees, should be forwarded to The Registrar, University College, P.O. Box 78, Cardiff, CF1 1XL. Please quote 0555. [3725

C.C.T.V. JUNIOR TECHNICIAN

required to assist studio engineer in operation, maintenance and development of a 3-camera colour CCTV system incorporating telecine and U-matic videocassette copying facilities.

Basic knowledge of T.V. theory essential, experience in servicing VTR's and cameras an advantage.

Day release available if required. Salary c. £1,400 p.a. according to age and experience. Luncheon vouchers. Non-contributory pension, free life assurance.

Phone: PETER MAKOSZ at (01) 499 0031, ext. 274. or write with details of experience to:—

**T.V. DEPT.,
HAMBRO LIFE ASSURANCE LTD.,
7 OLD PARK LANE,
LONDON W1Y 3LJ.**

[3728

ELECTRONIC VACANCIES

Engineers

Draughtsmen ● Designers

Service and Test Engineers

Technicians ● Technical Authors

Sales Engineers

£1,600-£5,000 pa

Permanent or Contract

Phone MICHAEL NORTH
01-388 0918
MALLA TECHNICAL STAFF LIMITED
334 Euston Rd., London NW1 3BG

[95

WIRELESS TECHNICIAN

required for

EDINBURGH CITY POLICE

Salary Scale £1,644-£2,040 with placing according to qualifications and experience.

Applicants should have knowledge of V.H.F. and U.H.F. apparatus, also be able to diagnose and repair faults on such apparatus. A current driving licence is also essential. Applications to the: **Recruiting Officer, Edinburgh City Police, Recruiting Department, 7 Chambers Street, Edinburgh, EH1 1HR.**

[3711

SENIOR VIDEO ENGINEER

Senior Video Engineer wanted to operate and maintain telecine and video tape recording equipment for company in Basildon. A.C.T.T. rates honoured. 40-hour week. 18-20 working days holiday p.a. Relocation assistance given. For further particulars contact:

THE E.V.R. PARTNERSHIP
Christopher Martin Road, Basildon Industrial Estate, Basildon

[3717

Find your place in British Gas

TELECOMMUNICATIONS

—Field Maintenance

Eastern Gas are seeking to recruit Technicians for their Communication and Instrumentation Section based at Hertford.
These posts will involve all aspects of maintenance on the Eastern Gas Integrated Communication System.

Technician II (Communications/Instrumentation)

Proven ability in Communications/Instrumentation is a prime requirement for this post. Previous experience with an appropriate equipment manufacturer or user would also be desirable.

Technician II (Message Switching)

The person appointed would specialise in the repair and maintenance of an extensive teleprinter network. He will also, on occasions, assist with the maintenance of the Communications equipment associated with this network.

The salaries for both posts will be about £2,000 per annum depending on age and experience with excellent prospects for promotion to higher grades and salaries rising to approximately £2,500 per annum. A current driving licence is essential.
Write or telephone for application forms quoting reference 3703/4228 to Mr. H. A. Lloyd, Personnel Officer, Eastern Gas, Star House, Potters Bar, Herts., within ten days of this advertisement.

EASTERN GAS

[3724

Join the EMI Service Team at Hayes

EMI

The international music, electronics and leisure Group.

We urgently require

Electronic Repair & Calibration Engineers

required for the repair and calibration of a wide range of electronic instrumentation, including oscilloscopes, DVMs, pulse generators, power supplies etc.

Applicants should be aged at least 18 years and should have had at least two years background in electronics. Further training will be given in appropriate cases.

Close Circuit Television Engineers

for the servicing and commissioning of CCTV, VTRs etc.

Applicants should be aged at least 19 years, and must have had some experience in television receiver servicing.

For both of these positions, starting salary will be up to £2,300 per annum according to age, experience and ability.
37½ hour week, plus paid overtime.

Don't delay, for further details telephone or write to M. Ford, 01-573 3888 Ext. 2268, EMI Service, 254 Blyth Road, Hayes, Middlesex.

3738

We're not absolutely certain that the men we're looking for even exist.

We are Racal-Mobilcal – a world-famous name in radio communications equipment.

We are looking for seven outstanding men to take up new posts as our Technical Managers in seven Middle Eastern countries.

And frankly, the qualities we consider necessary for these positions are so demanding, we know for a fact that there can only be very few men who could make it. Each man must be qualified technically in radio communications, because he will supervise the commissioning, installation and maintenance of mobile radio systems. He will liaise with the armed services and other Government agencies of his particular country. And train their local operatives. He must have the management ability and the diplomatic presence to be able to represent the Company in discussions at the highest level with the country's government and armed services.

He will, in fact, be Racal-Mobilcal's front man, technical adviser and diplomat in residence.

And therefore, ideally, he should have a command of Arabic. (But we'll settle for at least the ability and willingness to learn something of the language rapidly).

That is what we're looking for – seven outstanding men to become Racal-Mobilcal in the Middle East.

In return, this is what we're offering:

An initial four year tour of duty, with generous leave arrangements.

An excellent salary which lines up with the job.

Full accommodation for each successful applicant and his family.

And very good prospects for further promotion within the Racal Group after the initial four year tour.

Joining Racal would be joining a world-famous Group which has achieved record profits for the last eighteen successive years. A world name in electronics. And a world leader in many product areas.

Can you convince us that at least one of the seven men we're looking for does, in fact, exist?

Write in strictest confidence, giving all relevant details, to **David Elsbury, Managing Director, Racal-Mobilcal Ltd, 464 Basingstoke Road, Reading, Berks, RG2 0RY, England.**

Preliminary interviews will be set up at convenient locations.

RACAL
The Electronics Group

[3699

FARINON ELECTRIC OF CANADA

is a leading manufacturer of Microwave Radio and Multiplex equipment located outside Montreal.

Openings presently exist in our Field Department for Commissioning Engineers.

The Job

— Installation, alignment, testing and commissioning of Microwave radio and multiplex systems.
— Involves extensive travel throughout Canada including the Northern Regions.

The Applicant

— Experienced in field system testing of solid state radio in the range 150 MHz to 12 GHz having baseband capabilities to 960 channels or video.
— Fully conversant with state of the art tests and capable of evaluating results obtained.
— Knowledgeable on Microwave propagation phenomenon such as multipath.
— Be eligible for Canadian Landed Immigrant status and driver's licence.

This is a responsible career position offering unusual benefits to the right person.

Please send complete resume to:—

Farinon Electric
657 Orly Avenue
Dorval, Quebec,
H9P 1G1
Canada
Attention: Chas. Henry

[3690

Computer Machinery Company Ltd

require a

Systems/Engineering Instructor

Computer Machinery Company Ltd, the leading UK manufacturer of Key-to-disk data preparation equipment are expanding their Education and Training Department at their new Education Centre, located in Hemel Hempstead, Herts.

The successful applicant will be required to assist the training team with existing courses, the development of new courses and modern training aids.

Essential qualifications for the position include training experience, preferably with electronic digital systems and an ability to absorb new system detail quickly and create new aids and methods to meet our training objectives.

The position offers excellent career prospects and job satisfaction with some UK and Overseas travel. Salary will be negotiable according to relevant experience and relocation expenses could be given where necessary.

Apply in writing or telephone with personal career details to:

Ken Abbott,
Education and Training Manager,
Computer Machinery Company Ltd.,
Maxted Close,
Hemel Hempstead, Herts.
Tel: Hemel Hempstead 61266 Ext. 284

[3704

South Africa TV Design/ Development

A well-known international group requires a capable Design/Development Engineer for its new monochrome TV factory at Pietersburg. He will be responsible for:—

- managing the development laboratory;
- establishing production quality standards;
- ensuring that the model, designed in Europe, conforms to South African design specifications, and
- new components evaluation, including supplier assessment.

Candidates, aged over 30, should have HNC Electronic Engineering with at least five years experience in modern TV development. Experience of solid-state techniques is highly desirable and a knowledge of German would be useful. Two to three months training in Europe will precede appointment to South Africa. Subsequent promotion to Chief Engineer is a possibility.

Pietersburg is a pleasant town in an area of magnificent scenic beauty. At a height of 4,000 feet, it has a superb climate and every amenity.

Please write with full details which will be sent direct to our client. Please list separately any company to whom your application should not be sent.

R. Llewellyn,
MSL ADVERTISING SERVICES LIMITED,
17 Stratton Street, London, W1X 6DB.

[3710

TELEVISION ENGINEER

required to join a small but enthusiastic team operating a

TELEVISION UNIT FOR HORSERACING

If you have an HNC, City and Guilds, or equivalent qualification and have experience in operating and maintaining outside broadcast television equipment and VTRs together with a willingness to travel and to work in a demanding field, then this Company offers you:—

1 the opportunity to join an organisation that is forward looking and is planning to develop and expand in the field of television and electronics;

2 a job that is located in varied surroundings on British racecourses;

3 a basic salary of between £2,700-£2,900 plus expenses when on location.

If you are interested, please write or telephone for a Company form to:—

Mr. F. T. Dixon, Racecourse Technical Services Ltd.,
88 Bushey Road, London, S.W.20
Tel: 01-947 3333

[3712

TELEFUNKEN: SOUTH AFRICA

Television transmission will commence for the first time in South Africa at the end of 1975. Electra Television, the franchise Telefunken distributors in South Africa, will be marketing Telefunken Colour and Black and White receivers during 1975. Our Service Organisation is being vastly expanded, and we are recruiting the following key personnel:—

SERVICE MANAGERS

To be in charge of Service Branches in the major cities in South Africa. Thorough knowledge of all service procedures such as budgeting, costing and invoicing, work progress, stock and staff control as well as a good technical background with particular reference to semiconductor colour receiver circuitry would be desirable. Salaries negotiable from £5,500 per annum.

T.V. INSTRUCTORS

To instruct technicians, apprentices, field service operators as well as trade staff, in the theory and practice of colour television installations and repairs at their respective required levels. Salaries negotiable from £4,000 per annum.

TELEVISION TECHNICIANS

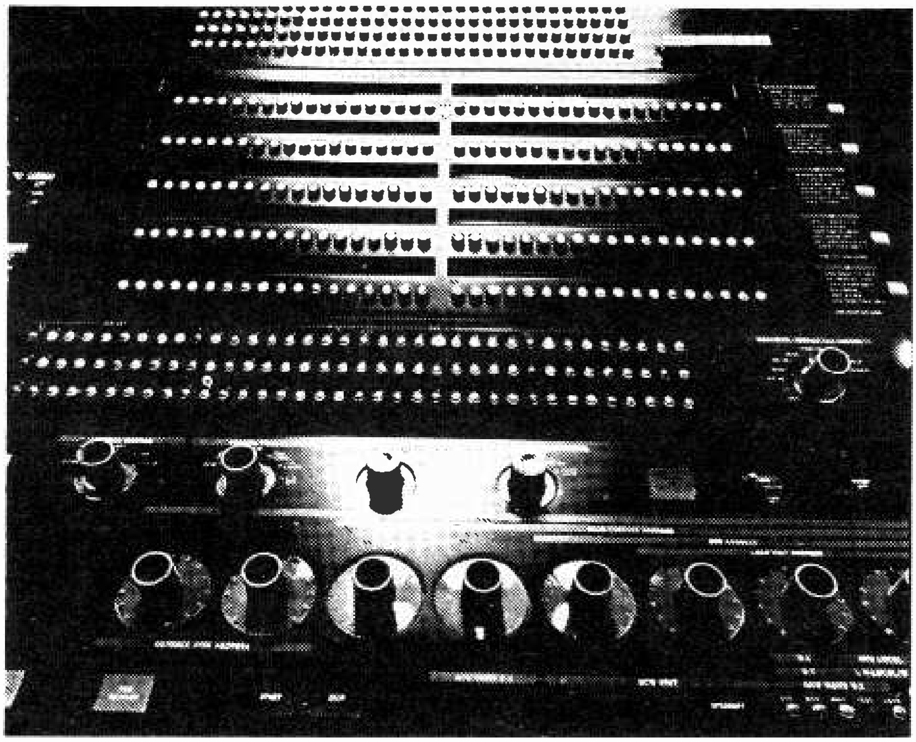
To take charge of all repairs of colour receivers in various centres throughout the Republic of South Africa and in some instances to take charge of a smaller branch or to supervise a group of learner technicians.
Thorough knowledge of the PAL colour systems especially in respect of semi-conductor circuitry is required. Salaries negotiable from £3,500 per annum.

As Telefunken will be a major brand in the South African Market, rapid expansion is expected, leading to promotion and increase in responsibilities. The company operates a Medical Aid Scheme, a Pension Fund and other fringe benefits. Removal and, immigration assistance will be provided.

As interviews will be arranged in May and June, 1974, your application should be addressed as soon as possible to:—

Mr. R. B. Hartog,
C/o Messina (Tvl.) Development Co. Ltd.,
29/30 St. James's Street,
LONDON, SW1A 1HB.

[3713



We want to meet Customer Engineers who understand people as well as machines

Today, IBM Computers play a vital role in industry, science, government and commerce. Just as vital are the skilled Engineers who keep them running. Because of their close involvement with the customer, we call them Customer Engineers. This could be your first step to a highly rewarding future with one of the world's most successful companies.

Your job as a Customer Engineer

There are several avenues within IBM Customer Engineering. At present most of the opportunities lie with our General Systems Group. Here you will be responsible for the servicing and maintenance of medium and large scale Computer Systems. You'll receive a first class training–initial and continuous.

Qualifications

Ideally you should be educated to ONC/HNC or equivalent. Essential requirements are a logical mind, a good mechanical aptitude, and a knowledge of electronics and a current driving licence. A Service background though not essential is desirable.

Your Prospects

Starting salaries are excellent. In addition IBM offer many fringe benefits such as a non-contributory Pension Scheme and free Life Assurance. It is also IBM policy to promote from within.

Write today

Write with details of your age, qualifications and experience to: Anne Dare, IBM United Kingdom Limited, 389 Chiswick High Road, London W.4. quoting Ref. WW/92065.

IBM

[3684

MARINE RADIO SERVICE ENGINEER

As one of the world's leading companies in radio communications equipment and navigational aids, and one of Britain's biggest exporters in this field, we are constantly developing, constantly expanding.
Due to this continual expansion we now require Service Engineers at our Tilbury and Grimsby depots and at our headquarters in Wandsworth to service our marine communications equipment.
Formerly an experienced radio officer, you will have had at least three years experience at sea in the servicing and maintaining of all types of ship borne communications equipment.
We offer an excellent salary and fringe benefits such as contributory pension scheme and sickness benefits.
Write or telephone giving details of career to date to:

DAVID R. STILES
Personnel & Training Officer
Redifon Telecommunications Limited
Broomhill Road, Wandsworth,
London SW18 4JQ
Tel: 01-374 7281

[3753

BRUNEL UNIVERSITY
Dept. of Electrical Engineering and Electronics

RESEARCH IN ELECTRONIC SYSTEMS DESIGN

Applications are invited from recent graduates, preferably with some industrial experience, who hold good honours degrees in Mathematics, Electrical Engineering or Physics to undertake research leading to a higher degree in the following areas:

Computer Aided Design of Digital Systems
Information Processing Systems
Power Electronics Systems
Control Systems Design
Communication Systems

Research studentships will be available for suitably qualified candidates.

Please write to Professor Douglas Lewin, Dept. of Electrical Engineering and Electronics, Brunel University, Uxbridge, Middlesex.
[3732

PROJECT & COMMISSIONING ENGINEER

SHOULD HAVE GOOD THEORETICAL TRAINING IN ELECTRONICS PLUS ACTUAL EXPERIENCE OF PROFESSIONAL AUDIO EQUIPMENT IN BROADCASTING, RECORDING, OR WITH A SPECIALIST MANUFACTURER.

Apply in writing to

MR. R. SWETTENHAM
HELIOS ELECTRONICS LTD.
161 HIGH STREET, TEDDINGTON
MIDDX., TW11 8HT

[3701

S&W

AN ENTHUSIASTIC

Electronics Engineer is required for the servicing of a range of computer-assisted medical equipment. The candidate should have a sound electronic background with some basic knowledge of computer techniques and digital circuitry. Training will be given both in England and in the U.S.A. Preference will be given to applicants residing in the West London area.

Please write for application form to:

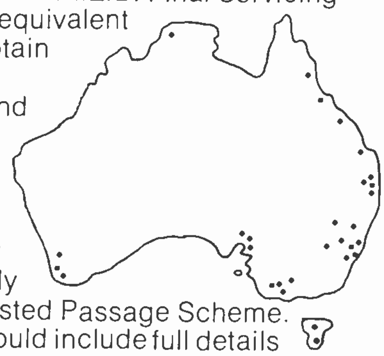
SIMONSEN & WEEL LTD.,
Hatherley House,
Hatherley Road,
Sidcup,
Kent.

3735

RADIO RENTALS AUSTRALIA NEEDS COLOUR TELEVISION TECHNICIANS.

Colour television starts officially in Australia on 1st March, 1975, and Radio Rentals Pty. Ltd., Australia's largest television rental organisation, have an expansion programme which will create vacancies for suitably qualified technicians in Sydney, Melbourne, Brisbane and other centres. Radio Rentals Pty. Ltd. is a member of the Thorn Group of Companies and is associated with the British Radio Rentals organisation.

The vacancies will be of interest to experienced colour television technicians holding the City and Guilds/R.T.E.E.B. Final Servicing Certificate with colour endorsement, or equivalent qualifications, who wish to settle and obtain permanent employment in Australia. All enquiries will be carefully considered and suitable applicants interviewed by an executive of the Company who will be visiting Britain in the near future. Successful applicants will be given firm offers of employment but will make their own arrangements for migration, possibly through the Australian Government Assisted Passage Scheme.



Applications for further information should include full details of personal status and qualifications and be addressed to:—

Mr. H. D. Wallace, Technical Director, Radio Rentals Pty. Ltd., P.O. Box No. 395, Crows Nest, New South Wales 2065, Australia.

[3726

OPPORTUNITIES in the ELECTRONICS FIELD

Men with analogue or digital qualifications/experience seeking higher paid permanent posts in: TEST — SERVICE — DESIGN — SALES.

Phone Roger Pearce, Ref WW4.

NEWMAN APPOINTMENTS
360 Oxford St., W.1.
01-629 7306.

3685

ELECTRONIC TECHNICIAN

required at

NORTHWICK PARK HOSPITAL AND CLINICAL RESEARCH CENTRE

To service and calibrate a wide range of equipment used for medical, surgical and engineering purposes. The successful applicant will work closely with medical and other professional staff.

Salary—Grade III—£1,845-£2,337.

The hospital will have over 800 beds by 1975 and is closely allied with the Clinical Research Centre. Good staff facilities and a pleasant working atmosphere. Active social club. Temporary single accommodation may be available.

Further particulars and application forms, returnable by June 14th, from Personnel Department, Watford Road, Harrow, Middlesex, HA1 3UJ. Tel: 01-864 5311.

[3740

TECHNICIANS AND ENGINEERS FOR ST. ALBANS AND LUTON

QUALIFIED OR NOT!

OPPORTUNITIES for challenging work on testing and calibrating valve and solid-state electronic measuring equipments embracing all frequencies up to u.h.f. in Production, Service and Calibration departments.

APPLICATIONS are invited from people of all ages with experience or formal training in electronics and from Ex-Services technicians.

HIGHLY COMPETITIVE SALARIES, negotiable and backed by valuable fringe benefits. Overtime normally available.

GENEROUS RE-LOCATION EXPENSES available in most instances.

CONDITIONS excellent; free life assurance, pension schemes, canteen, social club.

$37\frac{1}{2}$ hour, 5-day, working week.

WRITE or phone for application forms quoting reference WW

MARCONI INSTRUMENTS LTD,
Longacres, St. Albans, Herts
Tel: St. Albans 59292
Luton Airport, Luton, Beds
Tel: Luton 33866

A GEC-Marconi Electronics Company

THE QUEEN'S AWARD TO INDUSTRY 1971

94

DEVON AREA HEALTH AUTHORITY
PLYMOUTH HEALTH DISTRICT

ELECTRONICS TECHNICIAN

required to work on a varied and interesting range of biomedical tasks in an expanding well-equipped maintenance and development laboratory at Freedom Fields Hospital, Plymouth. The person appointed will join a small team responsible (to the Chartered Electronics Engineer) for the successful operation of a wide range of patient-orientated equipment. Development, construction and testing of special-purpose equipment is undertaken and safety and purchase decisions are made on new equipment. Some travel in South Devon and in Cornwall necessitates a current driving licence. Relevant experience is desirable and the minimum qualification is ONC (equivalent). The appointment will be in either of the following grades, depending on experience. (Salary scales are under review).

Medical Physics Technician IV— £1,530-£1,953

Medical Physics Technician III— £1,719-£2,211

Further details of the work may be obtained from Mr. L. R. Jenkin, Telephone PLYMOUTH 68080, Ext. 369.

Application forms from the Hospital Secretary, North Friary House, Greenbank Terrace, Plymouth PL4 8QQ.

[3693

Electronics Engineers up to £5000

Many jobs which would suit you down to the ground – either in the U.K. or overseas – are never advertised. Yet it will cost you nothing whatever to give yourself the opportunity to be considered for them.

Join the Lansdowne Appointments Register – used by hundreds of employers to select electronics engineers. You have nothing to lose, everything to gain – and it's all conducted in strict confidence. So post the coupon – find out exactly how you can make use of a service which is all the more valuable for being free!

To: Stuart Tait, Lansdowne Appointments Register, Design House, The Mall, London W5 5LS. Tel: 01-579 6585 (anytime – 24 hour answering service).

Please send me further details.

Name ....

Age (20-45 only) ....

Address ....

....

.... WW 22/5

lansdowne Appointments Register

97

Opportunities in Telecommunications

Men with a good telecommunications knowledge are required to be responsible for the telephone switching and transmission equipment on London Transport.

The work involves shift duties and consists of maintaining, testing and fault finding on the following types of equipment:—

(a) Automatic Telephone Exchanges and associated equipment.

(b) Multi-channel Carrier Systems and associated equipment.

A sound knowledge and experience of one of these categories of work is required. The possession of City and Guilds Certificates (or equivalent) in telecommunications subjects would be an added advantage.

The rate of pay, including variable bonus, averages £35.00 for a 5 day (40 hour week). Additional payments are made for overtime, night work and rostered Saturday and Sunday duties. Current weekly earnings, including payment for rostered overtime at week-ends, average £45.00. (These rates of pay are currently under review).

These positions offer valuable free travel on and off duty, certain privilege conditions for employees and dependants, and sick pay and pensions schemes.

Please apply in writing to:—London Transport (Ref: ATL), Chief Signal Engineer's Department, 270 Bollo Lane, Acton, W.3. or Telephone: Mr. Crowder, 01-748 9564.

LONDON TRANSPORT

3698

QUANTEL LIMITED

an expanding electronics company specialising in the APPLICATION OF DIGITAL TECHNIQUES TO TELEVISION requires a

GROUP LEADER

Applicants must have had at least five years' experience in the design of broadcast television equipment using both analogue and digital circuit techniques.

The successful candidate will lead a team devoted to the development of large complex digital video processing equipment.

Conditions of service and salary will be commensurate with the level of responsibility inherent in this post.

DEVELOPMENT ENGINEERS

Qualified development engineers with appropriate experience in the broadcast equipment field are also required to support the current programme of work.

The company provides first class opportunities for career development in modern well-equipped laboratories situated in the céntre of Newbury, Berkshire.

Please apply to:

The Personnel Officer
19 West Mills
Newbury, Berkshire
or telephone Newbury 5895

[3702

LABORATORY TECHNICIANS

BBC requires resourceful and energetic Laboratory Technicians for Equipment Department, Power Road, Chiswick (within easy reach of Gunnersbury Station).

The work is interesting and involves testing new electronic equipment made by the BBC for its colour television and stereo radio services. The work also covers analogue and digital techniques over a frequency range from d.c. to U.H.F.

Salary in the range £1,575 to £1,989, rising to a maximum of £2,268 per annum. Good opportunities for promotion to Senior Technician (salary max. £2,565) and Engineering Technician (salary max. £2,940).

Applicants lacking suitable experience may be placed initially on a training grade. Facilities available to obtain approved technical qualifications.

Good club and canteen facilities. 3 weeks annual leave initially. Pensionable posts.

Write for application form to: Engineering Recruitment Officer, BBC, Broadcasting House, London, W1A 1AA quoting reference 74E4028WW and enclosing addressed foolscap envelope. Closing date for completed application forms, 10th June 1974.

3683

BBC

DIRECTOR-COMMUNICATIONS BRANCH

. . . to represent the Scottish Home and Health Department on Central Government Committees and to discuss telecommunication systems with police, fire, prison and other Services for which the Department is responsible. The successful candidate will manage a professional branch engaged in the examination of problems associated with the planning, design, progressing of installation and maintenance of such systems. These include mobile radio, message switching and telephone systems, and networks and terminals to interface with computer based data processing and command and control systems. R & D work in these fields is also involved.

Candidates must be competent administrators with a wide knowledge of modern telecommunications practice both radio and line, and have appropriate experience of systems planning. They must be corporate members of IEE or IERE (1962 Regulations), or have equivalent academic qualifications. A broad knowledge of computer systems and peripherals an advantage.

Starting salary within the scale £6,300-£7,141. Non-contributory pension scheme.

For full details and an application form (to be returned by 17 June 1974) write to **Scottish Office,** Room 213, Personnel Division, 22/25 Queen Street, Edinburgh, EH2 1LY, quoting reference T/8617.

Scottish Home and Health Department [3719

Service Engineer

for Audio/Hi-Fi Department.

Good practical knowledge of leading makes. Attractive employment terms.

Write or telephone for appointment to:

JOHN KING (FILMS),
71 East Street, Brighton
Tel: 25918/27674

[3654

Small but rapidly expanding small Marine Electronic Company based in the South West seeks two ex-Marine Radio Officers—for installation and service work on small commercial craft and yachts.
Brief resume to:

BOX NUMBER W.W. 3707

SITUATIONS VACANT

CAN YOU WRITE CLEAR, concise technical handbooks? If you think you could, and have a thorough understanding in electronics, why not join us as a technical author. Obviously, previous experience would be an advantage but is not necessary as full training would be given. We have vacancies in many parts of the country. Starting salaries are high with excellent prospects for advancement. Box No. WW 3414.

ELECTRONICS TECHNICIAN Grade 3 required to assist in the construction, modification and maintenance of the electronic equipment in the Biophysics Department at Drury Lane, W.C.2. The work is varied and interesting and covers a wide range of analogue and digital techniques. O.N.C. or equivalent minimum qualification. Salary £1825 on scale rising to £2075 per annum including London Weighting. Apply in writing giving full details of experience and qualifications to The Head Clerk (Ref: WW 118324), King's College London, Strand, WC2R 2LS. [3425

HI-FI AUDIO ENGINEERS. We require experienced Junior and Seniors and will pay top rates to get them. Tell us about your abilities. 01-437 4607. [19

MEDICAL Physics Technician Grade III or II required in a small electronics laboratory with an existing staff of three. The laboratory is responsible for the maintenance and modification of all types of measuring and recording equipment. Good opportunities exist for original work in this area. Salary scale £1,719 to £2,211 or £2,040 to £2,661 p.a. plus £126 p.a. London Weighting. Application forms from: Mr. J. Norman, National Heart Hospital, Westmoreland Street, London, W1M 8BA. [3687

OXFORD University. Nuclear Physics Laboratory. Electronic Technician. A vacancy exists for a Technician in the Electronics workshop. Duties include servicing and maintaining a wide range of digital and analogue electronic equipment used in nuclear structure research, and the development and construction of new equipment. Applicants should possess a theoretical knowledge to about H.N.C. standard and a formal qualification would be an advantage. Proven practical ability in the field is considered essential. Salary will be within a range rising to £2,382, with eight weeks paid annual leave. Day release for relevant studies may be granted if appropriate. Applications giving full particulars of age, experience and qualifications should be sent to:— T. E. Green, Nuclear Physics Laboratory, Keble Road, Oxford. (Mention reference A.15.) [3696

PIANO P.C.B.'s for W.W. Electronic pianos. Enquiries to Baldock Electronics, 23 Turpins Way, Baldock, Herts. Tel: Baldock 2559. [3670

SEPTEMBER 74. Radio & Television Engineer, with full C & G Certificate or HNC Electrical Engineering plus Teaching Qualification and industrial and teaching experience. Apply Principal, Bermuda College Dept. of Commerce and Technology, Friswell's Hill, Devonshire, Bermuda 4-04. [3385

YOUNG ELECTRONICS TECHNICIAN required for the construction, testing and servicing of electronic equipment at our works in N.W.1. Very varied work. Qualifications: ONC or C&G or ex-apprentice or similar desirable. Excellent opportunity for right person with a small expanding company. Please write for an application form to: Young Electronics Ltd., 54 Lawford Road., London, NW5 2LN. [3641

ARTICLES FOR SALE

AARVAK ELECTRONICS, 3-channel sound-light converters, from £18. Strobes, £25. Rainbow Strobes, £132.—12A Bruce Grove, N17 6RA. 01-808 9096. [23

BUILD IT in a DEWBOX quality plastic cabinet 2 in. x 2½ in. x any length. D.E.W. Ltd. (W.), Ringwood Rd., Fernwood, Dorset. S.A.E. for leaflet. Write now—Right now. [76

AMPEX FR 1400 14-channel Instrumentation Tape Recorder, £375. Ekco M5024 ttl Timer-Counter, £27. Solartron CD1400 db Oscilloscope. £125. Friden 8-hole paper tape punch & read units. £15 pair. Hewlett Packard Series 3900 12.5mm Tape Unit, £75. D.C. Amplifier, £4.50. Friden Flexowriter, programmatic, £125. Richard Totman. Gayefere, East Hill, Otford, Kent. Otford 3256. [3420

BACK NUMBERS from 1950 to 1962 of Wireless World, Practical Wireless and Radio Constructor for sale. Tel: 061-973 2519 [3406

ETHERMATIC 2 Automatic test equipment for production testing of audio equipment, consisting of 80 column card reader, Solartron 1426 D.V.M., Hewlett Packard 565A print out. Oscillator units, psu, etc., complete or will separate. Teleprinters 7B, £12. buyer to collect. Denby, 104 Rooley Lane, Bradford. [3419

CONSTRUCTION AIDS—Screws, nuts, spacers etc., in small quantities. Aluminium panels punched to spec. or plain sheet supplied. Fascia panels etched aluminium to individual requirements. Printed circuit boards—masters, negatives and board, one-off or small numbers. Send 6p for list. Ramar Constructor Services, 29 Shelbourne Road, Stratford on Avon, Warwks. [28

FURZEHILL Spectrum Analyser. Type 14526 3-30 MHz. As new. Marconi Spectrum Analyser. Type OA1094. 0-30 MHz with LF convertor. Good condition. 2—REDIFON GR410 SSB Tx/Rx with 24 volt transistor PSU. Good condition. 1—TF885A/1 Video Oscillator. 0-12 MHz. Good condition. 1—TF1165 Counter. As new. 1—TF1246 Oscillator. 40 KHz to 50 MHz. As new. 1—RT264/UPX6 Tx/Rx. Good condition. Offers are invited for single items, or as one lot. Please reply to North West Electrics. 769 Stockport Road, Levenshulme, Manchester 19. Phone: 061-224 4911. 9.30 am-6 pm Tues-Fri. 9 am-5 pm Sat. Closed all day Mondays. [3718

GENEVAC EC/12/4/1 vacuum coating unit. Substrate heater rotary work holder as new. Offers 061-428 3235. [3458

LADDERS 8ft 10in closed—21ft extended, £23.54, delivered. Home Sales Ladder Centre (WW2), Haldane (North) Halesfield (1) Telford, Shropshire. Tel: 0952-586644. [23

NIFFTY POWER SUPPLY—Ideal as a cassette recorder/radio battery eliminator—constructed in a neat plastic case, 10cm x 6cm x 5.5cm—consists of a mains transformer followed by a transistor regulator giving 8V. DC. at 225mA. This voltage could be adjusted by changing the zener in the regulator. Circuit and details supplied. A bargain at £1.50 including P. & P. Mail order only. Chris Harries, 2 Newlands Ave., Shirley, Southampton, SO1 5ER. [3417

PRINTED Circuit Board in 6 widths: 2 in., 2½ in., 3 in., 3½ in., 4 in. and 5 in. x any length; 1/16 in. single-sided fibreglass, 2p per 3 sq. in. Double-sided 1p per sq. in. P & P 5p per order. SAE quotations for other sizes and quantity discounts.—J. Knopp, 11 Connaught Gardens, Braintree, Essex, CM7 6LY. Tel. Braintree 25254. [15

RADIO TELEPHONE EQUIPMENT. Expand your radio telephone system. 12½ kc. G.P.O. approved units. PYE. COSSOR, G.E.C., ULTRA-BURNDEPT, etc., High Band. Marine. Lowband AM and FM. Exports to Africa and Middle East. Spa-Radio, 335/337. High Road, Cheltenham, Glos. [3229

SUPERB Instrument Cases by Bazelli, manufactured from heavy duty PVC faced steel, choice of 30 types, send for free list. Bazelli Instrument Cases. Dept, 22, St. Wilfrids, Foundry Lane, Halton, LA2 6LT, near Lancaster. [3646

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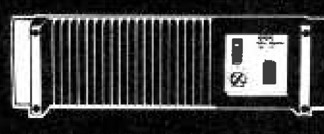

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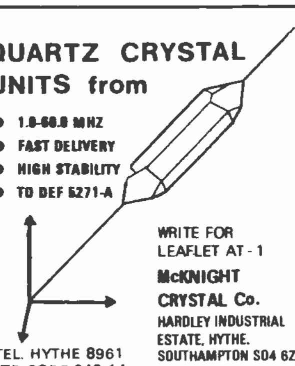

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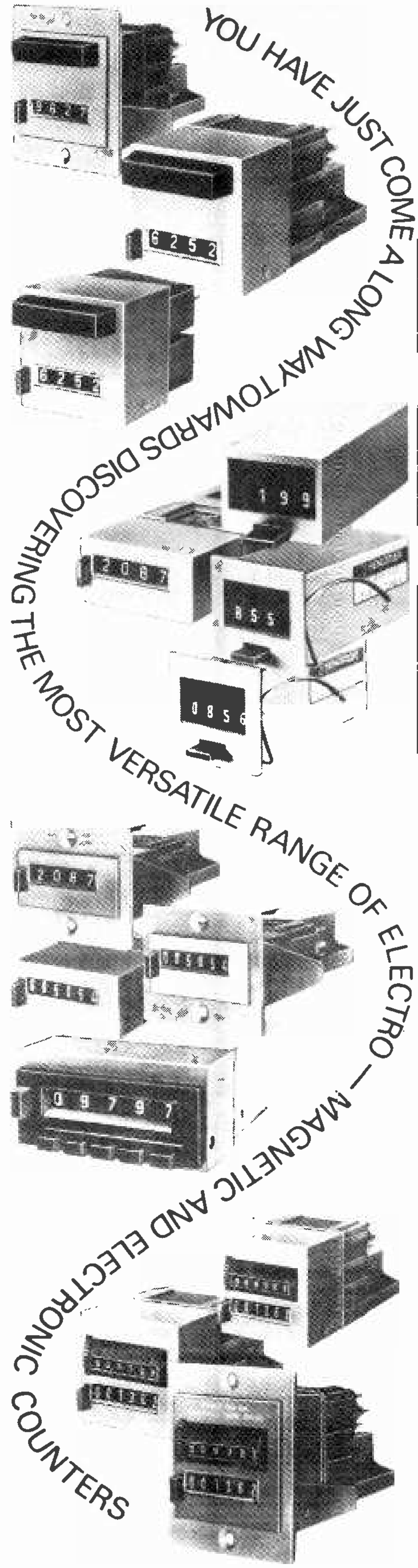

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Sensitivity	5mV/cm–10V/cm (Cascaded 500μV/cm calibrated with 4% accuracy.)	5mV/cm–5V/cm (Cascaded 1mV/cm approximate, uncalibrated.)
Y Accuracy	±2%	±3%
Inversion facility	Y1+Y2	Y2 only
Phase difference (X/Y plotting)	1° DC to 50kHz	3° DC to 50kHz
TIMEBASES		
Timebase accuracy	±3%	±2%
Input impedance	1MΩ into 18pF	1MΩ into 20pF
Main and delaying timebases	YES	YES
Mixed sweep	YES	YES
Timebase ranges	5ns/cm–1.0s/cm	5ns/cm–0.5s/cm
Mixed trigger facilities	YES, independent of shift controls	YES, but not independent of shift controls
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Automatic trigger	Preset level adjustment	Manual level adjustment
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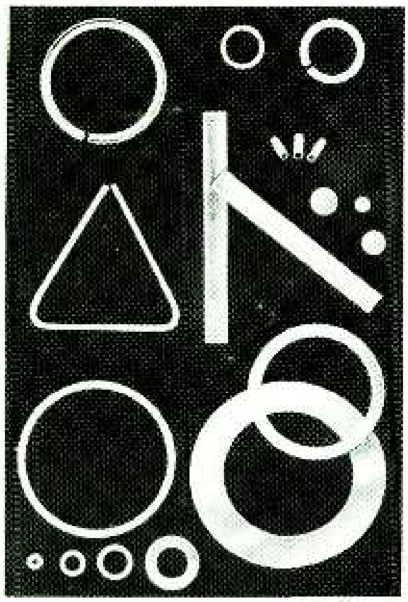

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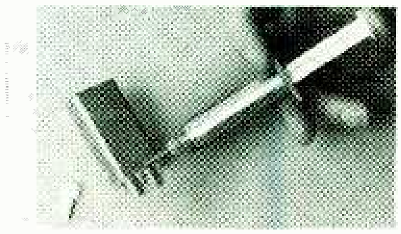

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Alloy Composition	62/36/2 Sn/Pb/Ag	60/40 Sn/Pb	96/4 Sn/Ag
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