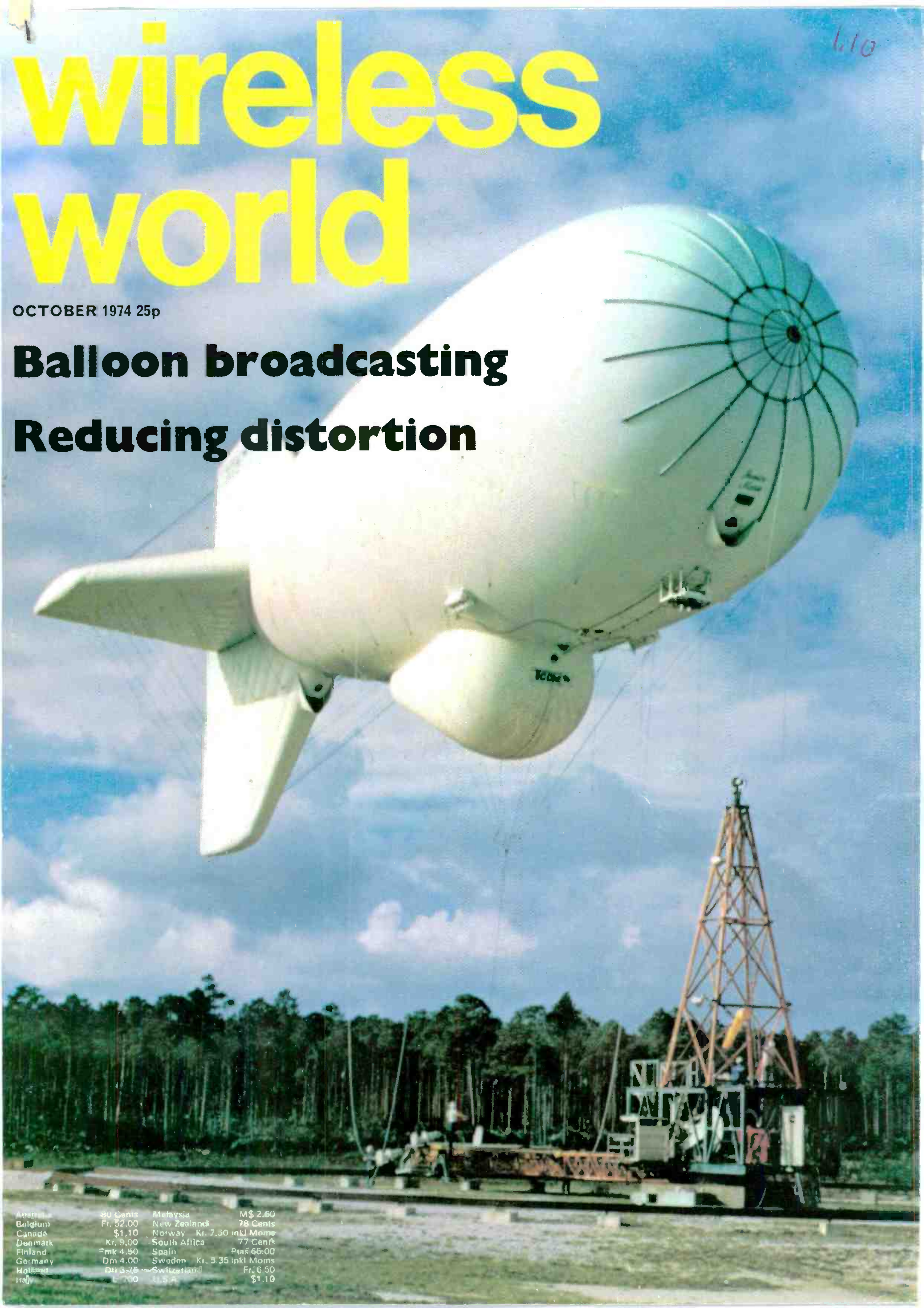
wireless world

OCTOBER 1974 25p

Balloon broadcasting

Reducing distortion



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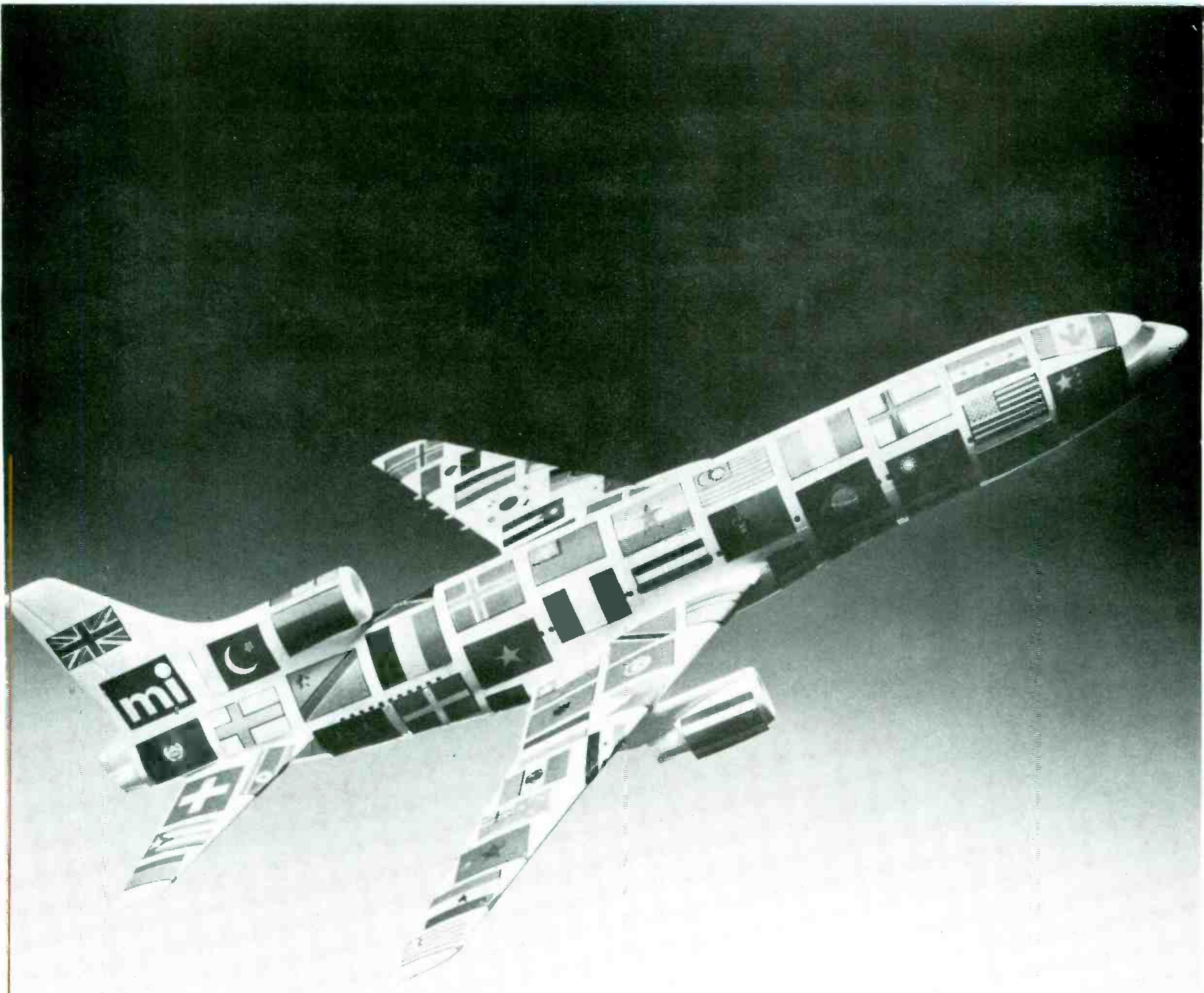
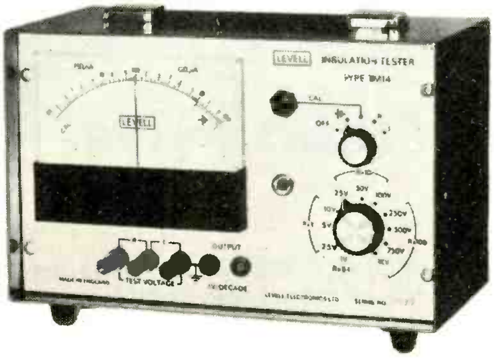


LOW COST TESTERS

LEVELL
PORTABLE INSTRUMENTS

INSULATION TESTER



A logarithmic scale covering 6 decades is used to display either insulation resistance or leakage current at a fixed stabilised test voltage. The current available is limited to a maximum value of 3mA for safety and capacitors are automatically discharged when the instrument is switched off or to the CAL condition. The instrument operates from a 9V internal battery.

RESISTANCE RANGES

10M Ω to 10T Ω (10^{13} Ω) at 250V, 500V, 750V and 1kV.
1M Ω to 1T Ω at 25V, 50V and 100V.
100k Ω to 100G Ω at 2.5V, 5V and 10V.
10k Ω to 10G Ω at 1V.
Accuracy ±15% +800 Ω on 6 decade logarithmic scale.
Accuracy of test voltages ±3% ±50mV at scale centre.
Fall of test voltages < 2% at 10µA and < 20% at 100µA.
Short circuit current between 500µA and 3mA.

CURRENT RANGE

100pA to 100µA on 6 decade logarithmic scale.
Accuracy of current measurement ±15% of indicated value.
Input voltage drop is approximately 20mV at 100pA, 200mV at 100nA and 400mV at 100µA.
Maximum safe continuous overload is 50mA.

MEASUREMENT TIME

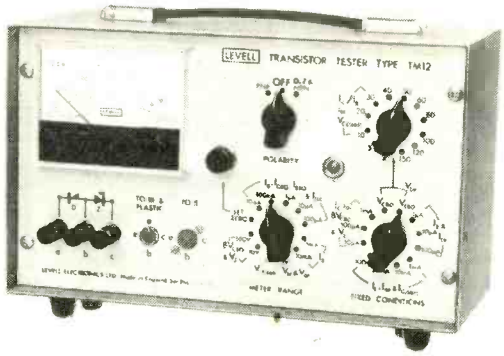
< 3s for resistance on all ranges relative to CAL position.
< 10s for resistance of 10G Ω across 1 µF on 50V to 500V.
Discharge time to 1% is 0.1s per µF on CAL position.

RECORDER OUTPUT

1V per decade ±2% with zero output at scale centre.
Maximum output ±3V. Output resistance 1k Ω.

type TM14 **£77**

TRANSISTOR TESTER



Tests bipolar transistors, diodes and zener diodes. Measures leakage down to 0.5 nA at 2V to 150V. Current gains are checked from 1µA to 100mA. Breakdown voltages up to 100V are measured at 10µA, 100µA and 1mA. Collector to emitter saturation voltage is measured at 1mA, 10mA, 30mA and 100mA for I_C/I_B ratios of 10, 20, 30. The instrument is powered by a 9V battery.

TRANSISTOR RANGES (PNP OR NPN)

I_{CBO} & I_{EBO}:	10nA, 100nA, 1µA, 10µA and 100µA f.s.d. acc. ±2% f.s.d. ±1% at voltages of 2V, 5V, 10V, 20V, 30V, 40V, 50V, 60V, 80V, 100V, 120V, and 150V acc. ±3% ±100mV up to 10µA with fall at 100µA < 5%+250mV.
BV_{CBO}:	10V or 100V f.s.d. acc ±2% f.s.d. ±1% at currents of 10µA, 100µA and 1mA ±20%.
I_B:	10nA, 100nA, 1µA . . . 10mA f.s.d. acc. ±2% f.s.d. ±1% at fixed I_E of 1µA, 10µA, 100µA, 1mA, 10mA, 30mA, and 100mA acc. ±1%.
h_{FE}:	3 inverse scales of 2000 to 100, 400 to 30 and 100 to 10 convert I_B into h_{FE} readings.
V_{BE}:	1V f.s.d. acc. ±20mV measured at conditions on h_{FE} test.
$V_{CE(sat)}$:	1V f.s.d. acc. ±20mV at collector currents of 1mA, 10mA, 30mA and 100mA with I_C/I_B selected at 10, 20 or 30 acc. ±20%.

DIODE & ZENER DIODE RANGES

I_{DR}:	As I_{EBO} transistor ranges.
V_Z:	Breakdown ranges as BV_{CBO} for transistors.
V_{DF}:	1V f.s.d. acc. ±20mV at I_{DF} of 1µA, 10µA, 100µA, 1mA, 10mA, 30mA and 100mA.

type TM12 **£77**

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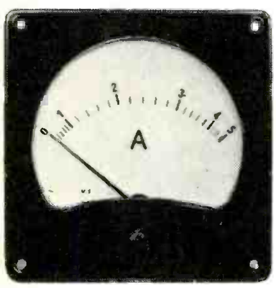
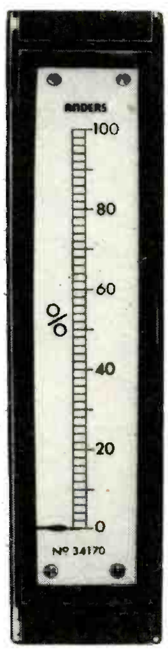
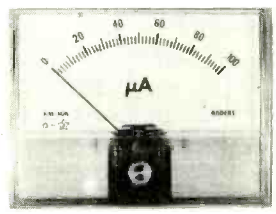


Vulcan Moving Iron. 4 models, 1·5″, 1·8″, 2·7″, 3·7″ scales. Voltmeters, ammeters and motor starting meters.

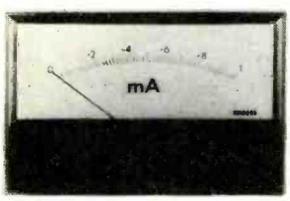


Profile 350 edgewise 4·3″ scale.
DC moving coil and AC moving coil rectified.
Horizontal or vertical mounting.

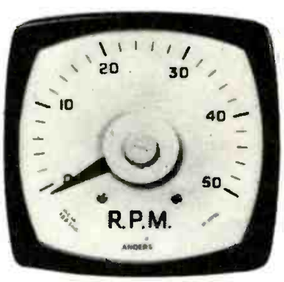
Recorders 60 or 120 mm. charts. Non-ink marking. DC moving coil and AC rectified.



Kestrel Clear Front. 7 models, 1·3″ – 5·25″ scales. DC moving coil, AC moving coil rectified, AC moving iron.



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



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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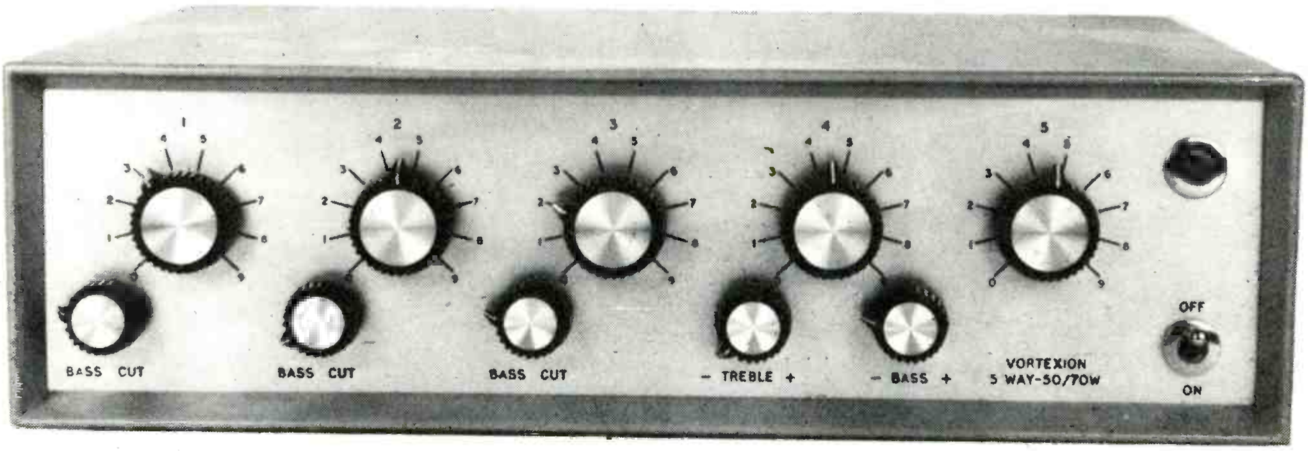

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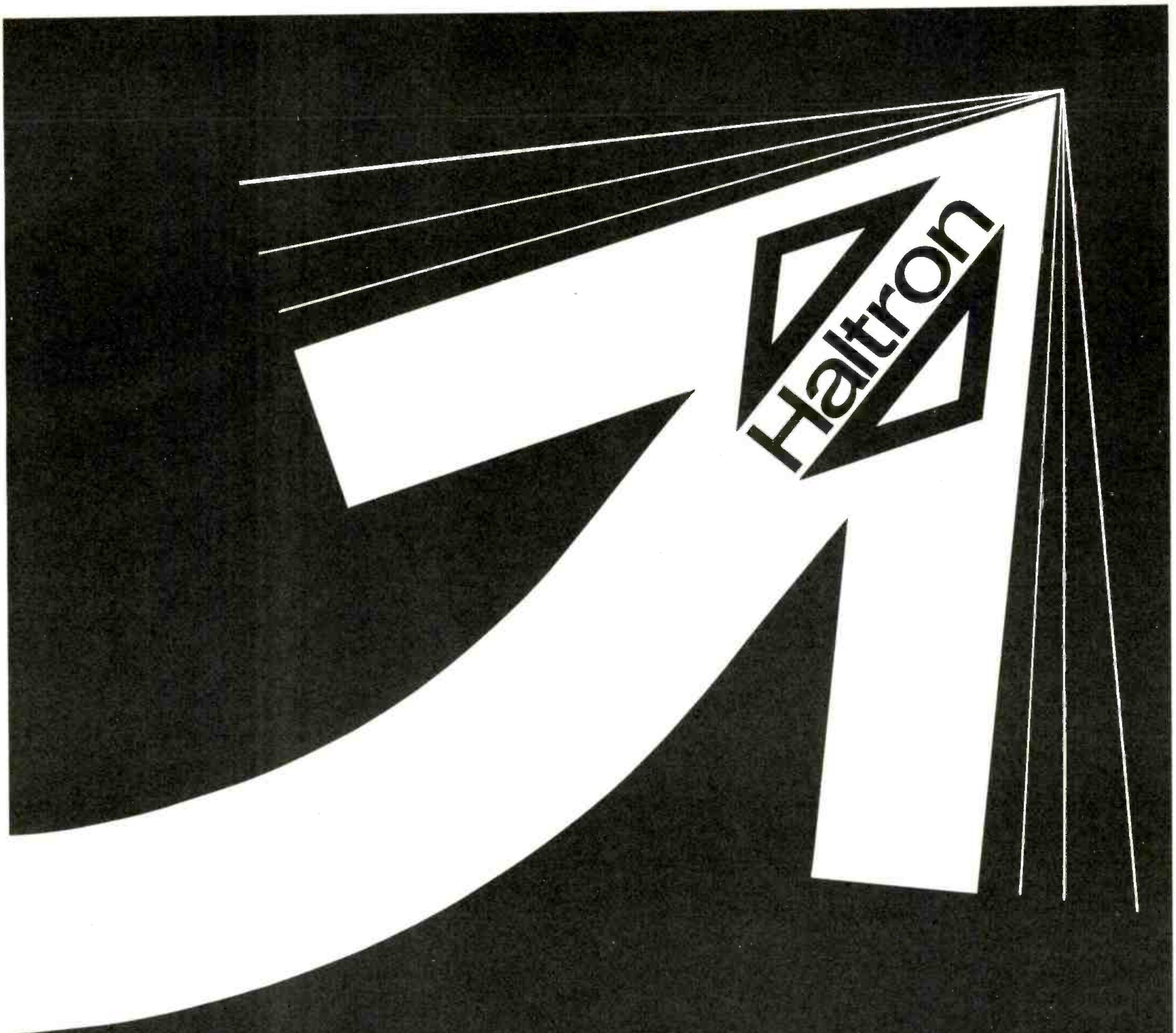

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You could easily make our 12-speed chart recorder faster than you thought possible.

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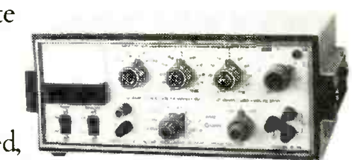
Otherwise just clip the coupon and we'll send you the complete Heathkit catalogue.



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Wayne Kerr's B224 and B642

The B224 is a manually operated bridge, the resistive and reactive terms being independently set to a null indicated on the meter. A rechargeable battery is fitted in order to make the instrument portable.

The B642 balances itself automatically. The meters read real and quadrature terms and highly stable analogue outputs are provided which are directly proportional to capacitance and conductance above 10Ω impedance and also to inductance and resistance below 10Ω. One or two decades can be set to provide the first significant figures of the measurement, thereby increasing the meter sensitivity by 10 or 100 times. If a chart recorder is connected to the output of either term, drifts in component values to at least four significant figures can be observed.

SPECIFICATION

	B224 (Manual balance)		B642 (Autobalance)	
Frequency	1592Hz (internal) 200Hz – 50kHz (external)		1592Hz (internal) 200Hz – 20kHz* (external)	
Ranges for specified accuracy				
	0.1%	0.3%	0.1%	0.3%
C	100fF – 10μF	10μF – 10mF	1pF – 10μF	10μF – 10mF
G	1n℧ – 100m℧	100m℧ – 1k	10n℧ – 100m℧	100m℧ – 100℧
L	1mH – 10kH	100nH – 1mH	1mH – 10kH	1μH – 1mH
R	10Ω – 1GΩ	1mΩ – 10Ω	10Ω – 100MΩ	10mΩ – 10Ω

NOTE: 0.1% accuracy relates to parallel component measurements above 10Ω impedance. 0.3% accuracy relates to series component measurements below 10Ω impedance.

**Manual operation only.*

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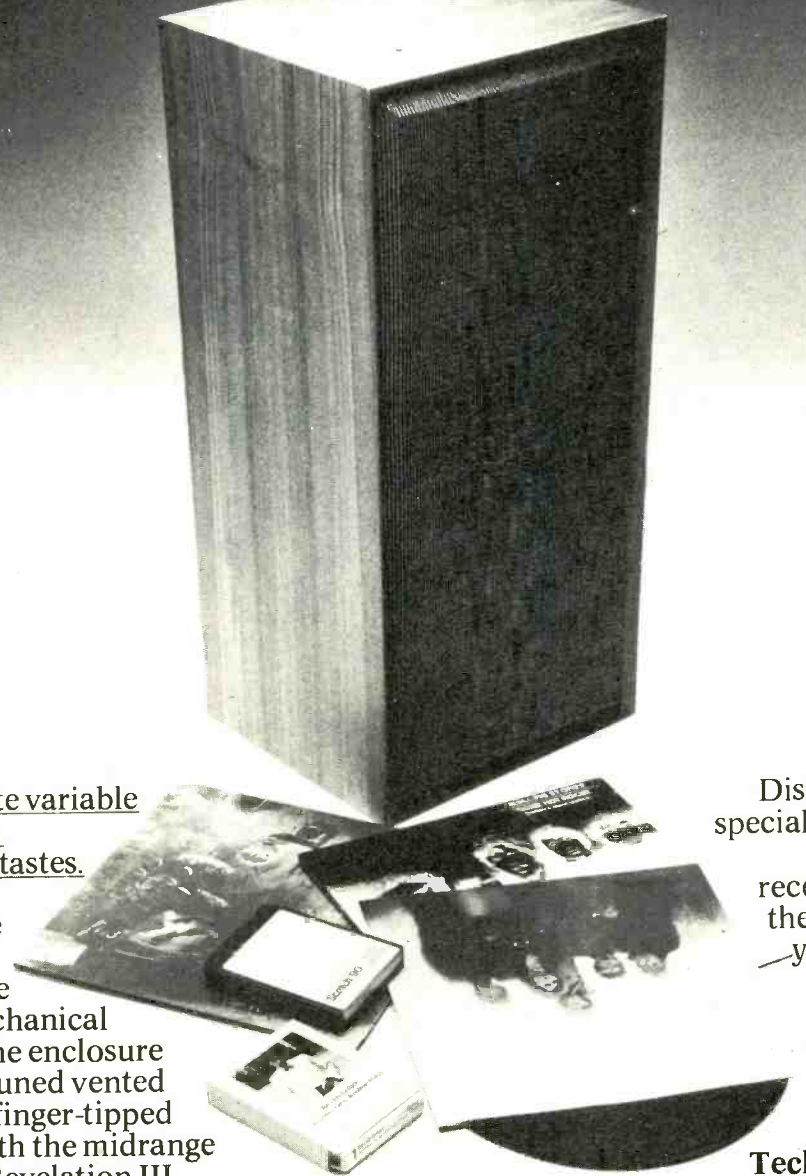

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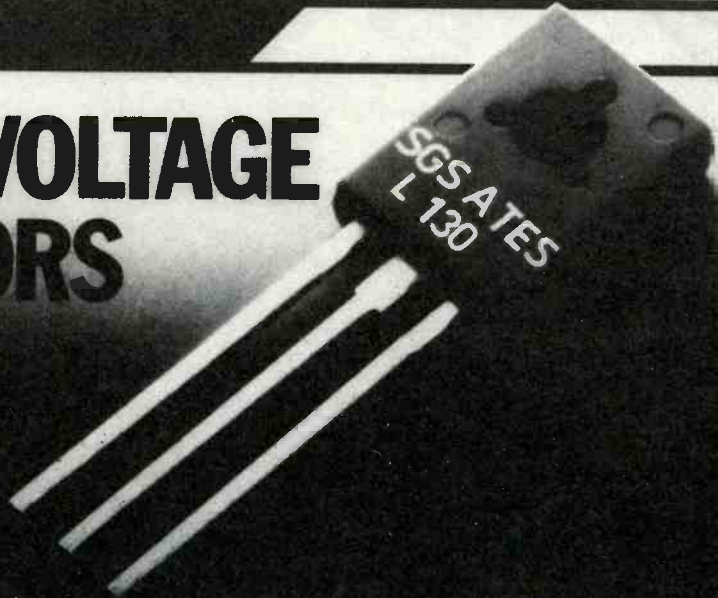
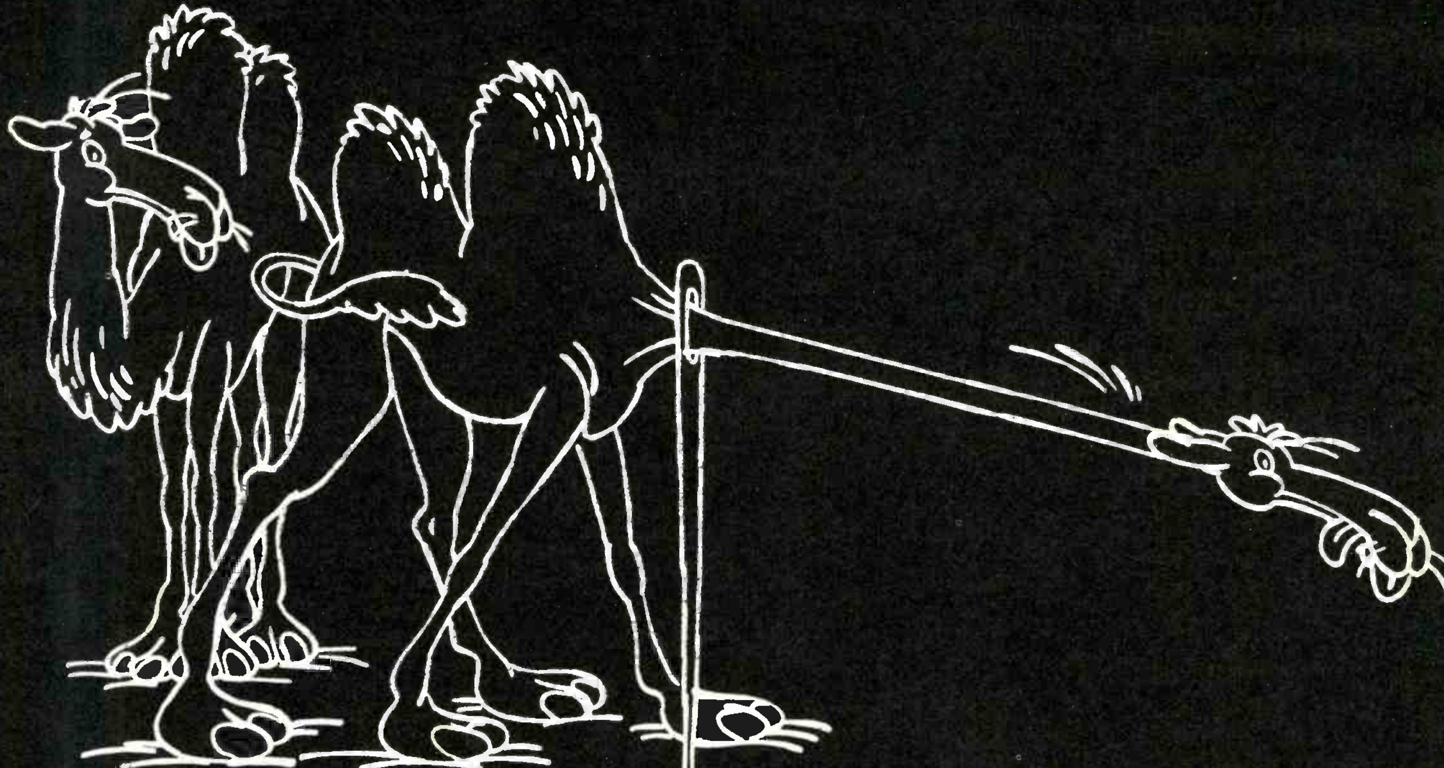
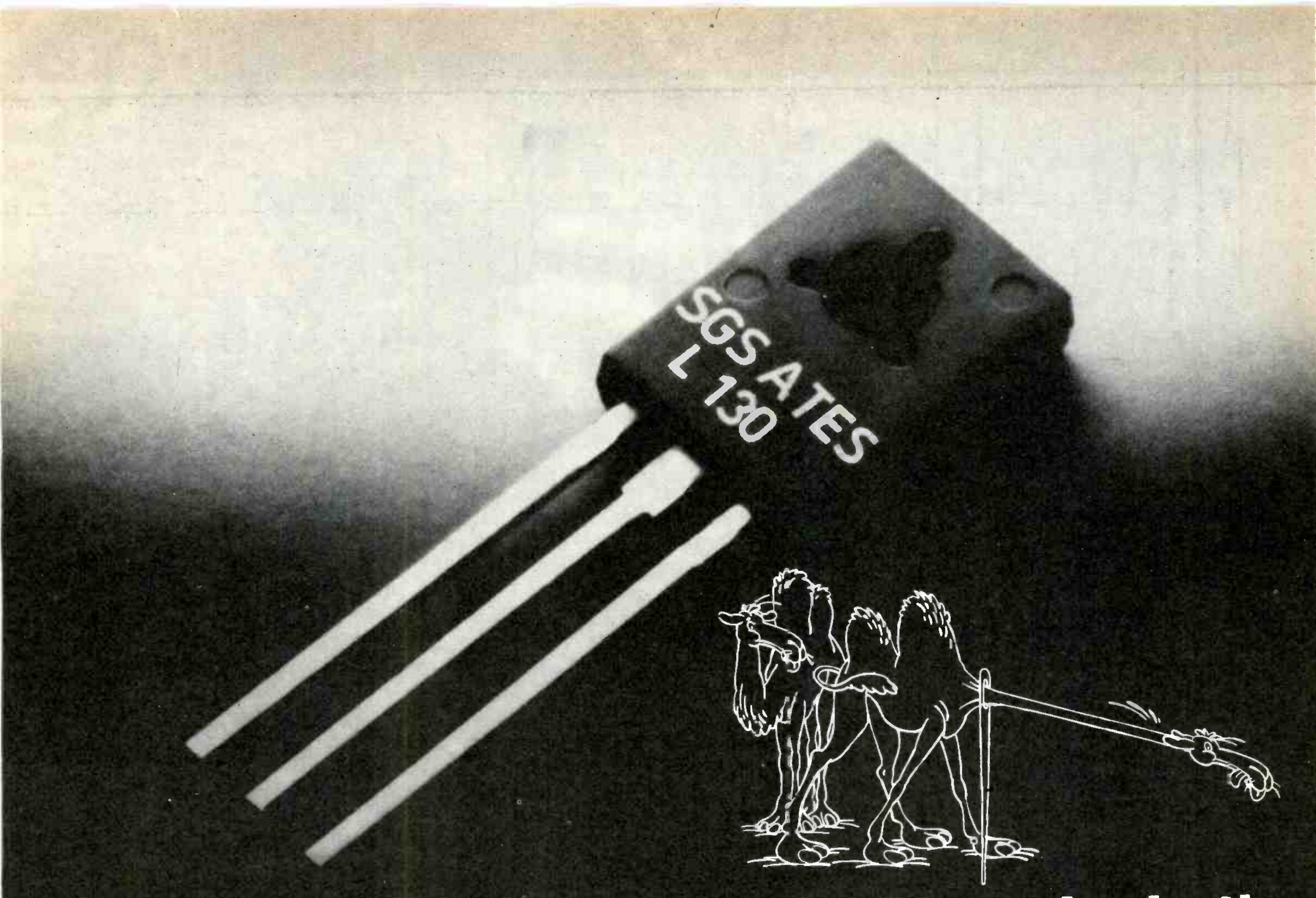


A regular and constant output



whatever the input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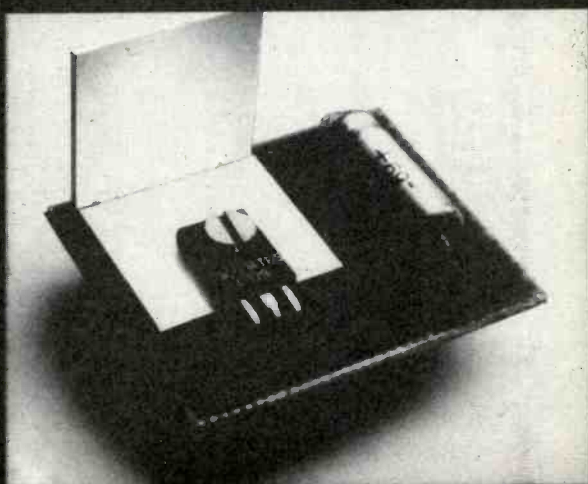
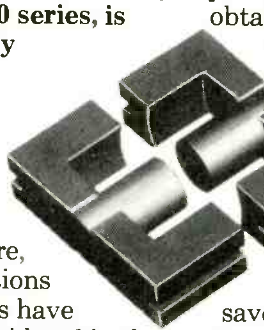


NEW CORES SPECIFICALLY FOR SWITCHED MODE POWER

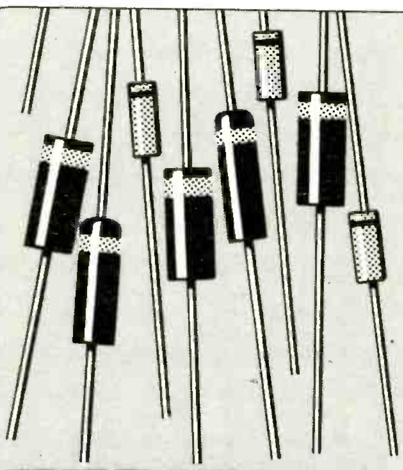
Designers of switched mode power supplies no longer have to use transformer cores of a material and shape which are meant for quite different applications. A new range of ferrite cores being introduced by Mullard, the FX3700 series, is intended specifically for the job.

Insulation and safety, the special stresses of switched mode operation, winding economics, modes of circuit failure, mechanical specifications and BSI requirements have all been carefully considered in the design.

The cores may be used in units where the input is derived from rectified mains or from batteries, and are suitable for designs covering a wide range of outputs. When used in 25kHz push-pull circuits at the unfavourable end of the application spectrum (supplying low voltage, 5V, output) d.c. output powers from 50W to 500W can be obtained. Higher outputs can be obtained in more favourable applications, and the cores can, of course, also be used in single-ended circuits.



An application note is available which not only simplifies transformer design but helps to save time, money and trouble elsewhere in the circuit. For a free copy and data on the cores please write to Dept. C.I.H., Ref: CPS/C23, Mullard Ltd., New Road, Mitcham, Surrey CR4 4XY.



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1-WATT TYPES

BZX61: DO-15 plastic encapsulation
7·5 to 75V
SOSWIFT Service and SELECT 61 Bulk Selection Service

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Please use reader enquiry service no. WW073 for data on all of the above types.

Linear power for S.S.B.

Three highly linear r.f. power transistors for single-sideband applications from manpacks to ship-to-shore transmitters are available from Mullard.

In all three the intermodulation products are typically more than 30dB down on full rated output. Under some conditions this figure is even better than 40dB. Furthermore, all three are electrically rugged and can withstand severe load mismatch.

The most powerful member of the family is the BLX15. Operating from supplies of up to 50V in the range 1·6 to 28MHz, it can supply 150W p.e.p. singly or 300W p.e.p. in push-pull. Also, the full power rating is maintained up to 108MHz in the c.w. mode.

The two companion types, the BLX13 and BLX14, operating from 24/28V supplies over the range 1·6 to 28MHz can supply p.e.p. outputs of 25W and 50W respectively.

All three transistors are in plastic 'capstan' packages. For full data please use reader enquiry service no. WW074.

Key to colour camera tv reliability

Millions of burning hours are being registered by Plumbicon* colour camera tubes in television broadcasting in the U.K. Some programme companies are reporting lives of over 7,000 hours. In telecine equipment, lives of over 10,000 hours are not uncommon.

If you are 'tubing up for colour', Plumbicon tubes from Mullard are a wise choice. There are 36 types to choose from. Use reader enquiry service no. WW075 for a wallchart.

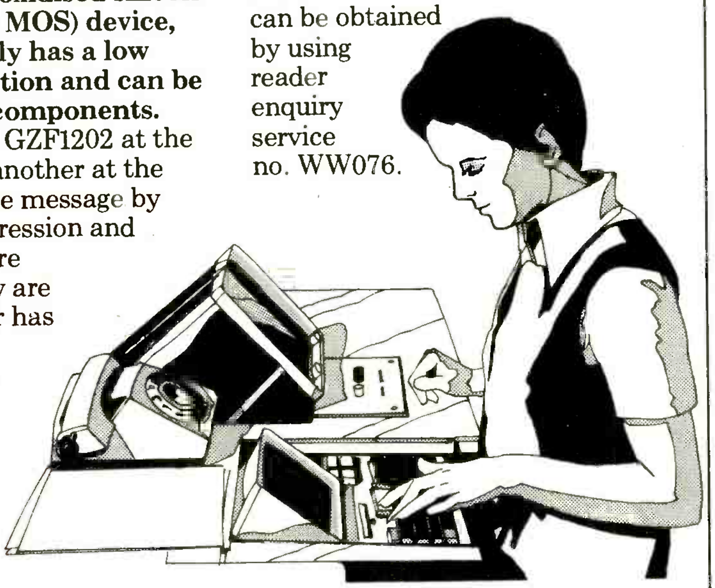
*Registered trademark for television camera tubes.

SINGLE-CHIP ERROR DETECTOR

What is virtually a complete sophisticated error detection system is contained in one 18-lead DIL integrated circuit recently announced by Mullard. Designated type GZF1202, it is a LOCMOS (local oxidised silicon complementary MOS) device, and consequently has a low power consumption and can be used with TTL components.

In operation, a GZF1202 at the transmitter and another at the receiver divide the message by a polynomial expression and the remainders are compared. If they are different, an error has occurred. The message is transmitted in its original form with the remainder added to the end.

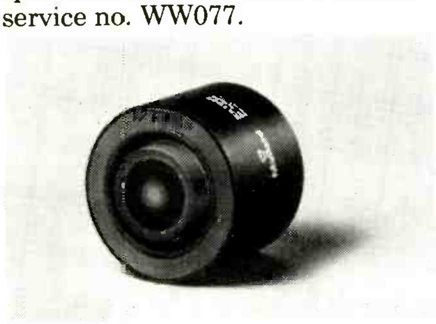
The GZF1202 provides for the use of six standard polynomials, and is thus suited for use in a variety of applications from modem interfaces to peripheral equipment such as disc stores. Samples of the IC are available for evaluation and data can be obtained by using reader enquiry service no. WW076.



A HUNDRED-THOUSAND TIMES BRIGHTER

Image intensifiers which enable you to see on an overcast moonless night, by amplifying light by as much as 100,000 times, are fully-engineered items in regular production at Mullard.

The intensifiers manufactured include single- and multi-stage electrostatically focused types and electrostatically focused microchannel inverter types. For information on the range and its special features use reader enquiry service no. WW077.



Contact Column

SECOND GENERATION BROADBAND TRANSISTORS

The Mullard company is no newcomer to the supply of components for TV distribution systems and similar applications. For nearly a decade it has made available broadband transistors, and types such as the BFY90, BFW30 and BFW16A are now well established.

With demands for lower and lower cross-modulation distortion and more and more channel capacity, a second generation of Mullard broadband transistors has appeared. Prominent among them is the BFR94. This has an f_T of 3GHz which is maintained at currents up to the unusually high region of 125mA. In this transistor, low cross-modulation, inter-modulation and second-order distortion are combined with excellent broadband and low-noise performance.

Moreover, the low cross-modulation behaviour is straightforward and does not depend on operation at critically favourable collector currents and output voltages. A shift–due to a change in temperature, say–does not therefore result in a rapid rise in cross-modulation distortion.

Another second-generation broadband device, the BFR96, can be used to drive the BFR94. It covers the range 40 to 860MHz, power gain is typically 8dB and typical output voltage is 600mV. Other types of transistor of similar interest are the BFR90 to BFR93. Data on all types mentioned can be obtained through the reader enquiry service no. WW078. *by 'Electron'*

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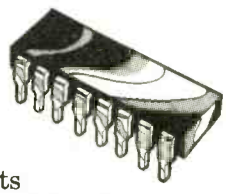
Wide range of TTL to Post Office Spec



The Mullard range of TTL integrated circuits approved and provisionally approved to the stringent Post Office Specification D3000 now comprises 22 types. They are being supplied to Post Office contractors and are to be offered to other equipment manufacturers who are concerned with very high standards of reliability.

All types in the D3000 range are functionally equivalent to types in the well-known GFB7400D series. Encapsulation is ceramic 14- and 16-lead dual-in-line.

The specification includes important overstress and endurance tests with exacting internal inspection requirements. It assures an extremely high standard of reliability and long life performance, and users can expect a component life of forty years with cumulative failures not greater than 2 per cent. For a leaflet summarising the range use reader enquiry service no. WW069.

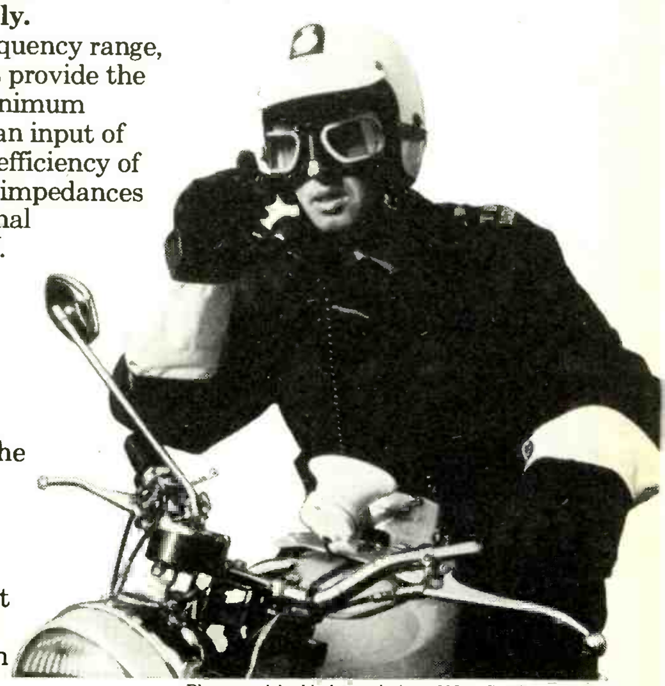
NEW MODULES FOR MOBILES

The highly successful u.h.f. amplifier modules manufactured by Mullard are to be followed up by two v.h.f. types. These are type numbers 437BGY and 438BGY covering the frequency ranges 148–174MHz and 68–88MHz respectively.

Apart from their frequency range, both the v.h.f. modules provide the same performance: minimum output power 18W for an input of 150mW with a typical efficiency of 45%. Input and output impedances are 50Ω, and the nominal supply voltage is 12·5V.

Among the operational features are the ability to withstand severe load mismatch and the provision for control of the output power by variation of the supply voltage. The operating temperature range is from −40° to +90°C.

By basing equipment on the modules, manufacturers can cut design time and also reduce the number of assembly operations. Furthermore, as the modules are untuned, no adjustment is needed in the test room. For provisional data please use reader enquiry service no. WW070.

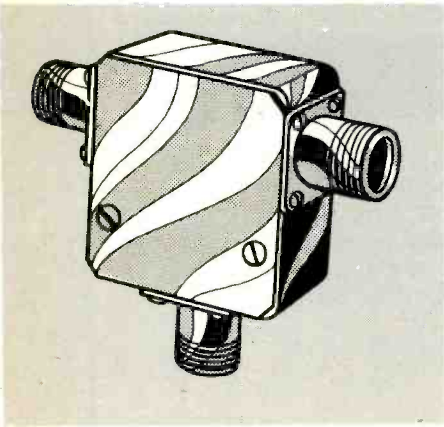


Photograph by kind permission of New Scotland Yard.

Mullard Communications Contact

Space-saving circulators

Significant savings in space and weight can be made in communications and radar equipment by using Mullard miniature circulators. Despite their small size, they feature the same low-loss characteristics and wide bandwiths as their full-size counterparts.



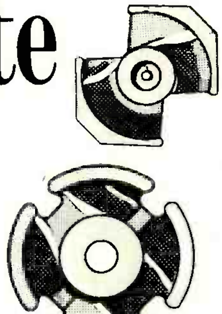
There are eight ferrite 3-port types capable of handling up to 300W in the u.h.f. region, and four microwave types rated at 50W.

The u.h.f. types are divided into 100W and 300W families. Bandwidths fall within the spectrum 470 to 1000MHz, and isolation is typically 25dB. Connectors are N-type with the option of HF 7/16 DIN 47223 connectors for the high power circulators.

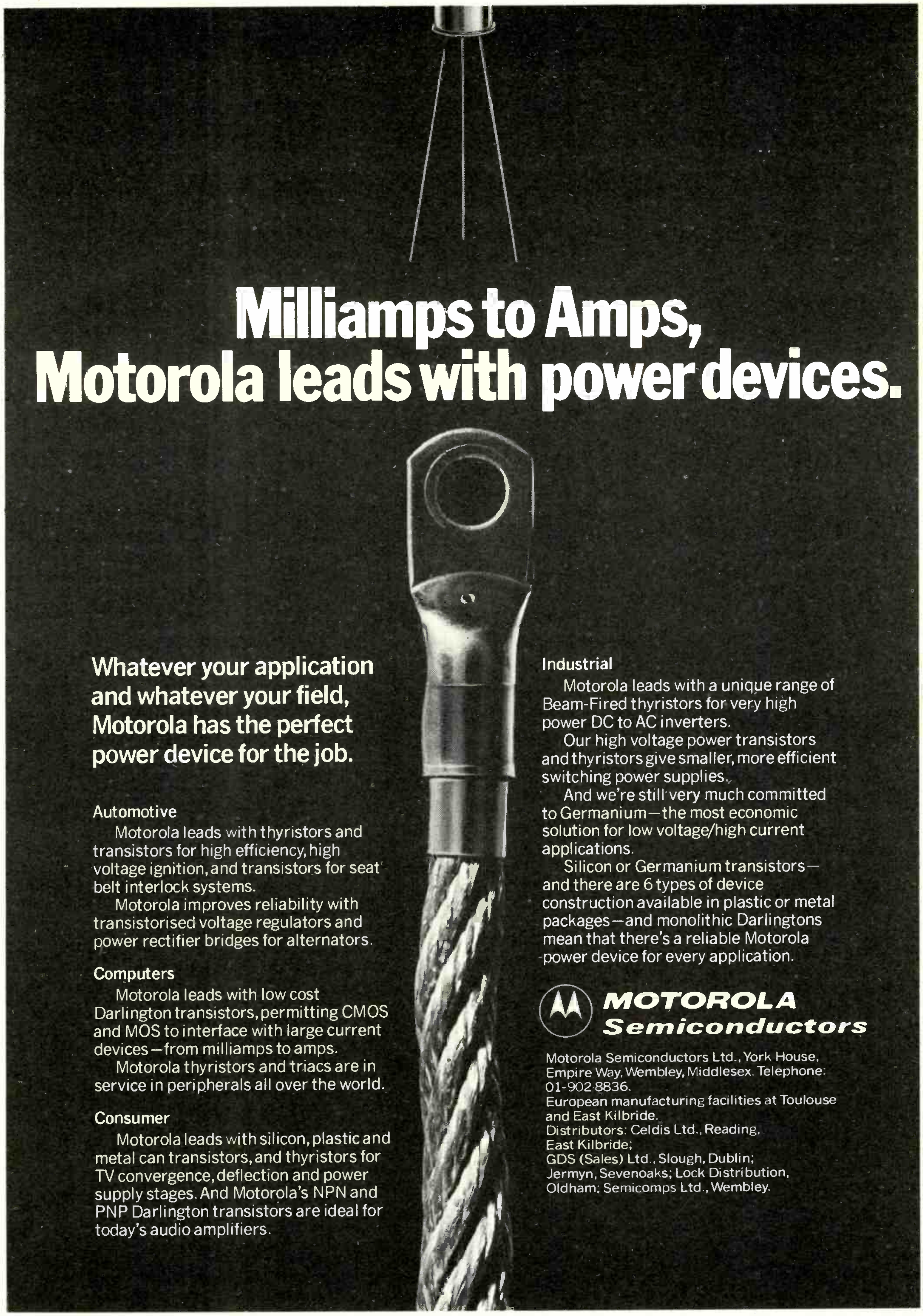
The four microwave circulators are broadband types providing coverage through the S, C and X bands, and isolator versions are available of each type. Isolation depends on the band and is typically between 23 and 27dB. Connectors are SMA coaxial.

For further information please use reader enquiry service no. WW072.

Which Ferrite Core?

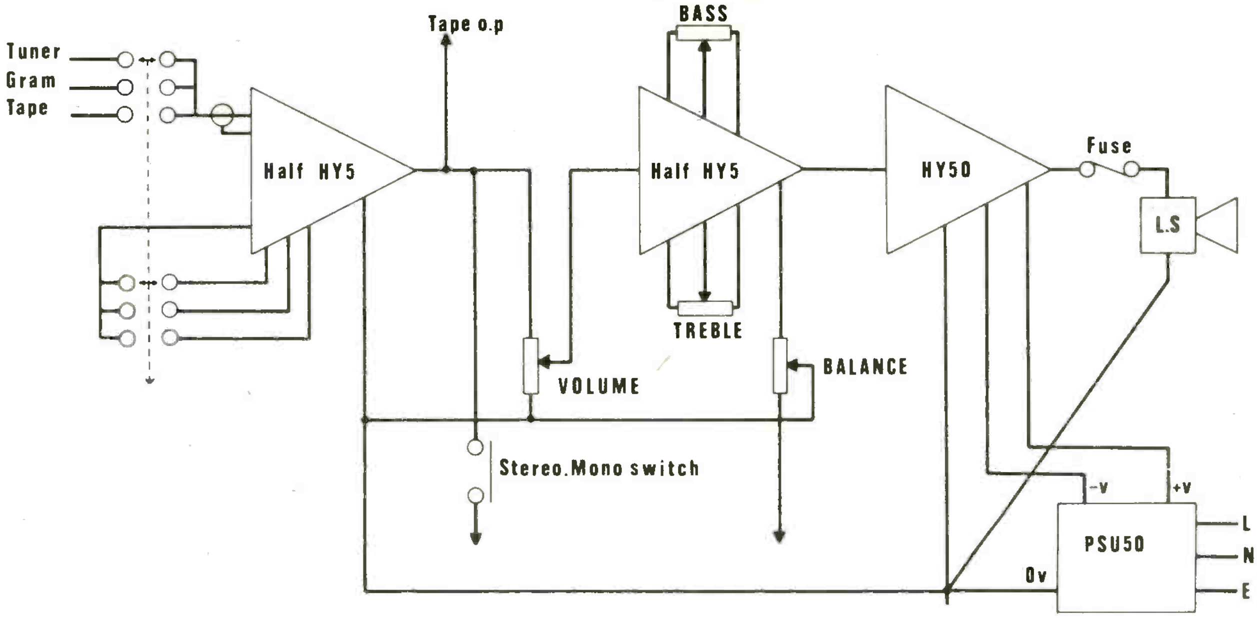


A useful aid to finding the right type of ferrite inductor or transformer core for any particular application is provided by a new wallchart from Mullard. All preferred design types in their various shapes, sizes and materials are clearly summarised. For a copy please use reader enquiry service no. WW071.

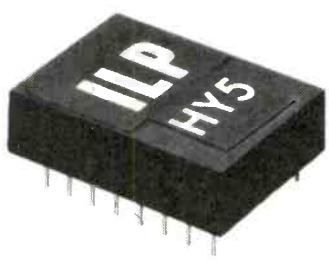

Milliamps to Amps,
Motorola leads with power devices.
Whatever your application and whatever your field, Motorola has the perfect power device for the job.
Automotive
Motorola leads with thyristors and transistors for high efficiency, high voltage ignition, and transistors for seat belt interlock systems.
Motorola improves reliability with transistorised voltage regulators and power rectifier bridges for alternators.
Computers
Motorola leads with low cost Darlington transistors, permitting CMOS and MOS to interface with large current devices—from milliamps to amps.
Motorola thyristors and triacs are in service in peripherals all over the world.
Consumer
Motorola leads with silicon, plastic and metal can transistors, and thyristors for TV convergence, deflection and power supply stages. And Motorola's NPN and PNP Darlington transistors are ideal for today's audio amplifiers.
Industrial
Motorola leads with a unique range of Beam-Fired thyristors for very high power DC to AC inverters.
Our high voltage power transistors and thyristors give smaller, more efficient switching power supplies.
And we're still very much committed to Germanium—the most economic solution for low voltage/high current applications.
Silicon or Germanium transistors—and there are 6 types of device construction available in plastic or metal packages—and monolithic Darlingtons mean that there's a reliable Motorola power device for every application.
MOTOROLA
Semiconductors
Motorola Semiconductors Ltd., York House, Empire Way, Wembley, Middlesex. Telephone: 01-902 8836.
European manufacturing facilities at Toulouse and East Kilbride.
Distributors: Celdis Ltd., Reading, East Kilbride;
GDS (Sales) Ltd., Slough, Dublin;
Jermyn, Sevenoaks; Lock Distribution, Oldham; Semicomps Ltd., Wembley.

I.L.P. (Electronics) Ltd

SHEER SIMPLICITY!



Mono electrical circuit diagram with interconnections for stereo shown



The HY5 is a complete mono hybrid preamplifier, ideally suited for both mono and stereo applications. Internally the device consists of two high quality amplifiers—the first contains frequency equalisation and gain correction, while the second caters for tone control and balance.

TECHNICAL SPECIFICATION

Inputs

Magnetic Pick-up	3mV.RIAA
Ceramic Pick-up	30mV
Microphone	10mV
Tuner	100mV
Auxillary	3-100mV
Input impedance	47kΩ at 1kHz.

Outputs

Tape	100mV
Main output	Odb (0.775 volts RMS)

Active Tone Controls

Treble	±12db at 10kHz
Bass	±12db at 100Hz
Distortion	0.05% at 1kHz
Signal/Noise Ratio	68db
Overload Capability	40db on most sensitive input
Supply Voltage	±16—25 volts.

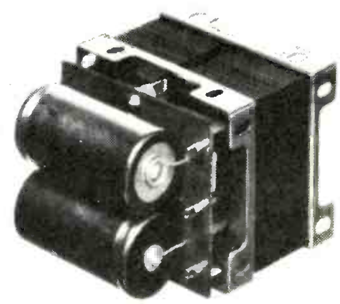
PRICE £4.50 + 0.36 V.A.T. P & P free.

The HY50 is a complete solid state hybrid Hi-Fi amplifier incorporating its own high conductivity heatsink hermetically sealed in black epoxy resin. Only five connections are provided: Input, output, power lines and earth.

TECHNICAL SPECIFICATION

Output Power 25 watts RMS into 8Ω
Load Impedance 4—16Ω
Input Sensitivity Odb (0.775 volts RMS)
Input Impedance 47kΩ
Distortion Less than 0.1% at 25 watts typically 0.05%
Signal/Noise Ratio Better than 75db
Frequency Response 10Hz—50kHz ± 3db
Supply Voltage ± 25 volts
Size 105 x 50 x 25 mm.

PRICE £5.98 + 0.48 V.A.T. P & P free.



The PSU50 can be used for either mono or stereo systems.

TECHNICAL SPECIFICATIONS

Output voltage	25 volts
Input voltage	210—240 volts
Size	L. 70, D. 90, H. 60 mm.

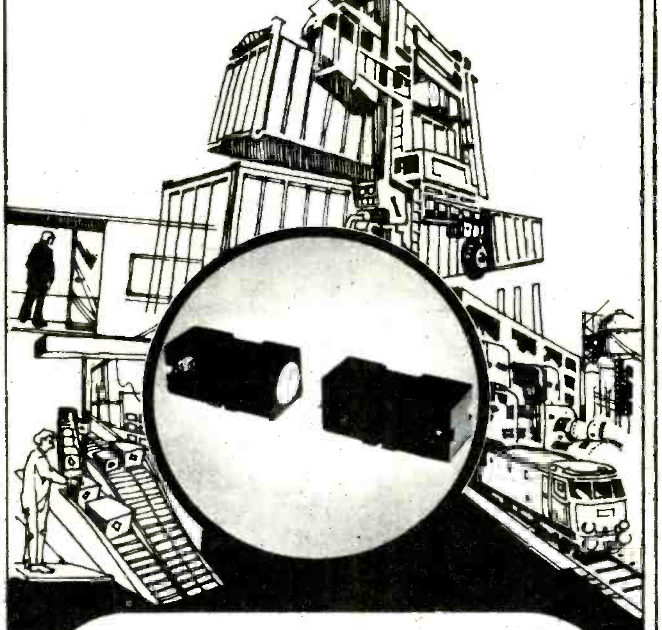
PRICE £5.00 + 0.40 V.A.T. P & P free.

TWO YEARS GUARANTEE ON ALL OUR PRODUCTS

CROSSLAND HOUSE · NACKINGTON · CANTERBURY · KENT

CANTERBURY (0227) 63218

Industrial Action with the JAMES SCOTT INDUSTRIAL microwave range of equipments



The James Scott range of Microwave equipment now offers industrial users a greater choice of alternative systems in robust, industrial, cast aluminium housings, for a wide variety of applications.
The range is made up of standard sub-assemblies which can be permutated to suit Individual application requirements.

Some Suggested Applications for these Units
Level controllers; Proximity alarms; Small object counters; Process control systems; Positioning systems; Door opening systems; Safety barriers; Presence/detectors; Train control systems; Vibration sensing systems; Intruder alarms; Road vehicle systems.
If any of the above are your problems or if you have a particular problem for which we could adapt a system please write or telephone for further information and technical literature to.

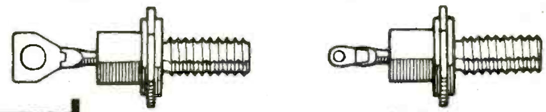
JAMES **SCOTT**
(Electronic Engineering) Ltd
CARNTYNE INDUSTRIAL ESTATE
GLASGOW G32 6AB
Tel: 041-778 4206

WW—065 FOR FURTHER DETAILS

New from AEI Semiconductors

Four shapes for your diode requirement

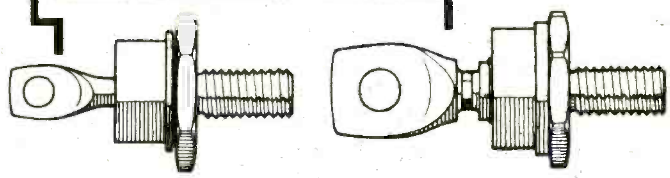
These four new diodes – comprising the "M" range – have been developed to meet demands for maximum availability at the lower price sector of the market. A 16 amps ,600v diode costs as little as 42p for quantities of 1000 or more. The range covers 6 to 70 amps, 50 to 800 volts.



Current/Voltage/Type No.

$I_{F(AV)}$ Amps	Type No. V_{RRM} 100	200	400	600	800
6	M6-100 M6-100R	M6-200 M6-200R	M6-400 M6-400R	M6-600 M6-600R	M6-800 M6-800R
16	M16-100 M16-100R	M16-200 M16-200R	M16-400 M16-400R	M16-600 M16-600R	M16-800 M16-800R
25	M25-100 M25-100R	M25-200 M25-200R	M25-400 M25-400R	M25-600 M25-600R	M25-800 M25-800R
40	M41-100 M41-100R	M41-200 M41-200R	M41-400 M41-400R	M41-600 M41-600R	M41-800 M41-800R
70	M71-100 M71-100R	M71-200 M71-200R	M71-400 M71-400R	71-600 M71-600R	M71-800 M71-800R

Suffix 'R' indicates reversed polarity (i.e. Stud Anode)



AEI SEMICONDUCTORS are in control

AEI Semiconductors Ltd., Lincoln.
Tel: 0522 29992
Part of GEC Electrical Components Group.

Also immediately available from:
Black Arrow (Electronics) Ltd: Bristol (0272) 294313
Coventry Factors Ltd: Coventry (0203) 24091
Farnell Electronic Components Ltd: Leeds (0532) 636311
LST Electronic Components Ltd: Chelmsford 69543
W. S. McMillan & Co. Ltd.: East Kilbride 38641/4
SDS Components Ltd.: Portsmouth 65311
T1 Supply Ltd: Slough 33411
J.V.N., Bromley, Kent: 01-464 1245

WW—031 FOR FURTHER DETAILS

Now suitable for U.K., European and American voltages...

Minimod, the versatile British made range of encapsulated power supplies first introduced in 1973, has now been extended to cover European and North American mains voltages (and is interchangeable with most American types). Normally available ex-stock, all units are fully stabilised with fold back current limiting – the 5V models have over voltage crowbar too!

STANDARD MODELS

Type Number	Output Voltage	Output Current Amps	Short Circuit Current mA (Typical)	% Regulation Line and Load (Typical)
PU01	5 ± 0.1	0.5	370	0.3
PU02	5 ± 0.1	1.0	770	0.5
PU03	15–0–15 ± 0.2	0.10	37	0.1
PU04	15–0–15 ± 0.2	0.20	84	0.1
PU05	12–0–12 ± 0.2	0.12	45	0.1
PU06	12–0–12 ± 0.2	0.24	120	0.2

Input voltage ranges 103 - 126V, 200 - 240V. 210 - 250V. Frequency 50 - 400 Hz all types.

Comprehensive specification given in brochure GT 29b which is available on request.

★SPECIAL DESIGN SERVICE

Custom built units for applications requiring different specifications are produced as part of our standard service. Try us first.

Gardners

Specialists in Electronic Transformers & Power Supplies.

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TRANSFORMERS LIMITED

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

WW—026 FOR FURTHER DETAILS

The symbol of sound quality.

Background Speakers
Outstanding results from small, inexpensive speaker enclosures. Sturdy cabinets either hand veneered in teak or covered in Black Vynide.

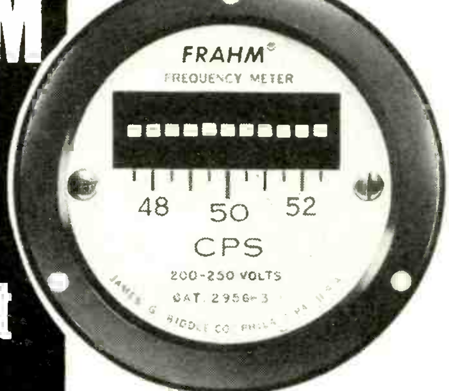
Power ratings from 1 watt RMS to 8 watts RMS.

W8DS. One of a range of four small speakers—bookshelf or wall mounting—slim line, square, wedge or corner cabinet fitting.

For further information and address of your local stockist write to: K.F. Products Ltd., Ashton Road, Bredbury, Stockport, Cheshire.

WW—013 FOR FURTHER DETAILS

FRAHM resonant reed FREQUENCY METERS



used as standards in many industries

- Accurate to ± 0.3% or ± 0.1% as specified
- Not sensitive to voltage or temperature changes, within wide limits
- Unaffected by waveform errors, load, power factor or phase shift
- Operational on A.C., pulsating or interrupted D.C., and super-imposed circuits
- Need only low input power
- Compact and self-contained
- Rugged and dependable

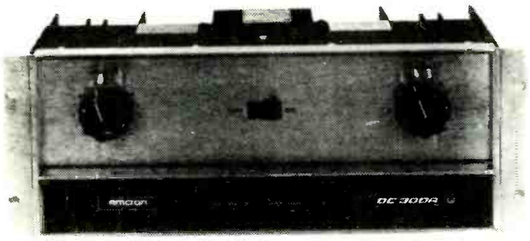
FRAHM Resonant Reed Frequency Meters are available in plastic and hermetically sealed cases to British and U.S. Government approved specification. Ranges 10–1700 Hz. Literature on these meters and Frahm Resonant Reed Tachometers available on request. Manufacture and Distribution of Electrical Measuring Instruments and Electronic Equipment. The largest stocks in the U.K. for off-the-shelf delivery.

Anders means meters

ANDERS ELECTRONICS LIMITED
48/56 Bayham Place, Bayham Street, London NW1. Tel: 01-387 9092

WW—058 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—010 FOR FURTHER DETAILS

British...

Wherever there is appreciation of fine sound reproduction, insistence is upon British loudspeaker systems. Renowned among the discerning for their outstanding quality, the products of Mordaunt·Short Ltd. are specified by professionals and by enthusiasts the world over. Choose them for your home - where the finest most concerns you.

DESIGN CENTRE LONDON

FEDERATION OF BRITISH AUDIO

...and world·wide.

Mordaunt-Short Ltd
Designers and Manufacturers of Quality Loudspeaker Systems

To receive immediately full information and the name and address of the Stockists nearest to you, please complete this coupon and return it to us direct.

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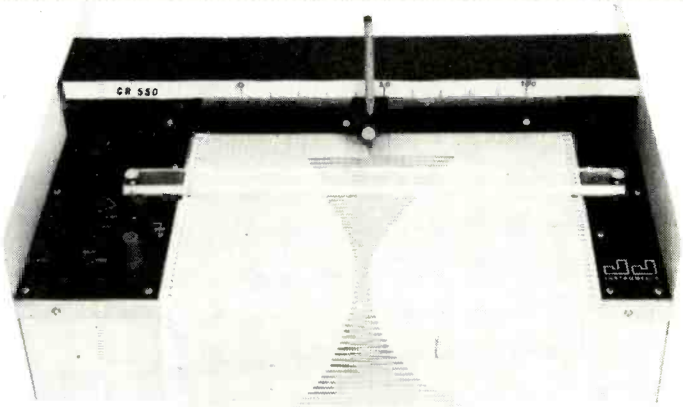
WW—085 FOR FURTHER DETAILS

C.R.550 recorder



Why pay more or less?

You could of course spend a lot more for a recorder which does no more – or there again "save" by plotting by hand!

If all you need is a high speed, sensitive, high impedance, 5 range, servo operated laboratory chart recorder suitable for horizontal or vertical use with a nine speed digitally controlled chart drive and electric pen lift.

BUY the CR550 at ...

PRICE ONLY £170 Exc VAT

SPECIFICATION

Accuracy	: at F.S.D. ± 0.5%
Writing Speed	: 200 mm/sec. approx.
Chart Width	: 270 mm
Ranges	: 10mV or 10µA., 100mV., 1V., 10V., 100V., F.S.D.
Chart Speed	: 1, 2, 5, 10 mm/min and 0.5, 1, 2, 5, 10 mm/s

JJ INSTRUMENTS

J.J. Lloyd Instruments Limited
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The symbol of sound quality.

KF

Hi-Fi Speakers
The KR range consists of five outstanding speaker designs with power ratings from 18 watts (music power) to 90 watts (music power).

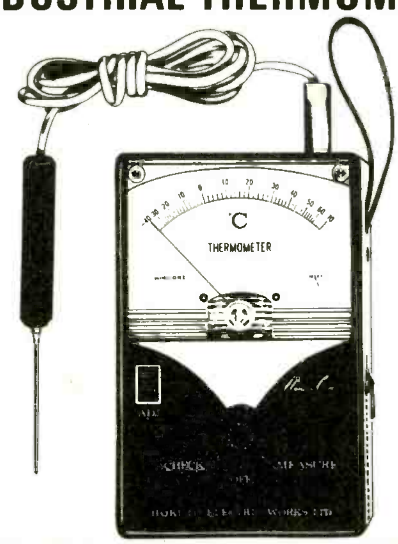
Made from selected high-density Swedish chipboard, the cabinets are hand-made, hand-finished and matched in identically grained pairs.
To ensure consistent sound quality, all speakers are individually tested before leaving our factory.
Ask for a K.F. demonstration and hear for yourself.

KR10. A two way, two unit system, typical of K.F. quality and design.

For further information and address of your local stockist write to: K.F. Products Ltd., Ashton Road, Bredbury, Stockport, Cheshire.

WW—014 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)

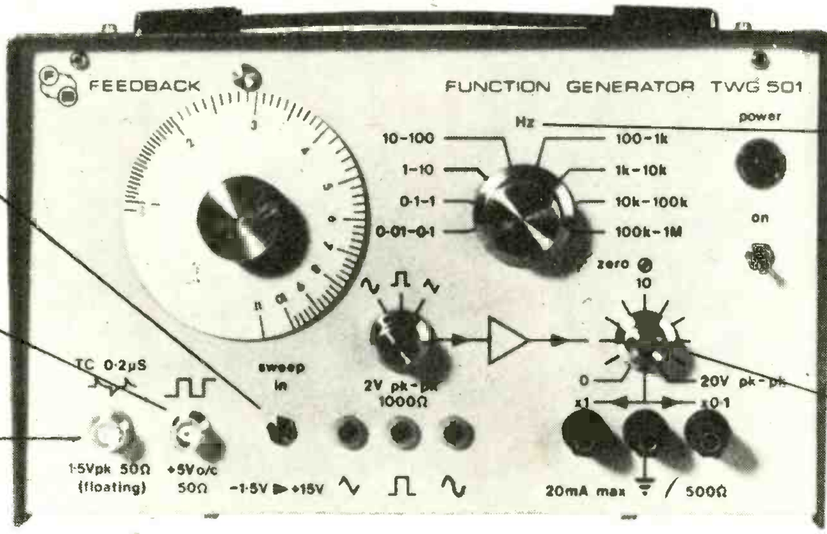
WW—050 FOR FURTHER DETAILS

This is why the TWG 501 performs the function of a good generator

Voltage control sweep 1 decade linear 4 decades exponential

Fast rise time square < 15ns with current sinking capacity for 5 TTL loads.

Trigger pulse



Frequency range 0.009Hz to 1.1MHZ

DC offset ±2V on X1 output

All seven outputs are simultaneously available with amplitudes constant over frequency range

Size: 254 x 121 x 157mm
Wt: 2.2kg

FEEDBACK INSTRUMENTS LTD Crowborough, Sussex. Tel: Crowborough (089-26) 3322

WW—086 FOR FURTHER DETAILS

KONTAKT 60

FOR INACCESSIBLE CONTACTS

—More than just a cleaner KONTAKT 60 guarantees perfect cleansing of contacts chemically in accordance with today's technology

KONTAKT offers the following advantages:

1. Dissolves oxides and sulphides the safe way without attacking contact substances.
2. Contains carefully selected solvents which do not attack plastics whereas they do dissolve resinified contact greases and dirt.
3. Contains **no silicone.**
4. Contains a light lubricant in order to avoid the contact paths being corroded.
5. Prevents further oxidation setting in.
6. Prevents 'creep' currents.

Because of these outstanding properties Kontakt 60 is one of the best and most popular contact cleansing agents in the world.

Users include: Rolls-Royce Ltd., C.E.G.B., South of Scotland Electricity Board, Trinity House Workshops, Kolster Brandes, Mullard, Plessey Co., etc.

OTHER KONTAKT PRODUCTS ARE:

70 Protective Lacquer
72 Insulating Spray
75 Cold Spray for Fault Location
80 Special Siliconized Polish
100 Antistatic Agent for Plastics
101 Dehydration Fluid

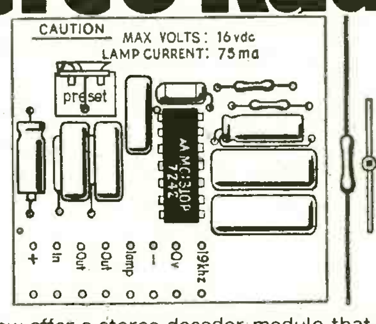
Write for full details of above or complete range of Kontakt products to:

SPECIAL PRODUCTS DISTRIBUTORS LIMITED
81 Piccadilly, London, W.1. 01-629 9556

WW—066 FOR FURTHER DETAILS

Stereo Radio

update your tuner.



Jermyn now offer a stereo decoder module that simply and easily converts your existing mono tuner for stereo reception. Multiplex output equipped tuners simply have the module plugged in, older types need the de-emphasis capacitor disconnected. The unit will do justice to the most expensive equipment.

Channel separation: Typically 40dB
Distortion: Typically 0.3% at 560mV RMS Composite input signal
Stereo switching: Automatic with lighted indicator
Power supply: 10-16 volts.

Assembled and fully tested with a no-strings 12 month guarantee the module costs an astonishing £6.90. Excluding VAT. (Also available as a Kit at £4.90.) Beat that!

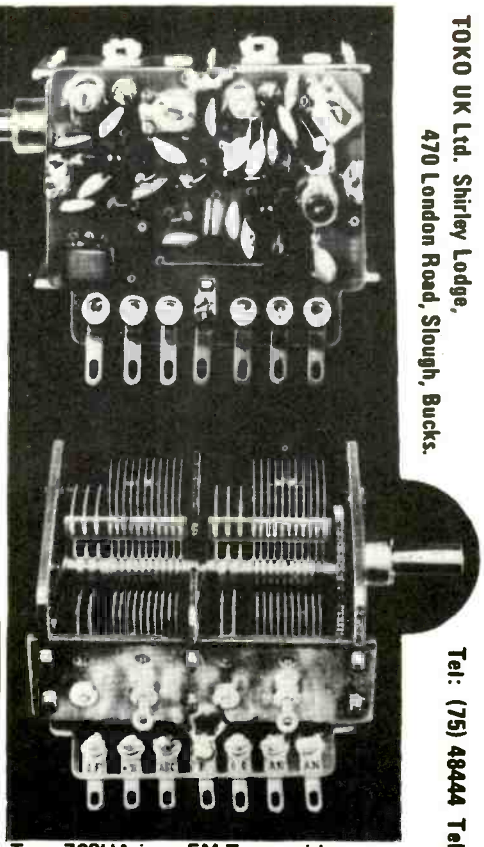
To Jermyn Industries
152 Vestry Estate
Sevenoaks, Kent

Please rush me ☐ Kit(s), ☐ made up Stereo decoders.
I enclose cheque/postal order for £
Name
Address

BARCLAYCARD welcome here

WW—009 FOR FURTHER DETAILS

TOKO *new low cost* AM/FM TUNER



TOKO UK Ltd. Shirley Lodge,
470 London Road, Slough, Bucks.
Tel: (75) 48444 Telex: 847185

Type 703UA is an FM Tuner with an associated AM gang. 87-109 MHz supply voltage +6 IF Bandwidth 400 KHz noise 10dB max. AFC $\pm$ 150 KHz at 108 MHz. 3 : 1 reduction gear 360° rotation AM gang 2 x 323 pf plus 12 pf trimmer.

WW—063 FOR FURTHER DETAILS

The symbol of sound quality.

Unit Audio

Superbly made speaker enclosures containing high quality units designed to improve your listening pleasure.
Ask for demonstrations of the KR6, PF6, PF8, MP6, MP138.

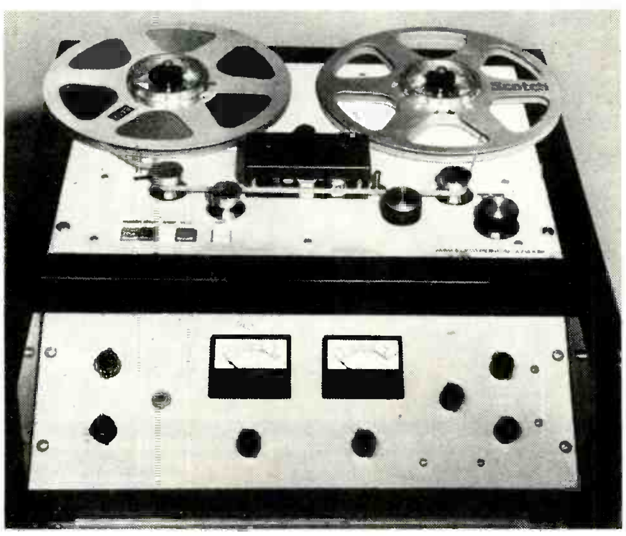
Power ratings from 8 watts (music power) to 20 watts (music power).

Illustrated here is the new **MP6.**

For further information and address of your local stockist write to: K.F. Products Ltd., Ashton Road, Bredbury, Stockport, Cheshire.

WW—015 FOR FURTHER DETAILS

TAKE A CLOSE LOOK



at a professional recorder that offers high performance, excellent reliability and is very easy to maintain. Ask yourself why so many commercial radio stations and recording studios are doing their best to wear them out, and not having much success. Decide if you need mono or stereo, console transportable or rack mounting versions and then inquire about prices.
We are sure you will be very pleasantly surprised.

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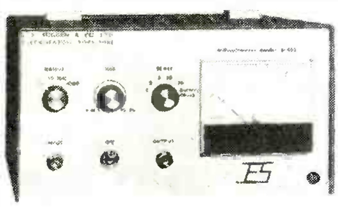
WW—064 FOR FURTHER DETAILS

DIOTESTOR IN-CIRCUIT TRANSISTOR TESTER

BRITEC LIMITED, 17 Devonshire Road, London SE23 3EN
Tel: 01-699 8844 Telex: 896161

WW—105 FOR FURTHER DETAILS

J E S AUDIO INSTRUMENTATION



Illustrated the Si 451 Millivoltmeter — pk-pk or RMS calibration with variable control for relative measurements. 40 calibrated ranges **£42.50**

Si 452 .... **£35.00**
Distortion Measuring Unit.
15 Hz — 20 KHz — .01%

Si 453 .... **£50.00**
Low distortion Oscillator.
Sine — Square — RIAA

J. E. SUGDEN & CO., LTD. Tel. Cleckheaton (09762) 2501
CARR STREET, CLECKHEATON, BD19 5LA

WW—042 FOR FURTHER DETAILS

DECADE BOXES

"Junior" Series—Resistance—1%

	Decades	Ohms Range	Ohms Resolution	£
J1	5	0– 1,111,100	10	**22.20***
J2	5	0– 111,110	1	**22.00***
J3	4	0– 111,100	10	**18.10***
J4	4	0– 11,110	1	**17.85***
J5	3	0– 11,100	10	**14.80***
J6	3	0– 1,110	1	**14.74***
J60	6	0– 1,111,110	1	**26.80***
J70	7	0–11,111,110	1	**31.50***

"Junior" Series—Capacitance—1%

	Decades	pF Range	pF Resolution	£
JC1	3	100– 111,000	100	**18.00***
JC2	2+var	30– 11,140	"infinite"	**18.90***

"Point One" Series—Resistance—0.1%

	Decades	Ohms Range	Ohms Resolution	£
R3	4	0– 1,111	0.1	**35.00**
R4	4	0– 11,110	1	**34.50**
R5	4	0– 111,110	10	**34.00**
R7	5	0– 1,111,100	10	**42.00**
R9	5	0– 111,110	1	**42.50**
R10	5	0– 11,111	0.1	**43.00**
R11	5	0–11,111,000	100	**49.00**
R20	6	0– 1,111,110	1	**51.00**
R21	6	0– 111,111	0.1	**51.50**
R22	6	0– 11,111.1	0.01	**56.00**
R30	7	0–11,111,110	1	**65.00**
R31	7	0– 1,111,111	0.1	**60.00**
R32	7	0– 111,111.1	0.01	**60.50**
R41	8	0–11,111,111	0.1	**73.00**
R42	8	0– 1,111,111.1	0.01	**70.00**

"Hundred" Series—Resistance—0.03%

	Decades	Ohms Range	Ohms Resolution	£
R400	4	0– 111,100	10	**68.53**
R401	4	0– 11,110	1	**71.66**
R402	4	0– 1,111	0.1	**73.04**
R403	4	0– 111.1	0.1	**77.03**
R600	6	0–11,111,100	10	**93.54**
R601	6	0– 1,111,110	1	**94.97**
R602	6	0– 111,111	0.1	**96.70**
R603	6	0– 11,111.1	0.01	**101.20**
R701	7	0–11,111,110	1	**110.62**
R702	7	0– 1,111,111	0.1	**112.35**
R703	7	0– 111,111.1	0.01	**116.88**
R802	8	0–11,111,111	0.1	**126.27**

DECADE BOXES continued

	Decades	Ohms Range	Ohms Resolution	£
R803	8	0– 1,111,111.1	0.01	**127.65**

High Dissipation—Resistance—1%

	Decades	Ohms Range	Ohms Resolution	£
HD1	5	0– 1,111,100	10	**75.00**
HD1/L	5	0– 111,110	0.2	**79.00**

High Dissipation—Inductance—5%

	Decades	mH Range	mH Resolution	£
L1	3	1– 1000	1	**60.00**
L2	2	1– 100	1	**45.00**
L3	2	10– 1000	10	**50.00**

"Hundred" Series—Inductance—0.3%

	Decades	mH Range	mH Resolution	£
L300	3	0– 1000	1	**200.00**
L400	4	0– 10,000	1	**260.00**

CAPACITANCE BOXES

Decades

	Decades	pF Range	pF Resolution	Accuracy	£
C3	3	100– 111,000	100	1%	**35.00**
PC3	3	100– 111,000	100	5%	**48.00**
C4	4	100–1,111,000	100	1%	**50.00**
PC4	4	100–1,111,000	100	5%	**75.00**

Decade plus Variables

	Decades	pF Range	Accuracy	£
VC4	3	50– 111,150	1%	**44.00**
VC5	4	50–1,111,150	1%	**61.00**
PVC5	4	50–1,111,150	0.5%	**95.00**
SVC5	4	50–1,111,150	0.1%	**390.00**
C500	4	50–1,111,150	0.2%	**180.00†**

SVC5 special. Details on application.

Variables

	pF Range	Accuracy	£
VC1	10– 260	1%	**20.00**
PVC1 Mk. 2	5– 200	0.5%	**71.50**
PVC2 Mk. 2	20– 1,120	0.5%	**65.00**
VC2	20– 1,130	1%	**30.00**
PVC4	0– 10	1%	**50.00**
PVC1/S	20– 120	0.5%	**45.00**

Switched

	uF Range	uF Resolution	Accuracy	£
C140	0– 140	1.0	5%	**105.00†**
C100	0– 100	1.0	5%	**89.00†**
C60	0– 61	0.1	5%	**80.00†**
C60P	0– 61	0.1	1%	**166.00†**

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Day 1 – Depart Heathrow 09.35 arrive Munich 11.15
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or
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Return flight is by scheduled airline of British Airways or Lufthansa between London and Munich. Accommodation in twin bedded rooms on a bed and breakfast basis at the Esso Motor Hotel. Return coach transfers between hotel and airport. Three days coach transfers between hotel and exhibition. Exhibition catalogue and entrance tickets. There will be a reception party to welcome you in Munich. A limited number of single rooms are available at a supplement of £6.00 per person.

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If you wish to visit Munich for the duration of the Exhibition we have organised a visit from Tuesday 19th November to Thursday 28th November, allowing 10 days/9 nights in Munich. The return flight is via Heathrow by scheduled airlines. Single room supplement of £27.00 per person.

Further details may be obtained by using the form below or by ringing Louise Griffiths: Tel. No. 0533-51211.

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electronica 74

6th International Trade Fair for Components and Production Facilities 21st-27th November Munich 1974.

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Combining compact, lightweight design with excellent colour fidelity this new single tube Shibaden camera fills the need for a high performance camera, small and simple enough for every CCTV application.
The HV-1500 has a unique Filter Integrated Colour Vidicon which does away with the usual complicated optical separation system and replaces it with a special vidicon filter, complemented by simple colour separation circuitry. The result is beautiful colour pictures, even in low light conditions, with no overlapping of images.
This simplicity of design also contributes to the camera's sturdiness. Coupled with the built-in automatic light sensitivity control, this makes the HV-1500 as easy to operate as a black and white camera.
Besides being ideal for all studio and outside broadcast uses, the simplicity, compactness and colour quality of the HV-1500 make it the perfect camera for applications such as surveillance, medical diagnosis, research and development and process control.

To see the HV-1500 in action, or for complete technical information, contact Shibaden's Technical Service Department at 01-203 4242/6 or write to:

Hitachi Shibaden (UK) Limited
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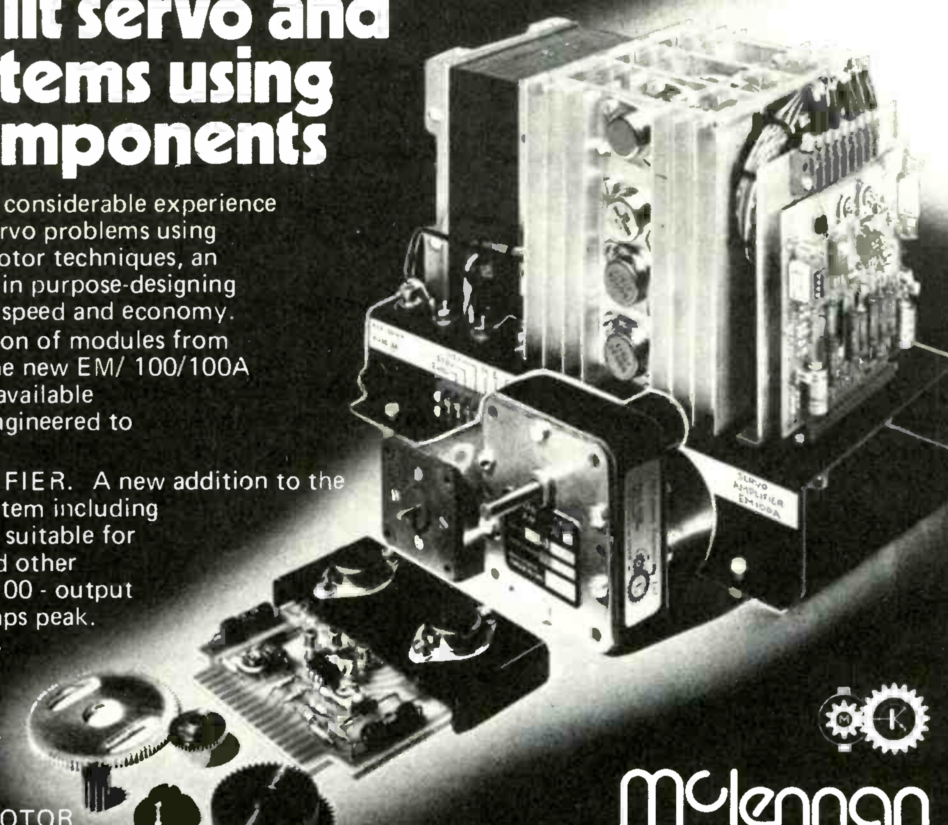
WW—119 FOR FURTHER DETAILS

Purpose-built servo and actuator systems using standard components



McLennan Engineering Ltd. have considerable experience in the solution of actuator and servo problems using synchronous, stepping and DC motor techniques, an important facet of our skill lying in purpose-designing around standard components for speed and economy.

The illustrations show a selection of modules from the standard range and include the new EM/ 100/100A servo drive system. All items are available individually or can be supplied engineered to custom-built systems.

1. EM 100/100A SERVO AMPLIFIER. A new addition to the range. A complete servo drive system including power supply which is eminently suitable for driving printed circuit motors and other servo motors up to 1/6 h.p. EM 100 - output ±24V, 4 amps continuous, 45 amps peak. EM 100A - output ±24V, 7 amps continuous, 75 amps peak.
2. DC SERVO AM 1006S. With integral potentiometer. Max continuous output Torque 14.6 kgcm at 7 r.p.m.
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McLennan Engineering Ltd
Kings Road, Crowthorne, Berkshire.
Tel: Crowthorne 5757/8.

WW—106 FOR FURTHER DETAILS

The ITC CTC-3X is a lot of camera for the money. £5500 buys you a high performance colour television camera, that can be used in studio, telecine, mobile or remote colourcasting.

It comes complete with f1.8 10:1 zoom lens, servo and cable controlled.

A view-finder monitor which can be easily removed or tilted both upward and downward.

A camera control unit which gives you remote controls including colour balance, iris, R.B. channel positions and gain, and on-off power and beam.

A separate mains lead that allows camera to be operated without CCU.

Plus features such as turret colour temperature correction filters.

A built-in colour bar generator.

A set of matched vidicon tubes. (Plumbicon® tubes available.)

A waveform colour sampler for easy colour balance adjustment.

That's the ITC CTC-3X. A lot of camera for £5500.

Also available is the SC 701P Genlock colour sync. generator at £1,100.

Plus the MEA 7100P six channel special effects generator at £2,100.

A two camera production unit featuring this equipment is available for hire with operators for £200 per day with a reducing rate for longer periods.

At Dixons Technical, of course.

Prices subject to VAT.

To: Dixons Technical,
3 Soho Square, London, W.1. Tel: 01-437 8811.

Please send me full details of the ITC CTC-3X colour camera and ancillary equipment.

NAME

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Dixons Technical Ltd OF SOHO SQUARE

WW/39A/10

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The first of a new range of high quality loudspeakers
This model employs three active drive units, the total range of which extends beyond the nine audible octaves.

By giving attention to all components and design detail the colouration and distortion is negligible and the energy distribution is as constant as possible.

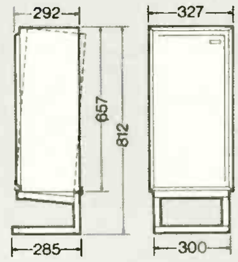
Five year warranty
Because of the precision required in manufacturing loudspeakers to a consistent specified performance, we can confidently predict that the Achromat 400 will have a long and trouble-free life when correctly operated.

We can therefore offer a five-year warranty on this loudspeaker system.

Stand
The Achromat 400 will give its most accurate reproduction in normal conditions when spaced at a distance of 10–20 cms above the floor.

The Goodmans Loudspeaker Stand CS3 is recommended and gives the option of vertical or 5° tilt positioning.

Specification
Drive units
Bass unit 26cm dia long-throw
Mid-range unit 44mm dia viscous damped dome radiator. Flush mounted
HF unit 25mm dia viscous damped dome radiator. Flush mounted

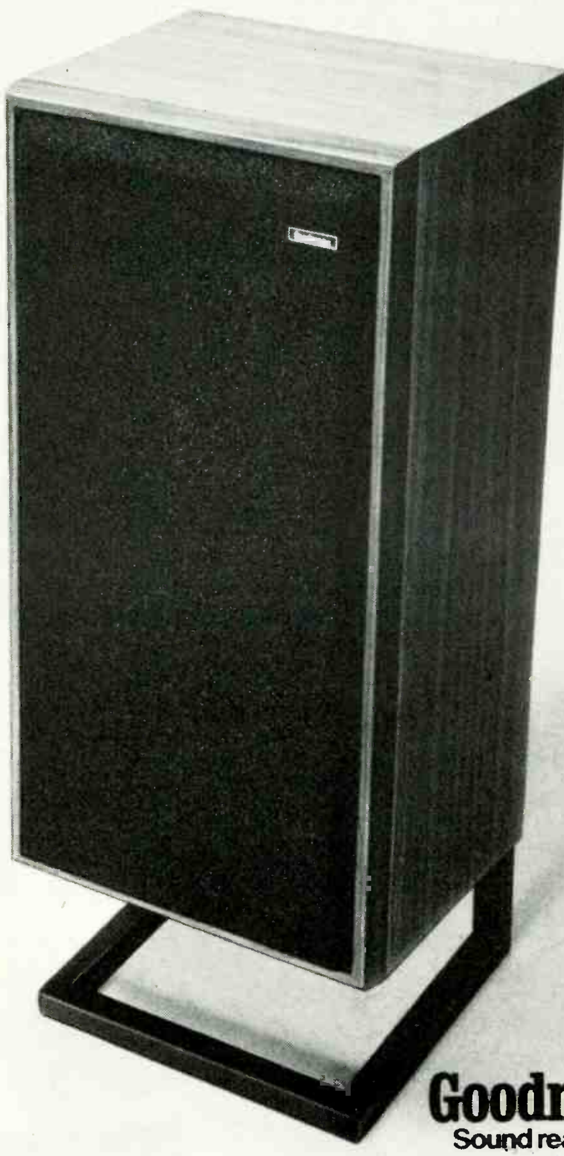


Frequency range 40–22,000 Hz ± 5dB
Nominal impedance 8 ohms.
The loudspeaker is suitable for use with amplifiers rated at 4 or 8 ohms.
Recommended amplifier music power rating 25 to 75 Watts
Sensitivity 12 Watts for 96dB at 1 metre
Effective enclosure volume 39.5 litres
Dividing frequencies 900 and 3,500Hz
Weight 16.5 kg (36 lbs) net
Recommended Retail Price £79.47+VAT
Stand £ 6.64+VAT

For illustrated details please write to
Goodmans Loudspeakers Limited
Downley Road, Havant, Hants PO9 2NL

THORN
A member of The Thorn Group

Goodmans Achromat*400



*from *Shorter Oxford Dictionary*
Achromatic 1. Optics – free from colour, not showing colour
2. Biol. – of tissue, uncoloured (1882) ie after staining
Achromatization – the action or process of removing colour

Goodmans
Sound reasoning.

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The complete mobile recording studio. Four totally independent channels. Sel sync on all channels. Mixing facilities. 63dB signal to noise ratio. Wide flat band-width.

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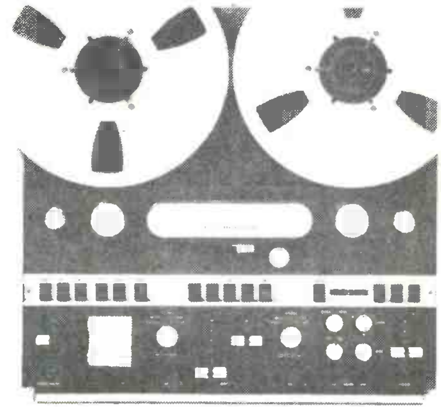

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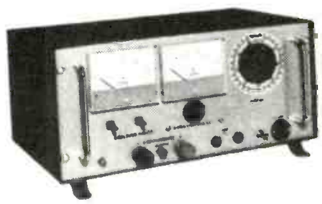

Type VRU/30/25—£166.75 + 8% VAT

Input 200–250V. 50Hz
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Output 1:0–30V. 25A. D.C.
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audix
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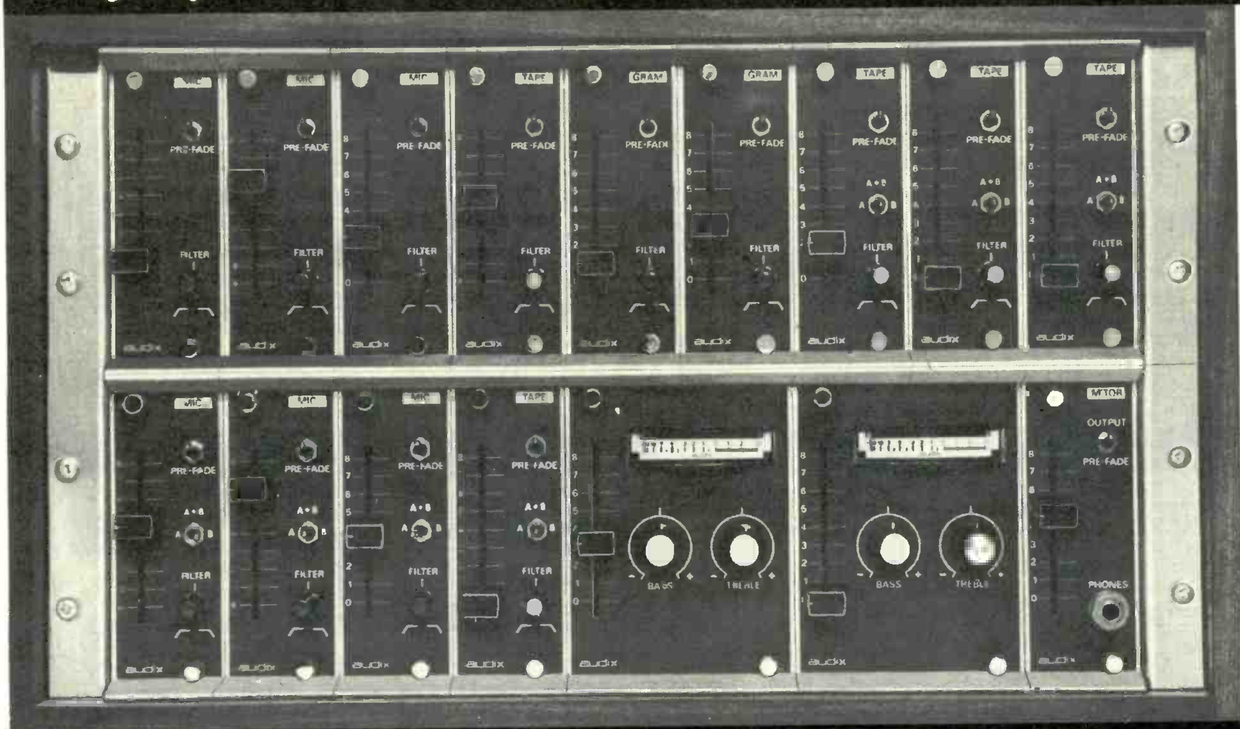
...and this is standard equipment!



The Capable MXT-200 Audio Mixer.

COMPARE YOUR REQUIREMENTS WITH THESE FEATURES THEN DESIGN YOUR MXT-200

OR ASK US TO.

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* Up to 15 plug in Mono, 2 group, or stereo input modules per combiner.
* Modules for Microphone, gramophone, Tape, Radio Cine and line sources.
* Exceptionally versatile bass and treble equalisation on one easy to use control.
* Linear motion faders for smooth mixing.
* Interlocked pre-fade listen switching.

Output Facilities

* Mono or Stereo Combiners with large scale VU or PPM metering, fit two combiners for 2 group working.
* Linear motion fader and separate Bass and Treble controls for output signal adjustment.
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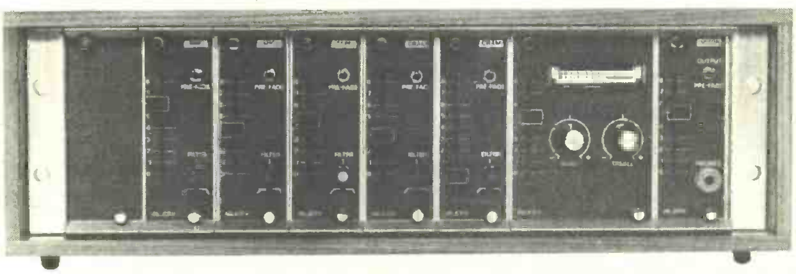
* Monitor Module with PFL/Output switching, headphone socket and line level output.



MXT-200 THE MIXER

The standard equipment is built up in 19 inch frames, each 9 modules wide. The frames may be stacked or placed end to end and housed in a console, rack or cabinet. You only order the input modules you now need. Additional modules may be plugged in the frames as your requirements change.

ASK FOR FURTHER INFORMATION

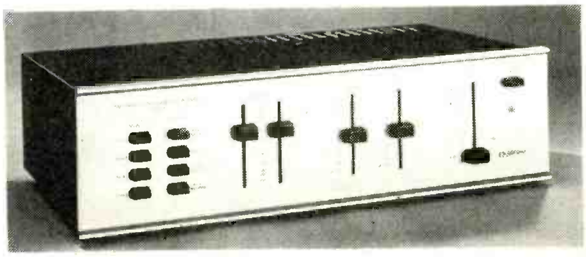
audix

MANUFACTURERS OF SOUND SYSTEMS AND ELECTRONICS

AUDIX LIMITED STANSTED ESSEX CM24 8HS
TELEPHONE BISHOP'S STORTFORD 813132
(4 lines) (STD 0279)

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.

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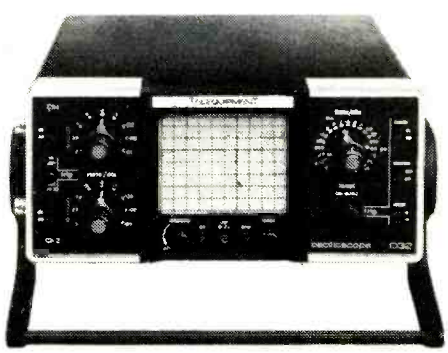
A brand new portable from Telequipment

The D32 Dual Trace 10 MHz Battery-Operated Oscilloscope

Probably the smallest and least expensive 'scope of its kind in the world. Telequipment's D32 offers a generous performance specification yet remains in the realms of reality where price is concerned. Weighing 10 lb. and only 4 x 9 x 11 inches in size, the robustly built D32 can be carried comfortably on any assignment.

Packed into its tiny frame is a specification with features normally associated with instruments twice its size. Priced at £250* (including rechargeable batteries) this dual-trace 'scope offers 10MHz bandwidth at 10mV/div. sensitivity; automatic selection of chopped or alternate modes; automatic selection of TV line or frame displays; the choice of battery or mains operation and a c.r.t. display which covers more than one third of its total front panel area.



Write now for full details and demonstration - you won't be disappointed.

*Provisional price exclusive of VAT.

TELEQUIPMENT

Tektronix U.K. Ltd.,
Beaverton House, P.O. Box 69, Harpenden, Herts.
Telephone: Harpenden 63141 Telex: 25559

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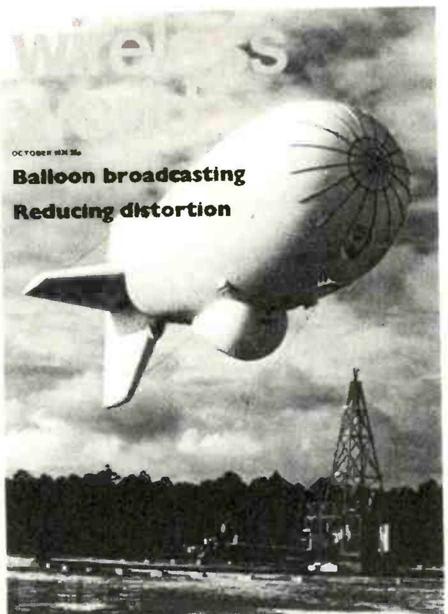
TQ10 9/74

wireless world

Electronics, Television, Radio, Audio

OCTOBER 1974 Vol 80 No 1466

SIXTY-FOURTH YEAR OF PUBLICATION



This month's cover picture shows one of the balloons used by the TCOM Corporation for broadcasting and communications and introduces an article on the system in this issue.

IN OUR NEXT ISSUE

(published October 23)

Quadraphonic broadcasting discusses current American proposals and suggests adopting a three-channel system that requires no increase in bandwidth.

Signal frequency meter. A digital instrument with an i.f. offset for the measurement of signals at receiver inputs.

Weather satellite station. A complete station for the reception of weather satellite cloud cover pictures transmitted in the 136MHz band.

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wireless world

The importance of status

The status of a job is more than an abstract consideration. It affects the way one is treated by other members of the community, in particular by one's employer (e.g. in the matter of salary), and it affects one's self-respect, which is important for psychological well-being. The status of people working in electronics is more bound up with that of technicians and engineers as a whole than with the subject or industry itself. It is therefore significant to many of us that in the past few months there have been two moves which could go some way towards improving the status of technicians and engineers as a whole.

First, the Technician Education Council has issued a policy statement which spells out in some detail the way it will put into effect its terms of reference, which are to "administer and keep under review the development of a unified national system of courses" for technicians and to "devise or approve suitable courses, establish and assess standards of performance and award certificates and diplomas as appropriate." Secondly, the Council of Engineering Institutions has been considering whether it might be replaced by a new, more influential body (an "Institution of Engineers") which would represent all chartered engineers directly instead of indirectly as at present. To do this the new organization would take over the "professional" as distinct from "learned society" activities of the existing engineering institutions. It would therefore be responsible for setting standards of education, training and experience, assessing qualifications of individual engineers, laying down rules of professional conduct and speaking with one voice—to the Government, the public, etc.—for engineers as a whole.

Welcome as these proposals for unification are, it is unlikely that such internal adjustments will provide the total answer to the status problem. They are rather like trying to pull oneself up by the bootlaces. Recognition of the status of engineers must essentially come from outside, from the public at large, and in relation to the status of other groups in the community. And such recognition depends on a number of psychological factors such as professional mystique (cf. medicine and the law), the power image resulting from collective action (cf. trade unions) and the aura of brilliant individuals (where in engineering are the equivalents of Einstein in science, Moore in sculpture or Solzhenitsyn in literature?). Another factor in the public recognition of status is the exclusiveness of certain honours. There is no Nobel Prize for engineering; one has difficulty in recalling whether any British engineer has been awarded the Order of Merit; and if there are some engineers who have become Fellows of the Royal Society it is only because they are by implication regarded as a kind of scientist. A more definite external standard against which British engineering workers are now being judged is the qualifications of similar workers in the other Common Market countries.

With these external conditions to contend with the British technician or engineer will certainly have a hard struggle to improve his status in society. But it is encouraging to see that those who represent him are at least starting the job by putting their houses in order.

Balloon broadcasting and communications

Airborne radio equipment for economical coverage of large areas

by R. A. Ilgner and A. A. Moghadam

TCOM Corporation, subsidiary of Westinghouse Electric, USA

The system described here uses helium-filled tethered balloons as high altitude platforms to provide reliable and economical telecommunications and broadcast coverage over large ground areas. Lightweight electronic equipment is suspended beneath the balloon, on a stabilized payload, making point-to-point as well as omni-directional communications practicable. The operating altitude is typically between 3,000 and 4,500 metres above sea level. From these heights, line-of-sight extends to distances of 200 to 250km, from the earth tether point, yielding ground coverage areas of 125,600 to 200,000 sq.km.

Lighter-than-air vehicles are not new to the communications industry. However, stability problems, lift restrictions and airborne powering difficulties curtailed their widespread use until recently when several technological advances were made. These include advances in materials technology, computer-aided aerodynamic design and electronic equipment miniaturization. The availability of light-weight, high strength materials such as Dacron, Mylar and Tedlar, together with new manufacturing techniques, have resulted in the production of a new aerodynamically stable tethered balloon, called an aerostat, which can lift large payloads to altitudes exceeding 4km. Off-the-shelf, light-weight, reliable electronics with low power consumption, utilizing integrated circuits, thin film, thick film, stripline and microstrip techniques, form the payload package. This unusual telecommunications and broadcasting system has passed the development stage and is already in operation. A working system in the Bahamas, operating at an altitude of 3,000 metres above sea level, provides communications coverage over an area of 125,000sq.km. with excellent performance. Fig. 1 shows a TCOM balloon and mooring system (TCOM stands for Tethered Communications).

The major components of the system are a balloon, a mooring system, power generation equipment, tether, telemetry and command equipment and the electronics payload.

The family of TCOM balloons ranges in size from the 1,400 cubic metres volume, 35m long Mark V, to the 17,000 cubic metres volume, 85m long Mark VIII. Selection of balloon size depends on lifting requirements and the operational altitude necessary for a particular application. Typical of these balloons is the Mark VII shown in Fig. 1. This 7,000m^3 volume vehicle has a length of 54m, a diameter of 17m, and a tail span of 25m. It operates safely in 190km/h winds. There are four stabilizers spaced 90° apart on the aft section of the hull. The ratio of volume to surface is high and the aerodynamic drag is low. A lift to drag ratio of 3 to 1 is normally obtained. Electrically powered blowers and valves automatically maintain the correct pressurization of the hull ballonet*. The latest developments in material engineering have been utilized to produce the multilayer laminate material used for the balloon's hull. The laminate weighs 280g/m^2 and consists of adhesive bonded layers of Tedlar, Mylar films and Dacron fabric arranged to give a high strength-to-weight ratio. The Tedlar film on the outside surface has excellent resistance to abrasion and weather. Two layers of Mylar film produce an effective gas barrier. The strong Dacron fabric provides the strength to withstand the loads induced by normal inflation, the attachment of hardware, in-flight loading, and a safety margin of at least 100%. The Dacron has good dimensional stability and imparts a high degree of tear resistance to the multilayer material.

Electronics. A typical payload can include up to one ton of communications equipment to be lifted to an altitude of 3km leaving at least 10% loading safety margin. This payload may include commercial and educational television, a.m. and f.m. radio broadcasting equipment; off-the-air receivers; translating equipment; high-density wideband communications equipment for multichannel voice and data transmission; mobile and maritime networks, and equipment performing numerous other functions such as: wide area paging, emergency radio broadcasting, wide area data collection, remote area meteorological observation, optical scanning and monitoring. Fig. 2 shows a typical payload package.

Broadcasting. The TCOM system has an inherent advantage over conventional broadcasting systems in its ability to cover a vastly greater area with a single transmission system. Lower costs, frequency conservation and performance improvement are the ultimate results. Since broadcasting in the United States is regulated by

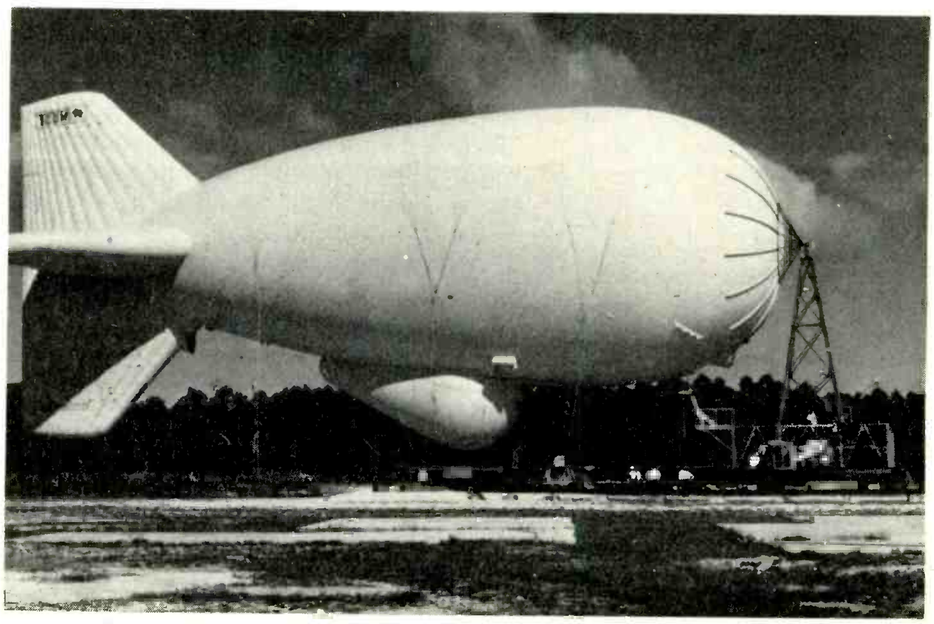

Fig. 1. Balloon and mooring system.

*An air compartment within the balloon envelope, used to adjust for changes of volume in the filler gas.

Fig. 2. Typical airborne electronics equipment.

the FCC (Federal Communications Commission) the regulations of that body are used here as a basis for comparing the performance of the TCOM system with that of conventional broadcasting systems. The FCC describes coverage in terms of field strength leading to Grade A or B picture quality. Considering the lower v.h.f. band, the median field strengths required for channels 2–6 are 2,500μV/m (68dBμ) for Grade A, and 225μV/m (47dBμ) for Grade B service. The factors affecting the actual received field strength are so numerous and difficult to predict that a statistical approach is used. This approach predicts field strength present in the best 50% of receiving locations for 50% of the time. Using the results of actual observations and considering a typical receiver system with assumed noise figure and antenna gain, the FCC provides charts to be used for estimation of field strength[1]. Conventional transmission is normally restricted, by practical considerations, to an effective tower height of 300 metres. A TCOM relay is nominally at an altitude of 3,000 metres. Using FCC standards, the chart in Fig. 3 has been developed. This chart indicates the obvious advantages of the TCOM system over conventional broadcasting. A TCOM system, with a lower effective radiated power (e.r.p.) of 2.5kW, provides a much larger and superior coverage than a conventional terrestrial system would provide with an e.r.p. of 10kW. FCC signal quality is based on a typical receiver with a noise figure of 12dB for v.h.f. and 15dB for u.h.f. and antenna gains of 6dB for v.h.f. and 13dB for u.h.f. Low-cost receivers with 6dB noise figure for v.h.f. and 8dB for u.h.f. and antennas with 13dB gain at v.h.f. and 18dB at u.h.f. are now available which can be utilized to provide still further improvements. Similar statistical techniques are used to estimate f.m. broadcasting service quality on a 50–50% basis. The objective field strength on this basis is 5,000μV/m (74dBμ) for principal cities, 1,000μV/m (60dBμ) for urban areas, and 50μV/m (34dBμ) for rural areas. Fig. 4 compares conventional and TCOM systems for f.m. radio broadcast coverage at frequencies of 88 to 108MHz.

Telecommunications. The TCOM platform, like a mini-satellite operating at a lower altitude, acts as a very tall tower for relaying wide-band telecommunications signals. In directional communications, parabolic antennas are mounted on this stabilized platform for reception and retransmission of wide-band communications signals carrying multichannel voice, data or programme messages.

Table 1 gives the performance analysis for a hypothetical path which satisfies national and international communications standards. In this table a typical 150km microwave path has been considered, and a complete performance analysis is presented for 2, 6 and 8GHz. The size of the airborne antenna is limited by the space availability, while the size of the ground antenna is constrained by the maximum beamwidth that can be tolerated by the required performance level. With the pointing error and the indicated permissible blow-down figures, a blow-down and pointing loss, proportional to the calculated antenna beamwidth, is included in the table. Free space losses are calculated and atmospheric absorption is estimated for moderate rain conditions.[2] Antenna gains are calculated for 55% efficiency. The assumed transmitter power of 20.0 watts is easily obtainable when a travelling wave tube is utilized. The circulator losses are included as transmitter and receiver losses for different frequencies. The receiver noise figures used are satisfied by typical off-the-shelf equipments.

The bandwidth used is adequate for high-density multichannel voice or equivalent TV transmission. Receiver threshold is the calculated value for the parameters included in the table. Adequate available fade margins are obtained for this illustration. The TV signal-to-noise ratio is calculated for CCIR white noise weighting of the M-system as used in the USA[3]. The worst channel noise figures, based on the receiver input power, can be realized by solid-state off-the-shelf equipment available on the market with the received signal strength indicated in the table. These figures meet or exceed all relevant CCIR requirements[4]. The system availabilities indicated in the table are based on CCIR reports[5], and show the high-performance quality of the TCOM system for high-density telecommunications and wide-band applications.

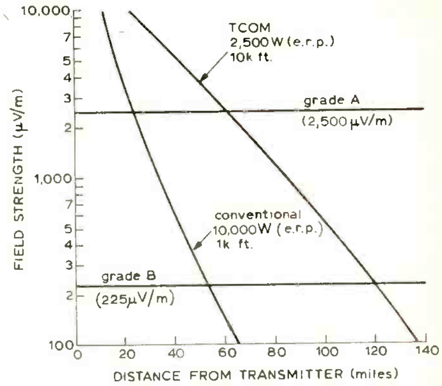

Fig. 3. Comparison of balloon borne and conventional broadcasting systems for coverage of v.h.f. television channels 2–6.

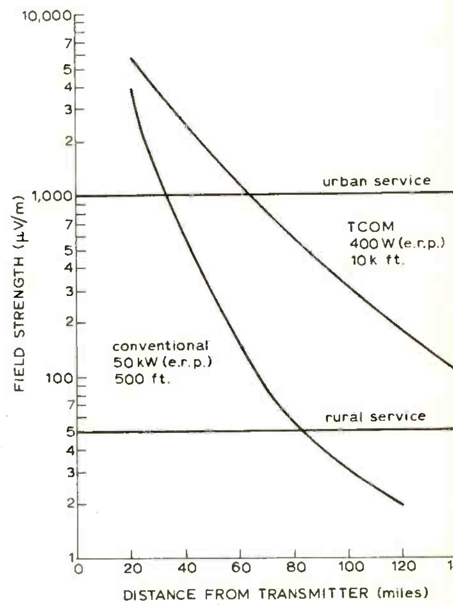

Fig. 4. Comparison of balloon borne and conventional transmission systems for coverage of f.m. radio broadcasting at 88–108MHz.

Table 1. Typical microwave performance

		2	6	8
Frequency (GHz)		2	6	8
Distance (km)		150	150	150
Antenna diameter (m)	ground terminal	4.5	4.5	4.5
Antenna beamwidth (°)	ground terminal	2.34	0.78	0.58
Antenna gain (dB)	ground terminal	36.88	46.42	48.92
Tx power (dBm)	ground terminal	43.00	43.00	43.00
Tx losses (dB)	ground terminal	1.00	2.00	2.50
EIRP (dBm)	ground terminal	78.88	87.42	89.42
Free space loss (dB)		141.92	151.48	154.00
Permissible blowdown (km)		6.0	2.1	1.5
Blowdown & pointing loss (dB)		1.50	3.50	4.50
Atmospheric absorption (dB)		0.15	7.00	10.50
Antenna diameter (m)	airborne terminal	1.8	1.8	1.8
Antenna beamwidth (°)	airborne terminal	5.84	1.95	1.46
Antenna gain (dB)	airborne terminal	28.92	38.47	40.97
Rx losses (dB)	airborne terminal	2.00	2.5	3.50
Rx input power (dBm)	airborne terminal	−37.77	−38.59	−42.11
Rx noise figure (dB)	airborne terminal	8.00	9.00	10.00
Rx bandwidth (MHz)	airborne terminal	30	30	30
Rx threshold (dBm)	airborne terminal	−81.23	−80.23	−79.23
Available fade margin (dB)		43.46	41.64	37.12
TV s/n ratio weighted (dB)		78.16	76.34	71.82
Worst channel noise (pWpO)		85	90	150
Availability w/freq. diversity (%)		99.999	99.999	99.99

Mooring system. A typical site includes two balloons flown from launching pads spaced about 800 metres apart. Each pad is equipped with a mooring system similar to the one shown in Fig. 1. The major elements of the mooring system are: a mooring tower, four close haul winches, a nose line winch, a work platform and a diesel powered hydraulic tether winch. The hydraulic winch, which operates the tether cable in-haul and out-haul, has a maximum pull of 6,400kg at a speed of 60 metres/minute. The complete mooring system is designed to freely rotate on a circular monorail track allowing the moored aerostat to weathervane, automatically minimizing the aerodynamic loads from surface winds. The work platform rotates with the balloon to maintain a steady relation to the aerostat.

Power generation equipment. The airborne power generation equipment typically consists of several Sachs-Wankel rotary engines of approximately 18h.p. (at 4,500r.p.m.), each directly coupled to a static brushless generator with a static voltage regulator. Compared to conventional engines, the Wankel rotary combustion engine is lighter, has better remote starting characteristics and contains fewer moving parts. Fuel consumption is also low. For a 5kW load, fuel consumption is slightly over 3kg/h (almost 5 litres per hour). The power equipment is suspended from a lightweight airframe structure and is easily removed for maintenance. The engine generator has proved capable of sustained power output of 5kW at an altitude of 3.5km. It is a three-phase brushless generator providing 400Hz, 120/208 volts a.c. with a static-type voltage regulator and a four-wire Wye winding.

Tethering cable. The general requirements for all balloon tethering cables are high tensile strength, high strength-to-weight ratio, low aerodynamic drag, low elongation, high flexibility, and good abrasion resistance. Nolaro cable satisfies these requirements and is one type of tethering cable used in TCOM systems. It consists of Dacron polyester filaments constructed in a no-lay (no twist) configuration and encased in a polyethylene sheath. The polyethylene sheath is impregnated with a carbon black compound to protect the inner Dacron filaments from ultra-violet radiation. Nolaro tethering cable with a diameter of 1.976cm has a weight of 291g/m and a breaking strength of 12,258kg. Under development, and nearing completion, is a conductive steel tether. This electromechanical coaxial cable will consist of a copper inner conductor insulated with TPX and armoured with high-strength steel wires providing the strength member and the outer conductor. High voltage from a ground based source will be transmitted to the airborne payload package via the conductive tethering cable. Utilization of this conductive tether will extend the operating time (with the balloon raised) up to six months.

Telemetry and command system. The telemetry and command system controls and monitors all the communications equipment on-board, and monitors the vital balloon functions including altitude, pitch, roll, heading, pressures, and temperatures. The system consists of a ground control section, typically housed in a mobile van, and an airborne section carried by the balloon. Depending on the project requirements, different means can be employed to perform this task. In one system, for example, low-power links carry high-speed data of up to 20kbits/s on two different frequencies, one for command and the other for telemetry. In standard multichannel communications applications, one voice channel can accommodate the necessary telemetry and command functions.

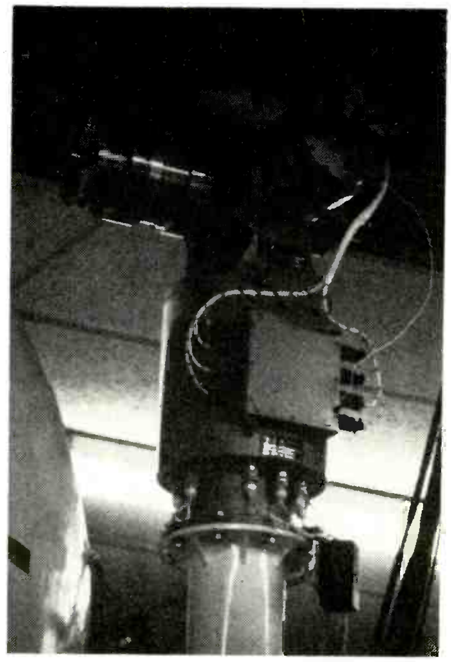

Fig. 5. Gimbal assembly for stabilization of the payload.

Stabilization. A high degree of stabilization of the payload is achieved by an airborne mechanical system consisting of a two-axis gimbal, an azimuth drive and a slip ring assembly package. The gimbal assembly acts as a pivot from which the entire airborne payload is suspended, in pendulum fashion, from the bottom of the balloon's hull. Fig. 5 shows the two coplanar (horizontal) axes of the gimbal assembly which are perpendicular to each other. Each axis is damped by a rotary viscous damper. The upper linkage on the gimbal assembly is attached to the balloon through a light-weight truss structure that distributes the airborne package weight and inertial loads throughout the balloon skin. The fixed shaft of the azimuth drive (with respect to the balloon) is attached below the lower gimbal linkage. The azimuth drive is the mechanical portion of the azimuth heading servo loop. The drive system receives an electrical signal from the servo electronics and converts it into mechanical rotation of the payload package to maintain proper heading with respect to north, as the balloon moves. The slip-ring assembly incorporated into the airborne package allows unrestricted azimuth motion between the payload and the aerostat. The ring is located at the upper end of the azimuth drive where it is attached to the lower linkage of the gimbal. An azimuth positioning of $\pm 0.5°$ pointing accuracy, controllable in $0.1°$ increments is achieved. The gimbal assembly isolates payload motion with respect to aerostat motion by a factor of 10 to 1.

Operational system. Since its inception, TCOM has established a number of facilities for development and operation of balloons and airborne electronics packages. In addition to TCOM executive offices in Rockville, Maryland, and the engineering and manufacturing offices at the Westinghouse Defense and Electronics Systems Center in Baltimore, Maryland, the TCOM corporation has established flight test facilities at Elizabeth City, North Carolina. In addition the corporation has set up an operational system at the Bahamas Evaluation, Test and Assembly Center on Grand Bahama Island. Numerous tests have been performed at this centre. A 4/6GHz microwave link connects the station to Nassau through the balloon. This link covers a distance of 200km. With 100W airborne transmitter power, a 1 metre parabolic balloon antenna, and a ground antenna of approximately 2 metres in diameter, the calculated signal strength of -35dBm is observed. Frequency diversity on the uplink and space diversity on the downlink will be implemented in the near future. Airborne receivers on the balloon pick up TV signals from Palm Beach (channel 4) and Miami (channel 5) stations in Florida, translate either of them to channel 11, and rebroadcast it over a 125,600sq.km area. A Grade B signal is obtained at the perimeters of the coverage area.

In-flight safety. Many factors are considered in selecting the operational site location. The required line-of-sight coverage establishes its general location. Within this general area, consideration is given to the air traffic flow patterns so that the site will be located outside aerodromes, approach and departure routes, airways and air corridors. An area of 6.3km radius from the centre of the site, with a ceiling of 4.6km, is reserved for a dual balloon station operating at 3.3km altitude. This restricted area is then published in Notice to Airmen (NOTAMS) and other aeronautical information publications, and is noted on aeronautical charts. The on-station balloons with flashing, high intensity strobes and illuminated tether become virtually lighthouses in the sky and are used by pilots as a navigational checkpoint, visible from long distances both by day and night.

References

1. FCC: Volume III of the Rules and Regulations of the Federal Communications Commission 1972, Part 73, pages 289 and 291.
2. Bell Telephone Laboratories: Transmission Systems for Communications, 4th Ed.; 1970, pages 442–444.
3. CCIR Recommendation 421–1, Volume V, Part 2, Annex III, pages 188–189.
4. CCIR Recommendation 395–1, Volume IV, Part 1, page 43.
5. CCIR Report 338–1, Volume II, Part 1, pages 114–127.

Reducing amplifier distortion

Avoiding conventional negative feedback by "error take-off"

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Error take-off is a method of overcoming the basic limitation of negative feedback which is increasingly limited loop gain with increasing frequency. Two practical configurations are discussed, a new bridge circuit with low output impedance offering a finite and worth-while improvement and an iterative circuit with higher output impedance having the ability to reduce distortion, in principle, by any arbitrary amount. The bridge circuit uses basically four resistors and two amplifiers, and the iterative circuit uses three resistors and an amplifier plus three resistors and two amplifiers per distortion-reducing stage.

Negative feedback incorporates two essential features into one system. These are the measurement of error voltage at the output of an amplifier to produce a voltage proportional to this error voltage, and the amplification of this proportional error voltage in such a way as to reduce the distortion. Usually this is done with one amplifier, but this has the serious disadvantage of limiting the amount of error reduction, which typically falls with increasing frequency. The error in an amplifier cannot be reduced to an arbitrary amount by using negative feedback alone because the gain at a given frequency is inherently limited if oscillation is not to occur.

Error take-off, which avoids Nyquist instability, can be used in principle to reduce error by any arbitrary amount. Basically the measurement of the voltage proportional to the error is very easy; it can be done with just two resistors when an inverting amplifier's output is compared with the system input (Fig. 1).

In audio and line transmission we are interested in non-linear distortion reduction rather than error, so I now refer to distortion rather than error as it is more evocative. Distortion is defined as the notional voltage (V_D) which adds algebraically to the notionally undistorted signal $V_{in}R_2/R_1$ at the output to produce the output of $V_{in}R_2/R_1 + V_D$.

It cannot be too strongly stressed that distortion in this sense includes any fundamental components of the signal due to low gain as well as any noise and hum which the amplifier may have picked up. Once the simplicity of this concept of distortion is grasped the next step is to use a separate amplifier to take off the distortion from the distorted output.

Basic circuitry

It may be done in at least two ways: with a kind of bridge circuit shown in Fig. 2 (ref. 1) or by the iterative circuit of Fig. 3. In Fig. 1 the undistorted part of the output $V_{in}R_2/R_1$ balances off at the junction of R_1 and R_2 to produce zero voltage, the only voltage to appear at this point being proportional to the distortion.

Applying this to Fig. 2 and making

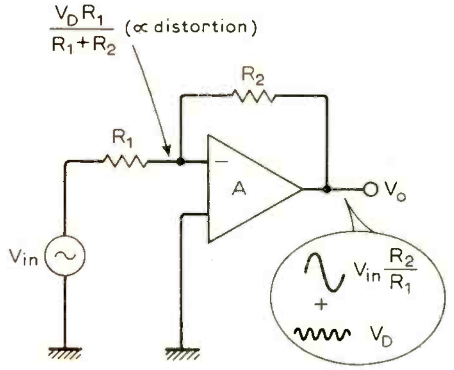

Fig. 1. Undistorted part of the output of this circuit balances out at the junction of R_1 and R_2 leaving a voltage $V_D R_1/(R_1+R_2)$, which is proportional to the amount of distortion.

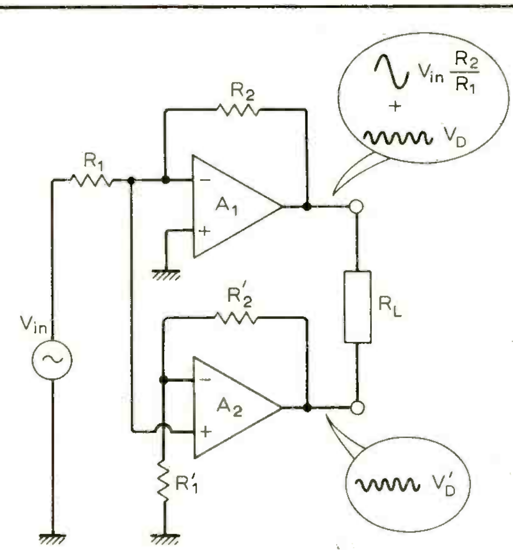

Fig. 2. The distorted part of the signal is taken off from the R_1, R_2 junction of Fig. 1 and returned through A_2 to the load to largely eliminate the distortion V_D.

$R'_1 = R_L$ and $R'_2 = R_2$ produces an output V'_D at A_2 which in both amplitude and phase matches V_D. By taking R_L to the output of A_2 instead of to the usual earth the error is taken off the original distorted output.

Examination of Fig. 2 shows the basic way in which error take-off differs from negative feedback and also why it is less prone to oscillation. It is because the output of the second amplifier A_2 in principle does not affect the output of A_1. This I call "non-interaction".

The iterative circuit of Fig. 3 is also based on a voltage proportional to the distortion appearing at the junction of R_1 and R_2. But this time, although for $R_A = R_B = R_C$ the voltage amplitude is the same, V_D, it is inverted so that when the distortion V_D is applied to R_A it is cancelled out by the voltage applied to R_B. The error in doing this, due to A_2 being finite, is corrected by A_3 and its associated resistors—a process which may be iterated indefinitely.

Examination of the circuit shows up an important design principle, that of "rigidity of interconnection". For $R_A = R_B = R_C$, V_1, V_2 and V_3 would have the same rigidly fixed effect on the output. In addition, R_1 to R_6 are rigid components, as distinct from the operational amplifiers which are not because their gain varies with frequency among other causes.

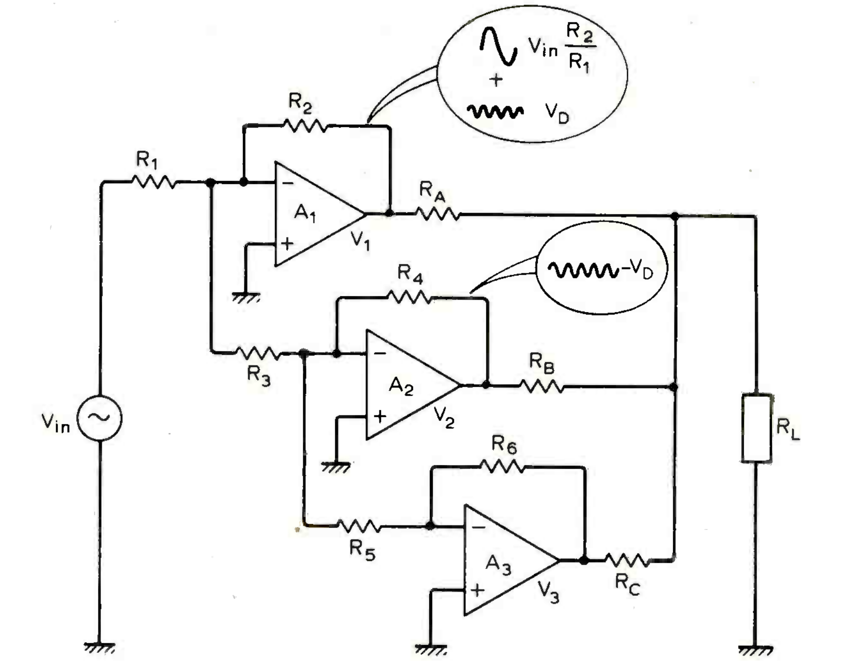

Fig. 3. Iterative circuit, in which the error is cancelling the distortion at R_A through R_B is corrected by a third signal from R_C, which process can be carried out indefinitely.

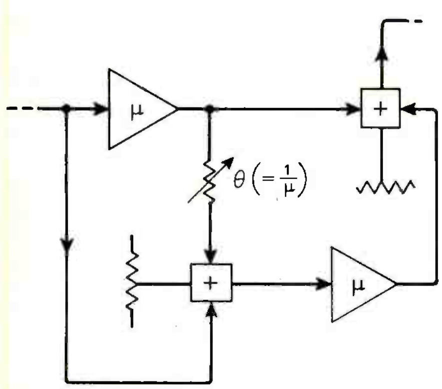

Fig. 4

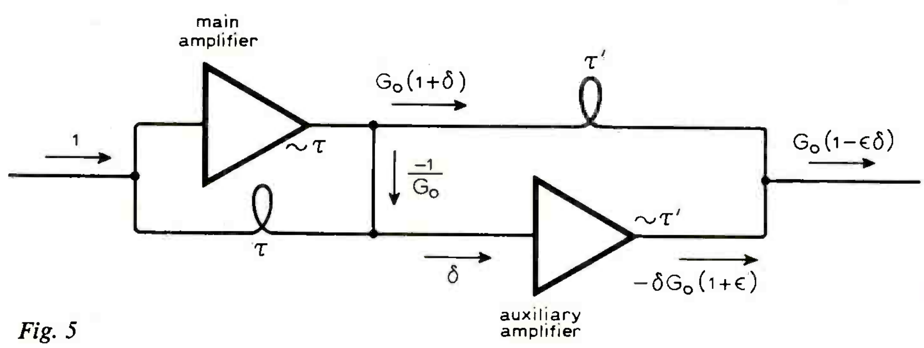

Fig. 5

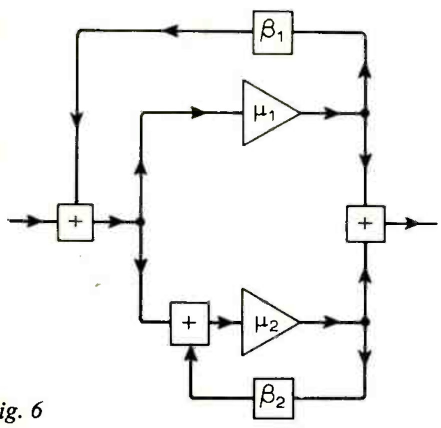

Fig. 6

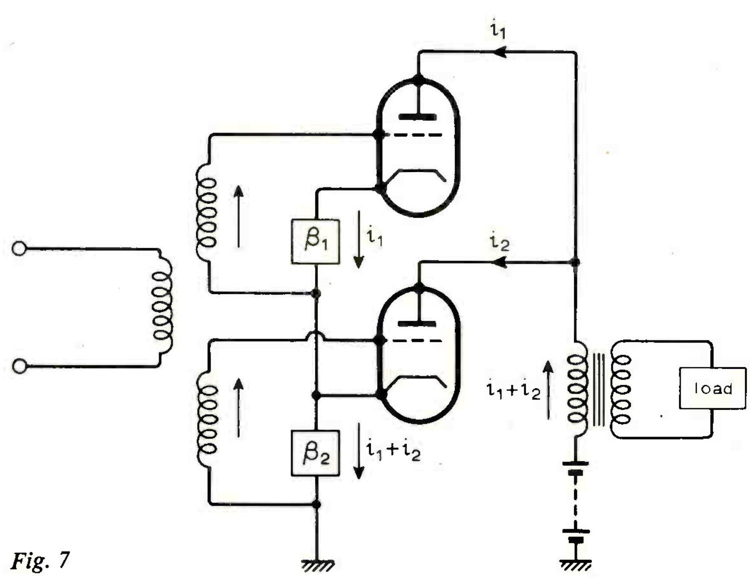

Fig. 7

Related techniques that pre-date error take-off are H. S. Black's feedforward, Figs. 4&5, and McMillan's multiple feedback, Figs. 6&7.

Historical note

There are two important schemes which predate error take-off. The first is Black's feedforward[2] (Fig. 4) which falls down because of the unstabilized amplifiers. For this reason Black used negative feedback; in Black's own view he did not invent it: "... applicant uses negative feedback for a purpose quite different from that of the prior art ..." in the process forgetting feedforward (ref. 3).

Feedforward surfaces again in another form in which a delay line and transformer play essential parts[4]; Fig. 5 is an example.

Just as I was telling myself that error take-off was novel, by pursuing references I found McMillan's multiple-feedback system[5].

This is well-developed in theory but is incapable of achieving any worth-while practical results as in all the engineered circuits the distortion of the output transformer is not dealt with! Figs. 6 & 7 are separate examples of theory and practice. To the best of my knowledge, however, the circuit of Fig. 2 is quite novel.

Although resistors are shown in Fig. 2, they could be impedances. If R_1 and R'_1 were retained but R_2 and R'_2 were replaced by capacitors then a very much more accurate integrator could be constructed than is possible using conventional circuitry.

Conditions for minimizing distortion (which are similar to those for balance in a bridge) are $R_2/R_1 = R'_2/R'_1$ for Fig. 2 and for Fig. 3 $1+(R_2/R_1) = R_4/R_3$ (assuming $R_3 \gg R'_1$, $R_5 \gg R_3$ and $R_A = R_B = R_C$).

Limitation of negative feedback

Could a negative feedback system do what error take-off does? Consider the circuit of Fig. 8 and its amplitude-frequency plot, Fig. 9. For $R_2 \gg R_1$ the feedback is as shown and the maximum amount that it is possible to apply without bursting into oscillation is depicted. This is a basic limit and cannot be overcome by additional amplification within the loop in the region P to Q which will usually cover the audio range. Additional amplification in the loop would help at frequencies below P but it would be essential for it to have a flat frequency response and a gain of one between P and Q.

Performance comparison

If the performance of the conventional virtual earth amplifier of Fig. 8 is compared with that of the error take-off circuit of Fig. 2 it can be shown by conventional theory that, in Fig. 8, the output voltage is

$$V_A = V_{in}\frac{R_2}{R_1}\left(\frac{1}{1+\dfrac{R_2}{A_1R_1}}\right) \approx V_{in}\frac{R_2}{R_1}\left(1-\frac{R_2}{A_1R_1}\right)$$

$$\approx V_{in}\frac{R_2}{R_1} = V_i\left(\frac{R_2}{R_1}\right)^2\frac{1}{A_1}$$ and the gain is

$$G = V_A/V_{in} \text{ or } \frac{R_2}{R_1}\left(1-\frac{R_2}{A_1R_1}\right)$$

Now the voltage component due to $V_{in}R_2/R_1$ (Fig. 2) is balanced to zero at the junction of R_1 and R_2 and so may be ignored when working out V'_D, i.e. only the contribution of V_D need be considered, which has the value

$$\frac{V_DR_1}{R_1+R_2} = V_{in}\frac{R_2^2}{A_1R_1^2}\cdot\frac{R_1}{R_1+R_2}$$

$$= V_{in}\frac{R_2^2}{A_1R_1^2}\cdot\beta.$$

$$V'_D = -V_{in}\left(\frac{R_2}{R_1}\right)^2\frac{1}{A_1}\left(\frac{\beta A_2}{1+\beta A_2}\right)$$

where $\beta = R_1/(R_1+R_2)$, $R_1 = R'_1$, $R_2 = R'_2$ and $A_2/(1+\beta A_2)$ is the gain for a conventional non-inverting amplifier (β in the numerator, which is the conventional feedback factor, allows for the attenuation of R_1 and R_2).

$$\therefore V'_D \approx -V_{in}\left(\frac{R_2}{R_1}\right)^2\cdot\frac{1}{A_1}+V_i\left(\frac{R_2}{R_1}\right)^2\frac{1}{\beta A_1A_2}.$$

To find the voltage across R_L subtract $V_{D'}$ from V_A

$$V_A - V'_D = V_{in}\left(\frac{R_2}{R_1}-\left(\frac{R_2}{R_1}\right)^2\frac{1}{\beta A_1A_2}\right)$$

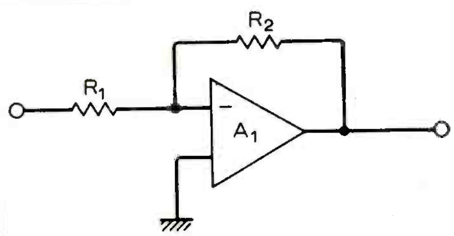

Fig. 8. Distortion of the balanced error take-off circuit is reduced by βA_2 compared with the virtual earth circuit above.

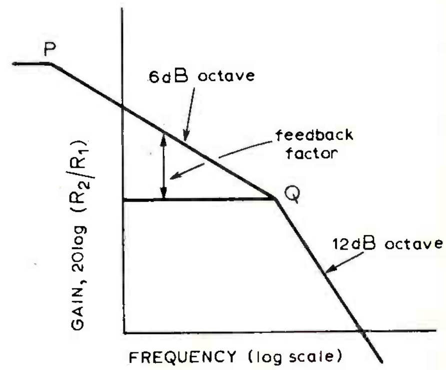

Fig. 9. Error take-off permits distortion to be reduced while avoiding the stability limit of negative feedback amplifiers which cannot be overcome by additional amplification within the loop in the region P to Q.

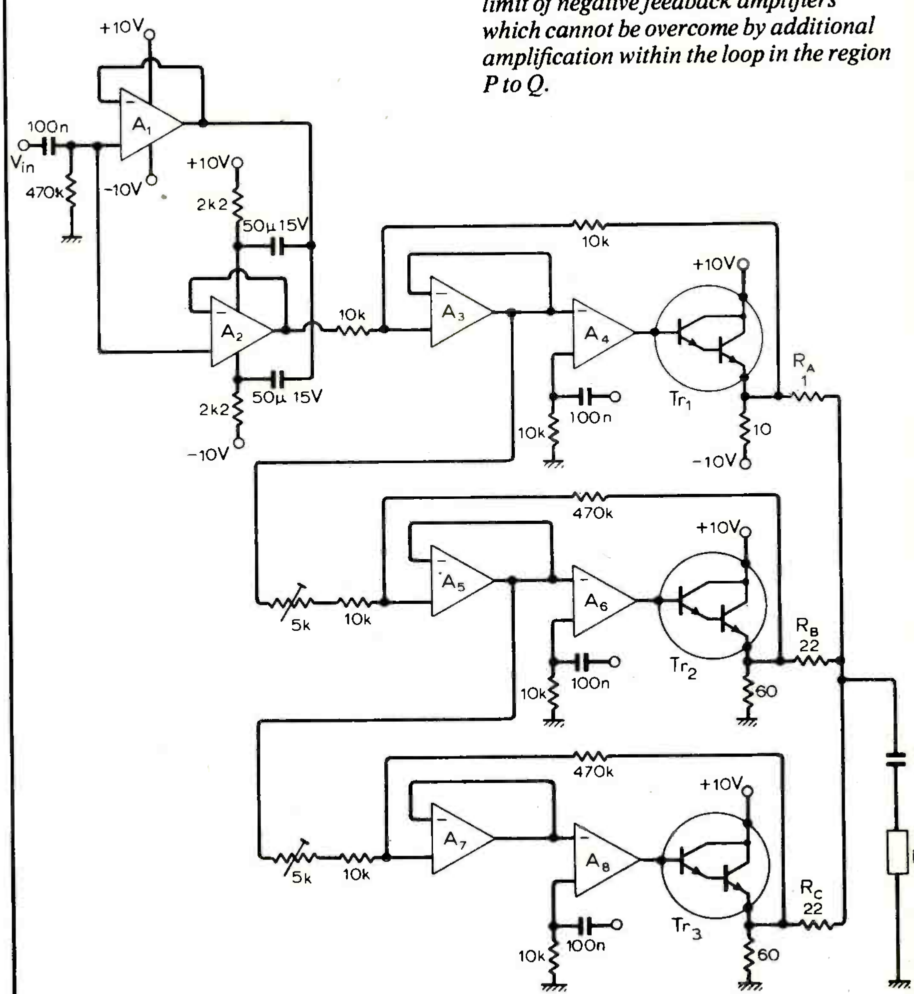

Fig. 10. Practical circuit of single-ended amplifier based on Fig. 3 circuit. Op-amps are 741 types, and power Darlington transistors type MJ4000.

Therefore the gain for the error take-off configuration, G_{ET}, is

$$\frac{V_A - V_D}{V_{in}} = \frac{R_2}{R_1}\left(1 - \frac{R_2}{R_1 \beta A_1 A_2}\right).$$

Comparing the conventional circuits gain, V_A/V_{in}, with G_{ET}, the distortion has fallen by an improvement factor βA_2, a considerable improvement.

The above analysis assumes accurately-known resistors. By setting the resistors R_1' and R_2' associated with A_2 to $R_1(1+\Delta)$ and R_2 $(1-\Delta)$ it can be shown that the distortion V_D is reduced to ΔV_D for $A\beta \gg 1$, i.e. 1% resistors would reduce it to one-hundredth of its former value. This demonstrates that the circuit is not abnormally sensitive to lack of stability in the circuit resistors.

Iterative circuit

By assuming that $R_2 \gg R_1$ the attenuation from the output (Fig. 3) of A_1 to the junction of R_1 and R_2, $R_1/(R_1+R_2)$ may be approximated by R_1/R_2. In addition, for A_1, A_2, A_3 etc., if we choose the lowest value of A for $A_1 A_2$ we may write A^2 and get a pessimistic answer, which is acceptable.

With these approximations and assuming $R_A = R_B = R_C$ the uncancelled error (Fig. 3) for two stages is $R_2^3/A^2 R_1^3$ and for n stages $R_2^{n+1}/A^n R_1^{n+1}$.

But the summing resistors attenuate the gain by a half for two stages and $1/n$ for n stages, so that the gain for two stages is

$$\frac{R_2}{2R_1} - \frac{R_2^3}{2A^2 R_1^3}$$

and for n stages

$$\frac{R_2}{nr_1} - \frac{R_2^{(n+1)}}{na^n R_1^{(n+1)}}$$

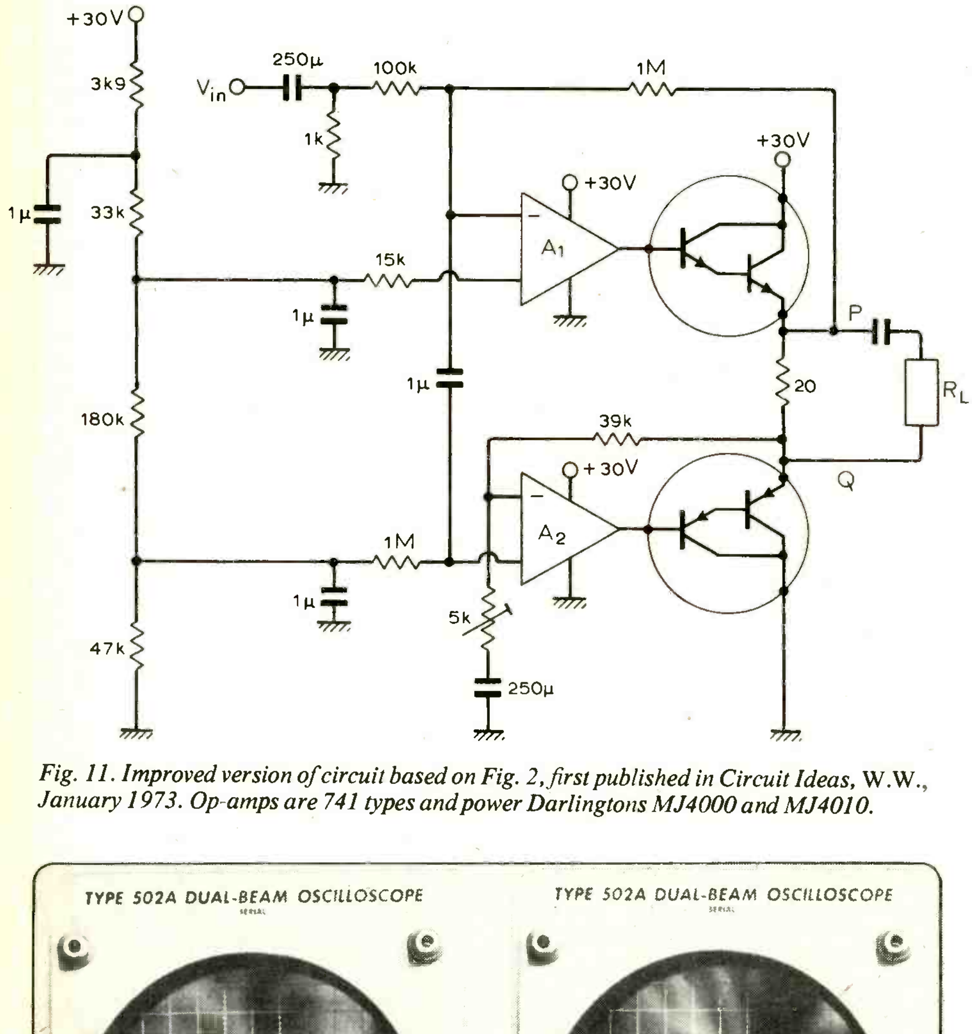

Fig. 11. Improved version of circuit based on Fig. 2, first published in Circuit Ideas, W.W., *January 1973. Op-amps are 741 types and power Darlingtons MJ4000 and MJ4010.*

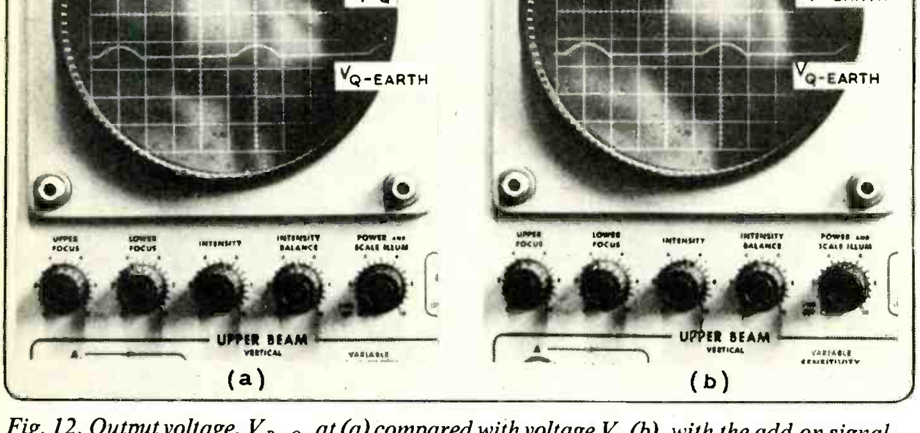

Fig. 12. Output voltage, V_{P-Q}, at (a) compared with voltage V_P(b), with the add-on signal (lower traces).

Experimental circuits

Two separate circuits have been built, the first based on Fig. 2, the second on Fig. 3. The circuit around Fig. 2 has already been published[1], so the single-ended version based on Fig. 3 will be described.

It is desirable for a circuit for general use to have a high input impedance and to be capable of working from a high impedance source. If R_1 is connected directly to the voltage source (Fig. 3) then, if parasitic capacitances and the input current of A_1 are to have negligible effect, R_1 will be about 10kΩ, and the resistance of the signal source would enter directly into the take-off effect.

A normal voltage follower would solve this but at the cost of introducing some distortion. In the practical circuit, by bootstrapping the supply rails to A_2 (Fig. 10), the distortion is much reduced because all A_2 is called on to do, in effect, is maintain a low source impedance relative to a 10-kΩ load since its conditions are kept constant apart from what it sees as a current supplied to it by the 10-kΩ load. Amplifier A_1 provides the bootstrap voltage. (Even a germanium transistor could have a wide bandwidth if used under no load conditions with a broad-band A_1.)

Amplifier A_3 transmits the voltage at the junction of the two 10-kΩ resistors with negligible distortion since by the nature of things it is very small. Its function is to enable the 10-kΩ resistor plus 5-kΩ potentiometer associated with A_5 to function without loading the two 10-kΩ feedback resistors. Amplifier A_5 functions similarly while A_7 is included to enable the effect of a further stage to be studied. This stage was found to have negligible effect and so was unsoldered.

The output of A_3 is connected to A_4, which drives the output Darlington pair. The chain A_3, A_4, Tr_1 forms a conventional operational amplifier. Devices A_5, A_6, Tr_2 and A_7, A_8, Tr_3 form two further operational amplifiers with different feedback resistors to provide different gains to compensate for the higher resistors R_B, R_C with which they are connected to the load point. Resistors R_B and R_C are, as far as the main amplifier A_3, A_4, Tr_1 is concerned, part of the load and so it is necessary to have them as high in value as possible to avoid wasting output power.

Bridge circuit

An improved version of Fig. 2 will now be described. It is principally of interest as an introductory circuit to the system; apart from its low output impedance its performance is not as good as the second circuit from the point of view of a power amplifier.

The input voltage is applied to the 1-kΩ resistor (Fig. 11) which is 1% of the 100kΩ equivalent to R_l of Fig. 2 so that if the source impedance varies from zero to infinity in resistance the error take-off signal at Q will vary by only 1%. The junction of the 1MΩ and 100kΩ resistors is coupled to the input of A_2 by the 1-μF capacitor, allowing d.c. conditions at P and Q to be adjusted independently to enable the standing current through the 20Ω resistor to be designed. The 5-kΩ pre-set resistor enables the distortion to be adjusted to a minimum; a voltage is introduced on the 15kΩ resistor for this purpose from the bias potential divider.

The waveforms (Fig. 12) of P to earth, the inverse of Q to earth, and the voltage between P and Q (Fig. 12) show clearly the effect of error take-off on distortion. The inverse of Q to earth is used as a reference on the waveforms.

I believe that the applications of error take-off are numerous and that this article has just scratched the surface. It should have application in those many problems where the negative feedback-zero mechanism approach falls down because the speed of response is insufficient and more feedback is impossible to achieve on grounds of stability.

References

1. Reducing distortion by error add-on, *Wireless World,* January 1973 (Circuit Ideas, p.32).
2. US Patent 1686792. Transtating system, by H. S. Black, 1928.
3. US Patent 2102671, page 2 line 69. Transtating system by H. S. Black.
4. Feedforward error control, *Wireless World.* May 1972, p.232.
5. McMillan. Multiple-Feedback Systems. US Patent 2748201, May 1956.

October meetings

LONDON

2nd. BKSTS—"Commercial radio—first year of Capital" by G. O'Reilly at 19.30 at Thames Television Theatre, 308–316 Euston Road, NW1.
3rd. RTS—Discussion on "The 'stars' in television" at 19.00 at South Bank TV Centre, Upper Ground, SE1.
4th. IEE—Discussion on "Instrument interfaces" opened by D. C. Loughry and R. C. M. Barnes at 14.30 at Savoy Pl., WC2.
8th. IEE—Discussion on "Secure supply for instrumentation and computer loads" opened by K. Bishop, Dr M. James and A. S. Watters at 17.30 at Savoy Pl., WC2.
8th. AES—"Electroacoustic quantities and units" by Rex N. Baldock at 19.15 at the IEE, Savoy Place, WC2.
9th. IERE—Colloquium on "H.F. heating circuits and techniques" at 10.00 at 9 Bedford Sq., WC1.
9th. BKSTS—"8mm—precocious child or maturing adult?" by C. T. Davies at 19.30 at Thames Television Theatre, 308–316 Euston Road, NW1.
10th. IEE—"Engineering innovation in a service industry—Post Office telecommunications" by J. H. H. Merriman at 17.30 at Savoy Pl., WC2.
11th. IEE—Colloquium on "Low cost educational instruments" at 14.30 at Savoy Pl., WC2.
14th. IEE—Colloquium on "Integrated communication systems for military applications" at 10.30 at Savoy Pl., WC2.
15th. IEE—"Laser induced gas breakdown" by Prof. C. Grey Morgan at 17.30 at Savoy Pl., WC2.
15th. IEE—"Automation in television and the theatre" by Dr I. R. Young at 17.30 at Savoy Pl., WC2.
16th. IEE—Colloquium on "Information systems" at 10.30 at Savoy Pl., WC2.
16th. IEE—"Acoustics in space and time—a developing technology" by Prof. E. A. Ash at 17.30 at Savoy Pl., WC2.
16th. IERE/IEE—"Technician Education Council" by F. Fidgeon at 18.00 at 9 Bedford Sq., WC1.
16th. BKSTS—"Laser beam telerecording" by D. Swan at 19.30 at Thames Television, 308–316 Euston Road, London NW1.
17th. IERE/IEE—Colloquium on "Electronics in audiology" at 10.00 at 9 Bedford Sq., WC1.
17th. IEE—Colloquium on "Kalman filtering—its application and limitations" at 14.30 at Savoy Pl., WC2.
17th. RTS—"Visual aids in training simulators" by Dr A. M. Spooner and C. Arthorne at 19.00 at South Bank TV Centre, Upper Ground, SE1.
18th. IEE—Colloquium on "Parametric amplifiers" at 10.30 at Savoy Pl., WC2.
18th. IEE—"Distance-protection comparator with signal dependent phase-angle criterion" by Dr L. Jackson at 17.30 at Savoy Pl., WC2.
24th. IEE—"Electrotechnology and economic prosperity" by Dr B. C. Lindley at 17.30 at Savoy Pl., WC2.
24th. RTS—"The AVR2 video tape recorder" by M. Salter at 19.00 at South Bank TV Centre, Upper Ground, SE1.
29th. IERE—Colloquium on "Signal processing in communications systems" at 10.00 at 9 Bedford Sq., WC1.
30th. BKSTS—"Electronic film making—past and present" by Walter Kemp, Dr Spooner et al at Thames Television Theatre, 308–316 Euston Road, NW1.

BATH

8th. IERE/IEE—Seminar on "Advances in telecommunications" at 18.00 at the University.

BOLTON

17th. IERE—"Current trends in semiconductors" by Dr K. J. Dean at 18.15 at Bolton Institute of Technology.

BRISTOL

15th. IEETE—"An introduction to space science and technology" by G. G. E. Lewis at 19.30 at Bristol Royal Hotel, College Green.

CAMBRIDGE

24th. IERE/IEE—"The electronic organ—the organ of the future?" by C. C. H. Washtell at 18:00 at Swaffham Prior Church, Swaffham Prior.

CARDIFF

9th. IERE—"Charge coupled devices" by Dr J. D. E. Beynon at 18.30 at Dept. of Applied Physics and Electronics, UWIST.

CHATHAM

17th. IERE—"Modern colour television receivers" at 19.00 at Lecture Theatre 18, Medway and Maidstone College of Technology, Maidstone Road.
23rd. IEETE—"Electronics to help the police" by A. T. Burrows at 19.30 at Medway and Maidstone College of Technology, Horsted Centre, Maidstone Road.

CHELMSFORD

24th. IERE—"Recent advances in display techniques" by D. W. G. Byatt at 18.30 at the Civic Centre.

CHIPPENHAM

23rd. IERE/IEE—"The digital data network" by M. Foulkes at 18.00 at the Canteen, Westinghouse.

COSFORD

2nd. IERE/R.Ae.S.—"Redundancy in aviation systems" by R. K. Barltrop at 19.15 at RAF Cosford.

DORKING

9th. IEE—"Modern scientific techniques of art object authentication" by Dr S. J. Fleming at 19.30 at Seeboard, Burford Sports Pavilion.

EVESHAM

3rd. IERE—"Digital television" by Speaker from I.B.A. at 19.30 at BBC (Evesham) Club.

FAREHAM

30th. IERE—"AUTONULL—the suppression of large interfering signals in single and multi equipment installations" by M. M. Zepler at 18.30 at H.M.S. Collingwood.

FARNBOROUGH, Hants.

24th. IERE/IEE—"Automatic weather stations" by H. R. S. Page at 19.00 at Farnborough Technical College.

GLASGOW

29th. IEETE—"Hi-Fi and stereo equipment" by T. D. Simmons at 19.00 at Institution of Engineers and Shipbuilders in Scotland, Rankine House, 183 Bath Street.

LEICESTER

17th. IERE—"Digital differential analysers and analogue computers" by W. Forsythe at 19.00 at the University.

LIVERPOOL

16th. IERE—"Colour television—from the studio to the viewer" by C. White at 19.00 at Dept. of Electrical Engineering and Electronics, the University.
28th. IEETE/IEE—"The future development of further education courses for technician engineers and technicians, related to the establishment of TEC" by A. T. Bardo at 18.30 at Electrical Engineering Laboratory Block, the University.

NEWCASTLE UPON TYNE

2nd. IERE—"Sonar and underwater communications" by Dr V. G. Welsby at 18.00 at Main Lecture Theatre, Ellison Building, Newcastle upon Tyne Polytechnic.

READING

16th. IERE—"Colour televison" by A. C. Maine at 19.30 at the J. J. Thomson Physical Laboratory, University of Reading, Whiteknights Park.

SOUTHAMPTON

23rd. IEETE—"The electronic organ" by speaker from Henri Selmer & Co Ltd at 19.30 at the Polygon Hotel.

SWANSEA

23rd. IERE/IEE—"What are the wild waves saying? —an early history of radio detection" by V. J. Phillips at 18.30 at University College of Swansea.

SWINDON

29th. IEETE—"Aerials and their uses" by Dr J. R. James at 19.30 at Kings Head Hotel, Wood Street.

WEYMOUTH

17th. IERE—"Underwater acoustic imaging" by S. O. Harrold at 18.30 at South Dorset Technical College.

Research Notes

Huge radio galaxies

Radio galaxies 3C236 and DA240 are now known to be among the largest objects in the universe. Their overall dimensions are typical, not of single galaxies but of large clusters of galaxies. This discovery may seem less surprising in that most of their bulk is made up of thin gas, nevertheless the sheer extent of these radio sources will give astronomers plenty to theorize about.

The new realization of the extent of these well-known radio sources comes as a result of measurements with the Westerbork Synthesis Radio Telescope (WSRT) in the Netherlands. The size of a radio galaxy is the size of the emitting region. The emissions are the result of "synchrotron radiation", in which very fast electrons travel through a magnetic field. Interaction with the field makes the electrons spiral along the lines of force, radiating radio frequency energy. Not surprisingly, the intensity of the radiation falls off towards the edges of a source and the problem is to get enough resolution from the radio telescope to be able to distinguish the weak outer areas from the intense inner ones.

One difficulty is that the dishes used in the telescopes have side lobes in their radiation patterns. In the WSRT, which has twelve 25-metre dishes, the main side lobe has a response which amounts to some 4% of the main beam. Fortunately it is possible to allow for this in the computer processing of the results of an observation. In the case of the larger of the sources, 3C236, it proved possible to measure radiation from regions emitting only 0.001 of the power of the "brightest" regions. Contour maps of "brightness" have been prepared, also a simulation of what the sources would look like if they were transmitters of light not radio waves.

The enormous extent of these sources, especially 3C236, which is some 17 million light years across, means that, if they began life as small objects which exploded, they must have been radiating enormous amounts of energy since their creation tens or hundreds of millions of years ago. Another point arising from the observations depends on the fact that such source contains at least two strongly emitting regions. The fact that the energy from both regions must traverse adjacent parts of space to reach the earth will enable astronomers to use the waves as "probes" to obtain information about the thin gas which exists in space between clusters of galaxies.

Nature, Aug. 23, 1974, p. 619 and p. 625

Magneto-electric material

A composite material which converts voltages into magnetic fields and vice versa has been produced by Philips Research Laboratories, Eindhoven. It is an alloy of barium titanate and cobalt ferrite. Barium titanate is piezo-electric and cobalt ferrite is piezo-magnetic. Applying an electric field causes the titanate to change shape, which in turn compresses the ferrite and produces a magnetic field. If a magnetic field is applied the reverse sequence takes place to give an electric output. The composite material is a better converter than the best known simple material (chromium sesquioxide) with similar converting properties.

Watching crickets' ears

Biologists at Cornell University are measuring the mechanical vibrations of the eardrum of the cricket as part of a programme of research on the mechanism of hearing. The ear of the cricket Gryllus pennsylvanicus is conveniently situated on the foreleg. A laser is used to illuminate the eardrum; back-scattered light is phase-modulated when the eardrum vibrates and this makes it possible, using an electronic system, to detect movements as small as 0.1 angstrom. The basis of the measuring system is to beat the back-scattered light with unscattered light in a photomultiplier. Any phase difference gives an output signal. Movement of the cricket's body also causes phase shifts. To enable such relatively slow gross movements to be cancelled a lock-in system is used. The back-scattered light passes through an optical phase shifter which is continuously modulated by vibrating a piezo-electric element which forms part of the phase-shift system. This provides a reference signal which enables the optical system to be automatically adjusted to keep the mean phase angle of the scattered light constant. Rapid variations about the mean can then be detected without interference from slow gross movements.

Science, July 5, 1974, p.55

Solid state optical recorder

First steps have been taken towards the development of a solid state optical recorder. The initial steps include the advent of extended red film, development of (AlGa)As laser diodes that emit continuously at wavelengths in the 700nm region and the use of a TeO_2 acousto-optic beam deflector as the horizontal line scanner in a TV-rate laser display.

Wideband modulation data indicates that laser diodes can be conveniently modulated up to 250MHz for wideband film recording applications. Frequency response, distortion, spurious spectral component and noise data indicate that the quality of the modulated output is equal to or better than that achieved in the past using a gas laser and an external beam intensity modulator. It appears from the data taken to date that the exposure energy source requirements for 100MHz wideband film recording systems are well satisfied by a laser diode of the type that has been tested, provided that the continuously emitted power is in the 10 to 15mW region.

Data is currently being taken to determine the characteristics of the record spot that can be formed from the diode output and the quality of film recordings that can be made. Development work has been undertaken by RCA with partial NASA support in producing the 700nm laser diodes.

Tuned reeds up to date

The tuned reed or vibrating cantilever resonator, once popular among radio-control enthusiasts, appeared in an interesting new form at the 1974 European Conference of Circuit Theory and Design at the IEE. H.M.S. Zakaria of Racal-Amplivox Communications makes tiny reeds, only a few millimetres long, by a selective etching technique on a sort of printed circuit board. These are given a d.c. bias and driven electrostatically via coupling plates positioned below the free ends of the cantilevers. This makes for a compact, neat arrangement compatible with other kinds of miniaturized circuitry.

The Q of such a resonator is not particularly high (it rises to about 1000 if the resonator is put in an evacuated container) but is adequate for a number of applications for audio-frequency selective calling systems, etc. The capacitive coupling lends itself to an arrangement in which the input goes to one plate and the output is taken from another; an earthed plate between the active ones reduces stray coupling between input and output. If required, several output plates can be associated with each resonator to give a "fan-out". It is also possible, in theory at least, to couple resonators mechanically as well as electrically. In this way complex filters could be constructed. The useful frequency range is from a few tens of Hz to a few tens of kilohertz.

Pocket laser

A battery-powered neodymium-yttrium aluminium garnet laser has been designed at the Royal Radar Establishment, Malvern. It delivers 0.5-joule pulses capable of making small welds or punching holes in metal foil. The size is $77 \times 70 \times 53$mm and the weight 420 grammes. The laser rod is energized by a photo-flash discharge lamp. This lamp is supplied with 40-joule pulses from a 750µF capacitor charged to 330V approx. from a 12-V nickel-cadmium battery and transistor inverter.

Optics and Laser Technology, Aug. 1974, p. 174

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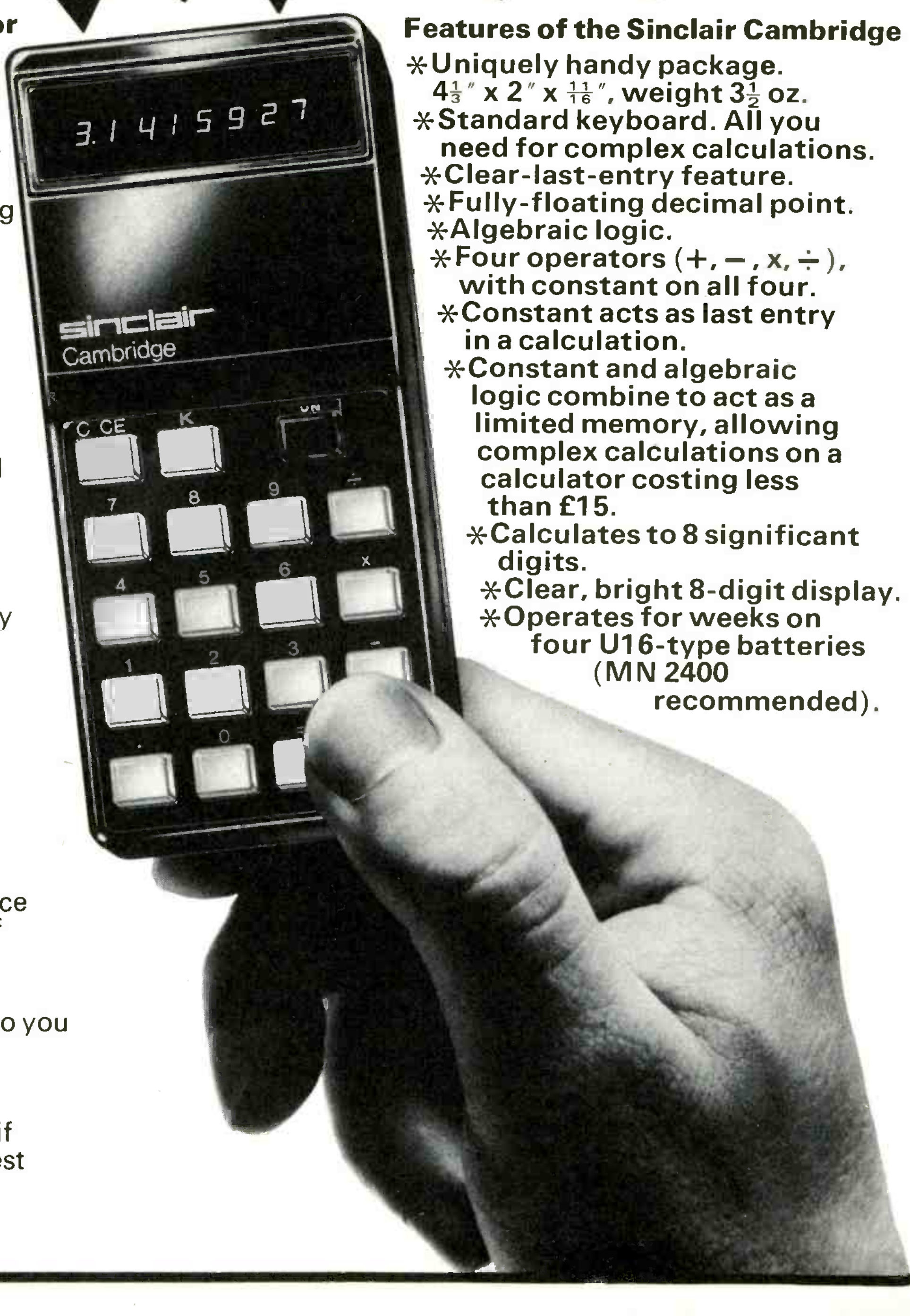

An advanced 4-function calculator in kit form

The Cambridge kit is the world's largest-selling calculator kit.

It's not surprising – no other calculator matches the Sinclair Cambridge in functional value for money ; and buying in kit form, you make a substantial saving.

Now, simplified manufacture and continuing demand mean we can reduce even the kit price by a handsome £12·50. For under £15 you get the power to handle complex calculations in a compact, reliable package – plus the interest and entertainment of building it yourself !

Truly pocket-sized

With all its calculating capability, the Cambridge still measures just $4\frac{1}{3}$" x 2" x $\frac{11}{16}$". That means you can carry the Cambridge wherever you go without inconvenience – it fits in your pocket with barely a bulge. It runs on U16-type batteries which gives weeks of normal use before replacement.

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All parts are supplied – all you need provide is a soldering iron and a pair of cutters. Complete step-by-step instructions are provided, and our service department will back you throughout if you've any queries or problems.

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***Uniquely handy package. $4\frac{1}{3}$" x 2" x $\frac{11}{16}$", weight $3\frac{1}{2}$ oz.**
***Standard keyboard. All you need for complex calculations.**
***Clear-last-entry feature.**
***Fully-floating decimal point.**
***Algebraic logic.**
***Four operators (+, −, x, ÷), with constant on all four.**
***Constant acts as last entry in a calculation.**
***Constant and algebraic logic combine to act as a limited memory, allowing complex calculations on a calculator costing less than £15.**
***Calculates to 8 significant digits.**
***Clear, bright 8-digit display.**
***Operates for weeks on four U16-type batteries (MN 2400 recommended).**

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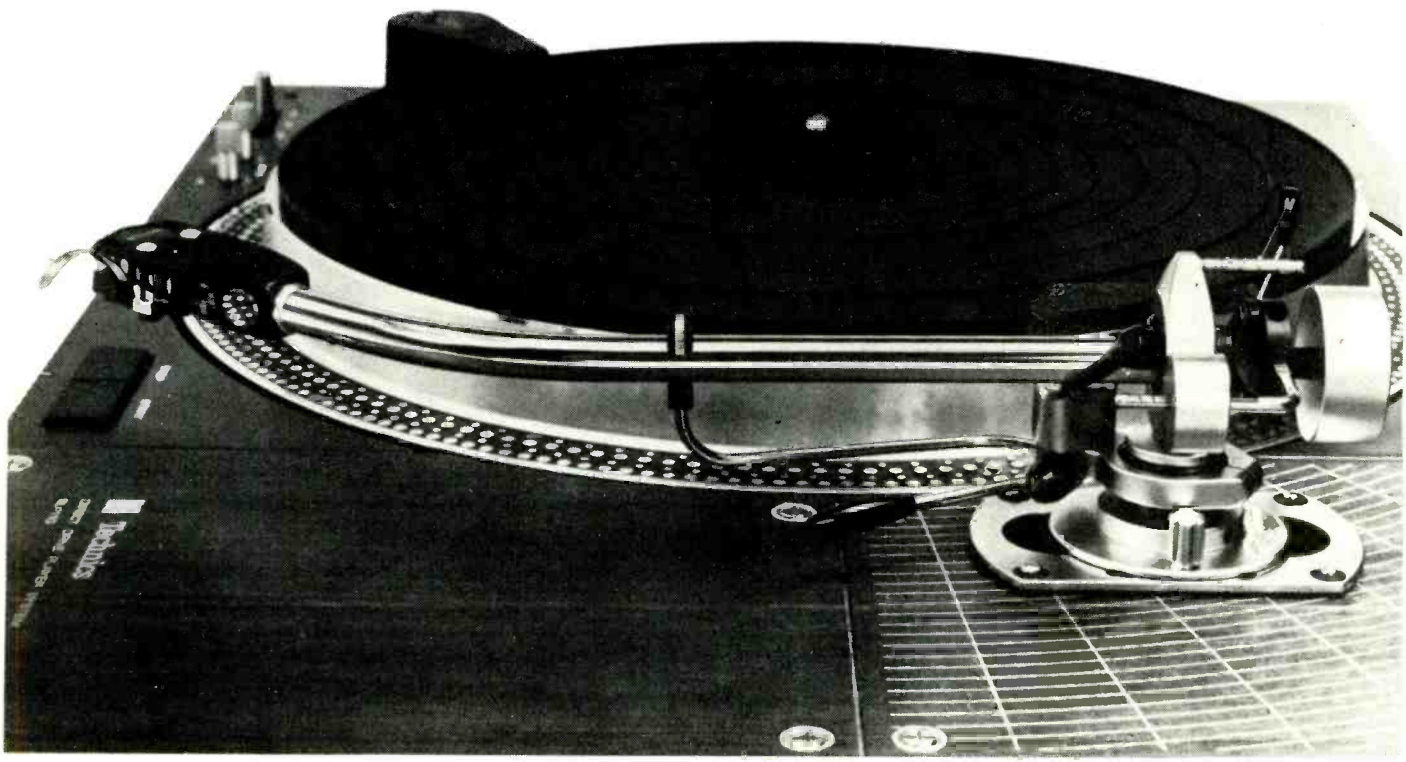
Can be seen but not heard



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News of the Month

Security for diamonds

A 14-camera security survey system is being installed in a diamond mine about 150 miles North-West of Francistown in Botswana. Each c.c.t.v. camera has its own associated picture monitor and a movement in any of the areas guarded by the alarms will automatically switch the output of the relevant camera on to a monitor providing a large screen picture. This will be recorded automatically on a time-lapse video tape recorder, which is employed to reduce tape usage by producing a series of "stills" rather than a continuous tape.

The monitors are located in a control centre which is approximately 400 metres from the camera locations. The chief security officer also has a master monitor which can be switched to any monitor plus a time-lapse v.t.r. in his office at a location 800 metres from the camera points. Particularly important in this installation are the precautions necessary to prevent corrosion due to the high saline content of the extremely large quantities of water used in the mining processes. The Orapa diamond mine which has a high output of industrial and other diamonds is being equipped with the EMI Surveyor c.c.t.v. system.

Electronic licence plate

The lowly licence plate, the last item considered when buying a car, someday may be the most important when it comes to highway safety, traffic control, anti-theft protection, vehicle inspection and automatic toll billing. It also may prove to be a very effective way of transmitting emergency radio messages between motorists and the police.

The key to such an automatic and almost instantaneous multi-purpose system is an electronic licence plate proposed by the RCA Microwave Technology Centre in Princeton, New Jersey. The system, which would cost only a few dollars when manufactured in quantity, would perform three basic functions: respond with a vehicle's identifying code number when electronically interrogated; receive and transmit radio messages to and from a vehicle; and serve as a transponder for use in a co-operative collision avoidance radar.

The heart of the licence plate is an antenna system capable of receiving radio signals at one frequency and re-broadcasting the signals at double that frequency. The addition of an integrated circuit coder would enable the licence plate to transmit an electronic signal that distinctly identifies the vehicle carrying it.

This feature could be used in a number of ways. Electronic interrogators (microwave transmitters/receivers) placed along streets and highways as part of a data processing network could provide automatic vehicle monitoring of buses, police cars, ambulances, trucks and cabs. This information could be used to provide improved scheduling of buses and speedier and more efficient dispatching of ambulances, police cars, cabs and trucks. It also would enable trucking firms to monitor vehicles carrying valuable cargoes, thus reducing the risk of highjacking.

In addition, the system could alert police as soon as the identifying number and location of a vehicle known to be stolen appears. Likewise, authorities could be alerted to vehicles whose owners had ignored summonses for traffic violations.

The electronic interrogators, equipped with Doppler radar speed sensors, could automatically record the identifying number of any vehicle exceeding the posted speed limit by a significant amount. A "you are speeding" signal could also be transmitted to the driver via the electronic licence plate.

The system could be expanded to limit access of vehicles to certain areas by adding special codes to the basic identification numbers. For example, entry to restricted parking lots could be limited to designated vehicles.

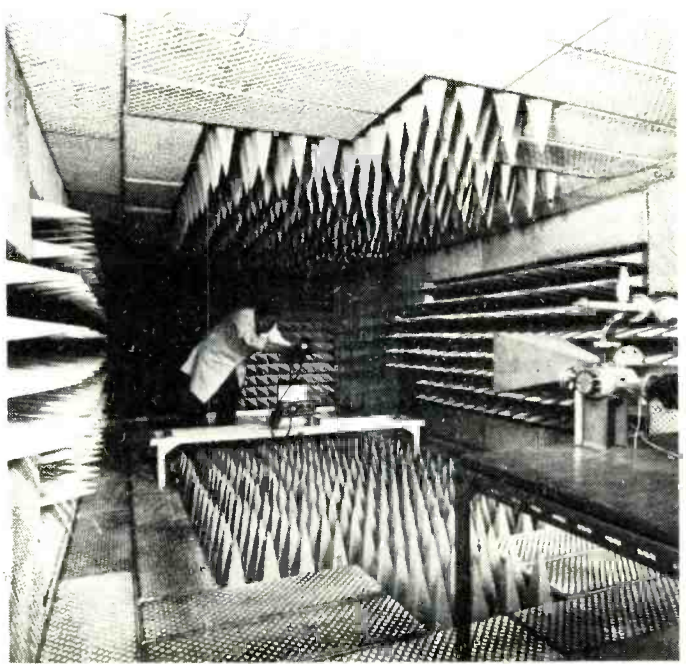
Vehicles with special codes could bypass coin toll collectors at bridges and turnpike entrances. The vehicle's identifying number would be automatically recorded from the electronic licence plate, and its owner would be periodically billed for accumulated toll charges.

Inspection stations, an RCA scientist points out, could be automated to test vehicles to manufacturers' specifications. An electronic interrogator would read the car's identifying number and automatically programme the inspection equipment to check for compliance with the manufacturer's specifications for that particular car or truck. The licence plate could also be used to receive safety messages from fixed roadside transmitters or police cars. Examples of such messages are ice, snow, fog, or accident ahead, vehicle going the wrong way into a one-way street, or car going too fast for conditions.

The driver of a disabled car could use his electronic licence plate to transmit a coded call for assistance to either fixed roadside receivers or possibly to passing police cars or other public vehicles. The main components of the electronic licence plate are described as a "printed-circuit antenna covered by a visual display of the licence number of the vehicle, a frequency doubler, a modulator, and an r.f. detector." It would be 12 inches long, 6 inches high, and about a half inch thick. The electronic licence plate meets all of the requirements for a second harmonic reflector to be used in a highway collision avoidance system radar (see *Wireless World* May, June 1974 "Clutter free radar for cars").

Millimetre-wave radio

Scientists of the Nordern Division, United Aircraft Corporation in the US have developed a new millimetre-wave radio transceiver for frequencies of 22 and 39GHz. The radio, which is an economical and practical answer to many applications for short-haul transmission of both voice and data, initiates a series of the Division's related telecommunications products. It is intended for point-to-point transmission of digital information and can transmit and receive voice and data information simultaneously. As an economical alternative to cable installations, the radio weighs less than 30lb and is 21in in diameter and 21in in depth. Error rate is claimed to be extremely low and the unit is constructed to withstand



Accurately controlled microwave power levels can be launched into this anechoic chamber being used by G. & E. Bradley Ltd for the accurate calibration of measuring instruments for the monitoring of microwave radiation.

adverse weather including extremes of heat and cold. Power may be supplied from a station battery or from 115V alternating supply.

The US Federal Communications Commission decided to open up new frequencies centred at 18.22 and 39GHz to meet the growing demand for communication facilities. Nordern's new millimetre-wave radio has been developed specially for operation at these frequencies.

Supercable

A cable capable of carrying 100,000 telephone conversations simultaneously is to form a new high-capacity backbone for Britain's telephone network linking Birmingham, Manchester and London by the end of the decade.

As the cable breaks new ground in laying techniques and even production technologies, several short lengths probably of no more than a few kilometres are expected to be laid during October to give suppliers experience of laying the new cable. The main laying operation will begin early next year and the Birmingham–Manchester section should be completed by May 1976. In terms of the number of calls it can handle, the cable capacity is such that it can carry twice as many telephone conversations as all the existing transmission systems at present serving its route.

The new cable has 18 coaxial pairs and will be equipped with 60MHz systems, compared with the 12-tube, 12MHz equipped cables now widely used. Two coaxial pairs (one for each direction of transmission) can carry up to 10,800 telephone conversations or an equivalent mix of telephony, telex, computer data and TV.

The 60MHz line system uses frequency division and multiplexing occupying the frequency spectrum between 4 and 60MHz in which 12 broadbands of 900 circuits each can be assembled to give the capacity of 10,800 telephone circuits. In view of the probable use of digital transmission methods on the trunk telephone system within the working life of the cable, the Post Office has specified a stringent digital performance for the cable.

Oil rig communications

The use of radiotelegraph error-correcting equipment is to become more widespread in ship-to-shore communications for offshore oil rigs in the North Sea. Most of these rigs use teleprinters to transmit technical and commercial data, via the Post Office coast stations, to their offices ashore. To achieve the high degree of accuracy needed many of these rigs have installed Marconi Autospec terminals as part of their installation. Autospec enables radio communication to be achieved in all but the worst conditions of fading and interference without the need to employ a return radio path to request retransmission. The latest version, Autospec II, is more compact than its predecessor and provides a greater degree of accuracy. Both terminals are compatible although the special error correction code has been further developed and in Autospec II includes character element interleaving to overcome the effect of long interference noise bursts and fades on the radio path. There is also a visual indication of error detection which allows the operator to make an assessment of the circuit efficiency at any time and take appropriate action when conditions on the radio path are unfavourable to reliable transmission.

Spare parts

The instant availability of commonly needed parts for mobile two-way radio is the aim of a product called Spare-Pac recently unveiled by Motorola Communications and Electronics. Each kit consists of the following classifications or parts: semiconductors, resistors, capacitors, potentiometers, fuses, switches, relays, speaker, microphone cartridge, coiled cord, coils, chokes, transformers, control knobs, pilot lamps, connectors, sockets and miscellaneous parts. The kits are designed primarily for the Mocom-70 or Micor mobile two-way radios.

Simple f.d.m. using comb filters

A technique for combining two channels into one audio channel while allowing them to be retrieved with reasonable separation has been developed in Japan. It has especial attraction in telephone communication, allowing channel capacity to be effectively doubled. The technique, called comb frequency division duplex, can also be applied to howlback suppression in loudspeaking telephony allowing an excess loop gain of 20dB. For ordinary telephony, a separation of 30dB can be obtained.

In the duplex system, two input channels are fed through complementary comb filters, the pass bands of one filter corresponding with the stop bands of the other. They are then additively combined, transmitted on a single channel and, at the receiving terminal, fed through comb filters having similar characteristics to the input filters. Separation depends on the type of comb response chosen. For example, filters with squared cosine and sine amplitude characteristics give about 10dB separation, and filters with fourth-power cosine and sine characteristics give about 23dB separation. A modified fourth-power response can give as much as 30dB separation. "Distance" between comb "teeth" is typically 200Hz.

There is, of course, some degradation of speech quality but in expensive transmission systems, especially satellite communication systems, maximizing efficiency is a prime consideration, even at the expense of some quality. The technique is potentially much cheaper than the complicated vocoder systems, in which speech is synthesized from narrow-band control signals. The comb filter response can be derived by digital filter synthesis techniques and, with the advent of charge-coupled analogue delay lines, can be implemented without recourse to analogue-to-digital converters, shift registers and digital-to-analogue converters.

The technique was described at the recent International Congress on Acoustics, held at Imperial College, London, in July, by Yoshimutsu Hirata, of the department of electronics and communications, Waseda University, Tokyo.

Briefly

Beer on tap. A pocket paging system has been installed at the North Euston Hotel, Fleetwood—when the beer runs out, they simply radio for more.

Style plus the advantages of electronic push-button "dialling" are features of the latest telephones to be tried out in London. If trials go as the Post Office expects, the new 'phones will later be made available progressively in other parts of the country.

Mains rejection tracking filter

Using a tracking "n-path" filter with wide dynamic range

by K. F. Knott, B.Eng., Ph.D., M.I.E.E. and L. Unsworth, B.Sc.
University of Salford

The filter described greatly reduces interference at mains frequency and harmonics on wideband signals without seriously affecting these signals. It has the ability to track changes in the mains frequency, enabling very sharp rejection characteristics to be obtained. Useful rejection is maintained up to the 5th harmonic. The filter is based on the well-known principles of the commutating *CR* network but several improvements have been made to extend the dynamic range of this network without sacrificing signal bandwidth. For example, at mains fundamental a rejection greater than 40dB is maintained down to signal levels of 50mV r.m.s., the signal bandwidth being 100kHz. Consider the situation in which *N* identical capacitors are switched into a *C-R* network in sequence at a rate of Nf_o Hz (Fig. 1).

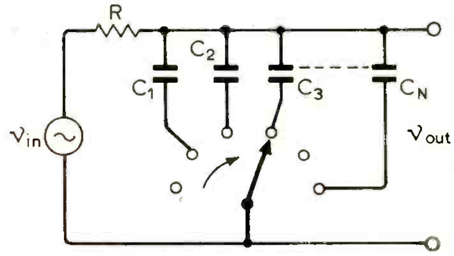


Fig. 1

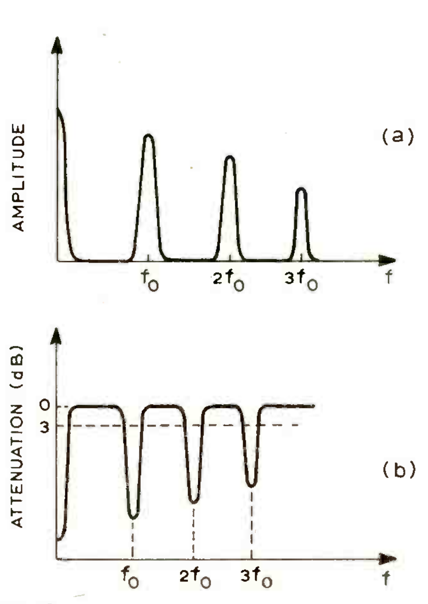


Fig. 2

The transfer characteristic of the network has the form indicated by Fig. 2(a), i.e. the network acts as a comb filter, the centre frequencies of which are set by the commutating frequency of the switch.[1] Alternatively, if the output is taken across the resistor the transfer characteristic of Fig. 2(b) is obtained.

If the commutating frequency, Nf_o, is controlled to follow variations in f_o, the filter has the ability to track varying-frequency input signals therefore enabling the use of sharp notches while maintaining high attenuation. This is in contrast to fixed-frequency notch filters such as the bridged-T network. Although the mathematical treatment of commutating filters is well established it is useful to describe their operation in a non-mathematical way for the purpose of discussing problems which arise in the design of an instrument.

Principle of operation

Suppose the input signal v_{in} in Fig. 1 is sinusoidal at a frequency f Hz. If f is equal to nf_o, where n is an integer, the input signal will be in synchronism with the switch and each individual capacitor will be switched in at the same instant in each cycle of the input waveform. Each capacitor will charge up to the corresponding instantaneous value of the input waveform. This is analagous to sampling the input waveform with N/n samples per cycle. Obviously the upper limit on n is $N/2$.

The voltage waveform across *C* will not be sinusoidal but will resemble a "staircase" replica of the sinusoidal input voltage. The voltage across *R* will be the difference between the sine-wave and the staircase waveform. Consequently the action of the filter necessarily introduces high-frequency switching noise. An illustration of this noise is shown in the photograph of Fig. 3, which was taken for the case with f_o = 50Hz, $n = 1, N = 16$.

Consider now the action of the filter if f is a non-integral value of f_o. The input is no longer in synchronism with the switch and each individual capacitor will be switched in at varying points in successive cycles of the input waveform. The voltage across each capacitor will therefore be averaged to zero and the voltage across *R* will be equal to the input voltage. At input signal frequencies very much lower than f_o the switch may be considered to be rotating so rapidly that all *N* capacitors appear to be connected simultaneously. The circuit can then be thought of as a simple network with a time constant of *NCR* i.e. the voltage across *R* is down by 3dB at a frequency $1/2\pi NCR$ Hz. At input frequencies much higher than f_o the switch may be considered stationary and the network thought of as a simple network with a time constant of *CR*. This usually means that the voltage across *C* is very much smaller than the input voltage at frequencies greater than $Nf_o/2$ even though the commutation is no longer effective. Hence the voltage across *R* will be almost equal to the input voltage. The switching has the effect of reflecting the loss-pass response about f_o, $2f_o$, etc, thereby generating the comb-filter response of Fig. 2(a). The bandwidth is $2/N$ times the bandwidth of the original low-pass sections, i.e. $(2/N)(1/2\pi CR) = 1/\pi NCR$.

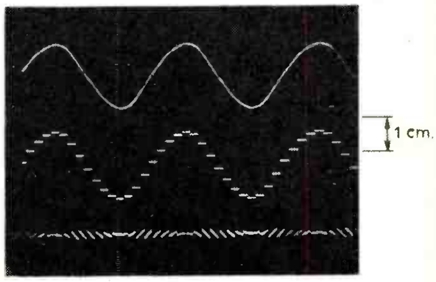


Fig. 3

Design considerations

The desirable characteristics of a tracking mains interference rejection filter may be summarized as follows.

1. Minimum degradation of the signal which is to be transmitted through the filter.
2. Wide dynamic range and signal bandwidth.
3. High rejection of the fundamental and lower harmonics of the mains frequencies bearing in mind that interference signals are liable to fluctuate in amplitude.
4. Ability to track changes and rates of change of the nominal mains frequency.

As point 4 is subsidiary to the operation of the filter it is considered briefly before proceeding to a more detailed discussion of points 1, 2 & 3.

Tracking requirements

Statutory limits of the mains frequency in this country are 49.5Hz and 50.5Hz, although the likelihood of these limits being reached is low under normal circumstances. The rate of change of mains frequency is governed by the inertia of the generating plant and it is extremely unlikely that a rate of change of 0.1Hz/min. would be exceeded. The tracking requirements are modest therefore and the circuit described later has an adequate performance.

Rejection, signal bandwidth and dynamic range

A convenient way in which to discuss the performance of the filter is to consider the various properties of the basic circuit and then discuss how these properties may be improved. The basic filter, omitting the tracking loop, is shown in Fig. 4.

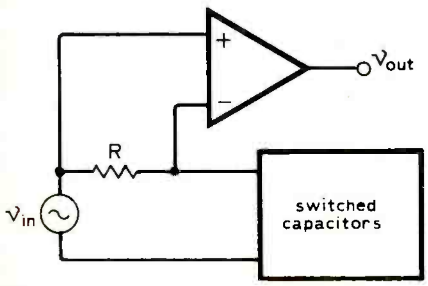


Fig. 4

Considering firstly the rejection characteristics of this circuit, as illustrated in Fig. 2(b), the sharpness of rejection is proportional to *NCR*. In theory one can obtain a very high *Q*-factor by choosing an appropriately large value of *NCR*. But an interference signal is likely to have a fluctuating amplitude. Suppose, for the sake of argument, that a 50-Hz interference signal was fluctuating sinusoidally in amplitudes with a period of ten seconds. Obviously this may be considered as a double-sideband signal with a carrier at 50Hz and sidebands at 50 ± 0.1Hz. If the *Q* of the filter at 50Hz were greater than 50/0.2 the sidebands would not be greatly affected. Although the analysis of sinusoidally modulated mains interference is a fictitious case it serves to illustrate that one must not have too high a *Q*-factor if fluctuating interference signals are to be rejected. Also, the step response of the filter is determined by its *Q* such that a slow response would result if a very high value of *Q* were used.

Theoretical magnitudes of rejection obtained at the synchronous frequencies can be found fairly easily by numerical analysis for specific values of *N*. The procedure is explained in the following paragraph.

Consider a sinusoidal input signal of frequency nf_o Hz. In the steady-state condition the voltage across each capacitor will reach the value of the input sine-wave averaged over the period for which the capacitor is connected. The voltage across each capacitor may be assumed constant provided that the *CR* time constant is large compared with the time spent on each capacitor and also if there is negligible discharge of the capacitors during the time between consecutive connections, i.e. $1/f_o$ sec. The waveform across the capacitors will thus be as illustrated in Fig. 5.

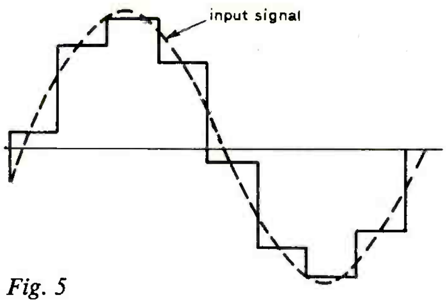


Fig. 5

The Fourier analysis of this type of waveform appearing across the capacitors may be found numerically by the "jump" technique.[2] As an example, suppose *N* were equal to 16. The analysis yields the result that for input signals of frequency f_o, $2f_o$ and $3f_o$, the fundamental components of the waveforms across the capacitors are respectively 0.97, 0.95 and 0.905 times the input. This would lead to rejections of 30.4, 26 and 20.4dB respectively if these fundamental components alone were subtracted from the input signal. However, these figures may be improved by weighting one of the inputs of the subtractor. In this way infinite rejection can be achieved at one of the synchronous frequencies, i.e. f_o, $2f_o$ or $3f_o$, etc. For example, if the circuit were trimmed to effectively increase the 0.97 figure to 1.00, the theoretical rejections at f_o, $2f_o$ and $3f_o$ would be ∞, 33 and 23dB respectively.

Considering, secondly, the dynamic range of the circuit, it was mentioned previously that the commutating action of the filter introduced high-frequency switching noise. Being more specific, if a 50-Hz signal were present at the input, switching noise would be introduced at $50N+50$, $50N$, $100N$, $150N$. . . etc, Hz. Furthermore, amplitudes of the switching noise components are at fixed levels below the 50-Hz signal. In general, the switching-noise component amplitudes decrease as *N* increases. As there is obviously a practical limit to the value of *N* the output of the basic filter will contain components of switching noise which will limit the dynamic range of the filter.

The simplest way in which to improve the dynamic range is to add a low-pass filter to the output as shown in Fig. 6, this of course reducing the signal bandwidth. To exploit the rejection properties of the commutating filter this low-pass filter should have negligible attenuation up to say $(N/2)50$Hz and high attenuation at $N50$Hz. The inevitable choice would be an active *R-C* filter.

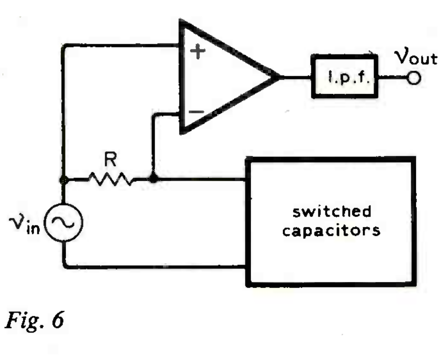


Fig. 6

Good dynamic range and signal bandwidth can be achieved if a low-pass filter is inserted in the position shown in Fig. 7.

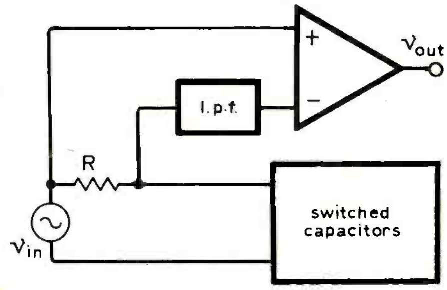


Fig. 7

The low-pass filter must again have a very sharp cut-off but unfortunately this cannot be achieved without introducing phase-shift in the pass-band. As a result the rejection decreases since the interference signals present at the differential amplifier inputs will no longer be exactly in phase.

This disadvantage may be overcome by inserting an all-pass filter in the signal path, having exactly the same phase response as the low-pass filter so that the interference signals present at the inputs of the differential amplifier are now always in phase, resulting in the final block diagram of Fig. 8.

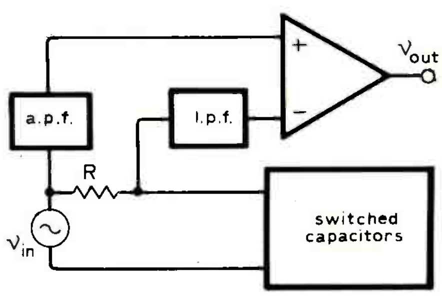


Fig. 8

Unfortunately the wanted signal now undergoes the phase-shift of the all-pass filter. This may or may not be important depending on the application.

To summarize, the filters based on the block diagrams of Figs 6, 7 & 8 have the following properties:

Fig. 6—high rejection, low signal bandwidth, good dynamic range

Fig. 7—high signal bandwidth, good dynamic range, moderate rejection

Fig. 8—high signal bandwidth, high rejection, good dynamic range but unsuitable for applications which require little phase-shift through the filter.

All of these characteristics may be obtained from the constituent parts of Fig. 8 by a suitable switching arrangement, though not simultaneously.

Choice of *N* and *CR*

Good rejection and tolerable levels of switching noise without overdue circuit complexity can be achieved with $N=16$. If a bandwidth of 1Hz at 50Hz is specified, i.e. $Q=50$, the filter will have a negligible effect on a wideband signal. Also, with a half-bandwidth of 0.5Hz reasonable rejection will still result at frequencies between 49.8 and 50.2Hz, i.e. the filter would reject a 50-Hz interference signal even if its amplitude were fluctuating over periods as short as 5s and further with a Q of 50, the time constant of the filter is 0.3s so that a rapid response to step changes in interference level is achieved.

Complete layout

The complete block diagram of a practical mains rejection filter is shown in Fig. 9. A switching arrangement has been adopted to make maximum use of the characteristics of the commutating network.

In position 1 (cf. Fig. 8) there is high signal bandwidth, high mains rejection, good dynamic range but considerable phase-shift between input and output. Position 2 again yields high signal bandwidth and good dynamic range but moderate mains rejection (cf. Fig. 7). However, the phase-shift is now constant over the audio range of frequencies. This is accomplished simply by shorting out the all-pass filter. The effect of the phase shift of the low-pass filter is to reduce the rejection of mains frequencies. However, the 50-Hz rejection is improved by introducing a simple lead network (C_1, R_1)

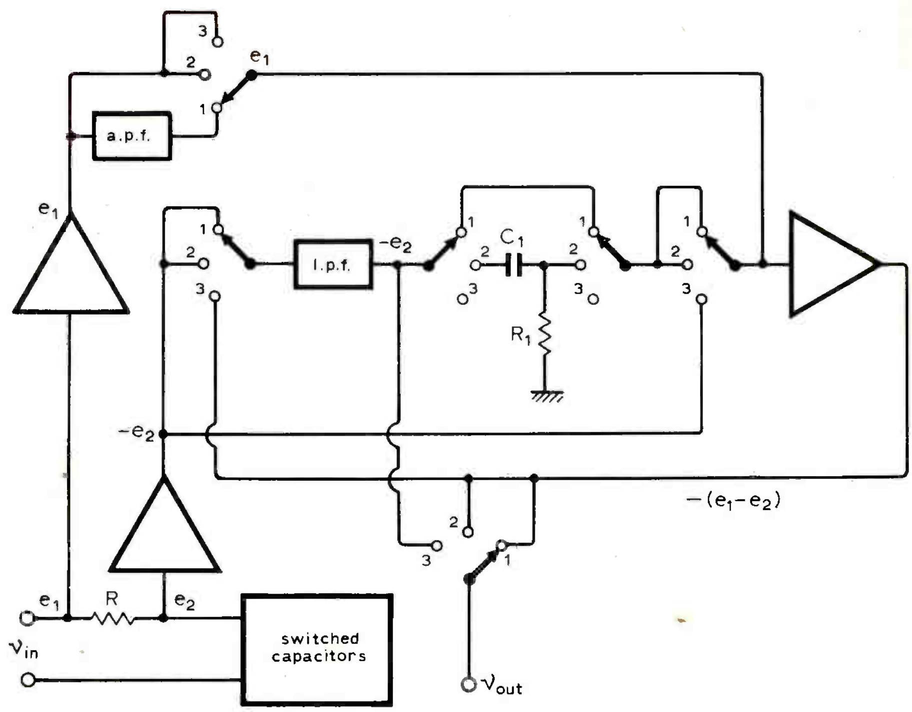


Fig. 9

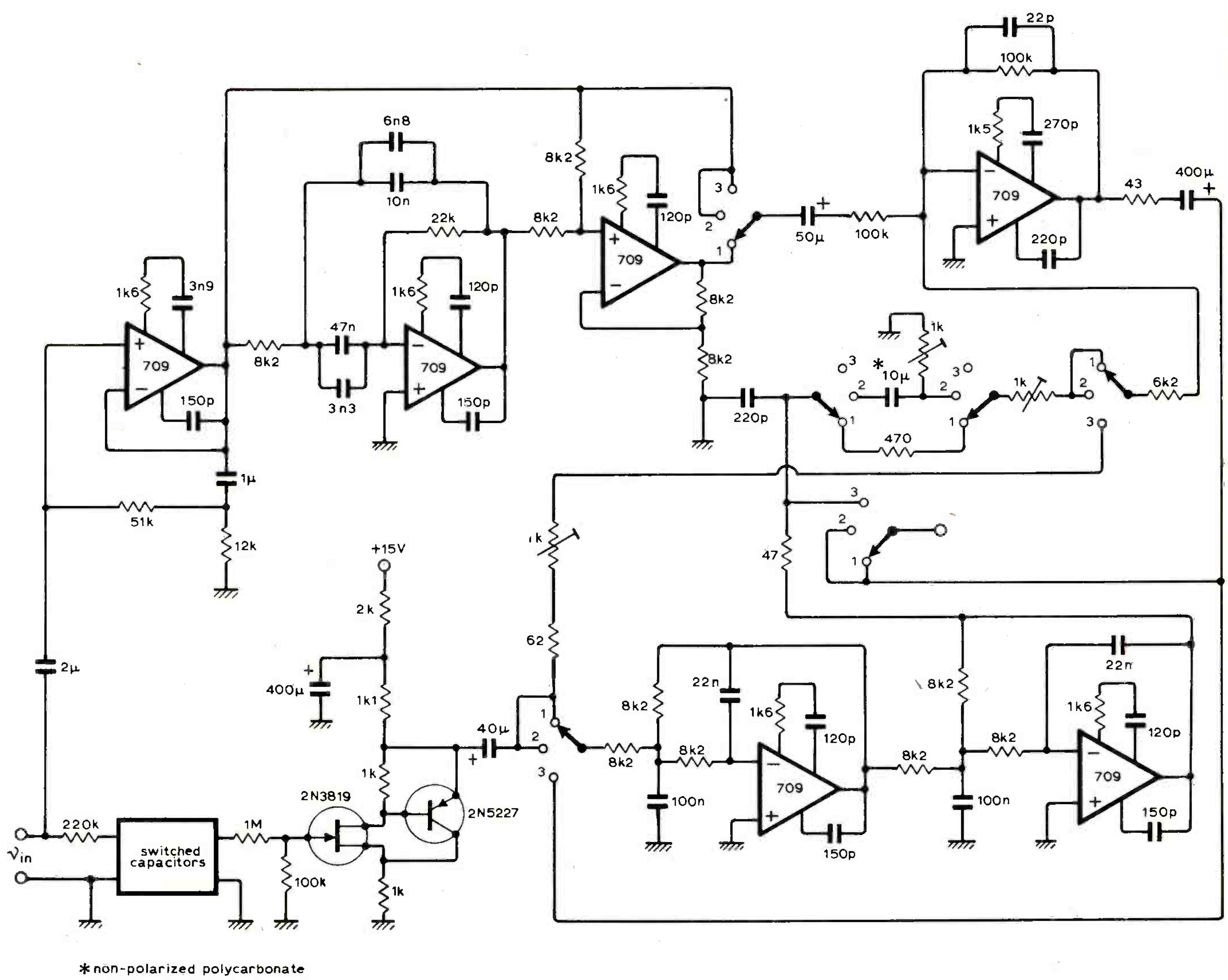


Fig. 10

chosen so that at 50Hz, though not at higher harmonics, the interference signals are exactly in phase at the inputs of the differential amplifier.

Position 3 gives high mains rejection, good dynamic range but low signal bandwidth, determined by the low-pass filter (cf. Fig. 6). This position was found to be desirable in certain applications where high frequency signals cause problems.

The low-pass and all-pass filters are both non-inverting and need to be preceded by buffers. Because an adder is far easier to align than a subtractor with its four variables we made the buffer preceding the all-pass filter a follower and the other an inverter, thus enabling an adder to be used to derive the required difference between the interference signals.

The circuit diagram corresponding to the block diagram of Fig. 9 is shown in Fig. 10.

Commutation

The 16 capacitors must be commutated electronically at 16 × mains frequency. Any one of a number of methods may be used to this end and the technique chosen is to drive two 8-way multiplexers alternately, both consisting of eight m.o.s.f.e.ts, each of which is switched on in turn with consecutive input clock pulses. The multiplexers are connected thus

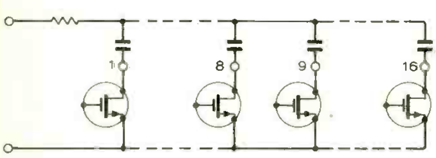


Fig. 11

The f.e.ts 1 to 16 are therefore arranged to switch on in turn. An 800-Hz clock (described later) drives a four-stage binary counter, the output of which is a 50-Hz square wave.

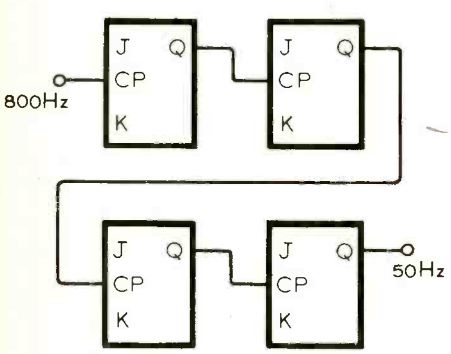


Fig. 12

In Fig. 12 all J and K inputs are permanently high. The 800-Hz clock is used to drive the two multiplexers. Consider just one multiplexer. Each f.e.t. is energized in turn as consecutive clock pulses appear at the input but, after eight pulses, the clock waveform must be diverted to the second multiplexer which then switches capacitors 9 to 16 and then back to the first multiplexer, etc.

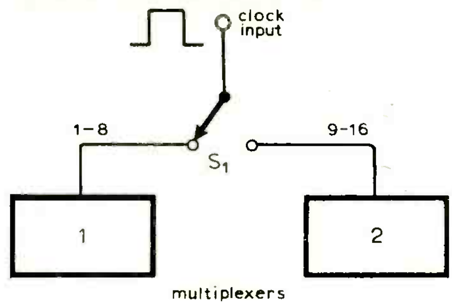


Fig. 13

Referring to Fig. 13, switch S_1 must toggle every eighth clock pulse. Now the output of the counter of Fig. 12 toggles every eighth clock pulse and so switch S_1 may be simulated as follows

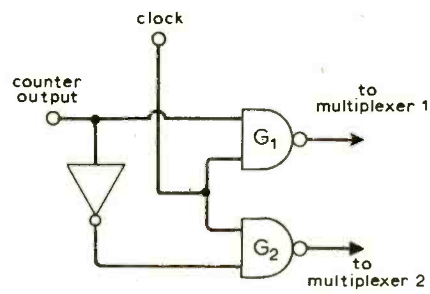


Fig. 14

When the counter output is high, gate G_1 is enabled and its output will then consist of the 800-Hz clock waveform. Meanwhile G_2 is closed. After eight clock pulses the counter output assumes a low state and gate G_2 is now enabled while G_1 closes.

Tracking oscillator

A multivibrator with a pulse repetition rate of N × mains frequency will provide the clock waveform. If the mains frequency changes slightly, then so must the multivibrator repetition rate to maintain synchronism.

Consider the following circuit

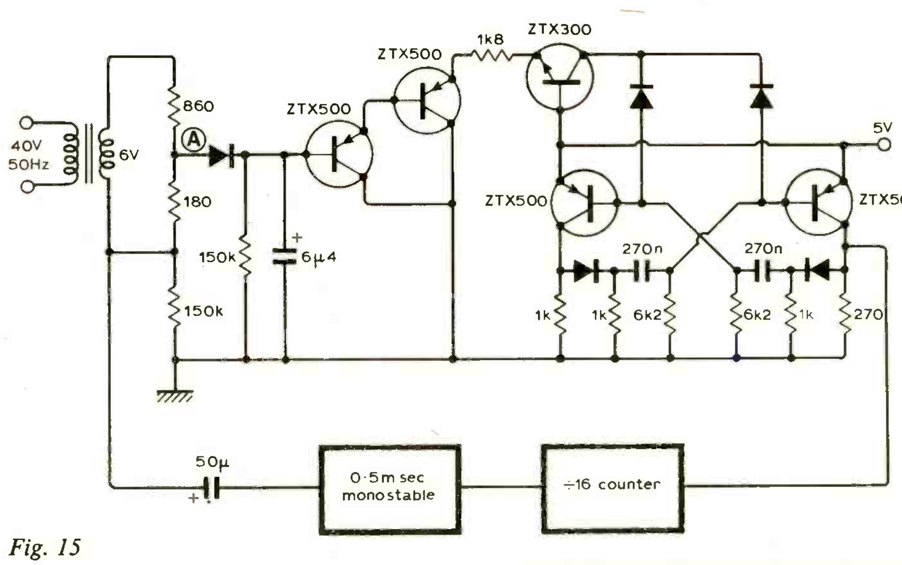


Fig. 15

The waveform at point A will be a 50-Hz sinewave with a pulse superposed on it:

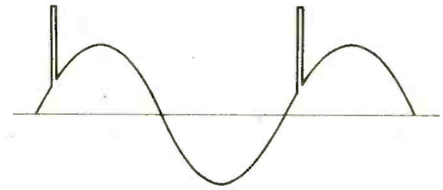


Fig. 16

When the multivibrator is synchronized to the mains frequency, the 0.5ms pulse will sit on the sinewave at some particular point. If the mains frequency now changes slightly, the pulse will climb up or slide down the sinewave and if the peak value of the waveform of Fig. 16 is detected, the resulting voltage can be used to vary the multivibrator rate to maintain synchronism with the mains.

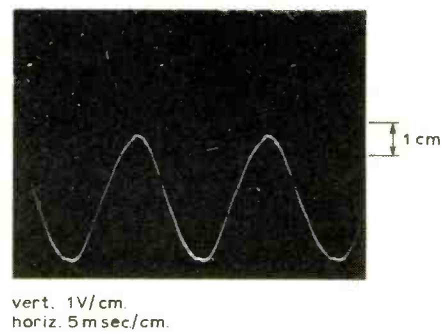


Fig. 17

Fig. 17 shows a photograph of the waveform at point A. The monostable of Fig. 15 is based on that given in reference 4.

A graph of p.r.r. versus mains frequency is shown below

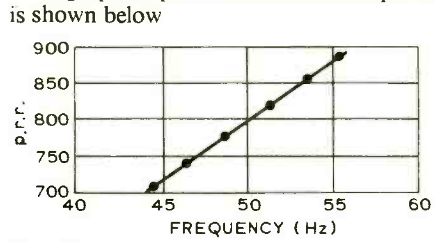


Fig. 18

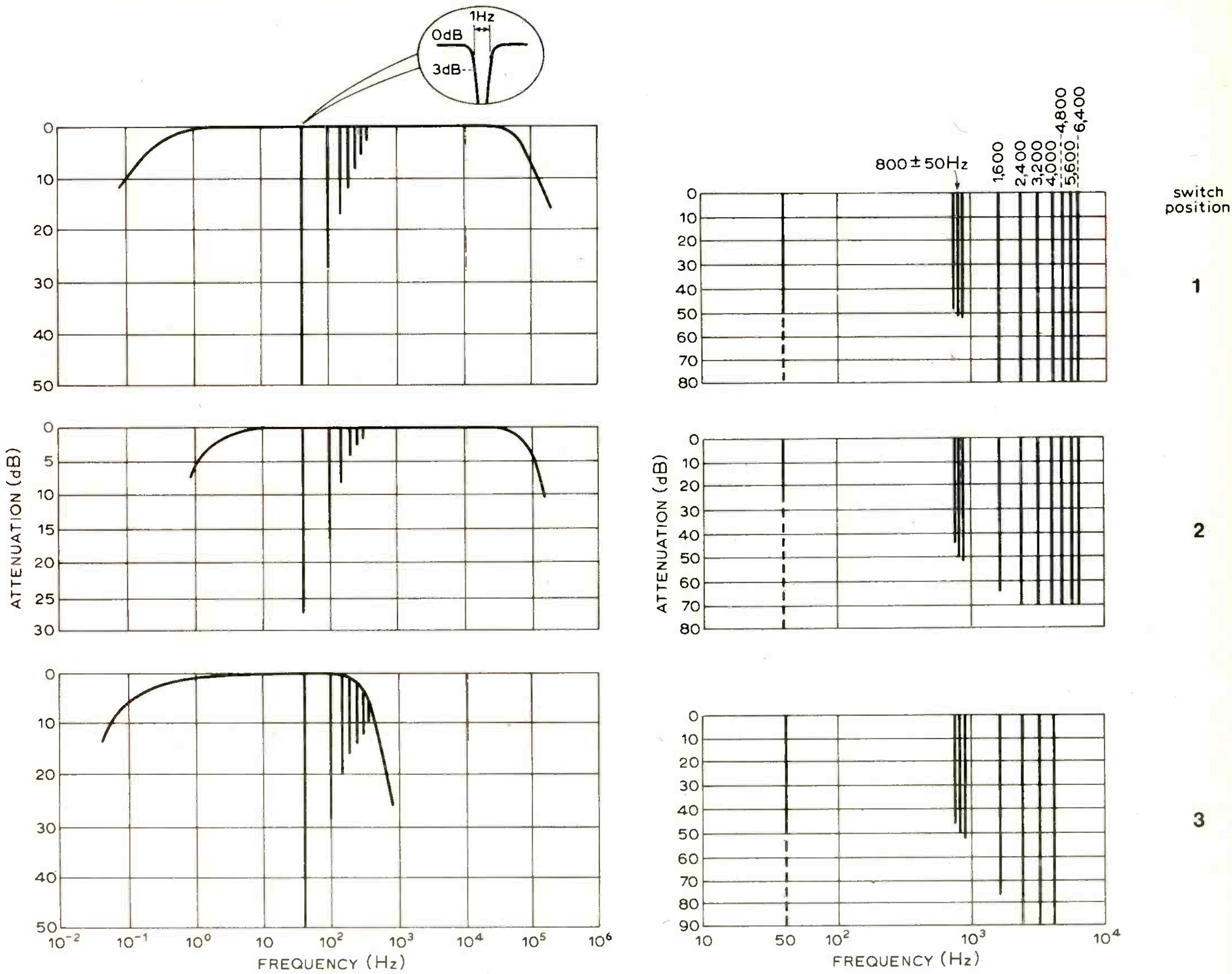


Fig. 19

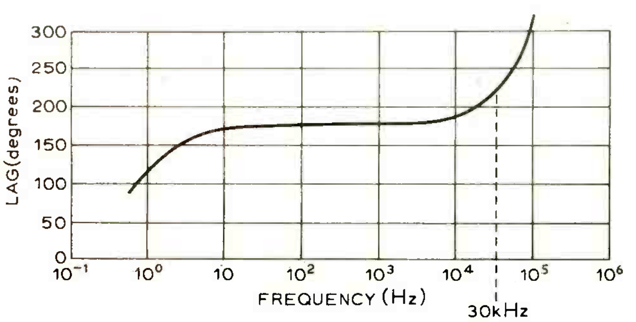


Fig. 20

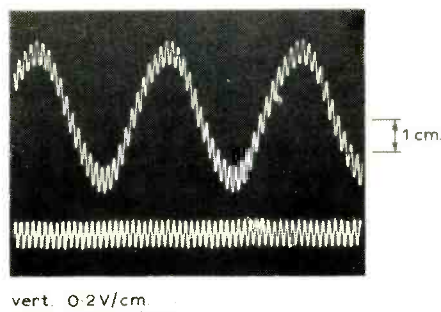


Fig. 21

Performance

In position 1 (see Fig. 19, top left), 50dB of rejection at 50Hz was maintained down to 100mV and up to 2V rms and 40dB of rejection down to 50mV. A bandwidth of 100kHz was maintained up to levels at which the slew rate of the operational amplifiers employed (709s) imposed restrictions.

The graphs on the right-hand side of Fig. 19 illustrate the relative amplitudes at the output terminals of an unwanted 50-Hz signal and its associated switching components, the input 50-Hz signal level being 0dB.

In position 2, 27dB of rejection was achieved at 50Hz, again from 100mV to 2V r.m.s. Phase response is shown flat from 2Hz to 30kHz in Fig. 20.

In position 3, 50dB of attenuation was measured between 100mV and 2V r.m.s.

The 3-dB bandwidth of all the notches of the left-hand graphs was approximately 1Hz.

Fig. 21 illustrates the effectiveness of the filter where the top trace shows a 1-kHz sinewave swamped by 50Hz and the lower trace displays the 1-kHz signal after being processed by the filter.

References

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2. Kreyszig, E. Advanced Engineering Mathematics, Wiley 1964.
3. Unsworth, L. Using junction f.e.ts, *Wireless World*, vol. 78 1972 p.222 (article covers pp. 219–22).
4. Cole, H. A. TTL trigger circuits, *Wireless World*, vol. 78, 1972, pp.31/2.

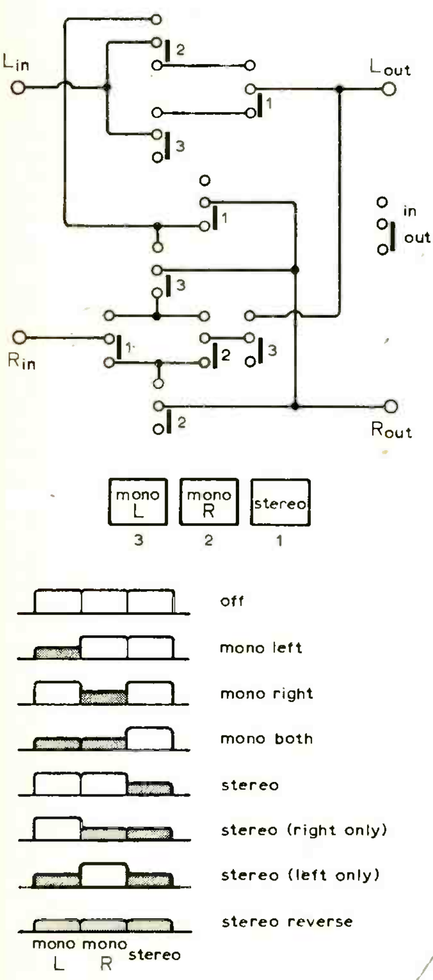
Circuit Ideas

Stereo/mono switching

In designing the channel switching for a stereo amplifier, it is desirable to achieve all the required stereo/mono configurations using as little hardware as possible. The most useful configurations are off; mono to left speaker, right speaker, or both; and stereo, left channel only, right channel only, both channels, and reversed. To achieve these eight combinations it is not necessary to use eight pushbuttons; as $2^3=8$, it can be done with just three pushbuttons. A simple logical reduction of the switching requirements leads to the circuit shown, which requires three 3-way pushbuttons.

J. V. Yelland,
Didcot, Berks.

In the t.t.l. monostable circuit by Mr Yelland (March 1973) the gates should have been shown as OR gates.

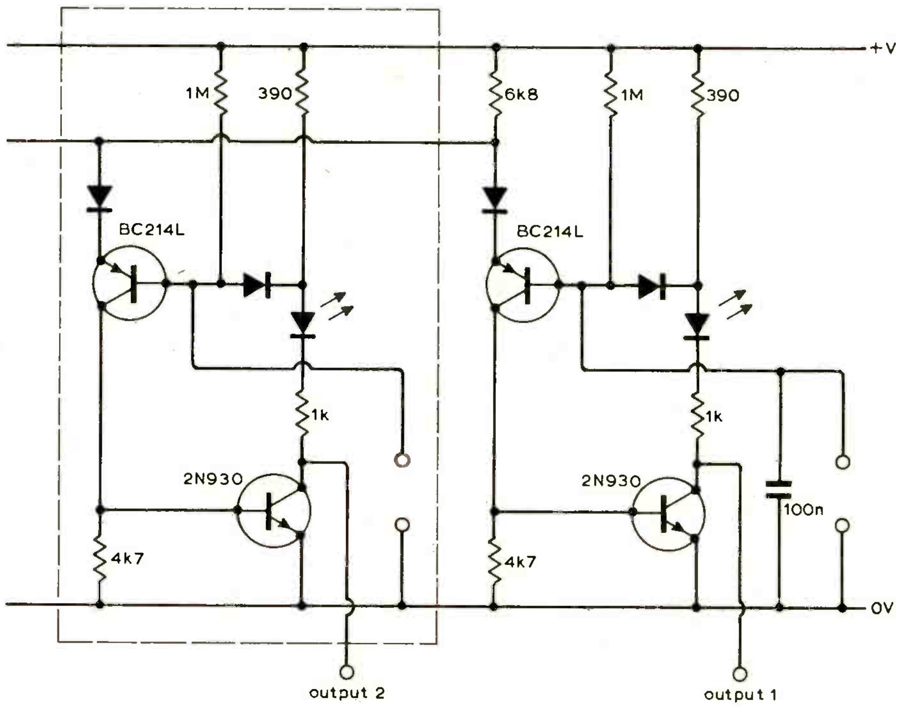


Self-cancelling touch button control

This method of touch button control has the advantage that the buttons automatically cancel each other and that a defined button comes on when the power supplies are applied. The circuit is extendable to larger numbers of buttons by cascading further sections as shown in the dotted lines.

The system operates by detecting skin resistance across a pair of contacts. The 0-volt contact would normally be the equipment front panel. Light-emitting diodes indicate which button is currently actuated; any type of l.e.d. capable of handling 20mA may be used. The supply voltage may be from 20 to 30 volts. Outputs may be used to drive f.e.t. analogue switches directly, varactor tuning diodes via a suitable diode resistor network, or relays via suitable buffer circuits. The capacitor briefly holds the transistor on when power is first applied, so ensuring that this stage always comes on first.

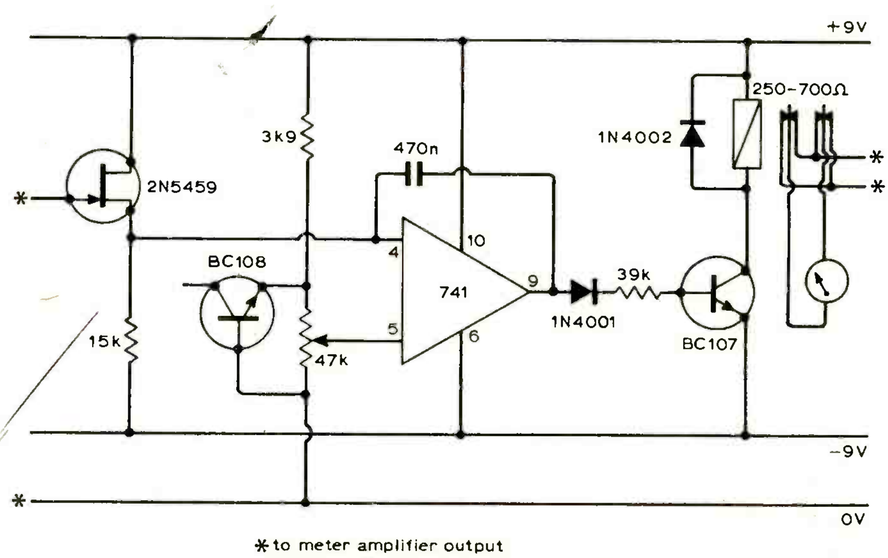
P. G. Hinch,
London SW15.



Auto polarity switching for voltmeters

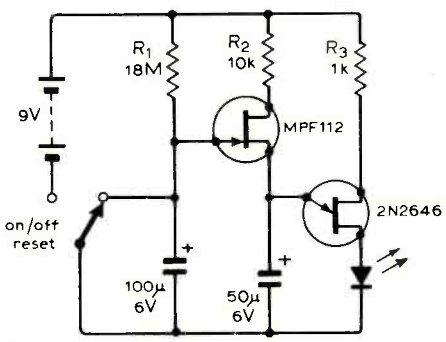
This circuit converts most high-impedance voltmeters to auto reverse-polarity switching. To prevent meter shunting an f.e.t. is used as the input element, the comparator is referenced to a zener-stabilized voltage, and a cheap silicon planar transistor is used as the zener for economy. Feedback is arranged in the comparator to provide fast switching. The relay can also be used to switch polarity indicators.

Hans Wedemeyer,
Vanse, Norway.



Simple flashing-l.e.d. timer

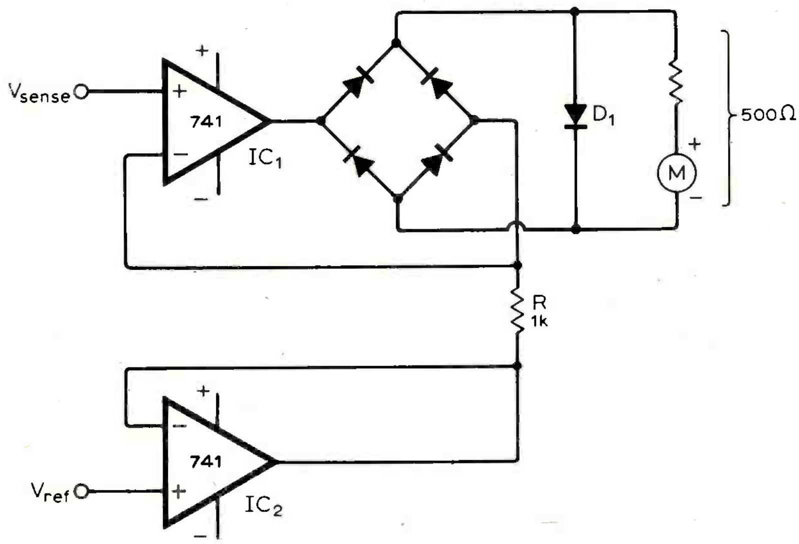
This circuit using only eight components is a unijunction oscillator controlled by an f.e.t. timer which causes the l.e.d. to flash after a time delay. In operation the unijunction passes a quiescent current of about 1mA, the f.e.t. is off until the 100μF



capacitor has been charged to about 1V via R_1. The f.e.t. then switches on and is part of the charging circuit for the unijunction oscillator with R_2 and the 50μF capacitor, which then pulses the l.e.d. at about 200mA pk. The circuit was developed as a simple cheap circuit for an egg timer but has numerous applications.
J. Jeffrey,
Chelsea College,
University of London.

Sensitive null indicator

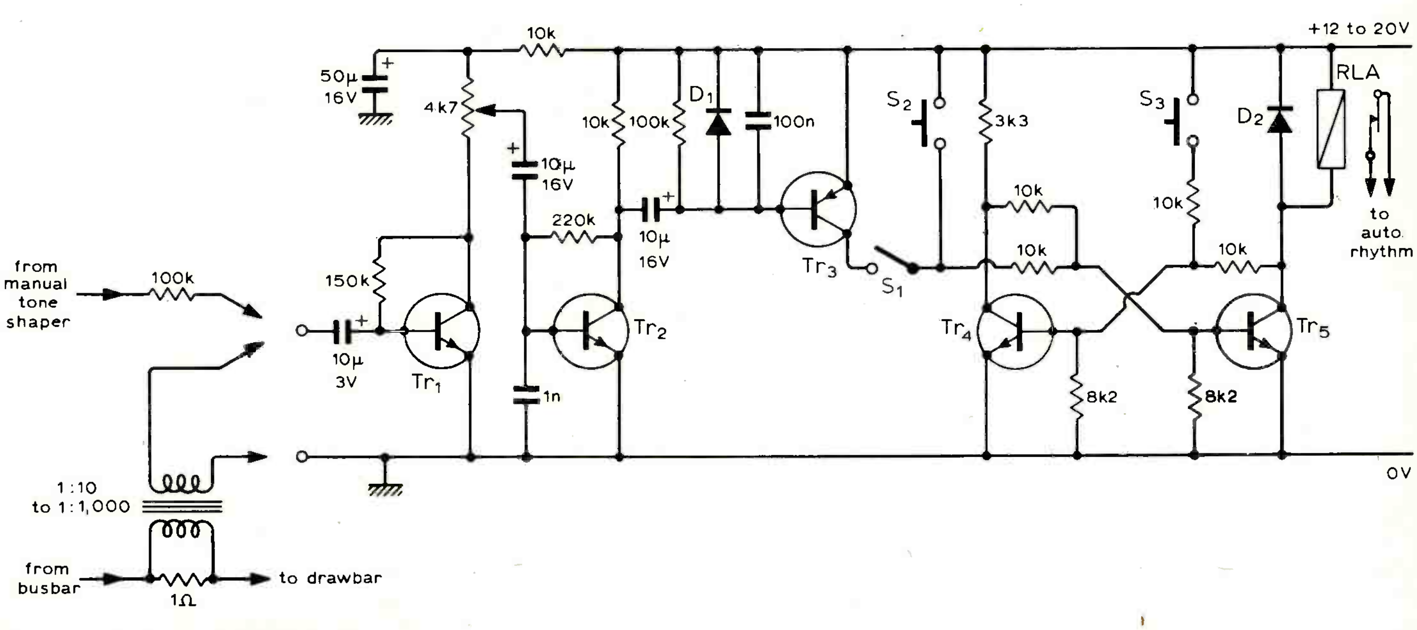
Intended as a tuning indicator for an f.m. tuner where the d.c. potential of the output is compared with a non-zero reference voltage, this circuit enables a standard left-hand zero meter to be used as a null indicator. It also has the advantage of presenting a high impedance to both the sense and reference voltages. It is an extension of the basic op-amp alternating voltmeter configuration, with the reference buffered by IC_2. A current i flows through the load R, such that $iR = V_{sense} - V_{ref}$. This current also flows through the meter, the diode bridge ensuring that there is always a positive deflection. The high gain and negative feedback around IC_1 overcomes the non-linearity of the bridge. As V_{sense} approaches V_{ref} the meter pointer moves towards zero, abruptly reversing its travel as the null point is passed. No setting up is needed, and with the component values shown f.s.d. occurs with a differential input of one volt. Diode D_1 protects the meter in the event of an overload. Any low leakage diodes can be used for the diode bridge.
A. S. Holden,
Leamington Spa.



Touch start of automatic rhythm device

Very few electronic organs manufactured before 1970 are equipped with facilities for remote control of an automatic rhythm device. This circuit is activated by an audio signal from the lower manual or pedal, making it possible for the performer to play the prelude on the upper manual and the pedal; when the first note is played on the lower manual, the rhythm accompaniment starts.

In the front end of the circuit two alternatives are shown; a high impedance input for connection to the lower manual toneshaper output of an electronic organ, and an electromechanical Hammond organ connection using a transformer and a series resistor. The transformer could be any radio output transformer. An incoming signal is amplified through Tr_1 and Tr_2 and turns on Tr_3. If S_1 is closed, a current passes through to Tr_5, triggering the bistable and causing the relay to pull-in. S_2 and S_3 and are used for manual start and stop.
K. B. Sørensen,
Copenhagen.



Digital speedometer using c.m.o.s.

2—Average-speed indication

by Adrian Bishop and Alan Woodruff*
*RCA Ltd (*now with NRDC)*

Part 1 dealt with the principle and circuit design of a digital speedometer constructed with c.m.o.s. digital integrated circuits. This second part describes an average-speed-calculating circuit that can be added to the basic speedometer. Calibration and power supply details for a complete speed and average-speed circuit are also given.

Average speed is simply distance travelled divided by the time taken. The general approach to performing this calculation is to accumulate pulses (representing distance) from the output of the speedometer phase-locked loop (CD4046AE) and then to divide this count by a second count representing elapsed time. The method of division is the customary logic technique of successive subtraction.

To keep the cost of the logic to a reasonable sum, a compromise between the rate of updating and the number of counters is inevitable. With the circuit shown in Fig. 10, an average-speed-determining division occurs every three minutes. The capacities of the distance and elapsed time counters limit the distance and time over which average speed can be calculated. These limits are unlikely to be exceeded in practice as the distance counter has a capacity of around 1500 miles and the time counter around 200 hours.

The sequence of events is as follows.

- At the start of a journey, both the distance counter and the elapsed time counter are reset to zero.
- Accumulation of distance and time pulses will continue until one of the

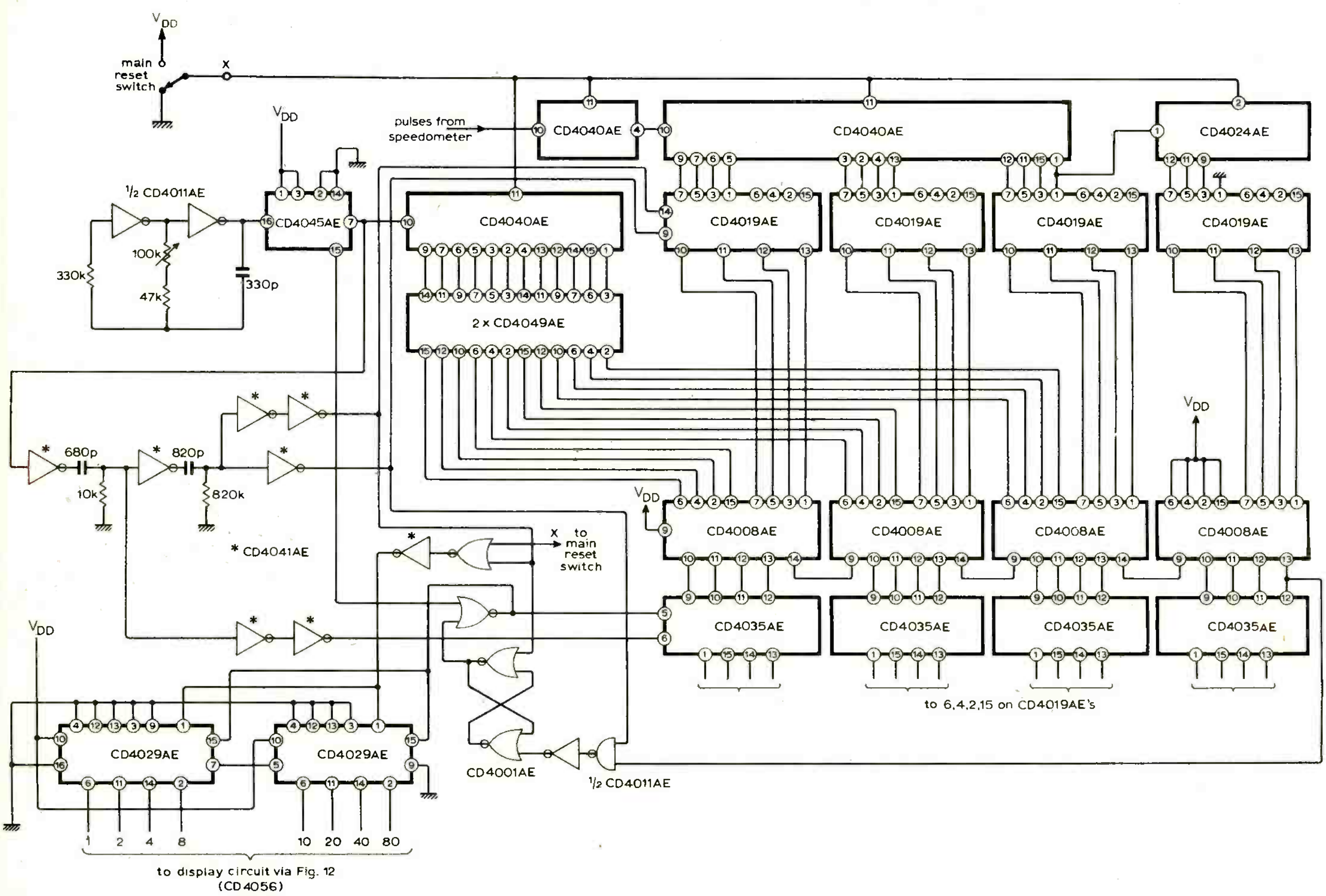


Fig. 10. Speed averaging diagrams. Three of the inverters shown (two at top left and one at middle bottom) are formed by connecting together both inputs of three of the CD4011AE NAND gates. 14-pin dual in-line packages have pin 7 connected to V_{SS} (earth) and pin 14 to V_{DD}. 16-pin packages have pin 8 for V_{SS} and pin 16 for V_{DD}. CD4045AE however has pins 1 and 3 for V_{DD} and pins 2 and 14 for V_{ss}. The CD4035AEs have pins 2 and 7 for V_{DD} and pins 3 and 4 for V_{SS}.

counters overflows or the power to the circuit is removed.

●Division of the two counts is carried out at regular intervals, determined by an oscillator, using the CD4008AE 4-bit adder/subtractor.

●The numerical value of the average is obtained by repeatedly subtracting the number of pulses in the time counter from the number of pulses in the distance counter until a negative result is obtained and counting the number of subtractions needed to achieve this. This is performed by recycling the result of each subtraction through the subtractor using the CD4035AE shift register and the CD4019AE AND-OR select gate.

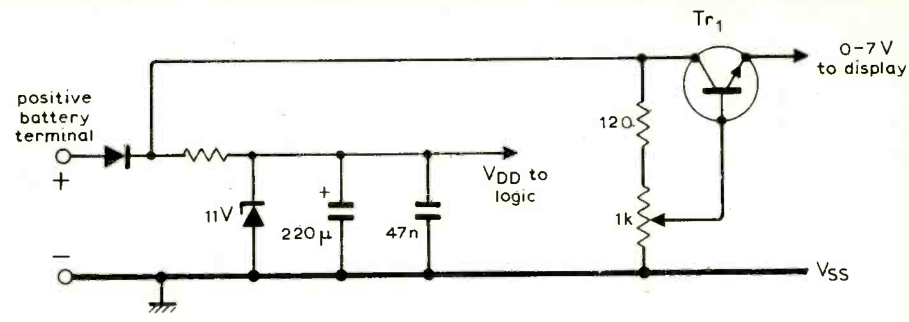


Fig. 11. In this speedometer power supply the logic system is protected by an 11-V Zener diode and two capacitors. A power transistor controls display brightness.

Distance counter

Pulses from the output of the speedometer phase-locked loop are counted by a series of three binary counters; two CD4040AE 12-stage counters and a CD4024AE seven-stage counter. The first CD4040AE divides the pulses by 512 (2^9) to scale the output to manageable proportions. Taking the pulses without division means dealing with larger numbers of pulses and consequently more subtraction devices than are justified by the accuracy of a two-digit display.

The pulses used to represent distance are counted in the second CD4040AE and the CD4024AE. The outputs from the counters are connected to a series of four CD4019AE devices.

Elapsed time counter

A time standard consisting of a 50-kHz oscillator, similar to the one used in the speedometer, is constructed using two NAND gates from a CD4011AE (other NAND gates on this chip are used elsewhere). Pulses from the oscillator are fed into a 21-stage CD4045AE divider which produces a pulse approximately once every three minutes. This oscillator also serves as a clock for the subtractor section. Each pulse is defined to be one unit of elapsed time, and they are counted by a 12-stage CD4040AE counter, which will be filled after approximately 200h. However, unless you are participating in donkey cart endurance trials, the limiting element of the average speed circuit is the capacity of the distance counter.

Divider operation

Average speed can now be calculated from these representations of distance and elapsed time. The binary number representing distance is fed from the distance counter via the CD4019AEs into four CD4008AE four-bit adder/subtractor packages, and the binary number representing elapsed time is also fed into the CD4008AEs. The time number is subtracted from the distance number, and the answer is clocked into a memory (four CD4035AEs), the outputs of which are connected back into the CD4019AEs.

The role of the CD4019AEs is now apparent—they act as quad input digital multiplexers and are used to select the right input data at the right moment. For the first cycle of subtraction the CD4019AEs allow the distance inputs into the subtractor; after this the control inputs on the CD4019AEs are changed to accept the output of the CD4035AEs until the repeated subtraction has been completed. Subtraction ceases when the result becomes a negative number, which state is indicated by a change in the state of the "sign" bit obtained from the output of the subtractors.

For each cycle of subtraction until there is a change in the sign bit the outputs of the subtractor are clocked into the parallel in/parallel out memory formed by the CD4035AE four-bit shift registers. Therefore the number of clock pulses needed to achieve a change in the sign bit (one clock pulse per subtraction) is the numerical value for average speed. These clock pulses are counted by two CD4029AEs—b-c.d. counters.

For simplicity only two digits display either speed or average speed. Common decoders and display drivers can therefore be used, and the desired inputs are selected by a switch that controls two CD4019AEs (Fig. 12).

Timing

The sequence of events begins on the negative going edge of the three-minute units time pulse, which appears at the output of the CD4045AE. This edge triggers two *RC* timing circuits that produce narrow true and complement signals that are fed to the CD4019AEs, which allow the outputs of the distance counters CD4040AE and CD4024AE to be connected to the subtractor inputs.

The true signal generated by the timing network also gates on the clock, which allows the result of the subtraction to be stored in the CD4035AE parallel-in/parallel-out memory. The clock signal used is the inversion of the 50-kHz clock (obtained from pin 15 of the CD4045AE), and this gives a very short dividing time.

The width of these control signals to the CD4019AE has been chosen to allow one clock pulse through to the CD4035AEs. When the control signals revert back to their normal state, the inputs to the subtractor become connected to the outputs of the CD4035AEs to allow the process of successive subtraction to proceed.

After the first cycle of subtraction, the clocking of the CD4035AE is allowed to continue until there is a change in the sign bit, indicating a negative answer. When this occurs the clock is stopped and remains disabled until the next negative-going edge of the units time pulse appears at the output of the CD4045AE. Then, irrespective of the sign bit indicating negative number, one clock pulse is allowed through to start the first subtraction, after which control of the clock is taken over by the sign bit.

Besides entering the CD4035AEs, the clock pulses are also counted by the CD4029AE counters. The division process takes only about 1ms, and it is therefore not necessary to use a memory (i.e. latches) between the counters and the decoders, as the display cannot follow the rapid changes that occur during the division.

This completes the details of the average speed logic. All that remains now is to discuss the power supply requirements, calibration and switching arrangements.

Power supply

The 3 to 15-V operating voltage range of c.m.o.s. permits the use of the simple 11-V Zener diode circuit, shown in Fig. 11, to power the logic system. Two decoupling capacitors across the Zener diode filter high-frequency and low-frequency noise from the battery voltage. The other diode protects the circuits should the speedometer be inadvertently connected to the battery the wrong way round.

A dimmer has been included so that the power supply to the display can be adjusted according to ambient lighting conditions. The dimmer is a simple variable voltage supply, from 0 to approximately 7V, consisting of a 1kΩ potentiometer with a limiting resistor controlling the base voltage of an emitter-follower power transistor, which must be provided with some form of heat sink. The displays can be turned completely off, or completely on for bright sunlight conditions.

Speedometer calibration

Drive ratios to speedometers vary from car to car; therefore some method of setting-up adjustment of the speed and average speed circuits is necessary and this has been achieved by the inclusion of a trimming potentiometer in each

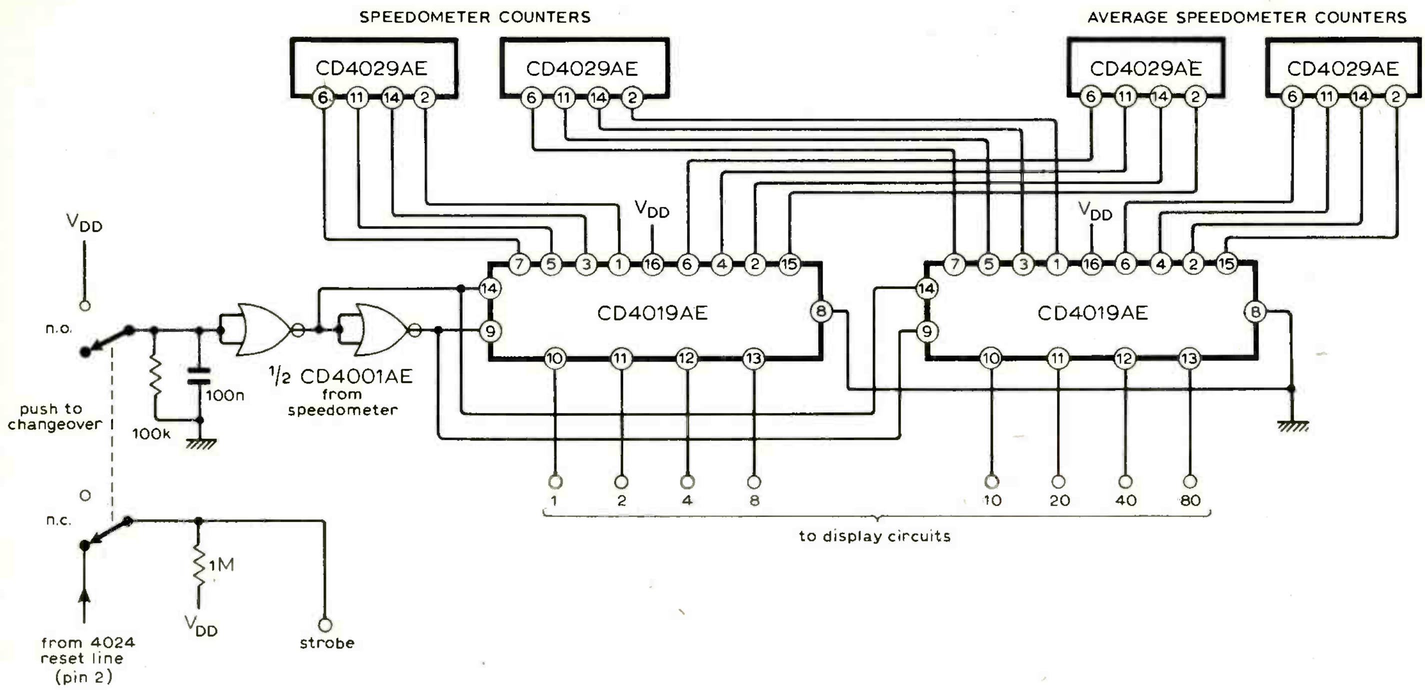


Fig. 12. Modification of output of speedometer and speed-averaging circuit to enable use of a common two-digit display. Speed is normally indicated, with average speed displayed by operating selector switch.

circuit. The digital speedometer is simply calibrated against the original speedometer by persuading a friend to twiddle the potentiometer while you drive carefully at constant speed. Above this speed there may be discrepancies owing to the non-linear response of conventional speedometers. The absolute accuracy of the instrument inevitably depends on the accuracy of the drive of the original speedometer, which depends on variations in tyre perimeter—a function of pressure, temperature and condition of the tyre. The digital speedometer is intrinsically more accurate than the conventional type inasmuch as it avoids the problem of the non-linear response of the cup to the whirling magnet. If you're really enthusiastic you can fit a calibrated bicycle wheel behind your car and take some sort of drive from that.

Assuming the speedometer has been set up as described, average speed can be set up without having to drive the car. This is achieved by capacitively coupling a signal from a separate *RC* oscillator included on the average speed board to the input of the speedometer pick-up coil amplifier. This will produce a certain constant speed reading on the display, and effectively simulates the car moving at constant speed.

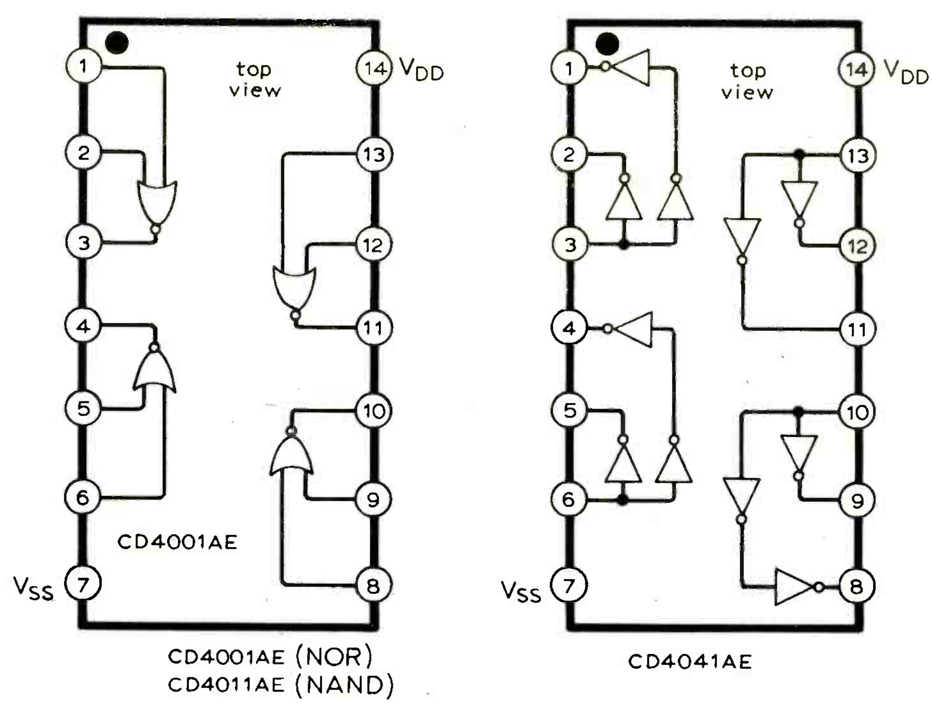
The average speed circuit is then set to zero, and after three minutes, this figure should be registered as the average speed. If it is not, as will almost certainly be the case, the potentiometer controlling the units time period should be adjusted in the appropriate direction, and the procedure repeated once again. Unfortunately this is an unavoidably time-consuming trial-and-error procedure. Nevertheless, once the average speed is correctly set up, the procedure should not need repeating unless you swap the speedometer to another car. Disconnect the calibrating oscillator after setting up.

Switches

To make the speedometer as flexible as possible, a number of manually operated switches have been included, and it is as well to summarise their functions.

Assuming a negative earth vehicle, it is advisable that the positive supply connection for the speedometer circuits be wired through the ignition switch of the car, to avoid unnecessary consumption of power when the car is parked. If you want to keep the average speed computation going while the ignition is off, as would be likely if you stopped for lunch or some other call of nature during a long journey, the best solution is to wire the positive supply for the logic via a separate switch direct to the battery and wire the display power supply through the ignition switch. A third possibility is to wire both logic and display supplies direct to the battery.

The function of the *sample-rate*



Connections for i.cs, omitted in Fig. 4 (part 1) and Fig. 10 (part 2). Note comments about connections for other i.cs in Fig. 10 caption.

selecting switch has already been described; it is a simple four-pole rotary switch that enables the display updating to proceed at an acceptable rate.

The *display selector switch* will determine whether speed or average speed is shown. Probably the best approach here is normally to display speed, and to obtain an average speed reading by depressing a push-to-hold switch. If it is preferred to display average speed continuously, a simple toggle switch can be used. Whatever type of switch is chosen, it also serves to ensure that the latches in the CD4056 decoders are enabled (see Fig. 12).

The *reset switch* is a single-pole, double-throw switch that resets the distance and time counters to zero by connecting them to the positive logic supply rather than earth.

The possibility of keeping the logic circuits connected to the battery while the car is parked underlines the remarkably low power consumption of systems designed using c.m.o.s. devices. The speed and average speed logic circuits, which include 36 c.m.o.s. devices and one bipolar op-amp, draw typically only 3mA, half of which is consumed by the op-amp. By comparision, the display drivers consume about 12mA, and the displays themselves can consume up to 0.5A, depending on the brightness setting.

Assembly hints

Assemble the boards with an earthed soldering iron to avoid the build-up of static charge on the c.m.o.s. devices.

Location of the pick-up coil on the back of the speedometer is fairly crucial. Having located the coil, it may be necessary to experiment with different values for the integrating capacitor to prevent the system picking up noise. This noise manifests itself in the erratic behaviour of the display at low speeds. Unfortunately this is once again a question of trial and error; try a 47-nF capacitor first.

Once the boards are assembled, check the speedometer board first without the average-speed board connected. This can be done without installing it in the car by capacitively coupling the average-speed-calibrating oscillator to the amplifier input with the pick-up coil connected as well.

If when you try out the circuits things are not as you might have expected, look for obvious simple faults such as incorrect device orientation, dry joints, solder splashes on the printed-circuit board, missing components, or reversed power-supply connections. If you suffer unexplained persistent faults and you have access to an oscilloscope, check through the circuits stage by stage from the front inwards as is usual practice.

Printed-circuit boards and integrated circuits for a slightly modified (one i.c. less) version will be available from Integrex Ltd, at P.O. Box 45, Derby DE1 1TW. Integrated circuits are also available from RCA distributors.

Literature Received

ACTIVE DEVICES

All data sheets and application notes on Signetics semiconductors and circuits are now collected into two volumes, costing £4.00 for the pair. Semicomps Ltd, Northfield Industrial Estate, Beresford Avenue, Wembley, Middlesex.

PASSIVE DEVICES

Mullard have produced a wall-chart to assist engineers in the selection of ferroxcube cores and formers for transformers and inductors operating at up to 15MHz. Mullard Ltd, Mullard House, Torrington Place, London WC1E 7HD WW401

A catalogue is available from ITW Electronics which gives full information on the Micromatic range of polypropylene and polyester film capacitors. The method of manufacture of the Micromatic capacitors is illustrated. ITW Ltd, 263 Farnham Road, Slough, Bucks. WW402

GENERAL CATALOGUES

The first Doram catalogue is now available. Doram is the new offshoot of RS Components (Radiospares) formed to make the RS range of components available to the general public. The catalogue is available at 25p from Doram, P.O. Box TR8, Wellington Road Industrial Estate, Wellington Bridge, Leeds LS12 2UF.

We have received a booklet from Inspec describing the abstracting, information retrieval and indexing services they provide. Inspec, Institution of Electrical Engineers, Savoy Place, London WC2R 0BL WW403

A brochure from EMI describes the full range of the company's activities from crime prevention to audio, from broadcasting to brain surgery. Publicity Department, EMI Ltd, 135 Blyth Road, Hayes, Middx. WW404

Services in the aviation communications field are described in a brochure from International Aeradio Ltd, Aeradio House, Hayes Road, Southall, Middx. WW405

EQUIPMENT

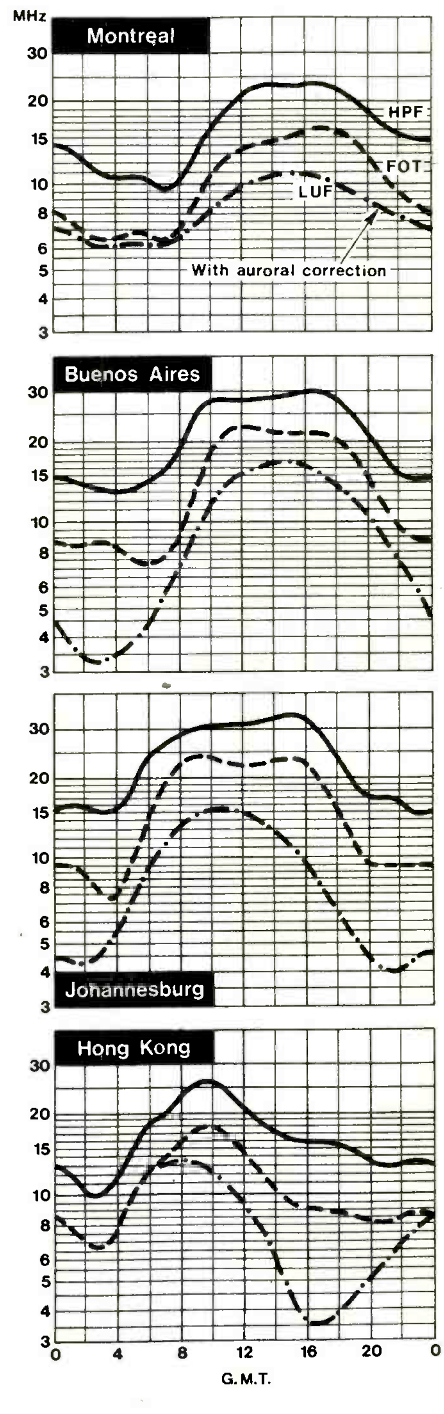
Kemo have produced a brochure to describe their work in system design and manufacture to specification. The firm's experience is in filter design and they can tackle almost any analogue or digital system working between 0.001Hz and 100kHz. Kemo Ltd, 9–12 Goodwood Parade, Elmers End, Beckenham, Kent. WW406

The range of Pertec peripheral units is described in a new leaflet from Computer Instrumentation Ltd, which covers both tape and disc systems. UCC/Computer Instrumentation Ltd, School Lane, Chandler's Ford, Eastleigh, Hants. WW407

HF predictions for October

The charts are based on a predicted solar index of 9. Comparison with previous sunspot cycles indicates that solar index will remain at or just below this value for the next two years. Magnetic disturbance is almost a daily occurrence at present and will probably continue so until next spring.

Seasonal changes bring about an improvement in daytime conditions as the upper end of the h.f. band becomes usable in the northern hemisphere. Trans-equator paths are just past their peak since seasonal change in the southern hemisphere is to lower frequencies and high noise.



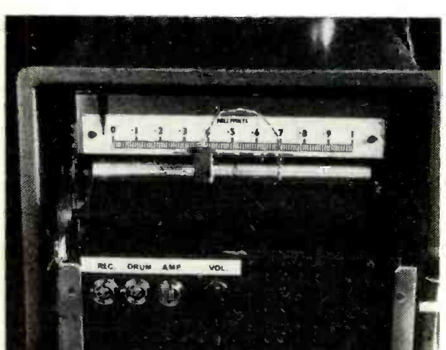
Letters to the Editor

Speaking meter

The tactual instruments which enable the blind to make multimeter measurements—originating from R. S. Maddever (Jan. issue 1973) and elaborated upon by G. P. Roberts (April issue 1974) and T. C. R. S. Fowler (Aug. issue 1974)—are cheap to make and are, no doubt, effective. There is, however, an alternative which, although not easy to make, may be purchased for less than £80 at present. I refer to the servo-operated chart recorder; this, fitted with a Braille scale, would give an easily observable indication to the blind user.

However, there is a variation of the chart recorder which must be the ultimate as far as the blind are concerned. This variation, which I developed in late 1971, first obtained notice as a speaking speedometer for car use, but at the time it was obviously an ideal instrument for the blind. Of course the idea is that the instrument speaks its readings, say between nought and 100, and these vocalized readings can be made, electrically, to represent any unit one wishes. I enclose a photograph of one of these speaking meters which was constructed round an old chart recorder. A tape head is fixed to the pointer of the recorder and bears on the surface of a magnetic drum, revolving at about two revolutions per second. The drum, in this model, has been recorded with a series of tracks ranging from nought to 100 in single digits, but other meters which I have constructed are recorded with even numbers only. The circumferential position of the recording on each track must be co-ordinated with the recordings on adjacent tracks so that when the head exactly bridges two tracks the readings are heard consecutively and with equal loudness. The result is rather like two men (or women) arguing with each other, but the overall significance of the reading—and the change in readings—is very easily assimilated by the brain, and indeed is much less prone to misinterpretation than is a visual pointer reading. Therefore it can be claimed that the speaking meter might have much greater application than to the blind alone; certainly where the eyes must be used for the monitoring of a process, while simultaneous meter readings must be taken (exactly as is the case with the car driver, by the way), then a meter which speaks its readings is ideal.

John T. Lloyd,
The University,
Glasgow.



Mr Lloyd's speaking meter.

Electronic piano design

I would like to reassure actual or potential constructors who may have been disturbed by Mr Mitchell's letter in the August issue.

The reliability and objectivity of Mr Mitchell's remarks leave something to be desired. He refers, without being specific, to "considerable circuit duplication". Now it should be clearly understood that while the piano *does* contain many duplicated circuits, *none* of these is redundant. Electronic pianos and organs can be designed along very much the same lines; the main differences being in the key circuits. Now in a polyphonic instrument (and any worth-while instrument must be polyphonic) each key must have an entirely separate piece of circuitry associated with it. In an organ these circuits are quite simple, but in a piano they are not, neither do they lend themselves to total integration.

On the subject of cost, it should be pointed out that the electronics represent only half of the total cost of the project. It does not seem to be possible to significantly cut the cost of the electronics even by a major redesign; they are already very simple and use cheap components.

There are only about three possible realizations of the oscillator section that are at all likely to be satisfactory in terms of frequency stability; these are *LC* oscillators, *RC* oscillators using high-gain op-amps, and full-octave synthesizers driven by a single oscillator. See the May 1974 *Wireless World* pp. 143–5 for details of the latter. Special i.cs of the "555" type probably are not stable enough. The most costly solution, the full-octave synthesizer i.c., is probably the best. The necessary buffers cost little.

I hope that those readers who ordered demonstration cassettes found them helpful; they were of course intended to demonstrate the characteristic "electronic-piano" timbre which differs somewhat from acoustic piano sound. My apologies are extended to anyone who was expecting anything musical; nothing of the sort was promised!

Geoff Cowie,
London, N10.

Doppler in loudspeakers

I note Mr Edgar's suspicion (Letters, August issue) that the end result of the mathematics may not correctly indicate the physical process, a situation very reminiscent of the argument that continued for much of the 1930s about the physical reality of the sidebands that appear when a carrier is amplitude modulated.

That the measured values of the Doppler sidebands agree almost exactly with the calculated values is, I think, reasonable proof that they have a physical existence and are due to Doppler (f.m.) distortion. It seems impossible not to believe in their existence when both the measurements and the mathematics are in agreement. The experimental technique eliminated any response by the measuring system to components other than those f.m. components due to Doppler, a point that was carefully confirmed.

Doppler distortion is the result of the modulation of the velocity of the cone due to a high frequency signal, by the velocity of the cone due to the simultaneously applied low frequency signal. I find it more difficult to think of this in terms of the physical position of the cone than in terms of the cone velocity, but one is the derivative of the other. At this stage in the problem, I think that it must be conceded that Doppler distortion really exists, though difference of opinion about the significance is still possible. Under the conditions set out in the contribution, i.e. small cones, wideband signal, I am certain that Doppler distortion is a more significant cause of aural distress than the amplitude distortion that has previously been considered to be the cause.

James Moir,
Chipperfield,
Herts.

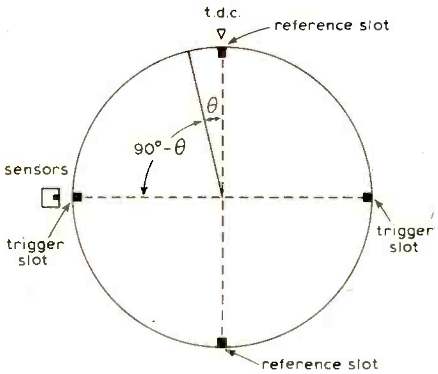
Electronic ignition

I was most interested to read J. R. Watkinson's article on the application of electronics to car ignition systems (July issue). It seems, though, that it is necessary to rethink the process from scratch. My own thoughts lie along the following lines:

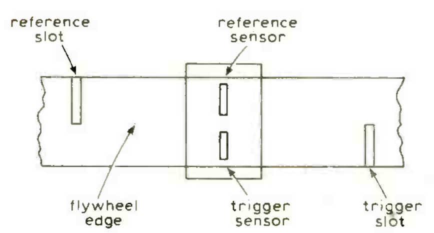
Timing. The requirement is to produce a triggering signal, to initiate spark generation, at an optimum point defined by the speed of the engine, its loading etc., to an accuracy of 1° or better. The main disadvantage of current practice is the error of the system:

(1) The transmission through a chain or belt drive to the camshaft, and a skew gear drive to the distributor shaft, introduces errors.

(2) Any inherent angular error is magnified by the half speed rotation of the camshaft.
(3) The actual ignition point is determined by the distributor cam profile, each cylinder being fired by a different cam, only one of which is considered in the set-up procedure. Minute differences in the cam profiles can produce appreciable angular errors.
(4) The system of governor weights to produce the required advance for a given engine speed can only approximate to the ideal advance curve.
(5) After quite a short period of use (say 20,000 miles) a significant amount of wear has occurred in the camshaft and distributor shaft drives, the distributor cam profiles, and the governor weights and springs, quite apart from the rapid wear of the contact points heel.



FLYWHEEL OF 4-CYLINDER ENGINE



These disadvantages could be overcome by a completely electronic set-up. The best place to take the timing from is the largest part of the crankshaft assembly, the flywheel, to provide the smallest angular errors. Two magnetic sensors would be mounted in the bellhousing to bear on the flywheel rim. Slots cut in the rim would provide the impulses (see diagram).

The trigger pulse would occur 90° before t.d.c., and the reference pulse 90° before that. The correct advance θ would be given by delaying the trigger pulse by $90° - \theta$. This would be calculated from the engine speed, represented by the time between the reference and trigger pulses.

Other information would be used to optimize the timing, such as manifold depression, engine loading, etc. Provision could be made to maximize performance by adjusting the timing, e.g. the timing could be advanced automatically to keep manifold depression at a maximum.

It should be possible to produce different programmes for the timing circuitry, so that one could adjust the timing from "maximum economy" to "maximum performance" or "high speed cruising" to "town driving", at the flick of a switch. The complete control circuitry would be in the form of an i.c.

Ignition. The disadvantages of the current system are mainly a low energy spark, coupled with high losses and interference from the distribution system. "Conventional" c.d. ignition raises the spark energy, but makes the interference problems worse.

In a completely electrical system, a sensor would be substituted for the distributor, solely to indicate which cylinder is to be fired. The c.d. generated pulse would be electronically directed to the required cylinder, without mechanical switches or spark gaps, through a purpose-built pulse transformer, to a redesigned spark plug. The spark should be bigger ($\frac{1}{4}$ inch perhaps?) and of higher energy than produced by current systems. Such a spark would ignite a larger area of the localized concentration of fuel quicker, and obtain a still faster and more even burn, allowing smaller advance angles to be used.

I believe that such a system would provide a considerable fuel saving, apart from a cleaner engine, on top of the savings obtainable with current c.d. systems —factors which are becoming more important. Now that attention has been drawn to improving ignition, I only wish someone could be persuaded to improve carburation, and we would be well on the way to the 100 m.p.g. car.
Paul Bloom,
Stamford,
Lincs.

"Data off the beat"

As a technical description of the experiment in providing personal radios with a data-handling facility which we and the Dorset Police have in hand, your article ("Data off the beat" p.221 July issue) is a perfect model of accuracy and clarity.

I would like, however, to set your editorial mind at rest: the experiment is indeed designed to assess the operational *worth* of the facility, as recommended by you at page 215 of the same issue. Unless it proves to be genuinely worth having, neither the police service nor we want to spend ratepayer/taxpayer money on any large-scale provision!
W. P. Nicol,
Director of Telecommunications,
Home Office,
London, SW1.

E.m.f. and p.d.

Why the problems with e.m.f. and p.d.? ("What is e.m.f.?" August issue). Some considerable number of years ago when I was being lectured on these misquoted and misunderstood electrical properties, the lecturer in charge of the class adopted an approach which I have frequently used in explaining electrical phenomena to non-electrical personnel. E.m.f. was quoted as a source of electrical energy available either from an unloaded battery or generator. Immediately any external load circuitry was connected to this source of electromotive-force a potential difference between the supply terminals and within the load was measurable.

I would suggest to Mr Scroggie and anyone else experiencing difficulty that they use this simple explanation of the difference between e.m.f. and p.d. rather than complicate the issue as at present our textbook authors seem to do.
C. A. Hill,
Kidderminster,
Worcs.

Electronic ignition

We read with interest the well balanced and informative article on electronic ignition by Mr Watkinson (July issue).

We would like to point out, however, that the principle of magnetic proximity detection in this application by sensing the desaturation of the trigger coil is unique to Mobelec Limited and is covered by our patent application.
Simon Baker,
for Mobelec Ltd.,
Oxted,
Surrey.

Communications services

In reply to "Vector's" Just Drop Me a Line (August issue) on the Post Office, IBA and BBC in which he commented upon the services they offer, in particular the conveyance of information and the parallel he made with similar American establishments; having just returned to the United Kingdom from a reasonably long visit to the United States, I am pleased to inform you that, in general, our communications media, in many ways, are superior to those of the United States. The American Telephone and Broadcasting Service should not be put forward as an example of "how to do it" in a vast area of information transmission.

Our telephone service offers more facilities, our television transmitters both monochrome and colour are frequently much better, our radio less prone to unwanted interference from adjacent stations and advertisements for chickens, sausages, etc. Rather than portray the United States as a country to copy, let us at least learn from their mistakes and make haste slowly. Examples of the reasoning behind this statement arise from the problems with NTSC and multi-path propagation which are considerably less with the PAL system.

Our radio personalities may be biased in their varied attitudes. However, regardless of whether or not one agrees with their particular comments, they are not cut off in mid sentence by Frank Purdue and his "personal chickens" and "the finest sausages" in the United States.

In general, having experienced the communications media in the United

States, I am extremely thankful for the services offered by the Post Office, IBA and the BBC. They should not rush in where wise electronics engineers fear to tread, other than gently.
C. A. Hill,
Kidderminster,
Worcs.

Damping factor

Referring to Mr Walker's letter on damping factor in your May issue, I should like to point out that another source or error is a by-product of distortion introduced by the feedback loop as well as the now familiar transient intermodulation distortions.

It is now well understood that the feedback loop is quiescent until a signal appears, and as it is usually several microseconds before the signal has reached the input via the feedback loop, during this short time the amplifier is operating without feedback and the output impedance is quite high, maybe several ohms.

This no doubt accounts for the woolly sounding "top" of present day amplifiers when compared with one that has no feedback loop, and means that it is quite nonsensical to quote damping factor figures, particularly the more impressive ones that are a by-product of excessively large feedback loops.

Finally, I recall that James Moir once wrote an article in this journal to the effect that in any case there is no point in increasing the damping factor beyond 4.
T. Marshall,
Goldring Ltd,
London, E11.

Logic nomenclature

In the design of two-state logic circuitry various designations are given to each of the two levels, but for the purpose of this letter I shall employ the terms "1" and "0". This is straightforward when considering the pure logic function only, but difficulties arise when electrical circuitry is involved and voltage levels have to be considered. Even here the situation would be simple if only one type of active semiconductor, say n-p-n, existed. In this case the "1" level could well be a positive voltage (say +5 volts) and the "0" level nominally zero volts.

Let this be called the normal logic. It is well known, however, that the same device could be employed equally well (but differently) if inverse logic is employed, in which case a "1" level becomes zero volts and the "0" level +5 volts.

Both normal and inverse logic are freely employed in practice, but it is unfortunate that the name commonly applied to normal logic is "positive" logic, whilst inverse logic is increasingly being described as "negative" logic. This gives rise to confusion in cases where both n-p-n *and* p-n-p devices are used in the same system. This commonly happens and in such cases three logic voltage levels exist, namely a positive level (say +5 volts), a zero level, and a negative level (say −5 volts).

The simple use of the terms "positive logic" or "negative logic" is now ambiguous, and can only cause confusion. I submit, therefore, that these terms should be dropped and a return made to "normal" and "inverse" logic. The following terms would therefore completely remove ambiguity:

n-p-n devices:
 positive normal logic
 "1" = +5V, "0" = 0V
 positive inverse logic
 "1" = 0V, "0" = +5V
p-n-p devices:
 negative normal logic
 "1" = −5V, "0" = 0V
 negative inverse logic
 "1" = 0V, "0" = −5V

The present misuse of the terms positive and negative has been introduced by non-electrically-minded logic designers. It is regretted, however, that certain semiconductor manufacturers and, even more unfortunate, engineering examination bodies, have also adopted this ambiguous nomenclature.
C. H. Langton,
College of Further Education,
York.

Sound and light

While reading the interesting letter from Mr McNaughton (July issue) it occurred to me that perhaps the most common association between colour and music, supported by the common use of terms such as "brightness" and "sparkling" in description, is likely to be a correlation of excitement. If this were so, perhaps a scale of colour temperature would fit experience better than Rimington's spectrum scale.

I must confess to having never experienced a colour organ but it seems clear to me that a bassoon is brown (almost mahogany!) in the lower register, a low trombone brown flecked with bright ridges, chunks of Beethoven are a glowing rusty orange (strings) with brighter colours introduced by the woodwind; flutes are yellow-white and the piccolo approaches blue-white, especially at close quarters. "Light" music is tinted (unsaturated) while green is difficult to find: perhaps I could force it on the oboe or clarinet. Green is also difficult to see among the orchestra, or in the radiation from an incandescent black body.
R. G. Key,
Mottram-in-Longdendale,
Cheshire.

Two stations on one receiver

I am prompted by the recent BBC experimental transmission in quadraphony, using the two stereo channels usually occupied by Radios 2 and 3, to wonder whether a single f.m. receiver could be modified to receive two stations at once.

A varicap tuned front end could be switched from one frequency to another by a step voltage at, say, 110 kHz and the output from the discriminator sampled during each voltage state. It would be necessary to have two a.f.c. circuits to control the levels of the master oscillator. The varicap diodes would have to be driven from a source with low impedance at the switching frequency but high impedance at v.h.f. The sampling frequency should be faster than twice the highest audio frequency transmitted in the composite stereo signal, which is about 53 kHz.

Obviously the technique would not be limited to just two stations, although perhaps the nine or so which are receivable in the London area would be a bit difficult. It is not clear that this method would be any cheaper than using a separate f.m. tuner for each station, however.
D. J. Jefferies,
Aberdeen University,
Scotland.

3D display from c.r.t.

The item entitled "Colour TV tube developments" in your April issue, describing the use of vertically slotted shadow masks, prompts me to suggest a possible method of producing a three-dimensional display.

It is proposed that a c.r.t. could be fitted with an electrode assembly and a shadow mask which would simultaneously display two different images. Instead of displaying each colour on every third vertical strip on the c.r.t., each of the two images would occupy alternate vertical strips on an all white screen. A second shadow mask, or a multiple lens, would be fitted to the viewing side of the screen in such a position that the viewers' left and right eyes would each see the appropriate image.

Such a device should produce a stereo vision effect, but in this simple form the black-and-white picture might be more useful for industrial monitors, computers and information displays than for entertainment purposes. It would be interesting to hear from you or your readers of any such developments.
N. C. Rogers,
Ealing,
London W.5.

F.m. tuning indicator

With reference to the article "Sensitive f.m. tuning indicator" in your June issue, does the author really believe that the concept of twin-lamp tuning is too difficult for the "non-technical user" to re-learn? Surely not.

And what of the merits of a two lamp system? Entering the listening area one can see at a glance if two lamps are of equal brilliance. But with a single lamp, there is no reference and one has to resort to turning the tuning knob.
J. Jaques,
Fane Acoustics Ltd,
Batley, Yorks.

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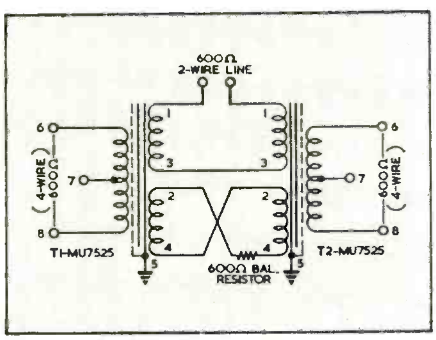

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WW—024 FOR FURTHER DETAILS

International Audio Festival and Fair—1974

Rather than attempt to describe, however briefly, the new equipment to be presented this year, we considered that it might be more useful to indicate to which stands visitors should go to investigate new products in their particular area of interest. We have not tried to obtain pre-Fair information this year, because we think that the time to give detailed information is after the exhibition, not in somewhat sketchy form before it.

In our December issue, therefore, we will present our detailed examination of the new products as usual, together with a summary of the lectures and discussion.

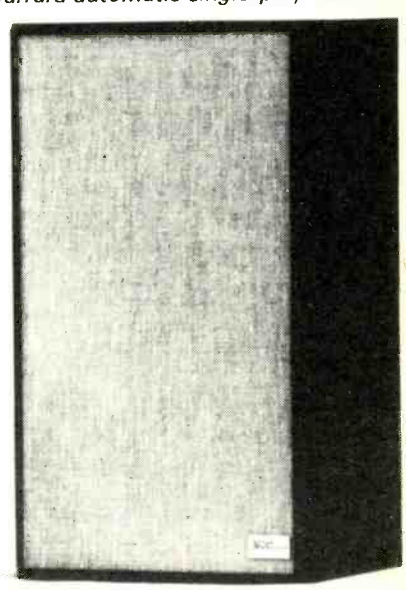
Stand No. D3 will be occupied by *Wireless World*, and editorial staff will be on hand during the exhibition for consultation. We intend to show some of the constructional projects published recently and are again sponsoring some of the lectures.

At the time this issue went to press, our information was still not complete; there may, therefore, be blanks and changes in stand numbers.

The 1974 International Audio Festival and Fair will be held at Olympia between October 28 and November 3. Opening times of the exhibition are 12 noon to 9pm on Monday and 10am to 9pm on all other days except Sunday November 3, when Olympia closes at 7pm. Admission is 50p.

	ACCESSORIES	AERIALS	AMPLIFIERS	SYSTEMS	ELECTRONIC COMPONENTS	HEADPHONES	KITS	LOUDSPEAKERS	MICROPHONES	ARMS, STYLI, CARTRIDGES	TAPE DECKS	TAPE RECORDERS	CLEANING EQUIPMENT	TUNERS	TUNER-AMPLIFIERS	TURNTABLES	TAPE	STAND	TRADE NAMES
AMS Trading			●			●		●						●				E6	Amstrad
Acoustical Mfg Co.			●					●						●				F2	Quad
Acoustico Enterprises			●					●			●	●		●	●	●		D7	Teac
AEG Telefunken								●							●	●	●	F12	
AGFA Gevaert	●																●	D18	
Antiference	●	●																G39	
Artifact Design	●																	E14	Encore
Audio Workshops		●																F8	Fuba
Bang and Olufsen	●		●	●				●		●	●				●	●		D12	
BASF	●											●					●	C5	
J Beam Aerials	●	●																G43	
Bib Hi-Fi Accessories	●												●					C15	
Boyd and Haas (Magnate)								●										F1	
Brahms			●	●		●		●										C14	
British Industrial Graphics	●																	G40	
Chuo Senko																	●	B4	TDK
Comsar																		C19	
Diamond Stylus	●					●				●								D20 E11 }	
Farnell Tandberg			●	●				●			●	●			●			E8	
JBL Feldon								●										A3	
Ferranti					●													G42	
Ferrograph	●		●					●			●	●		●				D13	
Gale Electronics & Design								●								G6	to	G9	Hervic/Microacoustics SAE, Soundcraftsmen
Garrard																●		B8	
Golding												●			●			G59	
Goldring	●					●				●			●		●			E4	
Goodmans	●			●			●	●			●							C16	
Edwardus								●											
C. E. Hammond			●									●		●				C8	Revox, Fisher
Hayden Laboratories						●			●			●						F3	Sennheiser
Hi-Fi Aids	●																	G18	
Highgate Acoustics			●	●		●		●		●	●			●	●	●		A2	Pickering, Perpetuum-Ebner, Harmon-Kardon, Alpha
Howland West	●		●			●		●		●			●	●	●			A7	Grado, Micro, Orbit, Lux, Luxor, Nikko
Impo Hi-Fi			●			●		●						●	●			E1	Dynaco, Major, Ess, Scintrex
Wireless World																		D3	
Josty Kit							●											G24	
JVC			●	●		●		●		●	●	●		●	●	●		C13	
KEF	●						●	●										B10	
G. & A. Kirsten																		B15	
Klinger Controls			●	●				●						●	●			F4	
Lloytron Electronics				●		●		●		●	●	●		●	●	●		G34	
3M	●																●	A6	
I. Markovits	●																	B1	
Metrosound	●		●					●		●			●	●		●		B9	Ortofon, Thorens
Modern Eng & Technology			●					●			●					●		G52	Gabraphone

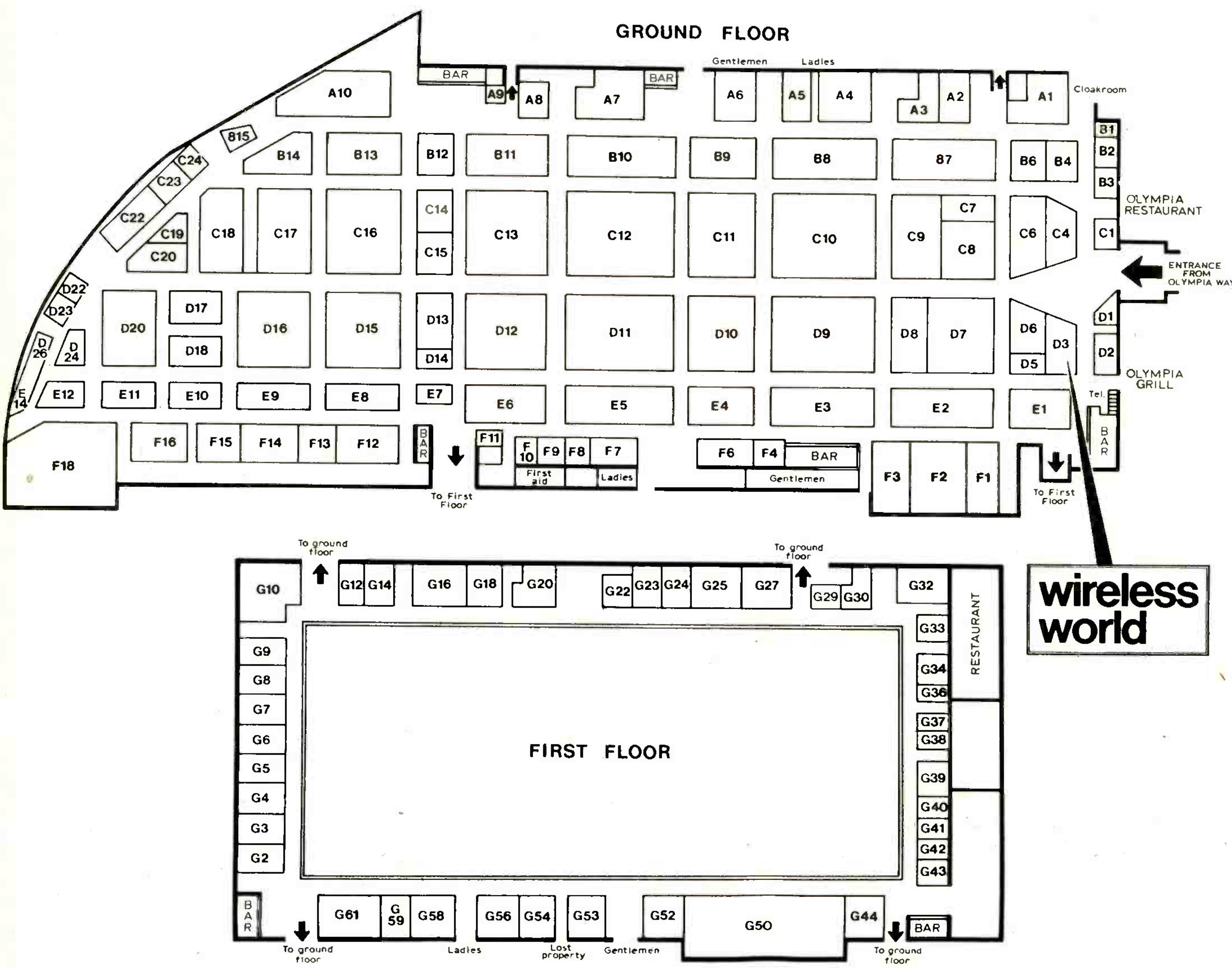
Garrard automatic single-play turntable.



Acoustic Research AR-3a/Improved speaker, which is similar to the AR-3a but with an improved crossover.

	AC	AE	AM	SY	EC	H	K	L	M	A,S,C	TD	TR	CE	T	T-A	TTS	TA	S	TN
B. H. Morris			●			●		●			●			●	●	●		C9	Trio
Motec																		D22	
Musonic	●									●			●				●	F13	
National Panasonic			●			●		●			●	●		●	●			D15	Matsushita
NEAL	●											●						G41	
Nu-Way Styli Components										●								G25	
Omex Products																		C4	
Philips	●		●	●		●		●	●	●	●	●	●	●	●	●	●	D11	
Photax																		B6	
Precision Tapes																	●	E3	
Pyser Britex			●			●		●						●	●			D8	Marantz
Quadrasonics				●														C20	
Quality Audio Supplies	●																	F10	
Rank Audio Visual			●			●		●	●	●	●	●		●	●			C10	Akai, Rotel, Empire
RCA																	●	B13	
Rola Celestion	●							●						●				E2	
Sanyo Marubeni			●								●			●	●	●		D5	
Scandinavian Audio Systems						●		●							●	●		D6	Scandyna
Sharp Electronics				●		●					●	●			●			C17	
Shriro			●					●		●	●			●	●	●		E5 D11	Pioneer, Audio Technica
SME							●			●								E6	
Sonab			●			●		●							●	●		C18	
Sony	●		●	●		●		●	●		●	●		●	●	●	●	C12	
Steepletone			●	●				●						●	●			F9	
Tannoy								●										A1	
Tape Music Distributors	●					●												D10	Koss
Tape Recorder Spares	●																	E9	
Graham A. Taylor																		D17	
Toshiba			●		●	●		●		●	●	●		●	●	●		B7	
Uher	●		●			●			●		●	●						G16	
Unitra Warsaw				●														E10	
Van Der Molen								●										G37	
Vernitron			●			●		●		●	●			●	●	●		A10	Sansui, Sonotone
Natural Sound Systems			●	●				●			●			●	●	●		G5	Nakamichi, Yamaha
Wilmex			●			●										●		C7	Era, Stax
Shure										●								B11	
Decca				●						●			●	●				D9	
Hisonic										●								B10	A.D.C.

Philips four-channel system, with SQ decoder. Designed for use with Philips motional feedback speakers.



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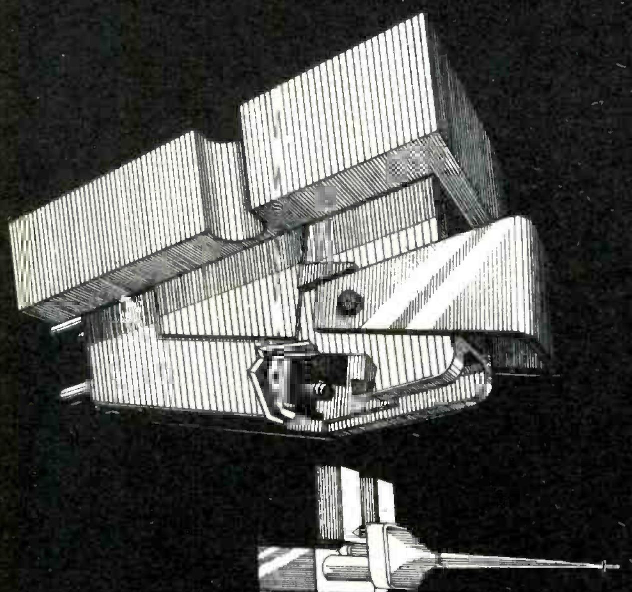

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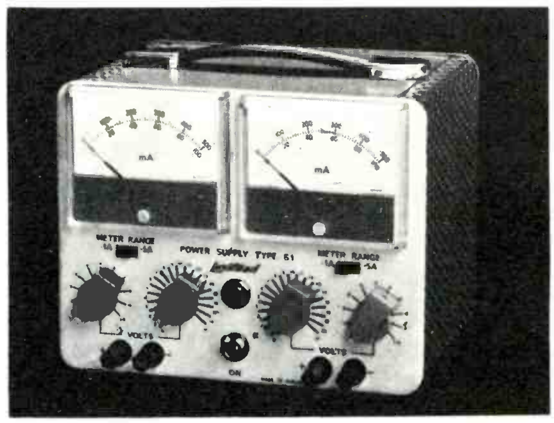

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WW—102 FOR FURTHER DETAILS

Current-differencing amplifiers

2—signal generation

by J. Carruthers, J. H. Evans, J. Kinsler and P. Williams
Paisley College of Technology

This article follows an earlier one on signal processing with current-differencing amplifiers of the CM3900 kind, circuits for which are given in Circards set 16. A third set of c.d.a. Circards will cover measurement and detection circuits. Details of how to obtain Circards appear at the end of this article.

The simple model of the current-differencing amplifier discussed in the previous article (August issue) is sufficient to explain the principles—but not enough to satisfy the customer placing his pennies on the counter. A fuller circuit is shown in Fig. 1 representing the relevant sections of one of these amplifiers, in this case the LM3900, though other manufacturers produce similar circuits. Transistors $Tr_{9,10}$ constitute the input current mirror coupling a current into the external feedback network that is the difference between the two input currents. Transistor Tr_8 is the only stage contributing voltage gain and its collector is the highest impedance point in the system—the most convenient point to place the compensation capacitor C since a small capacitance is sufficient to bring the cut-off frequency down to the required level. The single stage of voltage gain is buffered by $Tr_{4,3}$ to give a reasonably low output impedance with a current source capability of tens of milliamps.

The open-loop voltage gain is very much less than is available from standard op-amps, but at 60 to 70dB (1,000 to 3,000) is ample for most applications. The reduced gain allows the open-loop cut-off frequency to be increased to about 1kHz (c.f. the value of around 10Hz for 741 op-amp) without instability occurring at high frequencies when 100% negative feedback is applied (Fig. 2). As a result the open-loop gain is 10dB greater for these current-differencing amplifiers from 1kHz to 1MHz.

This is a fair statement for small-signal applications, but the slewing characteristics of the amplifiers are quite different. In the 741 and similar amplifiers the maximum current available for the capacitor is comparable for both positive and negative swings, bringing a slew-rate of about 0.5V/μs in both directions. In the current differencing amplifier described here, the capacitor C (Fig. 1) can be discharged rapidly by Tr_8 if the latter is over-driven, and the negative slew-rate is about 20V/μs. The charging path for the capacitor is via Tr_4 base and the slew rate is limited by the low base current to about 0.5V/μs, giving asymmetry to the rise and fall times of a pulsed output (Fig. 3). The resulting large-signal response when used as an amplifier is limited to around 10kHz by this positive slew-rate.

This is but the first generation of current-differencing amplifiers, designed for simplicity and economy. It is to be expected that circuits will gradually appear offering improvements in this and other directions. With the example of operational amplifiers as a guide, we can hope to see multi-megahertz current-differencing amplifiers before long. This could be achieved by removing or reducing the compensation capacitance, provided the circuit was not then used with heavy feedback.

It is possible to experiment with a similar circuit to see the general effects of operating at different currents and with different degrees of compensation. The circuit is shown in Fig. 4 and is based on one of the low-cost five-transistor packages such as CA3086, CA3046 etc. These have gain-bandwidths in excess of 500MHz demanding care in construction if good results are to be obtained. Transistors Tr_1, Tr_2 compose the current mirror, Tr_3 is the voltage amplifier and Tr_4 the emitter follower. Transistor Tr_5 acts as a constant-current load to the emitter follower though the slope resistance is less than that achieved by current mirrors. Bootstrapping the collector

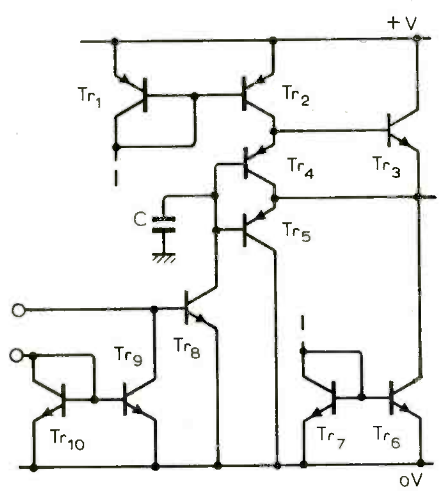

Fig. 1. Part of the LM 3900 current-differencing amplifier, to which the current mirror Tr_9, Tr_{10} couples a current into an external feedback circuit, via emitter followers, that is the difference between the two input currents.

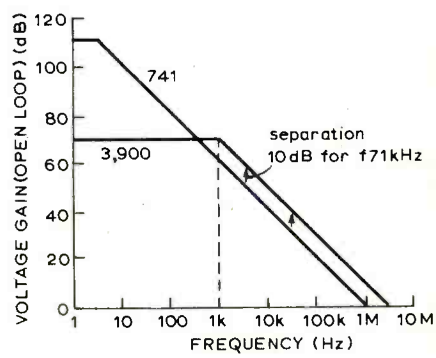

Fig. 2. Reduced gain of c.d.a. relative to 741 op-amp allows increased open-loop cut-off frequency. Open-loop gain is about 10dB greater from 1k to 1MHz.

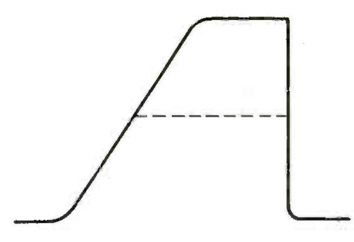

Fig. 3. Positive slew-rate is limited by the low base current in Tr_4 (Fig. 1) to about 0.5V/μs, giving asymmetry to the rise and fall time of a pulsed output.

load of Tr_3 increases the voltage gain giving some of the effects provided by the constant-current stage in the commercial amplifier. This circuit is in no sense a competitor for the complete i.c. but may help in understanding the techniques and limitations. (Possible values are R_1, R_2 47kΩ, R_3 470kΩ, C 10μF, with a supply of +10V.)

The control of direct voltages and currents is readily achieved with amplifiers of this class, with the simplest circuits requiring only the addition of a zener diode. Care has to be exercised if high stability is required since, as shown in Fig. 5, the output voltage depends on the direct voltage between the inverting input and ground. This is approximately 0.55V, changing with temperature by about −2.2mV/degC. As drawn, the zener current would be restricted to the amplifier input current of 30nA and an additional resistor between inverting input and ground would be needed to bring the current up to the level appropriate to the zener.

Sine-wave generation is by passive resonant or phase-shift networks, with the one change; that it is the current into the amplifier that is of concern. While conventional passive networks such as the phase-shift network of Fig. 6 can be adapted by using a suitably large resistance R' to force a current into the amplifier without loading the network, better results follow from designing alternative networks requiring a low-impedance load (i.e. the virtual-earth of the amplifier inverting input when used with shunt feedback).

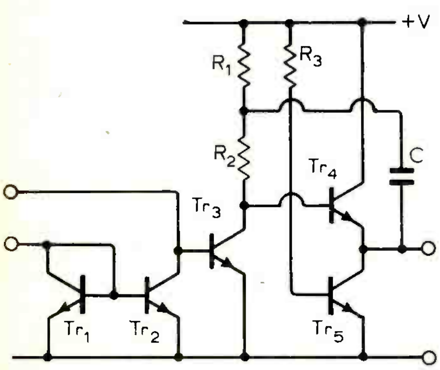

Fig. 4. By making a c.d.a. from a five-transistor i.c. the effect of altering the compensation capacitor can be investigated, gain-bandwidth products of 500MHz or more being possible.

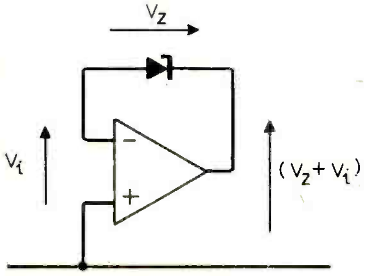

Fig. 5. Stability of voltage level in c.d.as can be improved by simple addition of a zener diode.

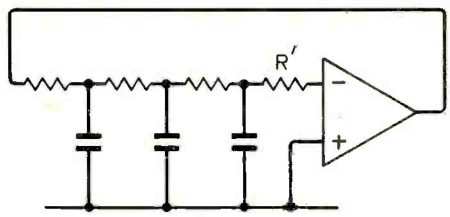

Fig. 6. Phase-shift network can be adapted for use with a c.d.a. by using a large resistance R' to force a current into the amplifier.

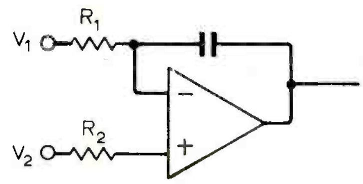

Fig. 7. Waveforms can be generated by subjecting a capacitor to alternate positive and negative current flows. Square/triangle generators can be simplified by fixing V_1 or V_2 and switching the other by a circuit that monitors integrator output.

A wide variety of waveforms can be generated by using the voltage across a capacitor subjected to alternate positive and negative current flows. Where the net charging current depends on the current-difference at the two inputs, novel circuits result. In particular, simplification of square-triangle generators is achieved by keeping V_1 or V_2 (Fig. 7) constant while switching the other from some positive value to zero under the control of a level-sensing circuit that monitors the output of the integrator.

With suitable scaling of the voltages and resistors the polarity of the net current is reversed using only a single diode/transistor/f.e.t., while the magnitude of that current is determined by an external control voltage. The resulting voltage-controlled oscillator is markedly simpler than is normally possible. If one or more of the voltages is replaced by a pulsed source, then staircase/ramp waveforms are produced depending on the magnitude, polarity and timing of the pulses. In each of these circuits, the use of a second amplifier can cancel the input current of the integrator amplifier to a first order, reducing the drift to a very small level.

There is no one-to-one correspondence between the circuits designed around operational and current-differencing amplifiers. It will take considerable time and effort to make sure that the advantages of the latter are exploited. The effort will not be wasted.

Titles of cards in set 17 of Circards (available shortly)

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12 wideband amplifiers
13 alarm circuits
14 digital circuits
15 pulse modulators
16 current-differencing amplifiers (signal processing)

Electricity *and* magnetism?—2

Riding on an electron: a relativistic approach to the nature of magnetism

by "Cathode Ray"

Last month we asked whether electricity and magnetism were two separate but related things or just two faces of one thing and if so what thing. We discovered that what to one experimenter was a wholly electric field was seen (quite correctly) by another to be accompanied by a magnetic field. And vice versa. The cause of the disagreement was the fact that the observers concerned were moving relative to one another. And when, using the ordinary textbook laws of electricity and magnetism, we worked out a set of equations for converting the electric and magnetic field specifications at one position to those at another in relative motion, we found a discrepancy, which could only be eliminated by introducing into both sets of equations a factor we denoted by β (some people call it γ), equal to

$$\frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$$

in which v is the relative velocity of motion and c the velocity of light and radio waves in space.

This was very interesting, because by a simple approach to the problem through well-known elementary Electricity we discovered the necessity for what is also the essential factor in the Lorentz transformations relating length, mass and time in Einstein's Special Theory of Relativity. This theory, implausible though it may appear, was the only escape from certain discrepancies that exist if one assumes that these basic quantities are the same for all. One of these discrepancies we found for ourselves in electro-magnetism. Another is the fact that the speed of light in space *(c)* is found to be always the same, regardless of the velocity of the measurer or of the source of the light. This seems as nonsensical as if a person trying to stand up in a racing car, and another motionless on the track, both reported identical wind velocities. But it is an experimental fact. And we have found that the factor β, which defines the effects of motion on length, mass and time, does the same for electric and magnetic fields.

Suppose we have two cathode-ray tubes side by side, The dotted lines in Fig. 4 represent the two rays or beams consisting of streams of electrons moving from left to right. This is happening in a part of each tube between anode and screen at the same potential, so the velocity, v, of the electrons is constant. The charge on one electron is e (1.6×10^{-19} coulombs) so, if there are n electrons per metre length of beam, the current *(I)*, being the total charge passing a fixed point per second, is nev amps.

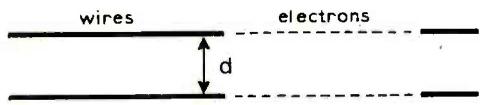


Fig. 4. The continuous and broken lines represent respectively the wire and cathode ray parts of two parallel circuits. Some curious results are obtained when the electric and magnetic forces between circuits are calculated in different ways.

Now consider the wires carrying this current to the c.r. tubes. They have been laid parallel to one another at the same distance apart (*d*) as the electron beams. These wires are electrically neutral or uncharged, because for every electron there is a proton forming a fixed part of the structure of the wire. So the negative and positive charges exactly cancel out. So there is no coulomb or electric force between the wires.

The textbooks tell us, however, that because of the magnetic interaction of currents two parallel wires carrying current in the same direction will attract one another with a force equal to

$$\frac{\mu(nev)^2}{2\pi d} = \frac{\mu I^2}{2\pi d} \text{ newtons per metre of wire,} \qquad (6)$$

μ being the local permeability, normally the "magnetic space constant", μ_o. Although the electrons in the beams are travelling enormously faster than those in the wires, they are much more widely spaced, and as I is obviously the same at all points in the circuit we see that nev is the same in both places. So the beams too will be magnetically attracted. And they would consequently deflect themselves towards one another, were it not that here there are no protons to neutralize the negative charges of the electrons. Being of like sign, the beams will repel one another, and the textbooks tell us that this force is

$$\frac{n^2e^2}{2\pi\epsilon d} \text{ newtons per metre} \qquad (7)$$

ϵ being the local permittivity, normally the "electric space constant" ϵ_0. So there will be a tug-of-war between these forces.

It is easy to predict which will win. The magnetic attraction *(6)* can be arranged as

$$\frac{n^2e^2}{2\pi\epsilon_0 d}\epsilon_0\mu_0 v^2$$

So, looking again at *(7)* we see that the ratio of magnetic to electric forces is $\epsilon_0\mu_0 v^2$. We noted last month that $\epsilon_0\mu_0 = 1/c^2$, c being the speed of light, so the ratio is v^2/c^2. The electrons can never move as fast as c, so the electric repulsion always wins. Even in a high-voltage c.r. tube v is much less than c, so v^2/c^2 is a very small fraction, and the total or net force is nearly all electric.

Combining the expressions for the separate forces we see that the total force can be written as

$$\frac{n^2e^2}{2\pi\epsilon_0 d}\left(1-\frac{v^2}{c^2}\right) \qquad (8)$$

If the term in brackets looks familiar it is because it is closely related to the relativity factor, β, which we have just repeated from Part 1. So yet another version of the net force per metre is

$$\frac{n^2e^2}{2\pi\epsilon_0 d}/\beta^2$$

which we can write more briefly still as

$$\frac{k}{\beta^2}$$

k being the electric part of the force. Unless $v=0$, β is always greater than 1, so we see that the net force (though positive, showing conventionally that the electric repulsion prevails over the magnetic attraction) is less than if only the electric force operated.

So here we have β turning up yet again! We originally saw it creeping into the situation where we found that what to one observer was a purely electric field was to another observer in relative motion a mixture of electric and magnetic fields. Then we noted that it was the essential factor in the Special Theory of Relativity. And now we have used textbook "Electricity and Magnetism" to find that our two electron beams acted on one another with a mixture of electric and magnetic fields and forces. But when we jumped on to an electron, so that all the electrons were (to us) standing still, there were no electric currents, so no magnetism, and the only force was what we are now calling (for short) k. Back in the lab., we were aware of the beam currents and the consequent magnetic force, kv^2/c^2.

So here we have a discrepancy between the force between the beams as measured at rest in the lab. (electric repulsion, slightly offset by magnetic attraction) and as measured by someone moving with the electrons, which to him are not a current, so magnetism doesn't enter in and the electric force is on its own.

But we have been using ordinary textbook formulae for these things, all innocent of relativity. So we naturally suspect that this discrepancy is another of those encountered when Einstein is ignored. The discovery that the discrepancy is β^2 makes the suspicion a virtual certainty. So let us take account of relativity.

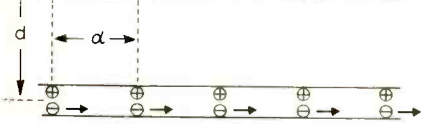


Fig. 5. This is an idealized model of the parallel wires in Fig. 4, showing the protons ⊕ and electrons ⊖.

Fig. 5 shows a sort of simplified model of the electric charges in a short section of the parallel wires. The charges are assumed to be distributed along each wire with a density n (of each kind) per metre. So the charge per metre is $\pm ne$. The protons or positive charges, being parts of the wire, are fixed. The electrons are supposed to be moving to the right with velocity v. (So the current, by convention flowing to the left, is equal to nev.) Without relativity one would say that as there are equal numbers of positive and negative charges on each wire it is electrically neutral, so there is no net electric field or force between them. But because the electrons are moving relative to the protons, we do have to take account of relativity. Let us divide the force per metre into four parts:

(a) Between the two lots of protons $(++)$
(b) Between the lower lot of protons and the upper lot of electrons $(+-)$
(c) Between the upper lot of protons and the lower lot of electrons $(-+)$
(d) Between the two lots of electrons $(--)$

Force $(++)$ is a repulsion, so is $+k$
Force $(+-)$ is an attraction, so is $-k$
Force $(-+)$ is an attraction, so is $-k$

All these are as seen by the fixed protons, or by ourselves using suitable lab. gear.

No question can arise about $(++)$, because all the charges concerned are at rest relative to us. But what about the moving electrons; doesn't some relativity correction have to be made where they are involved? However that may be, the essential fact is that in our "frame of reference" (call it S) all the electrons pass the protons simultaneously, so they must be spaced the same distances apart, so their charge density must be the same as that of the protons and the normal calculation for k holds good. We see that the net result of all three forces (a) to (c) is $-k$.

Calculation of the last one, $(--)$, is different though. To estimate this force we have to run alongside the electrons, in their frame (S'), where they are stationary and we can apply the electric force equation quite normally, so long as we use dimensions that apply in S'. The only factor in k that is subject to relativity is n, the number of electrons per metre. (d is at right angles to the direction of motion, so is unaffected.) The rest of k, $e^2/2\pi\epsilon_0 d$, we can abbreviate for convenience to p. We shall distinguish the electric force of repulsion between the two sets of electrons in S' as f_e, and the electron density here as n'.

It might seem reasonable to argue that as the protons in S see the moving electrons spaced the same as themselves (because the coincidences in distance also coincide in time) the electrons in S' see the (to them) backward-moving protons coinciding likewise and the spacings therefore equal. And before Einstein this argument certainly would have been unassailable. Even now most people find it obvious that if two events, such as electrons passing protons, occur exactly simultaneously (as seen, say, by someone stationed midway between the two events) they must be simultaneous, full stop. But Einstein showed that they are not simultaneous so far as anyone in relative motion is concerned. So if, having checked that when we are stationary relative to the protons the electrons coincide momentarily with them simultaneously all along the line, we transfer from S to S' by moving along with the electrons, we find that this is no longer so.

The first thing that we notice when we settle down in our new abode is that the protons are moving past with velocity $-v$. And because distances in a moving system (in this case S) are reduced by the factor $1/\beta$, according to Lorentz, the protons look closer together than they did when we were in S. And therefore there are β times more of them per metre. But that observation is really quite irrelevant, for we have done with the protons now and must concentrate exclusively on the electrons. We see these standing still, so their distances apart are not subject to Lorentz contraction. But they were so subject in S, so we can now say that in S' the distances between electrons are *de*contracted, or expanded. So there are fewer electrons per metre. Because the distances between them are β times greater than in S, the number of them per metre must be $1/\beta$ as many as in S. In symbols, $n' = n/\beta$. Fig. 6 shows a piece of one wire as it appears in S and in S'.

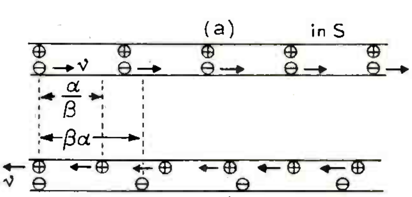


Fig. 6. In system S, in which the wires in Fig. 5 are stationary, each wire looks the same as in Fig. 5, (a). But in system S′, in which the electrons are stationary, each wire looks as at (b).

Because the electrons are standing still in S' we can use the standard equation for the repulsive force per metre between the two wires without any relativity complications. In our abbreviated form it is

$$f_e' = (n')^2 p$$

Having taken that in, we get back into S. It is a principle of the theory of relativity that the laws of nature are the same in all inertial systems, which means systems that are not accelerating or decelerating. So

$$f_e = f_e' = (n')^2 p = \left(\frac{n}{\beta}\right)^2 p = n^2 p\left(1 - \frac{v^2}{c^2}\right) = k\left(1 - \frac{v^2}{c^2}\right)$$

If we add this to the sum of the three forces (a) to (c), which we found to be $-k$, we get as the sum of all four forces

$$-k\frac{v^2}{c^2}, \text{ or } -\frac{\mu_0 (nev)^2}{2\pi d}, \text{ or } -\frac{\mu_0 I^2}{2\pi d}$$

Being negative it is conventionally a force of attraction. In fact, this is the standard formula (6) for the magnetic force of attraction between two parallel wires spaced d metres apart and each carrying a current I in the same direction. But from the way we arrived at it, *it is a purely electrical force*, due to an inequality in the balance of positive and negative charges in the wires when *both* are carrying current and account is taken of relativity—which we found we had to take into account last month in order to make sense of our assessments of fields existing in relatively moving systems, on a basis of schoolbook Electricity.

We also noted for future attention the voice of the sceptic who declared that magnetic forces couldn't possibly be actually the *same* as electric forces because one could distinguish between them by experiment. In particular, an electrically charged droplet floating in space is attracted by an opposite electric charge, but is totally unaffected by the strongest magnetic field. We now see that this argument is fallacious. The reason the charge doesn't respond to the "magnetic" field is that it is stationary therein, so it sees an exact balance between the positive and negative electric charges in the wires energizing the magnet, even though one lot of them is in motion. But directly the droplet itself moves it is in another frame of reference and sees an inequality of charge and therefore an electric field, which deflects it from its path.

The title question, then, has been

answered by the conclusion that "magnetism" can be accounted for by purely electric attraction and repulsion. Of course, this conclusion has been reached only for one simple case—parallel wires carrying equal currents in the same direction—but the principle is the main thing. The same demonstration can be very easily adapted to cover currents flowing in opposite directions, giving a force of opposite sign, repulsion. It is only a little more complicated to include unequal currents. In this case there are two different electron velocities, say v and u, and instead of v^2 in the numerator we get vu: This shows that there is no force if *either* current is zero. It is noticeably more difficult to deal with charges moving along non-parallel paths, and if you want to go into this I suggest you study "Classical Electricity via Relativity" by W. G. B. Rosser, Chap. 3 (Butterworth, 1968).

Having discharged (if that is the right word) my brief, I might now be expected to conclude the whole session and release you to read more interesting parts of this issue. But you might just find it worth while to tarry yet a few minutes while together we do some rather remarkable arithmetic.

In our Fig. 4 the current in each circuit will probably be less than 1mA, and the forces between beams and wires admittedly small. So let us take an example where the force should be quite appreciable; say 1 amp flowing in each wire having a cross-sectional area of 1mm^2. We know the current is equal to nev. Any book on electricity will tell us $e = 1.6 \times 10^{-19}$ coulombs. And some books will tell us that in copper there are roughly 10^{29} movable electrons per cubic metre. In a metre of our wire the volume is 10^{-6} cubic metres, so n is 10^{23}. From $nev = 1$, then, v is $1/(10^{23} \times 1.6 \times 10^{-19})$, or about 6.3×10^{-5} metres per second, or $0.06\dot{3}$ millimetres per second. Compared with which, a snail seems to be in a tearing hurry.

Seeing that the effects of relativity can normally be neglected even at supersonic jet speeds, can it seriously be maintained that velocities of this minute order can result in forces sufficient to drive electric motors? We found the ratio of "magnetic" to electric force between the beams to be v^2/c^2, and were it not for the charge-neutralizing effect of the protons this would apply to the wires too. The ratio of forces would be $(6.3 \times 10^{-5})^2/(3 \times 10^8)^2$, or 4.4×10^{-26}!

This figure begins to look less utterly insignificant if we take the trouble to work out the *unneutralized* electric force per metre of wire in our example. We know well by now that it is k, or $n^2 e^2/2\pi\epsilon_0 d$. n is roughly 10^{23}, e is 1.6×10^{-19}, ϵ_0 is nearly 9×10^{-12}, and let us suppose d is 0.01 metre (1 cm). Then the force is 4.6×10^{20} newtons. Or 46,000,000,000,000,000 tons! It is to this that the 4.4×10^{-26} ratio has to be applied. So the "magnetic" force turns out to be an appreciable 2×10^{-5} newtons, or 2 dynes. Which is the same as you would get by using the traditional formula for electrical attraction between parallel wires (equation 6).

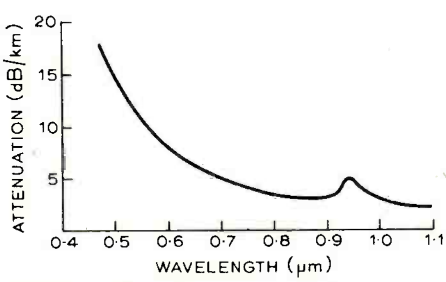
Low-loss optical fibre

Interest in the potential use of optical fibre waveguides in the telephone network, has resulted in recent dramatic reductions in fibre attenuation. There has been considerable expenditure and effort in laboratories in this country, as well as abroad, which has produced silica-based fibres with remarkably low losses of around 2dB/km. Groups at Standard Telecommunication Laboratories, Bell Telephone Laboratories and Corning Glass Works have used either germania or boric oxide to modify the properties of silica to produce an optical guiding structure.

However, a research team led by Professor W. A. Gambling at Southampton University has produced a new type of fibre with similarly low losses but based on an entirely different and unexpected material. The process by which the fibre is made is also new and has almost entirely eliminated the sharp absorption bands, associated with "water" impurity in the glass, that have affected most other fibres. This new solid-core fibre has extremely low loss over the entire wavelength range 0.4 to 1.1μm with minimum values of 2dB/km at the gallium arsenide and neodymium laser wavelengths.

The fibre has a core material comprising a phosphosilicate (P_2O_5/SiO_2) glass contained in a pure silica cladding. At first sight, this is an unlikely combination since glasses do not exist in bulk form having such a phosphosilicate composition. The big advantage is, however, that the addition of phosphorus pentoxide to silica does not increase the absorption and scattering losses as is the case with some of the additives (e.g., germania, titania) used by other workers. Further phosphorus is an abundant element, easily available and relatively cheap.

To produce the phosphosilicate glass a new technique comprising controlled chemical-vapour deposition has been devised. The starting materials are purified silicon tetra-chloride and phosphorus oxychloride, which are vaporized, mixed with oxygen and passed through a tube of silica cladding glass. The tube containing the flowing gas mixture is traversed through a fibre-pulling furnace which is operated at an appropriate temperature. Simultaneous oxidation and fusion occurs so that a clear phosphosilicate glass is deposited on the inner surface. A suitable thickness is obtained in about one hour. The composite tube is then collapsed



Spectral attenuation curve of 1.2km length of new phosphosilicate-core silica cladded fibre developed at Southampton University.

and drawn into a fibre using a specially-developed graphite resistance-heated furnace. Operating temperature, which can be in excess of 2,200°C, is monitored by a thermocouple to allow accurate control and repeatability. The fibres typically have a core diameter of 50μm, an overall diameter of 150μm and are drawn in lengths of about 1.2km. Numerical aperture can be varied up to 0.18 or more as desired by control of the relative concentration of phosphorus pentoxide in the core. Either a uniform, or a graded, refractive index can be provided in the core.

Even though the loss already achieved is extremely low it has been shown that the phosphosilicate core material is capable of further improvement. It is confidently expected that a transmission loss of about 1dB/km will be achieved with further purification of the starting materials.

In addition to ultra-low loss the fibres exhibit very low values of pulse dispersion and are capable of bandwidths of more than a gigahertz over lengths of 1km.

It will be recalled that two years ago the Southampton group announced a liquid-core fibre having the lowest loss (5dB/km) for any type of fibre at that time. It is still the best liquid-core fibre that has been produced anywhere and a 1km length was used to give the world's first transmission of a live colour television programme by the BBC.

Sixty Years Ago

From *Wireless World*, Oct. 1914:

The Amateur's Wish

Alas, Poldhu! thy blaring bugle note
Which oft at midnight pleased my list'ning ear;
And Clifden, too, thy mighty waves which float
Five miles apart, wide wafting signals clear,
For me are gone. My 'phones no longer sing
The music which was prompted by your sparks,
Nor can they tell, if still ye nightly fling
Abroad, meteorological remarks.
My watch ticks on, unchecked; I cannot fix
Its hands to Greenwich time, and set it right,
For Paris purring "tas" and "tuts" and "ticks"
Ne'er reach my ears. My aerial's gone from sight,
Gone Cleethorpes' mystic messages that thrill,
And turn my thoughts to men, and ships, and might.
Gone, too, Madrid, whose plaintive whistling shrill
I've heard, with straining ears, across the night.
My jigger lies, with coils and aerial-lead
In tight-packed drawer; it can no longer slide
To tune, helped in its work, to let me read
Far signals, by condensers on each side.
Shall I complain? No, never! From it far,
Such hobbies now must all aside be laid
Since I have heard the "ta-te-ta-te-ta"
My country sent to call me to her aid.
And so instead I'm tuning up a gun,
And learning how to shoot, to march, and wait
With hope, to help in things which can be done
By those who turn to drilling rather late.
And if I'm called away to leave my home,
Should I, before I go, just take a peep
To see that all within my wireless room
Is right, I know this thought will on me creep.
"When peace again doth reign, and war is done,
God grant my 'phones may sing of victory
In notes that spell the words of England's tongue,
Sent out by British hands on Norddeich key."

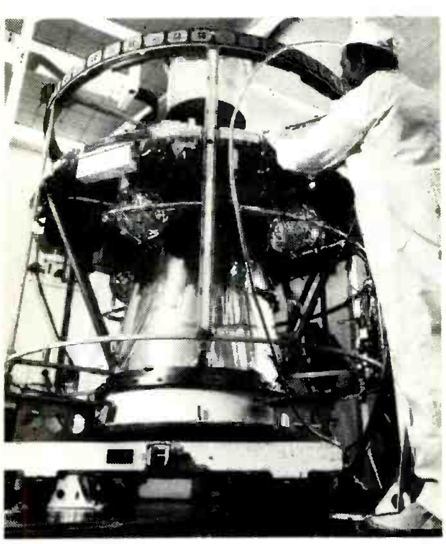
Aylmer A. Liardet.

British satellite launch

The second model of Britain's Skynet II, the first operational communications satellite to be built outside the USA or Russia is due for launch from Cape Canaveral in November by a Thor-Delta rocket. Coupled with this in Britain's space achievements is the scheduled launch of UK 5, the latest scientific satellite in the collaborative programme with NASA. This advanced X-ray satellite carries experiments provided by British and American researchers, and is designed to carry out the most comprehensive investigation yet initiated into X-ray sources in deep space including phenomena which might explain the existence of "black holes" in space.

Skynet II. This satellite will carry British defence communications over an area from the UK to the Far East. It will replace the smaller, US-designed and built Skynet I satellites. Skynet II is built in the form of a cylindrical drum with solar cells covering the entire curved surface. It measures approximately 78in long with a diameter of 75in. Launch weight is about 960lb.

Transfer of the satellite from its original highly elliptical orbit into synchronous orbit will be achieved by firing a solid fuel apogee motor contained in the satellite. The complete satellite will be spin-stabilized at about 90 revolutions per minute from the time second-stage burning ceases. However, once in synchronous orbit the communications antenna will be de-spun and controlled to point constantly at the Earth.



Skynet II undergoing check-out at the Marconi Space and Defence Systems' Portsmouth spacecraft factory.

During the initial manoeuvres and up to the time of its final positioning, the satellite will be controlled through an almost omnidirectional aerial system consisting of an array of cavity-backed dipoles operating at S-band and mounted in a single strip around the complete circumference of the satellite. Once the synchronous orbit has been achieved and the satellite has been turned into the correct position related to the Earth, a single horn antenna mounted on the spinning axis of the satellite can be brought into use to provide the main communications function of the satellite. This antenna, whose beamwidth is sufficient to cover the entire visible portion of the Earth's surface, will be mechanically de-spun and aimed at the Earth's centre. The S-band multi-dipole aerial will then be used to monitor all the functions of the spacecraft and to transmit commands to it.

UK 5. This all-British satellite was scheduled for launch by a US "Scout" rocket from an oil-rig-type platform situated three miles off the coast of Kenya. It is the first British satellite to carry a core store system for processing experimental data before it is transmitted to the ground and will also be the first British scientific satellite to use pulse code modulation for the telemetry link. UK 5 will carry a scientific payload of six X-ray experiments into a near equatorial orbit and should remain operational for at least one year. The experiments on board the satellite are designed to locate cosmic X-ray sources, including pulsars, and to measure their spectra, period, variation and polarization. The experiments are as follows: measurement of X-ray source positions and a sky survey in the energy range 0.3 to 30keV, University College London; sky survey in the range 1.5 to 20keV, University of Leicester; study of the spectra of individual sources in the 2 to 30keV range, Mullard; measurement of the polarization of X-rays from 1.5 to 8keV, University of Leicester; study of sources of high energy X-rays up to 2MeV, Imperial College, London; an all sky monitor in the energy range 3 to 6keV, Goddard Space Flight Centre.

The results of the six experiments will be fed in digital form through an interface unit into a data storage system. This will store the information gathered during each orbit and then transmit it to the ground as the satellite passes overhead the receiving network. Commands will be transmitted from the ground providing instructions to the spacecraft and its experiments for data collection in the next orbit.

Skynet II was designed and built for the Ministry of Defence by Marconi Space and Defence Systems Ltd, who were also prime contractors for UK 5.

Supernova probe

The United States and Great Britain are to undertake a joint rocket mission next June to aim an X-ray telescope at the remnants of a distant supernova. The project calls for the launch of a British Skylark sounding rocket from the Woomera Rocket Range in Australia towards the Puppis A supernova remnant, an object of intensive study for several years.

A supernova can originate in a large star at the end of its life when the final collapse is a cataclysmic event that generates a violent explosion, blowing the innards of the star out into space. There the material mixes with the primeval hydrogen of the universe. Later in the history of the galaxy, new stars can be formed from this mixture. Consequently, the study of remnants of exploded stars such as Puppis A could provide important information on the evolution of stars and galaxies.

A Wolter type 1 glancing incidence X-ray telescope designed and built by NASA will be used in conjunction with a high resolution position sensitive detector invented and developed by the Mullard group. The combination will permit structural details of the regions responsible for soft X-ray emission of Puppis A to be studied with high resolution.

Puppis A, the subject of previous study by sounding rockets and the Copernicus (OAO-3) satellite has been found to be one of the brightest soft X-ray sources in the sky. Telemetered data from the Skylark experiment will provide two-dimensional images of the X-ray-emitting regions of Puppis A which can be compared with previous observations to develop more precise models of the supernova phenomenon.

More about Apollo-Soyuz

The joint space-venture between the USA and Russia which involves the in-orbit docking of the Apollo command module with a Soyuz spacecraft is planned for launch on July 15, 1975 (see Space News, August 1974, p.287). During the mission, the crew will conduct important new technological and medical experiments. Atmospheric experiments will be conducted using a new technique for measuring constituents which are too chemically reactive to measure directly with a mass spectrometer. This will be accomplished by sending an optical signal from the command service module to a reflector on the Soyuz vehicle. The signal will be bounced back and scanned in the Apollo spacecraft to study the effects of the sun on atomic oxygen and nitrogen at orbital altitudes. Also included is an experiment in electrophoresis processing. An electric field is used to separate living cells and other biological materials from a flowing medium without decreasing their activity in near zero gravity conditions. Successful demonstration by the Apollo-Soyuz test project could lead to further development of space electrophoresis in shuttle missions, as a tool for medical research and therapy and contribute to such fields as immunology and cancer research.

Realm of microwaves

9—Basic measurements and instruments

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Most of the techniques used, together with the method of approach, in measuring what goes on in a microwave circuit are sufficiently different from other electronics practice to make an interesting topic of their own. As with the preceding articles in this series, the presentation of the subject is intended, not to preach to the converted, but to highlight the considerable differences in technique and technology that exist in the microwave region.

The trend in microwave measurements is toward more automated systems and for individual instruments to cover wider bandwidths with the minimum of operator intervention. While mentioning some of the more advanced systems, this article concentrates on the basic quantities to be measured, like power, impedance and frequency, and on certain types of instruments which have become universally accepted as the basic measuring tools.

To start with, there is a great difference in the approach to both measurement and design at microwave frequencies than at the lower frequencies. Quantities such as voltage and current, while still existing, have little practical significance and little attempt is made to measure them. Consider, for example, the hollow, metal waveguide form of transmission line wherein the wavelength is usually of the order of centimetres. The system is a d.c. short circuit, so a potential difference can only exist in so far as the electric field is varying, so that voltage is a function of position along the guide.

Electric current does not exist as a steady stream of electrons travelling uniformly from one end of the guide to the other, but as periodically circulating currents near the surface of the walls. Even if some current monitor were invented it would not give the total current, but only the bit flowing at the particular measuring point. Consequently it is the microwave power which is always measured and this is done directly by absorbing it into some load and either noting the rise in temperature or variation in resistance of this load.

Having either received or generated a microwave signal, one is then mainly concerned with transferring the power efficiently from one point to another, usually via other components such as filters, attenuators, isolators, directional couplers. Consequently, impedance becomes a vital parameter, governing the degree of mismatch between two points or components. Each type of transmission line, be it waveguide, coaxial line or microstrip, has a characteristic impedance which, for a given electromagnetic field pattern (mode) within the line is a real quantity and is a function of the cross-sectional dimensions of the line. A component, say a receiving antenna, which may have a complex or different impedance to that of the line will appear as a mismatch, causing some of the microwave power to be reflected. When a mismatch does occur, it can be compensated for by deliberately introducing a second mismatch a certain electrical length away so that the combined reflections cancel out.

Microwave impedance

The measurement of impedance in the microwave region illustrates one of the main differences in approach to this type of problem. A good definition of the microwave spectrum is that in which the various components and transmission line cross-sectional dimensions are comparable in size to the wavelength. The significance of this is that the electromagnetic field itself can be conveniently sampled and the perturbing effects of any obstacle in the transmission line can be readily measured.

The effect of a mismatch is to reflect some of the microwave power back down the transmission line, the exact amount depending on the degree of mismatch. This reflected power combines with the incident field to produce a resultant field pattern which is stationary in position along the guide as shown in Fig. 1. The quantities E_{max} and E_{min} depend, in value, on the amplitude of the reflected wave, while the position of the standing-field pattern with reference to the obstacle depends on the reactive effect of that obstacle. The distance between peak and null of the pattern is a quarter of the line wavelength, which can be different from the free-space wavelength.

Sufficient information is contained within a measurement of E_{max}, E_{min} and the minima position to determine the amount of reflected power, the obstacle impedance, whether the impedance has an inductive or capacitive component and the magnitude of this reactance. Also, a measurement of the distance between successive peaks or nulls of the standing-wave pattern yields the frequency. This impedance determination, either directly or indirectly, is the most common of all microwave measurements and the successful design of components and systems hinges upon it.

This is largely because microwave systems involve the transfer of power from one point to another, usually in applications where even small losses cannot be tolerated. Knowledge of such an impedance mismatch enables steps to be taken to either correct it or compensate for it. Again, the accuracy of most microwave instruments depends on the degree of mismatch that they present to the transmission line. With market competition high, such instruments have to operate over full waveguide bandwidths, or even wider in coaxial systems; so that the broadband mismatch is of fundamental interest to both the designer and the user.

Before going on to describe some ways and means of measuring impedance, it will be as well to list the parameters involved and their relationships with each other. Derivation of these equations will not be given here, but is simple enough and can be found

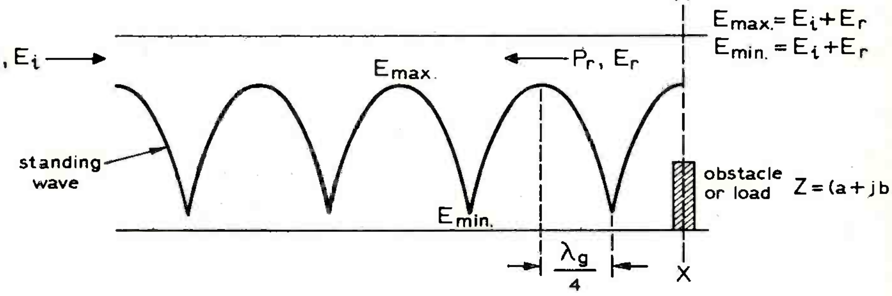

Fig. 1. Reflected wave from transmission-line discontinuity interferes with the incident wave to produce a standing-field pattern along the line.

in any of the wealth of literature dealing with transmission line theory.

Firstly then is a quantity called the voltage standing-wave ratio or v.s.w.r. and is obtained directly from probing the field pattern of Fig. 1. The v.s.w.r. is an indication of how well a load or an in-line component is matched to the transmission line impedance and is always quoted in the specifications of such devices. It is defined as the ratio E_{max}/E_{min} and, as such, can vary from unity for a perfect match ($E_{max} = E_{min}$) to infinity for a perfect short or open circuit ($E_{min} = 0$).

It is also possible to define the v.s.w.r. as the reciprocal of this giving values of between unity and zero and this used to be the earlier method. Now, however, apart from a few die-hards in British industry, fashion has succumbed to New World and Continental influence and the former definition is used. Although a variation of from $1 \rightarrow \infty$ is possible, in practice the v.s.w.r. is small. To give a feel for the figures: octave and waveguide-band components seldom have v.s.w.rs worse than 1.7, while precision and narrow-band devices are better than 1.1.

It is possible to obtain the amount of reflected power from a mismatch by expressing the v.s.w.r. in terms of a reflection coefficient. The standing-wave pattern is produced from the combination of the incident and a reflected wave which can be given electric fields E_i and E_r at the positions of measurement. Then E_{max} is given by $E_i + E_r$ and E_{min} by $E_i - E_r$, so that the v.s.w.r. becomes

$$\frac{E_i + E_r}{E_i - E_r} \quad (1)$$

One can also define a voltage reflection coefficient, ρ, as the ratio of reflected to incident voltage E_r/E_i, whereupon equation 1 can be written as

$$\frac{1+\rho}{1-\rho} \quad (2)$$

Taking the v.s.w.r. value of 1.7 mentioned above, the corresponding value of ρ is 0.26 and the power reflected, being proportional to the square of the voltage is thus 0.067. That is, 6.7% of the power is reflected from a mismatched object having a v.s.w.r. of 1.7, while the corresponding figure for a v.s.w.r. of 1.1 is only 0.23%.

Strictly speaking, the voltage reflection coefficient used in equation 2 is the modulus of a more general reflection coefficient containing relative phase information about the reflected wave. Such information is necessary when evaluating the reactive component of a mismatch and can be simply obtained by noting the shift in position of the standing wave pattern when the mismatch is replaced by some phase reference—usually a short circuit.

Again, there is a simple relationship between the reflection coefficient and load impedance, Z_L, on a transmission line. In general these will be complex quantities, so that the reflection coefficient is more fully given by $\zeta = \rho \exp j\phi$ where $\rho = |\zeta|$ and can then be written in terms of the load as:

$$Z_L = Z_o \left[\frac{1+\zeta}{1-\zeta}\right] \quad (3)$$

Z_o being the characteristic impedance of the line. Thus the absolute value of a complex load impedance can be obtained from an electric field measurement to give the ratio of E_{max} to E_{min} a length measurement to give the phase of the reflection coefficient and a knowledge of the characteristic impedance of the line—usually calculated.

Determining the characteristic impedance presents problems, especially in the case of waveguide. Coaxial line, balanced stripline and, to a fair degree of accuracy, microstrip have only transverse components of electric and magnetic fields and it is possible to define a single constant of proportionality between these, called the characteristic impedance. Waveguide transmission, though, involves both longitudinal and transverse fields and it is not possible to define a unique characteristic impedance. For instance, in terms of voltage, current and power, impedance can be given by V/I, P/I^2, V^2/P (r.m.s.), while strictly speaking V^2 and I^2 are the products of the complex and complex conjugate voltage and currents. Applying these familiar relationships to more everyday electrical problems will yield identical values of impedance, but not so in waveguide. In fact, the ratios of the different answers obtained are $(\pi/4)$: $(\pi^2/16)$:

But, in the great majority of cases, the reason for measuring load impedance is to tune out a mismatch and it is not necessary to know the absolute value, only that normalized to the characteristic impedance of the line. As the tuning device can also be normalized to the same impedance, it is satisfactory to treat the problem on a purely relative basis. In terms of the quantities actually measured, the impedance obtained is thus:

$$\frac{Z_L}{Z_O} = z_L = \frac{1+\zeta}{1-\zeta} \quad (4)$$

Bearing in mind that z_L is likely to be a complex quantity having normalized resistive and reactive components ($r \pm jx$), and that ζ is also complex, it is a simple matter to fully characterize the load impedance. This impedance obtained by measuring the standing-wave pattern is that existing at the plane or effective "terminals" of the mismatch or load, but is not the whole story of microwave impedance.

A very important transmission line property can be exploited because of the physically small distances involved; that is the ability of a length of line placed between the observer and the load to change the input impedance. In the case of Fig. 1, if the terminal plane is moved toward the left it will pass through differing phase relations between the incident and reflected waves which will alter the real and imaginary parts of the impedance as seen at this plane. Again, there is a simple relationship governing the input impedance to a length of transmission line terminated by some load

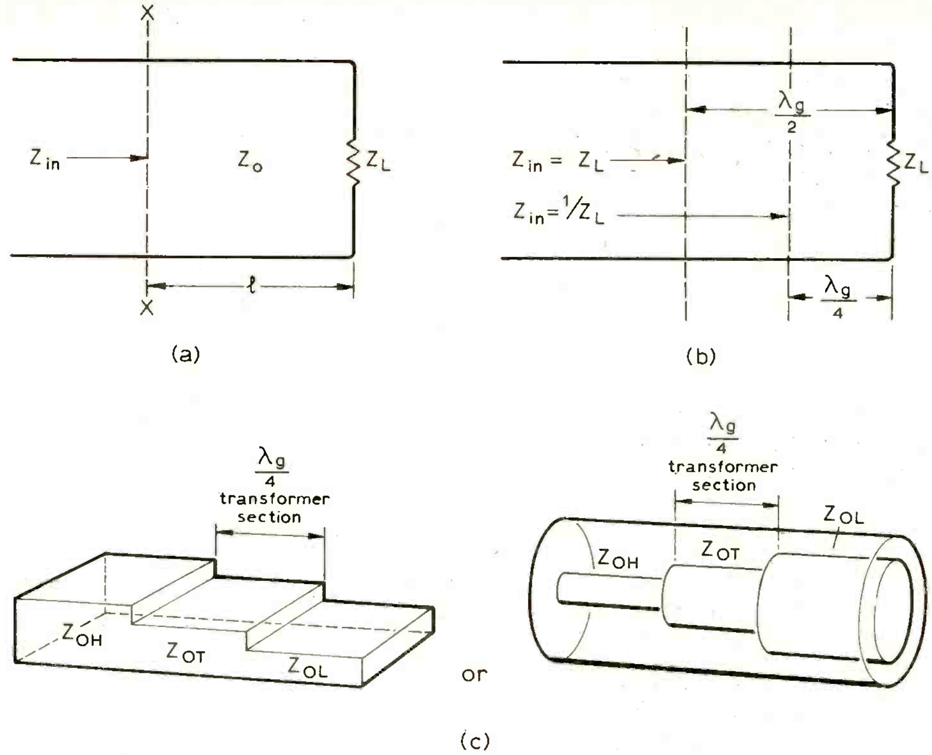

Fig. 2. Input impedance of loaded transmission line is a function of the position at which it is viewed; it repeats itself every half-wavelength (a) and inverts every quarter-wavelength (b). This latter facility is used to produce reflection less impedance transformers (c).

which can be obtained by extension of equation 4 by adding to the phase of the incident and reflected waves, an amount of phase corresponding to the length of transmission line. With reference to Fig. 2(a)

$$z_{IN} = \frac{Z_{IN}}{Z_o} = \frac{z_L + j\tan\beta l}{1 + jz_L\tan\beta l} \qquad (5)$$

where β is the phase constant and equal to $2\pi/\lambda_g$, remembering the transmission line wavelength need not be equal to the free-space wavelength.

The usefulness of this impedance transforming effect will be seen later where it helps in the matching of components. But there are some special cases worth pointing out here. When the observation plane XX is moved to a position such that $l = \lambda_g/2$ or multiples of $\lambda_g/2$ then equation 5 reduces to $Z_{in} = Z_L$, which is as if the load itself had been moved to the new terminal plane. A practical implication of this would be when some form of tuning device, say, had to be placed alongside a load or mismatch, which was inaccessible. If a suitable position could be found for the tuner which was a whole number of half-wavelengths away from the load, then the effect would be the same. This is only strictly applicable at one frequency and for large distances or lossy transmission media attenuation must be taken into account.

A second interesting effect occurs at the position where $l = \lambda_g/4$ when equation 5 becomes $z_{in} = 1/z_L$ and the load impedance viewed from this point has been inverted. Note that these are still normalized values if anybody is checking the units. This is an important property and is known as quarter-wave transforming and

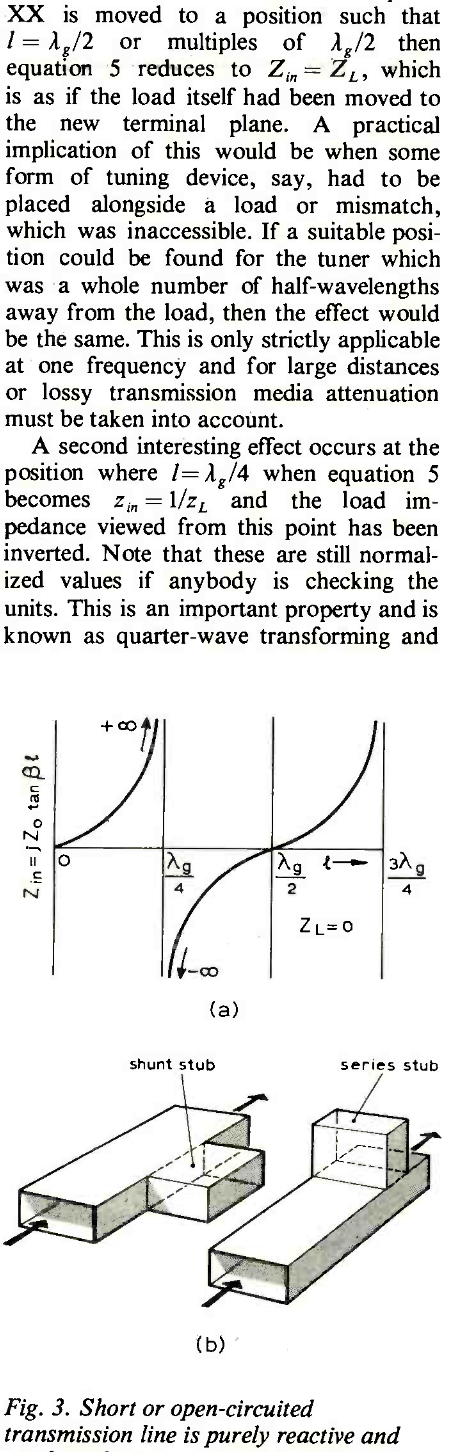

Fig. 3. Short or open-circuited transmission line is purely reactive and can be inductive or capacitive with any value between ± infinity depending on its length (a). This makes the series or shunt stub (b) a versatile matching element.

is widely used in microwave design. It performs the same function, without the isolation, as transformer matching does at lower frequencies, but without metres of wire for coils.

Consider Fig. 2(c) where the problem is to match sections of low impedance and high impedance line. We cannot just join the two sections together, for apart from causing a reflection due to the differing electrical impedance of the two lines, the physical discontinuity at the junction will disturb the field patterns and will appear as an additional susceptance. Looking from left to right in Fig. 2(c), the low impedance line Z_{OL} can be considered as the load, separated from the main transmission line of high impedance Z_{OH} by the $\lambda_g/4$ section of impedance Z_{OT}.

Moving to the left, away from the load, just into the transformer section sees Z_{OL} as the normalized impedance Z_{OL}/Z_{OT} which, as the movement continues, varies in accordance with equation 5. On reaching the end of the transformer, the impedance is inverted, to give Z_{OT}/Z_{OL}. To be matched, this should be made equal to the high impedance section, also normalized to Z_{OT}. Thus, $Z_{OT}/Z_{OL} = Z_{OH}/Z_{OT}$ or $Z_{OT} = \sqrt{Z_{OH}Z_{OL}}$, which gives the required characteristic impedance of the quarter wave transformer as the geometric mean of the impedance to be matched. By this means, any real impedance values can be matched and, by increasing the number of transformer sections, the match can be maintained over wide frequency bands (an octave or more).

When computing the variation of a complex load impedance with frequency and at the same time searching for the value and location of the best matching structure, the algebra becomes lengthy and tiresome and it is not always easy to see the best direction to follow. An invaluable aid to this type of problem is the circle diagram or Smith chart, which is a grid of interlocking circles derived from the relationships given earlier between impedance, reflection coefficient and v.s.w.r. By plotting an impedance on this chart, one can obtain a speedy, visual picture of how it varies with frequency. Examples on the derivation and use of the Smith chart have already been published in *Wireless World**. This article gives a very good explanation of the Smith chart and is well worth reading.

Apart from perhaps the characterization of some solid-state devices, the impedance or reflection coefficient obtained is required for the purpose of matching out the reflection, thereby maintaining an efficient power flow. For the instrument designer in particular, this is important to the measurement accuracy of the device he hopes to sell. Basically, the principle of matching is quite simple, although in practice it can be an extremely exacting task and uses the transforming property of a length of transmission line. By moving the plane of observation away from the load or mismatch, a point will be reached where the real part of the input impedance (load plus line) equals the characteristic impedance and is thus a match. All that is left is a reactive component, either inductive or capacitive. If, then, another reactance, but of opposite type, is introduced at this point, the combined reflections will cancel out and the line will appear matched.

The spanner to be thrown into this ideal-sounding works is the fact that almost all microwave systems are required to work over a band of frequencies and so matching becomes a compromise between complexity and v.s.w.r. The amount of headache this produces really depends on which type of market the circuit designer is aiming for. An instrument designer has to make components which function accurately over at least the standard waveguide bandwidths (up to an octave) and wider in coax, while a radar systems designer is usually only concerned with bandwidths of a few per cent.

Having found the best place to position the matching device and determined by measurement and calculation the necessary reactance, it remains only to translate this reactance into a physical structure. And here is another aspect of microwave technique which is markedly different from the remainder of electronics engineering. If, say, a capacitive reactance were needed, then it would not be possible to use the conventional solid-dielectric or electrolytic capacitor, simply because neither would appear as a lumped element. Their physical size, being a significant portion of a wavelength, would make the capacitance itself frequency dependent and conducting paths within the component which perhaps were only tens of nanohenries inductive possess a large reactance at GHz frequencies.

Bearing in mind that a component is classed as inductive or capacitive depending on the way in which it influences the phase relationship between current and voltage, then all that is required at centimetre wavelengths is something which will perturb the local electric or magnetic field so as to produce a similar effect. One finds that metallic objects in the transmission line, a sudden change in cross-sectional dimensions, or a piece of dielectric can all produce inductive or capacitive effects. So too, as we have seen, can a length to transmission line itself and as well as transforming an impedance can also be used in reactive matching.

Suppose that, instead of the load Z_L of Fig.2, the line is terminated in a short circuit, then $Z_L = 0$ and equation 5 reduces to $Z_{in} = jZ_o \tan\beta l$. Thus, neglecting losses, the input impedance to a short-circuited transmission line is a pure reactance, the exact value of which depends on the electrical length. As can be seen from Fig.3(a), when the stub length is less than a quarter wavelength, the reactance is inductive and covers all values from zero to infinity. Between $\lambda_g/4$ and $\lambda_g/2$ in length, the line impedance is a capacitive reactance, again varying between zero and infinity. Any value of reactance can thus be obtained from such a length of line, making it a versatile and effective matching aid. Fig.3(b) shows how, in waveguide, such a stub line would be connected to appear in shunt

*Hickson, R. A. "The Smith Chart". *Wireless World*, Vol. 66, 1960, pp. 2–9, 82–5, 141–6.

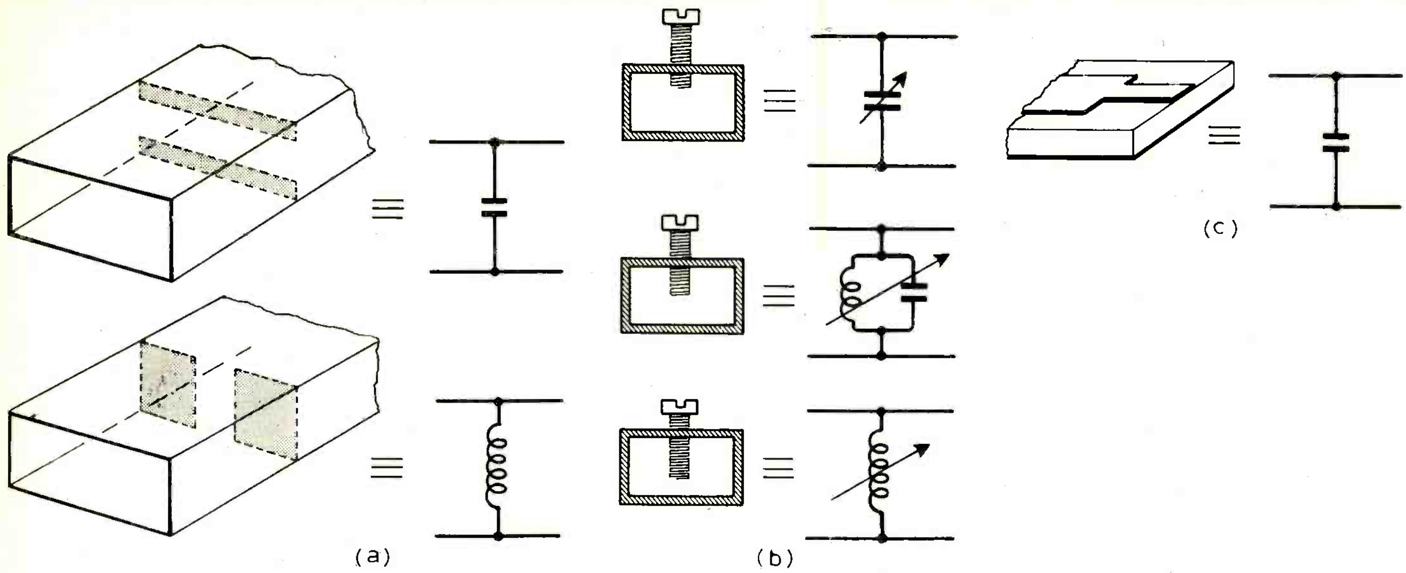

Fig. 4. Various reactive components: (a) inductive and capacitive crises, (b) inductive capacitive or resonant post, (c) microstrip capacitive step.

with the main line. Connecting it across the broad dimension of the guide would make it appear in series.

Some common microwave reactive components are shown in Fig. 4 and are capable of producing a wide range of practical values. Provided that the dimension of such an element in the direction of propagation is a small (<1/20) part of the wavelength, the actual inductance or capacitance is essentially independent of frequency. The ubiquitous screw, or post, is widely used as a matching and tuning device. For the first amount of penetration into the guide it appears capacitive, then passes through a resonant condition as penetration increases and finally becomes inductive. In waveguide or coaxial line the post provides a convenient method for tuning up the resonant sections of a filter and provides a method of mechanically varying the frequency of solid-state cavity oscillators. In the microstrip form of circuit discussed previously, components such as these are not so practical and the mechanical tuning of components is not normally done. When matching devices are required, then the appropriate reactance is produced either by an abrupt change in the transverse dimension of the strip component or by suitable stub-lines placed at right angles to the main line.

Impedance measurement

A lot of effort has been expended by manufacturers in producing test equipment and components of steadily increasing quality for the measurement of impedance and also progressing towards fully automated systems. All methods, however, are based on determining the magnitude and phase of the voltage reflection coefficient, usually as a function of frequency. The basic component for measuring these quantities, still going strong as a laboratory instrument, is the slotted line shown schematically in Fig. 5. It consists of a section of waveguide or coaxial line with a narrow slot several wavelengths long cut along its axis. With the dominant mode propagating, the slot does not interfere with any of the field components and thus causes no significant radiation. A metal probe penetrates through the slot into the guide and is attached to a sliding carriage, the position of which can be determined accurately with either a vernier scale or a clock gauge. To one end of the instrument is connected a source of microwave power and to the other, the component under test.

As we have seen, any mismatch will produce a standing-wave pattern along the guide due to the interference between incident and reflected waves and the carriage probe will couple to the electric field of this pattern to yield a detected output voltage proportional to the wave amplitude. By moving the probe carriage along the slot, a voltage reading can thus be obtained for the maximum and minimum values of the standing-wave pattern and, hence, the v.s.w.r. (leading to the reflection coefficient magnitude) which is the ratio of these two. To determine the complex part of the reflection coefficient, and hence the impedance, it is necessary to know whether the mismatch is inductive or capacitive and this information is contained in the phase difference between the indicent and reflected waves.

Its value may be obtained by comparing the standing-wave pattern produced by the mismatch with that from a known phase reference, usually a short circuit. Being nearly non-dissipative and non-reactive, a practical short circuit placed across the transmission line will produce a very large v.s.w.r. and standing-wave minima spaced at $\lambda_g/2$ intervals from the plane of the short itself. The measurement procedure is to place the short-circuit reference either at the same position as the unknown impedance or a known distance from it and to note the position of one of the standing-wave minima. This position will be different from that occupied by the minimum produced by the original mismatch and represents the phase angle of the impedance.

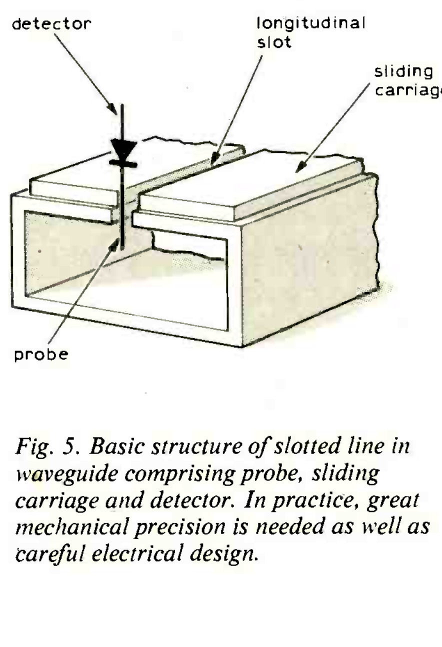

Fig. 5. Basic structure of slotted line in waveguide comprising probe, sliding carriage and detector. In practice, great mechanical precision is needed as well as careful electrical design.

Although accurate, the disadvantage of the above method is that it is restricted to spot-frequency measurements and thus, in the case of a wide-band component some poorly-matched areas might be missed. In addition, it is hardly a practical method to use for production quality control: a comprehensive check could price the component under test out of the market. However, with the advent of microwave sweep oscillators, now capable of covering almost any bandwidth and accurate test components, it is possible to obtain a continuous plot of impedance across the operating band of the device under test.

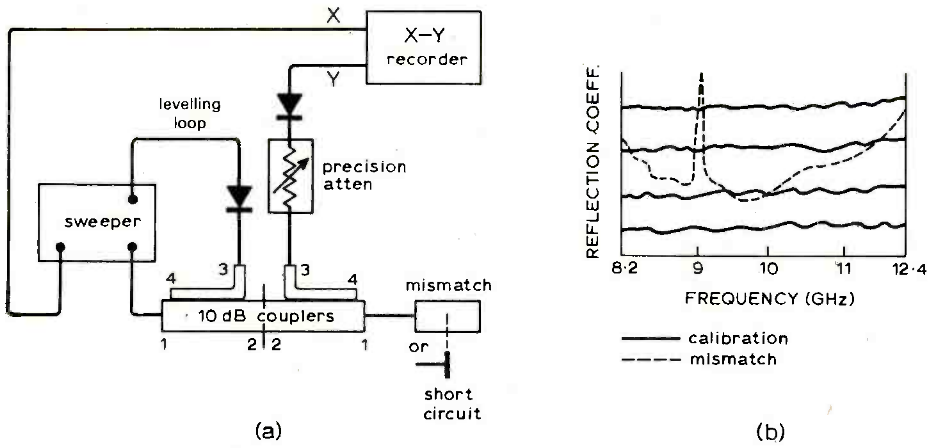

Fig. 6. Reflectometer set-up for the swept measurement of reflection coefficient (a) and the resultant recorder plot (b).

A test circuit for measuring the reflection coefficient on a swept frequency basis is shown in Fig. 6 (a).

Say the device to be measured is to operate over X-band (8.2–12.4GHz) then the microwave oscillator can be made to continuously sweep automatically across this band within times of typically many minutes to 0.01 seconds. If the measurement recorder were an oscilloscope, the latter rate would be chosen but for the XY recorder shown here, several tens of seconds for a sweep is more applicable. The X-travel of the recorder is synchronized electrically with the oscillator sweep. Forward and reflected signals are sampled by the directional couplers, shown here as 10dB models, which means that arm 3 couples out 1/10th of the power in the main arm of the device travelling in the direction 1→2.

Ideally, no power should couple to arm 4 as this could give rise to an additional reflected wave. But, alas, nothing is perfect and this is a small source of error in the measurement. The purpose of the levelling loop connected to the first coupler is to provide a constant amplitude signal over the band, which can be used as a reference so that only variations in the reflected power need be measured. The first step is to calibrate a scale of reflection coefficient along the Y-axis of the recorder and, to this end, a short circuit is put in place of the component under test.

As far as the detector in the second coupler is concerned, the reflected signal amplitude which it sees with the attenuator set at 0dB, represents a reflection coefficient of unity. If, however, attenuation is inserted into the line, then the decrease in amplitude can be interpreted by the detector as coming from a termination with a lower degree of mismatch. The two quantities are related by $-20\log_{10}\rho$ and is called the return loss (dB). So a short circuit padded out with say 10dB of loss appears as a reflection coefficient of 0.32 or a v.s.w.r. of 1.9. A calibrating grid can thus be drawn on the recorder for various values of return loss to simulate various mismatches. Finally, the short is replaced by the test piece, the attenuator set back to zero and the actual measurement superposed on the calibration. The result might be as shown in Fig. 6 (b) where, if spot frequency checks had been relied on, the sharp resonance at 9GHz could well have been missed.

One can go one step further and introduce a phase measurement and then display the swept plot in polar co-ordinates on an oscilloscope with a Smith chart graticule. By this means an empirical matching technique can be continuously monitored while the adjustment is going on, perhaps saving weeks of design effort of the rejection of a production component. Then, if one has the money, a computer can be introduced and programmed to carry out sets of measurements while continuously carrying out circuit error analysis and correcting for it and displaying the data for both active and passive devices in many convenient ways.

Whichever technique is used, the basic fact remains that at the short microwave wavelengths it is possible to monitor the effects of a reflected electromagnetic field from a mismatch by quite simple methods. Then, knowing the wavelength, the impedance of a load or discontinuity can be easily defined in terms of the amplitude and phase of the reflection which it produces.

Standard time satellite

A successful two-year experiment in broadcasting time and standard frequency signals from an earth satellite has just been completed by the US National Bureau of Standards. In the experiment, a frequency modulated 149MHz carrier wave was transmitted for two 15-minute periods a day from the Bureau's Boulder, Colorado laboratories to the US National Aeronautics and Space Administration's ATS-3 geostationary satellite. The signal is rebroadcast to earth on a 135MHz carrier to cover the North and South American continents, much of the Atlantic and Pacific Oceans and part of Europe and Africa, a total of 40% of the earth's surface.

Satellite-relayed signals have high signal-to-noise ratios, wide bandwidth (permitting flexibility in signal input) and line-of-sight propagation paths free from fading. In the future, a satellite system based on the experiment may offer continuous time and frequency broadcasts covering a large global area with a timing accuracy better than one one-hundred-thousandth of a second. The relayed signals were based upon the Bureau's frequency standard and "co-ordinated universal time", both maintained at the Boulder laboratories. A standard frequency 1kHz tone, second ticks, voice announcement of the time of day, satellite position and a time code were relayed to Earth within a bandwidth of 20kHz during the daily transmitting periods.

Accurate time recovery depends primarily upon accurate satellite position information. For instance, a 300-meter path represents a one-microsecond timing error. Charts prepared for users of the satellite time dissemination service give receiver-antenna direction information and propagation time delays.

The WW Annual

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Microphone survey

Principles of operation and construction followed by a tabular survey of professional and semi-professional microphones

by J. Dwyer

The microphone is nearly a century old. The author gives a brief account of that century and then describes the major principles in the construction and operation of the basic instruments. Pressure, pressure gradient and phase shift operation are described as well as the three basic polar patterns to which those operations correspond and the author makes a plea for the more careful definition of the terms hyper- and super-cardioid.

According to a reliable account[1] the first microphone diaphragm was Reis's sausage skin.[2] Reis had used two intermittently connected metal contacts and could transmit tones of differing frequency, but not intelligible speech.

Alexander Graham Bell used the first microphone, in his moving armature transmitter and receiver on June 3, 1875.[3,4] In the following years Bell improved upon it by using the diaphragm as the armature and using two pole pieces instead of one. The device was insensitive because the moving member required sufficient bulk to support the attractive force on the diaphragm. Balanced armature models were developed by Siemens,[5] Watson,[6] and Capps.[7]

Emile Berliner and Thomas Edison invented the variable contact carbon transmitter almost simultaneously in 1877. The word "microphone" was coined by David Hughes the next year. He described the principle of using a large number of small grains of carbon, and Henry Hunnings built such a microphone the same year. Edison patented the granular carbon microphone in 1889.

The moving coil microphone principle was discovered simultaneously by Charles Cuttris and Jerome Redding, in the United States, and by E. W. Siemens in Germany in 1877. Patents followed.[5,8] The modern instrument was developed by E. C. Wente and A. L. Thomas in 1931.[9]

The ribbon microphone was invented by Schottky and Gerlach in Germany in 1923. Although the pressure gradient principle had been explored by Pridham and Jensen, and Meissner (who filed his patent in 1919) for use in noise cancelling microphones it was H. F. Olson who made the first modern ribbon microphone in 1931, patented a year later.[10,11,12,13]

Olson, with J. Weinburger and F. Massa, also developed the combined unidirectional microphone.[14] A combined ribbon and dynamic microphone was developed by R. N. Marchall and W. R. Harry.

Piezo-electric effects had been observed by Becquerel in 1820 but the first crystal microphone, using a Rochelle salt element, was made by A. M. Nicholson in 1919. It was not until the crystal bimorph was invented in 1931 by C. B. Sawyer that there was sufficient output for these microphones to be practically useful.[15,16,17]

A. E. Dolbear described the condenser microphone in 1880 but a practical instrument did not arrive until that developed by E. C. Wente in 1916.[18,19]

Various other transducers have been used over the years[13,20,21,22,23] but the foregoing account covers those now in common use.

Operating principles

The mode of operation of the transducer depends on its construction. If the capsule is totally enclosed apart from an atmospheric pressure equalisation tube, then the diaphragm will react only to rapid changes in air pressure. If the capsule is not so big as to interfere with the sound waves the diaphragm will respond to sound from any direction since it is a pressure transducer.

The second mode of operation is pressure gradient. The diaphragm (Fig. 3) is exposed on both sides. A sound wave coming from direction A strikes the front of the diaphragm first and then reaches the back. In doing so it will have to move distance x, the path difference between front and back. If the wavelength of the sound is long compared with d (Fig. 4) the pressure change which occurs while the wave travels distance x will not be great. In the limit, when the sound pressure is constant there will be no difference along the path length x at all. At low frequencies x will be small compared with the wavelength and it can be assumed that P_1 to P_2 is a linear portion of the pressure curve, so that $P_1 - P_2$ genuinely represents the pressure gradient. Here the force on the diaphragm is proportional to frequency, and this is roughly true until

As the frequency rises, however, x becomes appreciable compared with the wavelength and, in the limit, reaches the point where $x = \lambda/2$. Here the pressure differences will be maximum, corresponding to twice the amplitude of the pressure wave.

The pressure gradient diminishes again as the wavelength decreases, until the path difference between one side of the diaphragm and the other is equal to the wavelength, and the pressures on either side of the diaphragm are equal. Here the force on the diaphragm is zero.

If the path length x is small enough the force on the diaphragm will be proportional to frequency throughout the audible range but, as x decreases, so does the sensitivity.

The pressure gradient microphone will only respond to the component of the incident sound along the axis of the microphone. Sounds from position C in Fig. 3 will have no effect on the diaphragm since pressures on either side of it are equal. Sounds from D will have the same effect as those from A but will be phase reversed since they move the diaphragm in the opposite sense. Between these positions, the response will vary as the cosine of the angle

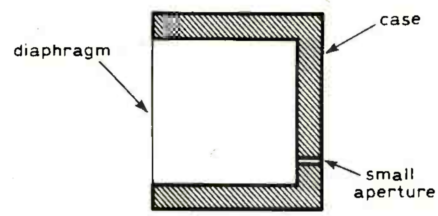

Fig. 1. Pressure operated diaphragm.

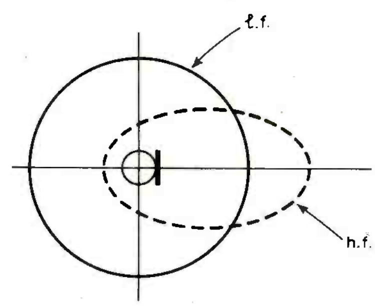

Fig. 2. Response of a pressure operated diaphragm.

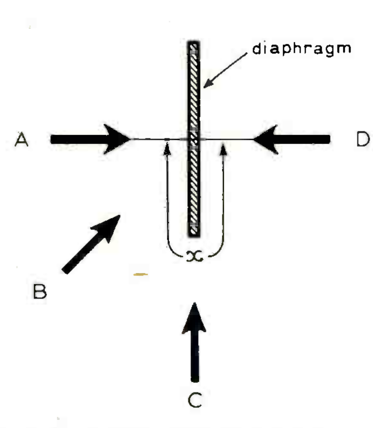

Fig. 3. Pressure gradient operated diaphragm.

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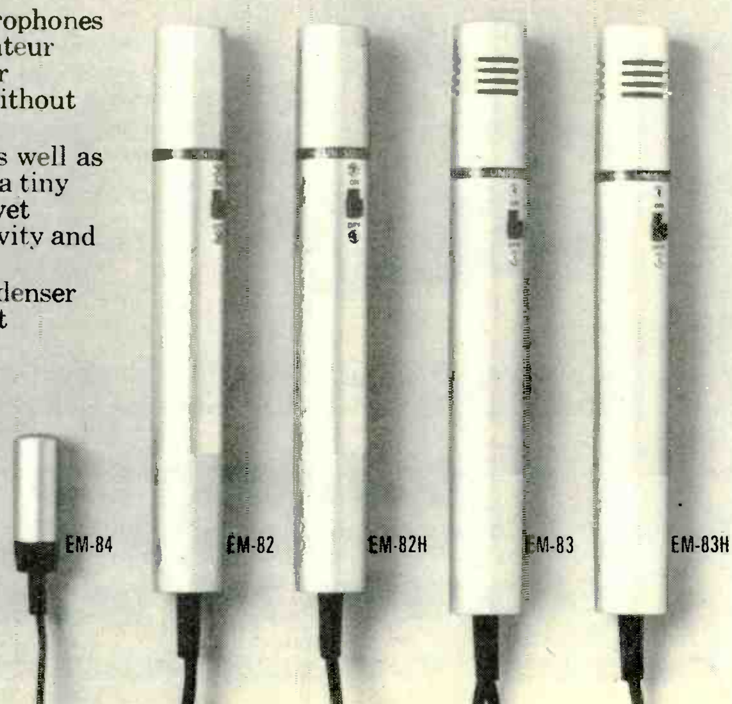

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of incidence, giving a polar diagram as shown in Fig. 5. The response is called bi-directional or figure of eight.

Fig. 6 shows a phase shift operated microphone, in which the amount by which the phase of the incident wave is shifted between the front and the rear of the microphone is related to the angle of incidence of the sound wave. In the diaphragm shown the path difference for a sound behind the microphone is zero because $d_1 = d_2$. This means that there will be no response to sounds coming from the back. If the sound comes from the front there will be a phase shift which will reinforce the motion of the wave impinging on the front of the diaphragm. For the arrangement shown the reinforcement will be maximum when $d_1 + d_2 = \lambda/2$, making the pattern frequency dependent, and in a practical microphone ports are provided for the high, medium and low frequencies to give a uniform response, as shown in Fig. 7. Here d_1 is the distance to the low frequency port, d_2 that to the mid frequency port and d_3 is that to the high frequency port. The three ports can be replaced by a long slot.[24] The direction pattern is described by $1 + \cos\theta$.

As the size of the ports or aperture tends to zero the microphone will tend to become pressure operated. As the size of the ports tends towards infinity, where the back of the diaphragm is open, the microphone will tend toward pressure gradient operation. When the apertures are between these sizes the microphone will act in a combination of pressure and pressure gradient operation.

Simple omnidirectional pressure and bi-directional pressure gradient microphones do not behave ideally. At high frequencies the omnidirectional microphone becomes large compared with the sound wavelength and its bulk shades high frequencies from the diaphragm. In addition, off axis high frequency sounds may not make the diaphragm vibrate because a peak and a trough of pressure may be acting simultaneously on the diaphragm across its diameter. On the other hand, high frequency reflections from a diaphragm with a diameter large compared with their wavelength may set up standing waves, causing pressure doubling, and tending to increase output at high frequencies. The result of all this is that the pressure microphone is directional at high frequencies.

Bi-directional microphones also have anomalies. The diaphragm of such a microphone may reflect high frequency pressure waves, which will not then reach the back of the diaphragm. As a result pressure operation gradually takes over at h.f. In theory any transducer can be made to operate in any mode. In practice some transducers are more suited to pressure and others to gradient operation.

Polar patterns and transducers

The derivations and combinations of various polar patterns are shown in Fig. 8. The distinction between super-cardioid and hyper cardioid seems unclear. The diagram shown in Fig. 8(e) is generally accepted as hypercardioid but is sometimes called supercardioid. It is obtained by the superimposition of a small omnidirectional pattern with a larger figure of eight diagram. It would be convenient if the supercardioid diaphragm were defined as the superimposition of a large omnidirectional pattern with

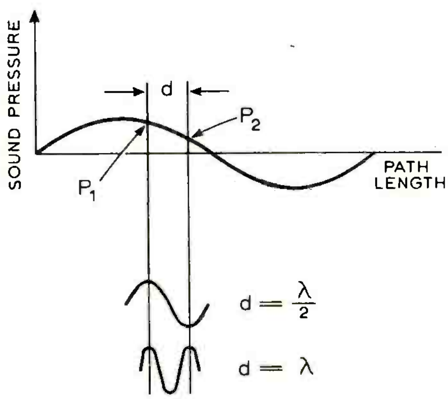

Fig. 4. Sound pressure versus path length for pressure gradient operation. See text.

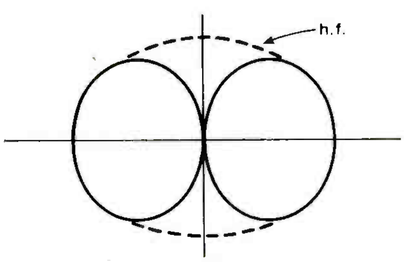

Fig. 5. Polar diagram of a pressure gradient operated microphone.

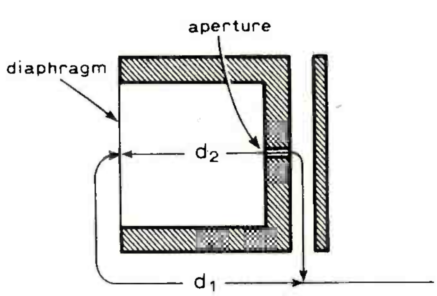

Fig. 6. Phase shift operated microphone.

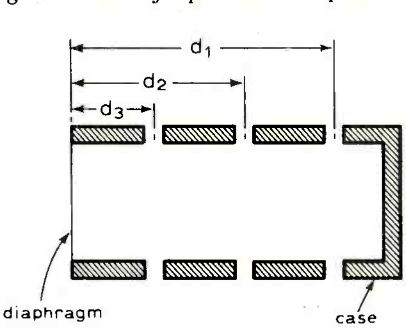

Fig. 7. Ported phase shift microphone to obtain an even response.

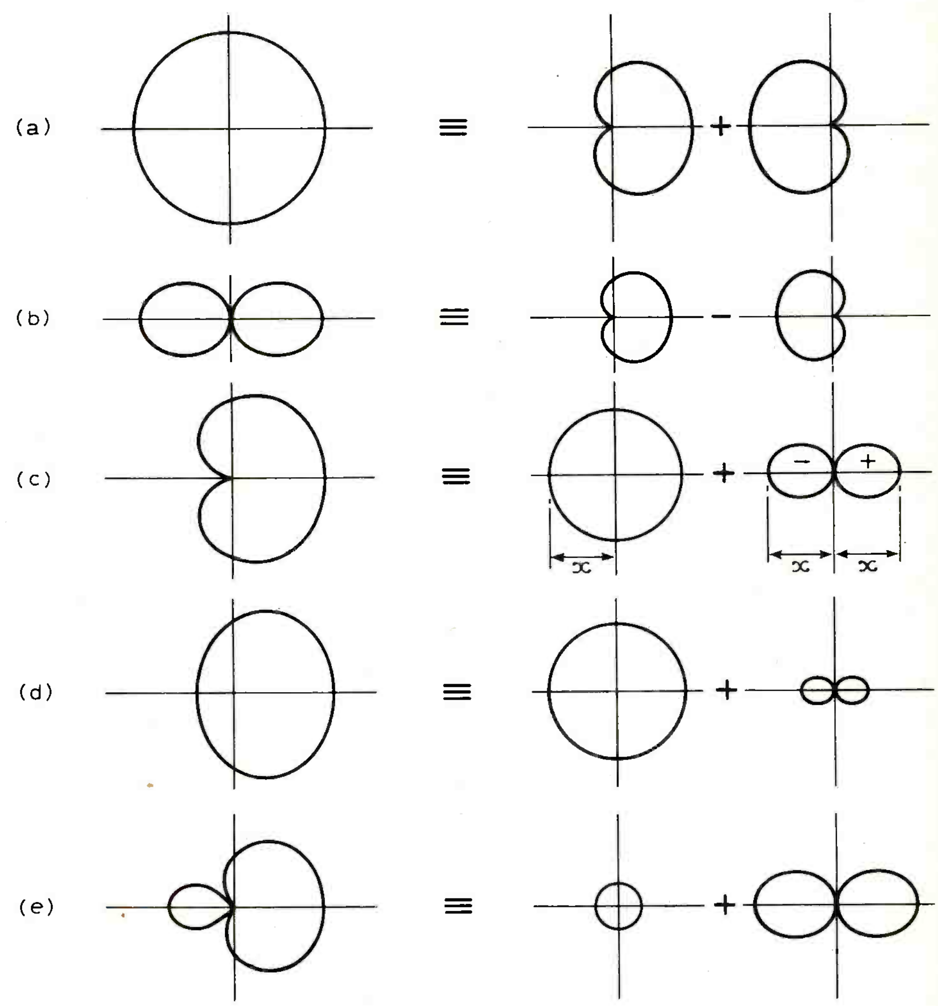

Fig. 8. Derivation of various polar patterns (a) omni-directional, (b) bi-directional or figure of eight, (c) uni-directional or cardioid, (d) supercardioid and (e) hypercardioid.

a smaller figure of eight. The BBC prefer not to use either expression and would refer to Fig. 8(e) as a Cottage Loaf.

Transducers are of two types. The constant amplitude type produces its maximum output when the displacement of the microphone diaphragm is maximum. For smooth frequency response the maximum displacement of the diaphragm must be constant.

Constant velocity transducers produce maximum output when the first derivative of the diaphragm's displacement is a maximum: in other words when the velocity of the diaphragm is maximum. For smooth frequency response the maximum velocity of the diaphragm, which is reached as it travels through its point of zero displacement, must be constant.

A diaphragm has a natural resonant frequency determined by its mass, size and the material used to make it. Fig. 9 shows the resonance curve. It will be seen that below the peak frequency the velocity of the diaphragm is rising at 6 dB/oct. This means that the amplitude of the diaphragm's motion is constant with frequency.

Below resonance, the compliance of the system is greater than its mass or resistance (an electrical analogy being that the system's capacitance is far greater than its resistance or inductance). The system is compliance controlled. Above resonance the mass of the system is the largest component of the mechanical impedance. This is mass control. At the peak the system becomes "resistive", as in an electrical circuit, and heavy damping, or "resistance control", can flatten out the peak to result in a flat response over a large part of the audible frequency range.

The construction of the crystal or ceramic microphone is shown in Fig. 10. The crystal microphone works on the piezoelectric principle, whereas ceramic microphones work on the different but related electrostrictive principle. Electrostriction is a form of elastic deformation induced by an electric field which is independent of reversal of the direction of the field. It is a property of all dielectrics and is thus distinguished from the converse piezo-electric effect, a field-induced strain which changes polarity upon field reversal and which only occurs in piezo-electric materials.[25]

Piezo-electric materials include Rochelle salt and ammonium dihydrogen phosphate. Two crystals are used in a bimorph to increase the output. The crystal or ceramic device is constant amplitude and so the diaphragm is compliance controlled to keep the resonant frequency well above the audible range. The diaphragm is made very stiff.

The source impedance of the crystal is mostly capacitive—1,000 to 2,000pF—and only short lengths of low capacitance cable can be used to convey the signal to an amplifier. The output level is high but the crystal is easily damaged by moisture and heat. Much the same applies to the ceramic microphone, though it is less sensitive to heat and moisture. When designed for practical output levels either type has a rough, limited frequency response making it unsuitable for high quality use. They are cheap, however, and

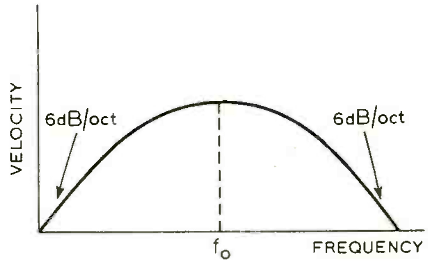

Fig. 9. Resonance curve of a constant velocity transducer.

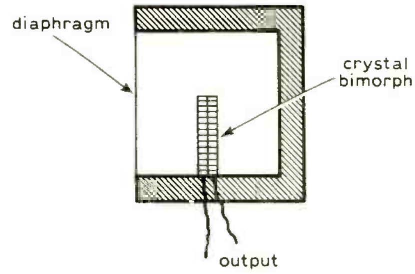

Fig. 10. Construction of the crystal or ceramic microphone.

the ceramic types can give a respectable frequency response if the output is kept low.

The variable reluctance or moving iron microphone is now rarely used, for reasons already outlined. The principle is that a magnet with a coil wound round it is placed close to a metal diaphragm through which part of the magnetic field is conveyed. Variations in the position of the diaphragm cause variations in the distance between magnet and diaphragm and consequent variations in the reluctance of the magnetic field. These variations induce voltages in the coil, which are then amplified. The system is a constant velocity one and a constant output is obtained through resistance control by heavy damping.

Moving coil and ribbon microphones work on the same principle that a voltage will be induced in a conductor that cuts a magnetic field.

The moving coil microphone is a constant velocity device and so is resistance controlled. Often a piece of silk or felt is put behind the diaphragm to act as an acoustical resistance. Resonant cavities are also used to add other resonances to extend the range. The main resonance is set around 700Hz.

The electrical impedance is about 30 ohms and a transformer us used to step this up to the usual 30, 150, 600 or 50,000 ohms. The moving coil microphone is ideally suited to pressure operation.

The diaphragm must be small to avoid the effect of phase shift across the diaphragm for high frequency off axis sounds, but the smaller the diaphragm the lower the output, so a compromise is needed. The moving coil microphone, often called the dynamic microphone, has a good output level, a wide smooth frequency response, a good transient response, is reliable and inexpensive. It is more in use than any other.

An accurate cardioid pattern is more difficult to obtain with the moving coil microphone than with a capacitor. It has an extremely frequency-conscious polar pattern when used as a cardioid, and various phase-shifting tubes, resonant chambers and apertures have to be used to overcome the problem. The sound quality of single element dynamic microphone is not as good as that of the ribbons or capacitors, but it is more robust than the ribbon and cheaper than the capacitor. Sometimes two frequency selective moving coil units and a crossover are combined in the same microphone.

A moving coil microphone with two cardioid units back to back can give an omnidirectional pattern when the two cardioids are added (Fig. 8a) or a figure of eight when they are subtracted (8b) or a simple cardioid with either out of circuit.

The ribbon microphone is a constant velocity device but resistance control cannot be used because the microphone is usually used as a bi-directional device, when

$$\text{force on diaphragm} \propto \text{frequency}$$

$$\text{velocity of diaph.} = \frac{\text{force on diaphragm}}{\text{mechanical impedance}}$$

Using mass control the impedance is proportional to frequency but so is the force on the diaphragm (because of pressure gradient operation). Therefore the velocity of the diaphragm is independent of frequency, which satisfies the requirements of a constant velocity transducer.

The result is to place the resonant frequency of the diaphragm or ribbon well below the audible range, from 3 to 12Hz. The primary inductance of the output transformer provides electrical damping.

The ribbon corrugations provide some control of the tension as well as increasing the mass of the ribbon and making it more rigid. It is still delicate though, and susceptible to rumble and wind. The ribbon exhibits the worst susceptibility to handling noise. The impedance is low and has to be increased by a transformer.

The pressure gradient path difference for sound waves is not only that round the ribbon but around the casing and pole pieces as well. The off-axis frequency response is often very good and self-generated noise is very low. Sensitivity is low, since only one conductor is cutting a magnetic field across a gap much larger than that in the moving coil microphone.

Ribbon microphones tended to be bulky in the past and their delicacy has tended to encourage their being abandoned in favour of the capacitor or moving coil types. They can be used for pressure operation by providing a cavity at the back of the ribbon to provide acoustical resistance. This resistance is usually in the form of a folded damped pipe with an aperture in it. With the aperture closed the microphone would give a pressure, omnidirectional response. With the aperture open the response is cardioid. A variable output aperture and set input aperture to the microphone can produce a variable response ribbon mic.[26]

Composite microphones with a moving coil and a ribbon element have been around since the 1930s. The ribbon usually gives a bi-directional response while the moving coil gives an omnidirectional response. With the system shown in Fig. 13, where the

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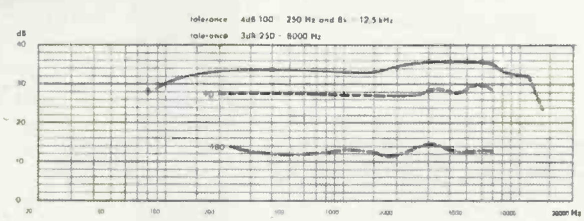

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elements are connected in series, changes in connection can give omni, figure-of-eight, or cardioids in either direction. The sensitivities of the units must be nearly the same. The connections are as shown. The moving coil unit becomes more directional at high frequencies so the output of the ribbon is rolled off at h.f. as compensation. The polar response in the working range is only satisfactory in the horizontal plane.

The highest quality microphones are of the capacitor type. These have high output level, a wide smooth frequency response and an excellent transient response, but they are very expensive, sometimes fragile in construction and very complex, requiring an external power supply and an internal impedance converter which requires d.c. power.

The diaphragm and a fixed backplate form a capacitor. The capacitance between them varies as the diaphragm vibrates.

$$\text{capacitance} \propto \frac{\text{area of plates}}{\text{distance between plates}}$$

$$\text{voltage on plates} = Q/C$$

$$\therefore \text{plate voltage} \propto Q \times \text{distance between plates}$$

If Q is a constant the voltage should be proportional to the distance between the plates. Thus the polarising supply is fed through a very large value resistor. Other methods of using this type of microphone include putting it in a bridge circuit, which may drift, or using the variable capacitance to modulate an f.m. carrier.

The capacitor microphone is a constant amplitude device and the resonant frequency of the system is increased to well over the audio range by compliance control, making the diaphragm tension high. The advantage of the capacitor microphone over other kinds is that it is equally amenable to all forms of operation. If the back plate has a large number of holes drilled in it the microphone is a pressure-gradient operated device and if there are fewer holes it is half pressure gradient and half pressure, giving a cardioid response.

For a bi-directional microphone the mass and tension of the diaphragm are reduced but the mechanical damping is increased with resistive cavities at the back of the diaphragm in the plate. Thus there is resistance control, and the impedance is independent of frequency. The force on the diaphragm is proportional to frequency for pressure gradient operation and the velocity is given by $U=F/Z$. Impedance Z is constant so the velocity is proportional to frequency, which is constant amplitude operation.

If a diaphragm is placed either side of the fixed plate the capacitor becomes remarkably versatile. If only one of the diaphragms is activated and the other is electrically disconnected then the response will be cardioid. Thus these are two cardioids back-to-back. The electrical addition of the two responses will produce an omnidirectional response and their subtraction will make the device bi-directional. Not only that, but the response of each side of the device will vary with the polarising voltage. Thus the patterns are continuously variable from a remote point between cardioid, omni, figure-of-eight and hypercardioid.

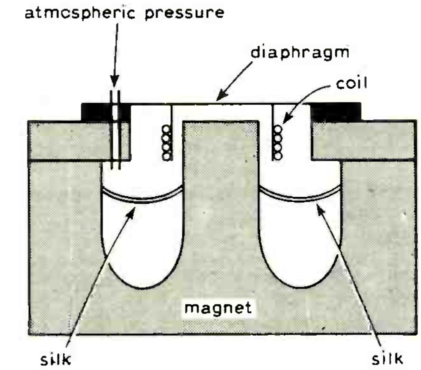

Fig. 11. Construction of the moving coil microphone.

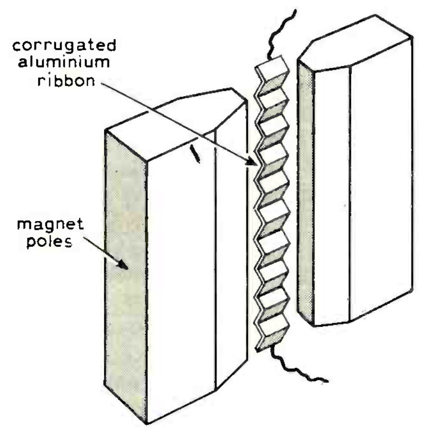

Fig. 12. Ribbon microphone constructional principle.

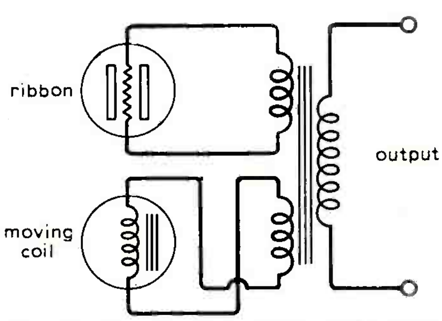

Fig. 13. Combination ribbon and moving coil system can provide different polar responses by changes of connection.

The capacitor microphone also has a high level uniform frequency response. There might be a slight peak in the high frequency range but this can be advantageous in situations where, some distance from the sound source, the air tends to disperse high frequencies. The main problem with the capacitor microphone is that it is complicated.

They need a separate power supply and some diaphragms are made of metal-flashed plastic, which can be affected by television lighting. The source impedance of the devices is a small capacitance, which means that there has to be an impedance converter right next to the capsules if the signal is not to be lost; a valve used to be used to give high input and low output impedance but nowadays an f.e.t. is favoured. Some microphones have d.c. to d.c. converters to step up a battery voltage to the required value. Some single diaphragm mics have a push-pull arrangement with a polarised plate either side of the diaphragm.

Batteries tend to be a liability whatever their use. They may last a long or a short time. They have to be replaced. If a battery is weak the microphone may only just be working. If the battery leaks, the microphone may never work again.

If a piezo-electric crystal or electrostrictive ceramic is bent or twisted it shows a voltage.[27] If that voltage is discharged during stress there will be a permanent voltage across the crystal when the stress is removed. This voltage can be used to polarise a capacitor microphone. The electret microphone is susceptible to high moisture and high temperature and the charge on the electret material may disappear after a few years; no-one knows how long electrets will last, though projections vary from a few months to a thousand years.[28,29,30]

Some of the electret mics now available have high output level, excellent transient response, low cost and are fairly reliable. But the frequency response is not yet as good as that of the dynamic and conventional capacitor designs and a battery is still needed to power the impedance converter.

These are the main types of microphone in wide use. The microphone in widest use is also the poorest—the carbon microphone. The possibility of replacing the carbon telephone microphone with an electret capacitor microphone[31] has been investigated but little else seems to have been done.

There is not room here to describe other specialised microphones, such as the gun and parabolic reflector types. Those seeking further study should read Mr Robertson's classic work.[32]

The use of microphones is also beyond the scope of this article except to say that the subject is sometimes controversial.[33] There are many good accounts of placing technique.[34,35,36]

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TABLE OF MICROPHONE PARAMETERS

Where information has been found difficult to obtain if has been omitted, also reference levels are omitted if not quoted in the manufacturer's literature. If prices are not quoted, these are available on application to the manufacturer. Sensitivity is expressed in mV (ref μb) or dB (ref IV per μb), unless otherwise stated and is consistent for each manufacturer.

KEY

MC—moving coil	G—gooseneck
C—capacitor	L—Lavalier
R—ribbon	H—hand
E—electret	S—stand

Maker & Model No.	Polar Response	Transducer	Impedance (ohms)	Freq. Response (Hz)	Sensitivity	Mounting	Price Inc. v.a.t. (£)	Remarks
ACOS								
70/12	omni	MC	200	50–15k, −10dB	−80dB re IV/μb	H or S	5.30	
70/11	omni	MC	50k	200–3k, ±3dB	−57dB re IV/μb	H or S	7.08	
ADASTRA								
EX220	cardioid	C	600	50–15k	−70dB	H or S		
B7105	cardioid	C	600	30–16k	−70dB	H or S		
B7107	cardioid	C	600	30–16k	−70dB	H or S		on-off switch
B1225	omni	MC	200/250	100–10k	−77dB	H or S		on-off switch
B1238	omni	C	600	20–13k	−74dB	H or S		on-off switch
AKAI								
ADM14	cardioid	MC	4.7	100–10k, ±5dB		S	7.50	
AKG								
D200	cardioid	2×MC	250 ±20%	30–17k	0.14mV/μb	H or S	40.00	
D202	cardioid	2×MC	300 ±20%	20–18k	0.16mV/μb	H or S	54.00	
D224	cardioid	2×MC	250 ±15%	20–20k	0.13mV/μb	H or S	72.40	
C12A	variable	C	50 or 200	30–20k	0.4mV/μb	S		
C24	variable	C	50 or 200	30–20k	0.4mV/μb	S		
C451	variable	C	200	20–20k	0.95mV/μb	S		
D11	cardioid	MC	500 or 50k		0.23 or 2.0	H or S		Front/back ratio 18dB
D11S	cardioid	MC	200		0.15	S		Front/back ratio 18dB
D12	cardioid	MC	200	40–12k, ±4dB	0.14	S	46.50	Front/back ratio 18dB
D14S	cardioid	MC	200 or 40k	50–15k	0.22 or 2.8	S	15.10	Front/back ratio 19dB
D58C	noise cancelling	MC	200 or 60	50–12k	0.08	S	19.45	
D160	omni	MC	240		0.13	S		
D190E	cardioid	MC	60 or 200	30–16k	0.23	S		Front/back ratio 18dB
D501	cardioid	MC	200		0.22	H or S		F/B ratio 18dB
D505	anti-noise	MC	200		0.2	H or S		
D707	cardioid	MC	200		0.16	H or S		F/B ratio 15dB
D900	hypercardioid	MC	200		0.3	H or S		Rifle, F/B 28dB
D1000	cardioid	MC	200		0.23	H or S		F/B, ratio 20dB
D109	omni	MC	60 or 200	50–15k, ±3.5dB	−98dB	H or L	20.50	
C414	switchable	FET C	200	20–20k	0.6mV/μb		173.00	switchable attenuator
BEYER								
M55ML	omni	MC	500 or 50k	70–16k, ±4dB	0.17 or 1.5	H or S	13.40	
M57	omni	MC	200	300–14k, ±3dB	0.2	H or S	17.68	
M64	cardioid	MC	200 or 37.5	100–10k, ±3dB	0.2	S	15.35	
M67N	cardioid	MC	37.5 or 500	40–18k, ±2.5dB	0.25	H or S	42.25	
M68	cardioid	MC	37.5 or 200	100–10k, ±3dB	0.2	G	24.00	switch
M69	cardioid	MC	37.5 or 200	50–15k, ±3dB	0.24	H or S	34.20	optional switch
M81HL	cardioid	MC	500 or 25k	50–16k, ±3dB	0.23 or 1.7	H or S	17.20	
M88	hypercardioid	MC	200	30–20k, ±2.5dB	0.25	H or S	83.00	cannon plug
M101N	omni	MC	200	40–20k, ±2.5dB	0.13	H or S	41.00	
M111N	omni	MC	200	50–15k	0.08	L	58.50	
M160	hypercardioid	double R	37.5 or 200	40–18k, ±2.5dB	0.1	H	90.70	
M260	hypercardioid	R	37.5 or 200	50–18k, ±3dB	0.09	H	36.20	
M320	hypercardioid	R	200	30–18k, ±3dB	0.1	S	43.25	
M360	cardioid	R	200 or 50	30–20k, ±2.5dB	0.14	S	118.15	"hand made"
M410	cardioid	MC	200	300–12k, ±3dB	0.25	H or S	26.00	heavy duty
M411N	cardioid	MC	200	200–12k	0.14	H or S	28.00	close speech
M500	hypercardioid	R	500	40–18k	0.13	H or S	40.70	
M818HL	cardioid	stereo MC	500 or 25k	50–16k, ±3dB	0.17 or 1.5	S	37.50	matched pair
Soundstar XI	cardioid	MC	200 or switched	30–18k, ±2.5dB	0.2 (low Z)	S	30.60	hum compensator
M550LM	omni	MC	500	70–18k	0.17		12.76	
M810N	cardioid	MC	500	50–16k	0.23		24.90	
M201N	hypercardioid	MC	200	40–18k	0.14	H or S	55.10	

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WW—110 FOR FURTHER DETAILS

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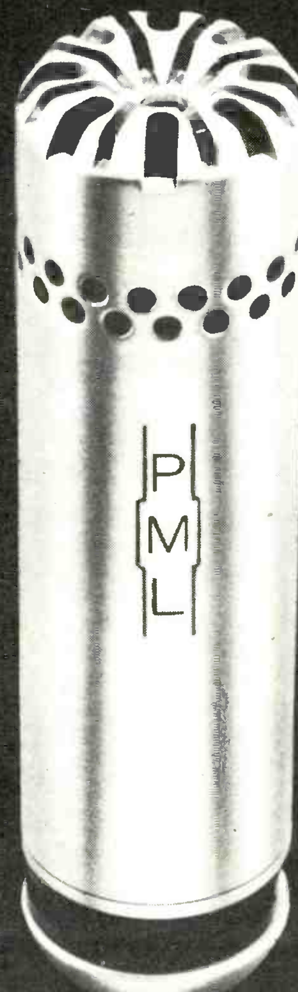

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WW—113 FOR FURTHER DETAILS

Maker & Model No.	Polar Response	Transducer	Impedance (ohms)	Freq. Response (Hz)	Sensitivity	Mounting	Price Inc. v.a.t. (£)	Remarks
CALREC								
CM450	cardioid	MC	200 or 37.5	5–16k, ±3dB	0.24	H or S		
CM600	omni	C	50 max	20–20k, ±2dB	1.5 adjustable	H or S	48.00	
CM652	cardioid	C	50 max	40–20k, ±2dB	1.5 adjustable	H or S	48.00	
CM654	cardioid	C	50 max	40–20k, ±2dB	1.5 adjustable	H or S	48.00	reduced bass
CM655	cardioid	C	30 or 50k	40–20k	1.5 adjustable	H or S	52.00	
CM656	cardioid	C	50 max	40–20k, ±2dB	1.5 adjustable	H or S		windshield
CC700	omni	C	250 bal	20–20k, ±2dB	1.5 or 0.3	H or S		
CC752	cardioid	C		20–20k, ±2dB		H or S		capsule
CC754	cardioid	C		20–20k, ±2dB		H or S		capsule
CC756	cardioid	C		20–20k, ±2dB		H or S		capsule
CM1000	omni	C	50 max	20–20k, ±2dB	0.3	H or S	62.00	
CM1050	cardioid	C	50 max	30–20k, ±2dB	0.3	H or S	62.00	
CM1051	cardioid	C	50 max	30–20k, ±2dB	0.3	H or S	62.00	reduced bass
EAGLE								
PRO M10	omni	C, E	600	30–17k	−70dB	H or S	28.48	
PRO M20	cardioid	C, E	600	30–17k	−60dB	H or S	28.48	
PRO M25	cardioid	C, E	600	20–18k	−70dBV	boom-arm	28.48	
PRO M5	special purpose	C, E	600	50–13k	−65dBV	tie clip	14.25	
C092	omni	C, E	600	30–16k	−75dBV (170μV)	H or S	12.50	
C096	cardioid	C, E	600	30–16k	−70dBV (310μV)	H or S	17.08	
UD76HL	cardioid	MC	600 or 50k	25–20k	−76dBV or −56dBV	H or S	26.16	
UD50HL	cardioid	MC	600 or 50k	40–14k	−74dBV or −54dBV	H or S	10.67	
DM94	omni	MC	50k	80–10k	2.6mV average o/p	H or S	9.53	
DM73	omni	MC	50k	60–14k	2.2mV average o/p	H or S	8.05	
DD6	special purpose	MC	600 or 50k	60–12k	−74dBV or −54dBV	L or S	9.73	
DD5	omni	C, E	600	600–9k	−70dB (310μV)	on base	12.20	
DD7	cardioid	MC	50k	60–9k	−54dB (2.8mV)	on base	10.80	
DM18HL	omni	MC	600 or 50k	60–12k, ±3dB	−57dB	H or S	11.55	
ELECTROVOICE								
DS35	cardioid	MC	150	60–17k	−56dB	H or S		
RE20	cardioid	MC	50, 150 or 250	45–18k	−57dB	H or S		
RE55	omni	MC	150	40–20k	−55dB	H or S		
635A	omni	MC	150	80–13k	−55dB	H or S		
660	hypercardioid	MC	150 or hi Z	90–13k	−56 or −55.5dB	H or S		adjustable Z
670V	cardioid	MC	150 or hi Z	60–14k	−58dB	H or S		adjustable Z
671	cardioid	MC	150 or hi Z	60–14k	−61 or −60dB	H or S	40.15	
RE10	hypercardioid	MC	150	90–13k	−150dB (EIA)	H or S	63.80	
RE11	hypercardioid	MC	150	90–13k	−56dB	H or S	68.20	
RE15	hypercardioid	MC	150	80–15k	−56dB	H or S	109.45	
RE16	hypercardioid	MC	150	80–15k	−56dB	H or S	113.30	
FOSTER								
DF1X	omni	MC	50, 600 or 50k	100–10k	57dB	H or S		with base
DF100	omni	MC	200	100–10k	82dB	H, S or L		
MDF623C	cardioid	MC	600 or 50k	200–10k	82dB	H or S		
DF72BC	omni	MC	600 or 50k	80–12k	60dB	H or S		
DF104BC	omni	MC	600 or 50k	80–12k	76dB	H or S		
MDF619BC	cardioid	MC	600 or 50k	200–10k	58dB	H or S		
DF106C	uni	MC	600	40–15k, ±4dB	74dB	H or S		
MDF611BC	cardioid	MC	600 or 50k	100–10k	76dB	S		
GRAMPIAN								
DP4	omni	MC	25–50k	15–15k		H or S		specify impedance on all mics
DP6	omni	MC	25–50k	15–15k		L		
DP8	omni	MC	25–50k	15–15k		H or S		
GC2	cardioid	MC	25–50k	15–14k		H or S		
GC3	cardioid	MC	25–50k	15–14k		desk		
GR1	semi-cardioid	R	25–50k	15–15k		S		F/B ratio, 10dB
GR2	Fig. 8	R	25–50k	15–15k		S		
LUSTRAPHONE								
4-20	omni	MC	30, 200, 600, 50k	70–14k	−88dB @ 30Ω	H or S		
4-30	hypercardioid	MC	30, 200, 600, 50k	70–14k	−88dB	H or S		
5-03	omni	MC	25, 200, 600, 50k	70–14k	−74dB	desk		
5-30	cardioid	MC	25, 200, 600, 50k	50–15k	−74dB	desk		
5-43	omni	MC	150, 600, 50k	200–11k	−77dB	desk		tailored freq. response
MELODIUM								
RM6	Fig. 8	R	50 or 200	30–18k, ±2dB	−81 or −76dB	H or S		
76A	cardioid	MC	10 or 200	100–15k	−83 or −71dB	H/S or G	21.84–23.18	industrial p.a.
78A	cardioid	MC	10 or 200	50–15k	−87 or −75dB	H or S	26.04–27.44	industrial p.a.
77A	omni	MC	200	40–17k, ±3dB	72dB	H or S		
79A	omni	MC	10, 200 or 80k	60–16k, ±3dB	−92, −82 or −56dB	H or L	16.36–22.68	
88	omni	MC	10 or 200	50–17k	−90 or −78dB	H or S		
C121	cardioid	MC	10 or 200	150–14k	−89 or −77dB	H or S	20.72–21.00	industrial p.a.
C133	cardioid	MC	10, 200, 15k or 80k	50–15k	−83, −71, −61 or −48dB	H/S or G	27.80–41.87	
NEUMANN								
KM83	omni	C	200	40–20k	1.0mV/μb	H or S		
KM84	cardioid	C	200	40–20k	1.0	H or S		
KM85	cardioid	C	200	40–20k	1.0	H or S		
KMS85	cardioid	C	150	40–16k	0.6 or 0.3	H or S		
KM86	variable	C	200	40–20k	0.8	H or S		

Maker & Model No.	Polar Response	Transducer	Impedance (ohms)	Freq. Response (Hz)	Sensitivity	Mounting	Price Inc. v.a.t. (£)	Remarks
U87	variable	C	200	40–16k	0.8	S		adjustable bass response
KM88	variable	C	200	40–16k	0.8	H or S		
U47	cardioid	C	150	40–16k	0.8 or 0.4	S		
SM69	variable	stereo C	2 × 150	40–16k	1.8	S		
KMA	omni	C	800 unbal.	40–16k	0.5	L		
KM73	omni	C	200 unbal.	40–16k, ±2dB	2.5	miniature		
KM74	cardioid	C	200 unbal.	40–16k, ±2dB	2.5	miniature		
KM76	variable	C	200 unbal.	40–16k, ±2dB	2.6	miniature		
KML	cardioid	C	50 or 200	40–16k, ±2dB	0.5 or 1.8	L		
U77	variable	C	200	40–16k	2.6, 5.0 or 3.0			bass cut sw.
PEARL								
FP92C or K	cardioid or omni	C, E	200	30–20k	0.5mV/μb	H or S		
M68	Fig. 8	ceramic	600	200–5k	0.775	H or S		noise cancelling
ND68	Fig. 8	ceramic	600	50–5k	0.775	H or S		noise cancelling
D44LS or BS	cardioid	MC	200 or 200/hi Z	100–13k	2.8	H or S		
LD18 or 19	omni	MC	200 or 200/hi Z	80–16k	−74dB	H or S		
RD16	cardioid	MC	200	40–16k	−70dB	H or S		
RD34	cardioid	MC	200	40–16k	−74dB	H or S		
RD36	cardioid	MC	200 or hi Z	40–16k	−74 or −54dB	H or S		
F67LS	cardioid	MC	200	40–16k	−74dB	H or S		
F67BS	cardioid	MC	200 or hi Z	40–16k	−74 or −54dB	H or S		
F69	cardioid	MC	200	50–12k, ±3dB	0.33mV/μb	H or S		
HM47	omni	MC	200	100–10k	0.15	L		
HM49	omni	MC	200	80–18k, ±3dB	−74dB	H or S		
CL3	omni	C, E	200	40–20k		L		
DC20	omni	C	200	30–20k	−56dB	H/S or L		
DC21	cardioid	C	200	30–20k		H/S or L		
DC63	variable	C	200	25–20k (omni)	−60dB	H/S or L		
DC73	cardioid	C	200	30–20k	−46dB	H or S		
DC73/12	cardioid	C	200	30–20k	−40dB	H or S		
DC96	cardioid	C	200	30–20k	−61dB	H or S		
EC71	cardioid	C	hi Z	40–18k, ±3dB	−58dB	L		
EK71	omni	C	hi Z	40–18k, ±3dB	−58dB	L		
SP84	omni	C	200	30–20k	−42dB	H or S		
SP85	cardioid	C	200	30–20k	−42dB	H or S		
ST8	variable	stereo C	200	30–18k	−44dB	S		
TC4	cardioid	C	50 or 200	30–20k, ±2dB	−52dB	H or S		
TC4B	Fig. 8	C	50 or 200	30–20k, ±2dB	−56dB	H or S		
TC4K	omni	C	50 or 200	30–20k, ±2dB	−56dB	H or S		
TC4V	variable	C	50 or 200	30–20k, ±2dB	−56dB	H or S		
VM40	omni	C	200	30–20k	−48dB	H or S	92.50	
VM40/12	omni	C	200	30–20k	−42dB	H or S	110.00	
VM41	cardioid	C	200	30–20k	−48dB	H or S	92.50	
VM41/12	cardioid	C	200	30–20k	−42dB	H or S	110.00	
M68	noise cancelling	ceramic	600	500–5k, −6dB		H or S	73.37	
HM49	omni	MC	200	50–18k, −6dB	−74dB	S	44.60	
HM47	omni	MC	200	100–10k, −6dB	−76dB	L	29.23	
RD34/36	cardioid	MC	200	40–16k, −6dB	−74dB	S	20.52–27.48	
RD16	cardioid	MC	200	80–12k, −6dB	−70dB	L or S	19.90	
LD18/19	omni	MC	200	80–16k, −6dB	−74dB	S	18.66–23.00	
D44LS/BS	cardioid	MC	200	100–13k, −6dB	−71dB	L or S	9.82–14.93	
FP92C/K	cardioid or omni	C	200	30–16k, −3dB	−66dB	S	78.97	
TCV4V	remotely variable	C	200	40–18k, −3dB	−56dB	S	123.74	
D696	cardioid	C	200	30–18k, −3dB	−61dB	S	107.25	
DC73	cardioid	C	200	40–17k, −3dB	−60dB	H or S	71.10	shock resistant
DC63	variable	C	200	30–18k, −3dB	−60dB	S	182.81	
DC20/21	omni or cardioid	C	200	30–18k	−56dB	S	54.10	
CL3	omni	C	200	80–17k, −3dB	32mV/pa	tie-pin	104.06	
PYE								
LBB9020	cardioid	MC	200	80–17k, −6dB	0.17mV/μb	H or S	43.20	
LBB9050	cardioid	2 × MC	200	25–19k	0.14	H or S	41.00	
LBB9100	cardioid	MC	200	50–16k	0.15	H or S	43.20	
LBB9101	omni	MC	200	35–18k	0.16	H or S	43.20	
LBB9102	cardioid	MC	200	50–16k	0.15	H or S	43.20	
LBB9105	cardioid	MC	200	80–17k, −6dB	0.17	H or S	43.20	
EL6042	omni	MC	200	30–20k	0.12	H or S	45.40	
LBB9003/05	special purpose	MC	200	50–15k		L	22.60	
LBB9005/05	cardioid	MC	200	50–16k		H or S	26.00	hum compensation
LBB9007/05	cardioid	MC	200	50–16k			32.40	on flexible stand
LBB9008/05	cardioid	MC	200	50–16k			28.00	on flexible stand
LBB9018/05	noise cancelling	MC	250	200–12.5k		H or S	26.00	
PHILIPS								
N8206/50	omni	MC	500	150–14k	0.18	H or S	7.15	
N8208	omni	MC	500	125–12.5k	0.18	H or S	3.85	
N8500	hypercardioid	C, E	< 1000	100–16k	0.25	H or S	16.00	
RESLOSOUND								
Reslogo	cardioid	MC	30, 250, 600 hi Z	50–15k	−59dB (hi Z)	H or S	44.00	glows in u.v.
S90	cardioid	C, E	30, 600, 50k	40–20k	−52dB (hi Z)	H or S	47.00	F/B ratio, −14dB
S80	cardioid	MC	30, 250, 600 or hi Z	50–15k	−59dB (hi Z)	H or S	37.00	F/B ratio, −14dB
UD1	cardioid	MC	30, 200, 600 or hi Z	10–16k	−58dB (hi Z)	H or S	27.00	F/B ratio, −14dB
UD3	cardioid	MC	30/600, 200/hi Z	100–16k	−58dB	head	17.00	F/B ratio, −14dB
PD3	omni	MC	30, 200, 600 or hi Z	30–17k	−88dB	H or S	15.00	on-off switch

Maker & Model No.	Polar Response	Transducer	Impedance (ohms)	Freq. Response (Hz)	Sensitivity	Mounting	Price Inc. v.a.t. (£)	Remarks
MPD	omni	MC	30–50	50–15k	−88dB	head	11.00	
MPD/D	omni	MC	30–50	50–15k	−88dB		20.00	desk stand
MR1	semi-cardioid	R	30, 200, 600 or hi Z	35–16k	−58dB (hi Z)	S	28.00	F/B ratio, −10dB
EM4000	omni	C, E	1k	40–14k	−68dB	tie clip	32.00	
EPM200	hypercardioid		150/600	150–15k	−42dB	parabolic gun		
Micom			300 basic	200–3.4k rising 7dB/oct ±1dB	−44dB			use with radio mics
ROSS								
RE320	omni	MC	50k	50–12k	−54dB @ 50kΩ	ball type	10.31	on-off switch
RE325	cardioid	MC	600/50k	50–14k	−54dB @ 50kΩ	H or S	11.69	on-off switch
RE330	cardioid	MC	600/50k	50–15k	−55dB @ 50kΩ	H or S	13.40	on-off switch
RE335	omni	MC	600/50k	50–17k	−57dB @ 50kΩ	H or S	14.05	on-off switch, windshield
RE350	cardioid	MC	600/50k	50–15k	−56dB @ 50kΩ	H or S	14.65	on-off switch
SCHOEPS								
CMT540U	cardioid	C	1k load	—	1.3mV/dyne/sq. cm.	H or S		l.f. filter
CMT441U	hypercardioid	C	1k	—	1.3mV	H or S		
CMT55U	omni or cardioid	C	1k	—	1.2mV, 1.5mV	H or S		p. response switch
CMT56U	omni-cardioid —Fig. 8	C	1k	—	0.9/1.0/1.1mV	H or S		
CMTS501U	switchable	C	1k	—	switchable	H or S		stereo mic
32U	omni	C	1k	—	2.0mV	H or S		
34U	cardioid	C	1k	—	2.0mV	H or S		
340U	cardioid	C	1k	—	2.0mV	H or S		l.f. filter
341U	hypercardioid	C	1k	—	2.0mV	H or S		
35U	omni or cardioid	C	1k	—	1.9/2.3mV	H or S		
36U	switchable	C	1k	—	switchable	H or S		
CMTS301U	switchable	C	1k	—	switchable	H or S		stereo mic
CMT42	omni	C	1k	—	1.5mV	H or S		
CMT44	cardioid	C	1k	—	1.5mV	H or S		
CMT440	cardioid	C	1k	—	1.5mV	H or S		l.f. filter
CMT441	hypercardioid	C	1k	—	1.5mV	H or S		
CMT45	omni-cardioid	C	1k	—	1.4/1.7mV	H or S		switchable
CMT46	omni-cardioid —Fig. 8	C	1k	—	0.9/1.0/1.1mV	H or S		switchable
CMT52U	omni	C	1k	—	1.3mV	H or S		
CMT54U	cardioid	C	1k	—	1.3mV	H or S		
CM62T	omni	C	1k	—	1.4mV	H or S		
CM64T	cardioid	C	1k	—	1.4mV	H or S		
CM640T	cardioid	C	1k	—	1.4mV	H or S		
CM641T	hypercardioid	C	1k	—	1.4mV	H or S		
MK2	omni	C	600min	20–20k	1.2mV	capsule		
MK3	omni	C	600min	20–20k	1.0mV	capsule		
MK4	cardioid	C	600min	40–20k	1.2mV	capsule		
MK40	cardioid	C	600min	80–18k	1.6mV	capsule		speech
MK41	hypercardioid	C	600min	40–20k	1.3mV	capsule		
MK5	omni-cardioid	C	600min	40–20k	1.0/1.2mV	capsule		switchable
MK6	omni-cardioid —Fig. 8	C	600min	40–16k	0.7/0.8/0.8	capsule		switchable
SENNHEISER								
MD441	supercardioid	MC	200	30–20k	−52dBm ref 1mW/10dynes per cm²	H or S	74.50	Bass and treble control
MD421	cardioid	MC	200	30–17k	−52dBm	H or S	53.50	bass attenuator
MD411HLM	supercardioid	MC	25k, 800, 200	50–12.5k	−35, −50, −56dBm	S		switchable impedance
MD402LM	supercardioid	MC	750	80–12.5k	−51dBm	H or S	14.60	
MD413	cardioid	MC	200	50–15k	−56dBm	H or S	42.20	1kHz notch filter
MD415	supercardioid	MC	200	60–15k	−56dBm	H or S		1kHz notch filter
MD408N	supercardioid	MC	200	50–15k	−56dBm	G	30.30	
MD4	Fig. 8 variable	MC	200	50–10k	−54dBm	H/S or G	36.00–40.00	noise cancelling
MD420	supercardioid	MC	200	200–10k	−53dBm	H/S or G	23.80–27.50	
MD21	omni	MC	200	40–18k	−52dBm	H/S or G	32.20	
MD21HL	omni	MC	200 or 30k	40–18k	−52 or 30dBm	H/S or G	33.70	switchable impedance
MD214U3	omni	MC	200	60–15k	−58dBm	L	55.00	
MD214N	omni	MC	200	60–15k	−58dBm	L	55.00	
MD2141	omni	MC	700	60–15k	−58dBm	L	55.00	
MD211N	omni	MC	200	30–20k	−56dBm	H or S	58.20	
MD321N	omni	MC	200	50–15k	−65dBm	H	81.80	
MD416	cardioid	MC	200	50–15k	−56dBm	H or S	53.00	shockproof
MD409	cardioid	MC	200	50–15k	0.18mV/μb	S	45.40	
MD412LM	cardioid	MC	700	50–12.5k		H or S	22.68	switchable filter
MKE201	omni	C, E	1.5k min. load	50–15k	−32dBm	H or S	34.65	
MKE401	hypercardioid	C, E	1.5k min. load	50–15k	−27dBm	H or S	40.45	
MKH415T	hypercardioid	C	20	40–20k	−32dBm	H or S	140.50	
MKH815T	hypercardioid	C	20	50–20k	−26dBm	boom	185.50	
MKH124	omni	C	150	40–20k	−48dBm	L	155.50–167.00	
MKH125T	omni	C	10	40–20k	−32dBm	L	165.00–176.00	
MKH105T	omni	C	20	20–20k	−32dBm	H or S	116.50	
MKH110	omni	C	90	1–20k	−32dBm	H or S	143.20	instrumentation
MKH1101	omni	C	90	0.1–20k	−52dBm	H or S	143.20	instrumentation
SHURE								
Unidyne IV 548	cardioid	MC	low or hi	40–15k	0.13mV/μ bar or 1.76mV/μ bar	H or S	42.90	basic model

Maker & Model No.	Polar Response	Transducer	Impedance (ohms)	Freq. Response (Hz)	Sensitivity	Mounting	Price Inc. v.a.t. (£)	Remarks
548S	cardioid	MC	low or hi	40–15k	0.13mV/μ bar or 1.76mV/μ bar	S	44.88	
548SD	cardioid	MC	low or hi	40–15k	0.13mV/μ bar or 1.76mV/μ bar	H or S	44.88	on-off switch
548SDCN	cardioid	MC	low or hi	40–15k	0.13mV/μ bar or 1.76mV/μ bar	H or S	46.86	heavy cable
549	cardioid	MC	25 to 50 or 250	40–15k	0.067 or 0.149	S		shock resistant
Unidyne III								
545	cardioid	MC	low or hi	50–15k	0.125 or 1.76	H or S	36.30–40.26	
545S	cardioid	MC	low or hi	50–15k	0.125 or 1.76	S	38.28	
545SD	cardioid	MC	low or hi	50–15k	0.125 or 1.76	H or S	38.28	on-off switch
545SDCN	cardioid	MC	low or hi	50–15k	0.125 or 1.76	H or S	40.26	heavy cable
545L	cardioid	MC	low or hi	50–15k	0.125	L	29.70	
544	cardioid	MC	low or hi	50–15k	0.125 or 1.76	G	34.98	
546	cardioid	MC	25 or 250	50–15k	0.067 or 0.158	S		shock resistant
Unidyne II								
55S	cardioid	MC	hi, med, low	50–15k	0.071 to 1.68	S	35.64	
55SW	cardioid	MC	hi, med, low	50–15k	0.071 to 1.68	S	36.30 to 40.26	on-off switch
55GS	cardioid	MC	hi, med, low	40–15k	0.67 to 1.58	S		heavy duty
Unidyne A								
580SA	cardioid	MC	high	50–13k	1.48	H or S		on-off switch
580SB	cardioid	MC	low	50–13k	0.105	H or S		on-off switch
Unidyne B								
515SA	cardioid	MC	high	80–13k	1.25	H or S	18.48	
515SB	cardioid	MC	25 to 250	80–13k	0.89	H or S	17.82	
515BG	cardioid	MC	25 to 250	80–13k	0.89	G	16.50	
515SBG	cardioid	MC	25 to 250	80–13k	0.89	G	17.16	push talk switch
515SBG18	cardioid	MC	25 to 250	80–13k	0.89	G		
Unisphere I								
565	cardioid	MC	150 or hi	50–15k	0.141 or 1.88	H or S	41.58	
565S	cardioid	MC	150 or hi	50–15k	0.141 or 1.88	S	42.90	on-off switch
565SD	cardioid	MC	150 or hi	50–15k	0.141 or 1.88	H or S	42.90	on-off switch
565SDCN	cardioid	MC	150 or hi	50–15k	0.141 or 1.88	H or S	44.88	heavy duty
566	cardioid	MC	dual	40–15k	0.071 or 0.154	S	62.04	shock resistant
Unisphere A								
585SA	cardioid	MC	high	50–13k	1.32	H or S	26.40	on-off switch
585SB	cardioid	MC	low	50–13k	0.105	H or S	25.08	on-off switch
585SAV	cardioid	MC	high	50–13k	1.32	H or S	31.68	vol. control
585SBV	cardioid	MC	low	50–13k	0.105	H or S		vol. control
Unisphere B								
588SA	cardioid	MC	high	80–13k	1.11	H or S	26.40	
588SB	cardioid	MC	low	80–13k	0.085	H or S	25.08	
588SBCN	cardioid	MC	low	80–13k	0.085	H or S	27.06	heavy duty
330	cardioid	R	switchable	30–15k	switchable	S	52.80	
300	Fig. 8	R	switchable	30–15k	switchable	S	63.36	
315	Fig. 8	R	switchable	30–15k	switchable	S		
315S	Fig. 8	R	switchable	30–15k	switchable	S	39.60	on-off switch
579SB	omni	MC	25 to 200	50–15k	0.1	H or S	28.38	on-off switch
578	omni	MC	150 or hi	50–17k	0.1 or 1.11	H or S		
5785	omni	MC	150 or hi	50–17k	0.1 or 1.11	S		on-off switch
576	omni	MC	25 or 150	40–20k	0.05 or 0.094	H or S		
533SA	omni	MC	high	40–11k	1.76	H or S	21.78	on-off switch
533SB	omni	MC	low	40–11k	0.141	H or S	21.12	on-off switch
533SAV	omni	MC	high	40–11k	1.76	H or S		vol. control
570	omni	MC	low	50–12k	0.084	L	41.58	
570S	omni	MC	low	50–12k	0.084	L	44.88	on-off switch
571	omni	MC	25 to 250	50–10k	0.079	H/S or L	40.92	
572G	omni	MC	25 to 250	50–10k	0.079	G	46.86	
560	omni	MC	low or hi	40–10k	0.149 or 1.48	L	18.48	
561	omni	MC	25 to 250	40–10k	0.141	G	13.86	
Studio								
SM5B	cardioid	MC	150	50–15k, +2.6dB	−79.5dB	boom	158.40	100Hz filter
SM5C	cardioid	MC	50	70–15k, −3dB	−84.0dB	boom	158.40	100Hz filter
SM7	cardioid	MC	150	40–16k, −5dB	−79.5dB	boom	138.60	equalization
SM56	cardioid	MC	30–50, 150–250	40–15k	−83.5 or −76.5dB	S	59.40	
SM57	cardioid	MC	30–50, 150–250	40–15k	−83.5 or −76.5dB	H or S	46.20	imp. switch
SM53	cardioid	MC	50 to 250	70–16k	−81dB	H or S	92.40	
SM54	cardioid	MC	50 to 250	70–16k	−81dB	H or S	100.98	pop filters
SM33	super-cardioid	R	*50 or 150*	40–15k	−87 or −81dB	S	92.40	
SM58	cardioid	MC	30–50 or 150–250	50–15k	−83.5 or −76.5dB	H or S	59.4	pop filters
SM50	omni	MC	50 or 150	40–15k	−84.5 or −78.5dB	H or S	49.50	
SM61	omni	MC	150	50–14k	−82.0dB	H or S	40.92	
SM60	omni	MC	50–250	45–15k	−81.5dB	H or S	30.36	
SM76	omni	MC	50 or 150	45–20k	−87.5dB	H or S	74.58	
SM51	omni	MC	50–250	70–12k	−82dB	L	44.88	rises at 6kHz
SONY								
F25S	cardioid	MC	320	80–13k	output 1mV	H or S	3.85	
F96H	omni	MC	10k	70–14k	output 5mV		3.85	
F96L	omni	MC	230	70–14k	output 1mV		3.85	
98L	cardioid	MC	230	70–14k	output 1mV		5.15	
99B	stereo cardioid	MC	200	80–12k	output 0.7mV		8.35	
ECM22P	cardioid	C, E	dual 600 or 250	20–20k	output 1.5mV		59.95	
ECM95S	cardioid	C, E	1.5k	70–10k	output 2mV		6.85	
ECM99	cardioid	C, E	250	50–12k	output 1.6mV		15.95	
ECM170	omni	C, E	200	20–16k	output 1.6mV		23.50	bass cut switch
ECM280	cardioid	C, E	200	30–18k	output 1.6mV		32.35	bass cut switch

Maker & Model No.	Polar Response	Transducer	Impedance (ohms)	Freq. Response (Hz)	Sensitivity	Mounting	Price Inc. v.a.t. (£)	Remarks
STC								
4037	omni	MC	30 or 300	80–10k	−76dB	H or S		
4038	Fig. 8	R	30 or 300	30–15k	−85dB	S or boom		
4104	noise cancelling	R	30 or 300	60–10k	−82dB	commen-tator's		F/B ratio, 15–20dB
4105A	cardioid	MC	30	60–10k	−82dB	hand		F/B ratio, 15–20dB
4136	cardioid	C	30 or 300	40–18k	−50dB @ 300Ω			F/B ratio >20dB
4021	omni	MC	30	40–12k	−80dB	S		ball and biscuit
4112	omni	MC	30	100–20k	−84dB	L or S		hum suppressor
4115	noise cancelling	R	30	150–10k	−85dB	H		lightweight
4136								
THORN								
TA24	cardioid	moving coil	low			S	10.69	
TURNER								
2203	cardioid	MC	200 load	50–15k	−57dB ref 1mV/µb	H or S	43.00	
2255	cardioid	MC	200 load	70–13k	−57dB ref 1mV/µb	H or S	31.72	
2302	omni	MC	200 load	50–15k	−57dB ref 1mV/µb	H or S	38.60	built-in switch
TTC								
MDFG11	cardioid	MC	dual 600 and 50k	10–10k	2.8mV @ 50kΩ	S	16.28	windshield
HDF619	cardioid	MC	dual	200–10k	2.2mV	S	16.50	
B7110	omni	C, E	800	50–13k	−65dB	L	13.75	
B1075	cardioid	MC	dual		−54dB @ 50kΩ	S	9.90	
DF100	omni	MC	600	100–9k	−76dB	L	6.93	
B1238	omni	C, E	600	30–13k	−74dB	clip	9.90	
DF72BC	omni	MC	dual	80–12k	−76dB @ 600Ω	clip	9.46	
B1060	omni	MC	dual	80–13k	−59dB @ 50kΩ		5.94	
DF1X	omni	MC	50, 500 or 50k		−110, −76 or −57dB			
UHER								
M136	omni	MC	low	50–15k	0.32mV/µb	H or S	8.32	
M154	omni	MC	low	150–10k	0.25mV/µb	H	20.5	remote control
M517	cardioid	MC	low	50–15k	0.28mV/µb	H or S	22.10	remote control
M534	cardioid	MC	low	50–16k	0.23mV/µb	H or S	20.00	
D109						L	22.00	
D190C						H or S	29.70	
D202CS						H or S	52.80	
D900C	hypercardioid					H or S	60.50	gun mic
M537	cardioid	MC	500	40–18k	0.23mV/µb	S	51.25	
M538	cardioid	MC	low	30–18k	0.14mV/µb	S	80.50	
M539	omni	MC	low	40–17k	0.18mV/µb	S	53.00	
M634	cardioid, stereo	MC	500	50–16k	0.23mV/µb	S	42.70	2×M534
UNISOUND								
EM82	omni	C, E	600	40–18k	−65dB ±3dB	H or S	13.00	
EM82H	omni	C, E	50k	40–18k	−46dB ±3dB	H or S	13.00	
EM83	cardioid	C, E	1k	40–18k	−65dB ±3dB	H or S	15.00	
EM83H	cardioid	C, E	50k	40–18k	−51dB ±3dB	H or S	15.00	
EM84		C, E	1k	40–16k	−65dB ±3dB	tie clip	13.00	

Manufacturers' addresses

ACOS, Cosmocord Ltd, Eleanor Cross Road, Waltham Cross, Herts EN8 7NX.

ADASTRA Electronics Ltd, Unit N22, Cricklewood Trading Estate, Claremont Road, London NW2 1TU.

AKAI, Rank Audio Visual Ltd, PO Box 70, Great West Road, Brentford, Middlesex TW8 9HR.

AKG Equipment Ltd, 182/184 Campden Hill Road, Kensington, London W8.

BEYER Dynamic (GB) Ltd, 1 Clair Road, Haywards Heath, Sussex.

CALREC Audio Ltd, Hangingroyd Lane, Hebden Bridge, Yorkshire HX7 7DD.

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

ELECTROVOICE, Gulton Europe Ltd, Special Products Division, The Hyde, Brighton BN2 4JU.

FOSTER, Adastra Electronics Ltd, Unit N22, Cricklewood Trading Estate, Claremont Road, London NW2 1TU.

GRAMPIAN Reproducers Ltd, Hanworth Trading Estate, Feltham, Middlesex.

LUSTRAPHONE Hi Fi Ltd, Unit 2 Browells Lane, Feltham, Middlesex TW13 7EL.

MELODIUM, Keith Monks Audio Ltd, 26–28 Reading Road South, Fleet, Near Aldershot, Hants.

NEUMANN, F. W. O. Bauch Ltd, 49 Theobald Street, Boreham Wood, Herts WD6 4RZ.

PEARL, Allotrope Ltd, 90 Wardour Street, London W1V 3LE.

PYE Business Communications Ltd, Cromwell Road, Cambridge CB1 3HE.

PHILIPS, Pye Business Communications Ltd, Cromwell Road, Cambridge CB1 3HE.

ROSS Electronics, 32 Rathbone Place, London W1P 1AD.

SCHOEPS, Feldon Audio Ltd, 126 Great Portland Street, London W1N 5PH.

SENNHEISER, Hayden Laboratories Ltd, Hayden House, 17 Chesham Road, Amersham, Bucks HP6 5AG.

SHURE Electronics Ltd, Eccleston Road, Maidstone, Kent ME15 6AU.

SONY (UK) Ltd, Pyrene House, Sunbury Cross, Sunbury-on-Thames, Middlesex.

STC, Hampstead Hi-Fi, 91 Heath Street, Hampstead, London NW3.

THORN Consumer Electronics Ltd, 284 Southbury Road, Enfield, Middlesex.

TURNER, Millbank Electronics Ltd, Bellbrook Estate, Uckfield, Sussex.

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

UHER (UK) Ltd, 15 Broomhills Estate, Braintree, Essex.

UNISOUND, Condor Electronics Ltd, 100 Coombe Lane, London SW20 0AY.

World of Amateur Radio

"Amateurs Girdle the World"

Exactly 50 years ago—in October 1924—British and New Zealand amateurs achieved what was perhaps their greatest triumph of all time: the spanning on "short waves" of the longest possible contacts that can be made on the Earth, a near antipodal path. They achieved this long-distance record not by chance but as the result of careful advance planning based on the realisation that because of the 12-hour time difference and the apparent peaking of h.f. signals at sunrise and sunset, there seemed every chance that a particularly good path would exist between the UK and New Zealand at a time of the year when these events nearly coincided.

In the autumn of 1924, a small group of British amateurs began transmitting and listening daily during the sunrise period on about 95 metres, using a daily changing code word for positive identification. On October 16, 1924 at 0600 GMT E. J. Simmonds, (G)20D heard a New Zealand amateur Ralph Slade, Z4AG calling a station in the United States, but did not make contact. On October 17 no signals from the Antipodes were heard but a cable was received next day from Frank Dillon Bell, Z4AA of Otago reporting 20D's signals with the correct code word. Then on October 19, the young Cecil Goyder, operating 2SZ, the station of Mill Hill School, London, successfully made contact with Frank Bell who then immediately afterwards made contact with Jack Partridge 2KF. The same day Gerry Marcuse, 2NM made contact with both Z4AG and Z4AK and the next day 20D made contact with Z4AA. These events were reported in *Wireless World* under the headline "Amateurs Girdle the World"—and it would not be overstating the case to claim that this was the pinnacle of all the efforts of the early twenties to open up the short waves. Afterwards, DX on h.f. became something of an anticlimax and one finds such reports as that of Stan Lewer, 6LJ logging 128 American stations at one sitting.

It is interesting to speculate, in the light of recent propagation research, whether these 3/3.5MHz contacts at the critical dawn/dusk period were made, not as usually supposed by "multi-hop" reflections, but rather by chordal hop (super-mode) propagation. Certainly it is clear that the antipodal and twilight paths across the equator are still of very special interest to all concerned with long-distance h.f. propagation.

Morse outmoded?

On both sides of the Atlantic the age-old controversy about Morse seems to be raging once again. While it is understandable that many would-be h.f. operators resent what they feel to be a waste of time in learning the code in order to use s.s.b., it is noticeable that very few amateurs who have become reasonably proficient in Morse operation seem to share the view that this is now an outmoded system of communication. As I have written elsewhere: "Newcomers who really wish to learn Morse operating are few and far between. The majority view it as a necessary evil that has to be surmounted before a Class A licence can be obtained. Yet once achieved, mastery of the code opens up a new world to the shortwave enthusiast and proves a source of endless satisfaction." Or, as Geoffrey Vore, W9QBJ, has put it recently in *QST*: "The greatest reason of all for c.w. use remains its complete satisfaction as an operating medium. Solid contacts with moderate to low power, simplified equipment (and expense) and a minimum of ulcer-producing tensions make c.w. operation sheer pleasure."

But those who believe that any recognizable personal characteristics in sending the code is a deviation from perfection may be a little horrified at the attempt by John Myers, W9LA to resurrect the "sideswiper key" fashioned as ever from a short length of hacksaw blade to "give real character to one's fist". He reminds us of the regional and national "accents" that once made sideswiper keying as individually distinctive as a fingerprint: the draggy Southern drawl; the flat drawl of the mid-West; the clipped British accent; the stutter—all he claims were reflected in the sideswiper so popular (some will say too popular) in the days before the electronic keyer or the latest vogue for keyboard "keyers".

With the current inflation rate for Japanese s.s.b. transceivers now at over 20 per cent per annum, amateur radio may well be facing a period when the low costs of c.w. operation will become once more attractive.

Field Day results

The 1974 National Field Day Trophy of the RSGB has been gained by the Ariel Radio Group, a BBC club. Leading single-station entry (Bristol Trophy) goes to the East Barnet Amateur Radio Contest Club. This year only 17 clubs and groups entered the main "double-station" contest but there were 76 single-station entries, six more than last year. Ariel used Quad aerials on the 14, 21 and 28 MHz bands and this type of aerial was used also by East Barnet on 14 and 28 MHz. West of Scotland were clear leaders on 7MHz using a Vee-beam with 1200-ft "legs" beaming south.

Licence changes

Two new classes of the amateur (sound) licence are now being issued in the UK by the Home Office. Class G (fixed operation) and Class H (mobile) both for overseas visitors who hold the equivalent of the UK Class B (v.h.f. phone-only) licence. Callsigns are being issued for these classes in the sequence G5MAA, G5MAB onwards.

Any American amateur holding an Extra Class licence may soon be eligible to apply for any specific unassigned callsign that he might want (e.g. "two letter" callsigns or callsigns based on operator's initials) on payment of a fee; at present such applications can be made only after holding a licence for 25 years.

In brief

The Amateur Radio Retailers Association are holding the third Midland National Amateur Radio and Electronics Exhibition at the Granby Halls, Leicester from Thursday, October 31 to Saturday, November 2 . . . R. J. Harry of the Directorate of Radio Technology of the Home Office will open a two-part RSGB meeting at the IEE, Savoy Place on the evening of Monday, November 25 on the subject of methods of interference investigation and suppression . . . the ARRL whose journal is *QST* is pained that the UK delegation should recently have proposed "QST" as a new Q-signal for the maritime radio service to mean "I hear your call, the approximate delay is . . ." But after hearing US and Israeli delegates speak against the proposal the conference adopted QOT instead . . . The ITU has instituted through the International Amateur Radio Club a new award for amateurs and shortwave listeners "Diplome des 100" for contacts with or reception of stations in 100 different member countries of the ITU (contacts after January 1, 1967 or after a country's ratification or accession to the Montreux Convention). Details from L. M. Rundlett, K4ZA, 206 East Amhurst Street, Sterling Park, Virginia, 22170, USA) . . . FCC has warned American amateurs from using amateur nets for "swap and shop" activity though agreeing that amateurs can occasionally use their stations to discuss the availability of a piece of amateur radio equipment for disposal . . . If you used any bands below 14.4MHz you had to put a filter on your power supply; above this frequency raw a.c. was permissible; mobile operation only above 56 Mc/s; you could operate on *any* frequency above 110 Mc/s (American amateur regulations at the time of the formation of the FCC exactly 40 years ago) . . . The RSGB has proposed that the Constitution of the International Amateur Radio Union should recognize the existence of the regional bureaux and all member societies are being invited to vote on the proposal.

PAT HAWKER, G3VA

Synthesized communications receiver

Principles of a synthesized receiver together with a description of the Racal RA1772 receiver

by R. F. E. Winn, B.Sc., M.I.E.E.

Racal Communications Ltd

The task of the communicator has always been to try to achieve a communication link for the highest possible percentage of the time. Use of the h.f. band, as an effective method of long-distance communication, increased rapidly as its possibilities became appreciated. Even with the introduction of submarine cables and satellites on high-density links, h.f. communication remains popular. A link is relatively inexpensive to set up, can be unobstrusive and ideal for medium-density traffic or person-to-person links. For military users the difficulty of interfering with a multi-frequency h.f. link is another attraction. Increasing traffic comes from maritime users because their requirement is both mobile and long-distance.

All of these reasons mean that the h.f. band is crowded and likely to remain so. Broadcasting, teletype, common carrier links, diplomatic channels and personal or amateur radio channels are only a few users of the band. In these conditions the engineer responsible for introducing or extending his radio equipment must try to ensure that the equipment does not have limitations which reduce the effectiveness of communication. Considering the task of the receiver which, when connected to a large antenna, may be faced with a mass of signals extending over 30,000kHz, requiring sometimes to be selective over a fraction of one kHz, with a range of signal levels which simultaneously may exceed 1,000,000:1 it is no wonder that the task is difficult, especially when the required signal is the smallest. Some specialist receivers are now in use which meet the requirements with limited flexibility. The receiver to be described meets the requirements with complete flexibility and some of its design considerations and characteristics are discussed.

Frequency selection

When assessing the requirements for a new receiver installation, the question of frequency selection is of prime importance. Most links are established on fixed frequency allocations and it is thus possible to consider crystal controlled receivers. An advantage of crystal control is frequency stability; a disadvantage is lack of flexibility. As the number of channels increases the attractions of frequency synthesis also increase.

Early synthesizer designs left much to be desired. The system of "direct" synthesis used a series of dividers and filters to produce the smallest required increments and then added, mixed and multiplied the resulting products to the output via yet more filters. This was bulky and expensive. The system is still used but although active filters have reduced sizes somewhat it is still expensive and it is only used where very fast frequency changing is a necessity. The "indirect" system of synthesis was introduced to counter the stringent filter requirements. A typical system works by using a voltage-controlled oscillator at the output frequency, mixing the frequency down with a selected one from a "comb" of frequencies and comparing it with a reference frequency which produces a locking voltage to the output oscillator. The system can be extended down to achieve the smallest frequency increment desired by a repetitive divide-and-add process. Whilst this system works adequately it still uses several filters and phase-lock loops and, as is the case with most linear circuitry, cannot easily be implemented in integrated circuit form without custom-built circuits. The advent of digital integrated circuitry provided the incentive to consider another method of "indirect" synthesis, where the phase-lock oscillator is merely divided down by a variable divider to a fixed frequency derived from the frequency standard. In the simplest system the comparison frequency is also the smallest incremental step, so that the complete synthesizer comprises one phase-lock loop. Using digital i.cs this can be compact, and ideal for packsets. With the present state-of-the-art it is possible to achieve variable frequency division from approximately 50MHz down to 100Hz and thus have 100Hz steps. Higher output frequencies, up to 100MHz, would require a prescaler of ÷ 2 and have a step size of 200Hz if the comparison frequency were maintained.

A more sophisticated form of digital synthesizer can be used which has a smaller step size than the comparison frequency; again, a divide-and-add system is employed. The advantage of the small size is maintained so that the synthesizer's inclusion within the framework of the receiver can be effected.

Oscillator purity

When used as the receiver local oscillator the synthesizer offers flexibility in the choice of frequency but an output must be produced which is pure enough to match the receiver requirements, because any spurious signals on the output will cause the receiver to have spurious responses. Fortunately with careful circuit design the output can be maintained to a purity of 100dB relative to the main output. Moreover with a digital synthesizer the number of spurious mechanisms is very small compared with those produced in a more traditional mixing-type system.

Noise on the output of the synthesizer is another form of spurious signal. This can also be minimized by ensuring that the maintaining circuit of the output oscillator has as high a Q as is practicable and by running the oscillator at the highest level possible. These requirements are somewhat contradictory in a semiconductor circuit especially when using varactors. Using a field effect transistor BFW 10 and maintaining an in-circuit Q of 50 it is possible to achieve a relative level of 100dB measured in a 3kHz bandwidth at 20kHz off. Reciprocal mixing is another term for the adjacent channel noise effect where a large unwanted signal offset from the wanted signal mixes with the noise sidebands of the local oscillator to produce a noise signal at the i.f., thus reducing the effective selectivity of the receiver filters as shown in Fig. 1.

One hazard which should be recognized in the simple, single-loop, digital synthesizer is the relatively "loose" method of control. Because the loop contains a high division ratio divider the loop gain is low. This means that any disturbance due to mechanical shock on the oscillator tuned circuits caused by sudden temperature changes may not be instantly corrected and this is true in any system with long intervals between correction. Correction can only occur at the comparison frequency intervals and faster or shorter-term errors remain uncorrected. For sophisticated transmission systems such as Kineplex a simple loop system is not good enough so that a multiple loop arrangement is required to maintain high speed correction and minimize the division ratio per loop. A further advantage of maintaining a high comparison frequency is that the speed of locking to a new frequency is also high.

The free-tune synthesizer

A synthesized receiver covering the h.f. band in 10Hz steps requires seven decadic switches which makes it difficult to tune in a s.s.b. signal. An alternative method of selection which is provided in the RA 1772 receiver shown in Fig. 2, consists of a shaft encoder coupled to a v.f.o.-type knob. The encoder changes the frequency of the synthesizer in 10Hz steps dependent on the rate at which the knob is rotated. In operation the illusion of a v.f.o. is obtained because the synthesizer locks very rapidly and the step size is small. For searching and monitoring, the free tune facility is provided whilst at the same time absolute frequency accuracy is maintained.

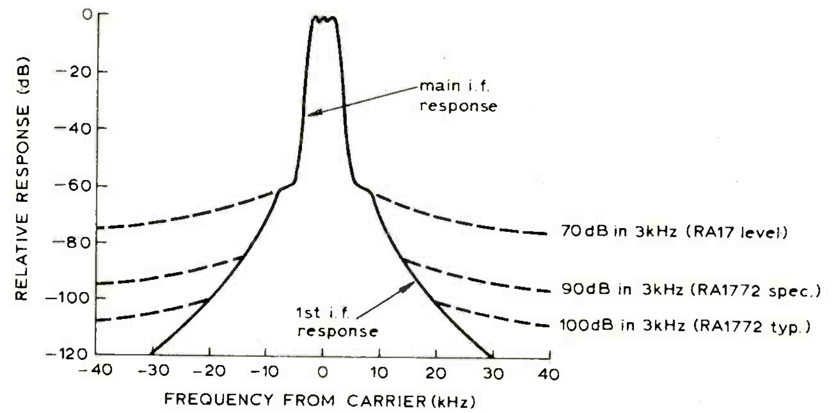


Fig. 1. Response of double superhet showing effect of reciprocal mixing, 3kHz bandwidth.

Receiver parameters

It is important to have a receiver which is sensitive to weak signals although there is a fundamental limit to sensitivity set by thermal noise in the receiver input circuits. Sensitivity is directly related to the amount by which thermal noise in the equivalent input resistance of the receiver is increased by the input circuits, the amount being defined as the noise figure. A noise figure of up to 10dB is the lowest level which can be reasonably specified in a h.f. production receiver although 7dB might be typical for the same equipment. This would be equivalent to a s+n/n ratio of 15dB for a 1μV signal using a 3kHz i.f. bandwidth or, providing the post filter noise is insignificant, 5dB for a 0.1μV signal using a 300Hz bandwidth. The latter figures demonstrate the reason for the continued popularity of c.w. over difficult links.

In practice, however, it is not normally the noise figure of the receiver which limits the detection of the small wanted signal but the simultaneous existence of atmospheric and man-made noise on the antenna. A far more severe limitation comes from the large unwanted signals also present, whose effect is often disguised. It is not sufficient to provide a high degree of single-signal selectivity, the dynamic selectivity must also be of a high order. Cross-modulation is a recognized effect where a large unwanted modulated signal transfers its modulation to the smaller wanted signal. It is a broadband effect, due to front end non-linearities and occurs in many receivers with unwanted signal levels of a few millivolts. In this respect the transistorized receiver is at a definite disadvantage with respect to the older valve types because a bi-polar transistor is basically a non-linear device. Some benefit may be obtained by front-end tuning to reduce the number of large signals entering the receiver but real immunity is only achieved by designing for a very high linearity. In the RA 1772 this is obtained by using high-level field effect transistors achieving levels of 300mV. At this level the effect is no longer a problem unless co-sited transmitters are set up in duplex operation or a mile-long Beverage antenna is pointed near a broadcast station. Blocking is also a broadband effect which results in the reduction of the wanted signal by a large nearby unwanted signal. It has been traditional to specify the unwanted level at which 3dB of level reduction is measured; this now occurs at such a high level, 500mV minimum, that other effects disguise and can prevent more than 1dB reduction from being seen.

Intermodulation. A rather more insidious effect than those mentioned is due to intermodulation distortion between two or more unwanted signals which produce discrete unwanted products. The unwanted products for second order i.ps occur at $f_1 \pm f_2$ e.g. at 10MHz for unwanted signals of 4.5 and 5.5MHz or 10.02 and 20.02MHz. Fortunately one of the two unwanted signals must be at least one octave removed from the position of the product which is, if interfering, the tuned position, so that r.f. tuning can reduce the level of one signal and hence that of the product. Half octave filters are selective enough for this purpose and are commonly employed. Third order intermodulation products are more difficult to remove. These occur at $2f_1 \pm f_2$ e.g. at 10MHz for signals of 10.02 and 10.04MHz or 9.98 MHz and 9.96MHz. Obviously it is impossible to remove these with conventional *LC* tuning and the only satisfactory solution is to arrange for a very low natural level of third order distortion. Specification methods vary but the most accepted method specifies the level of the two unwanted signals which together produce an unwanted product of 0dBμV (1μV). Most existing receivers if measured close-in (without benefit of r.f. tuning), would give a level of up to approximately 70dBμV (3mV). The equivalent performance of the RA 1772 receiver is 90dBμV (30mV), an order better. Since, however, third order intermodulation product levels increase at three-times the rate that the level of the unwanted signals increase, the unwanted level from a 70dBμV receiver when fed with signals of 90dBμV is at 60dBμV (1mV). Measured on this scale the improvement in level is three orders. It is only possible to assess the overall effect of third order intermodulation by analysing the total pattern of signals being received by the antenna. If the antenna is a large rhombic, for example, there may be several thousand signals received of levels up to 100mV and all these will combine in the receiver front end to produce many thousands of products. It is possible to deduce where the products fall, and at what level, from the pattern and level of the primary signals, and from the amount and degree of receiver preselection. Shown in Fig. 3 is the result of an analysis on a rhombic antenna where the highest level signals between 30 and 100mV were between 9 and 15MHz. The graph shows the mean

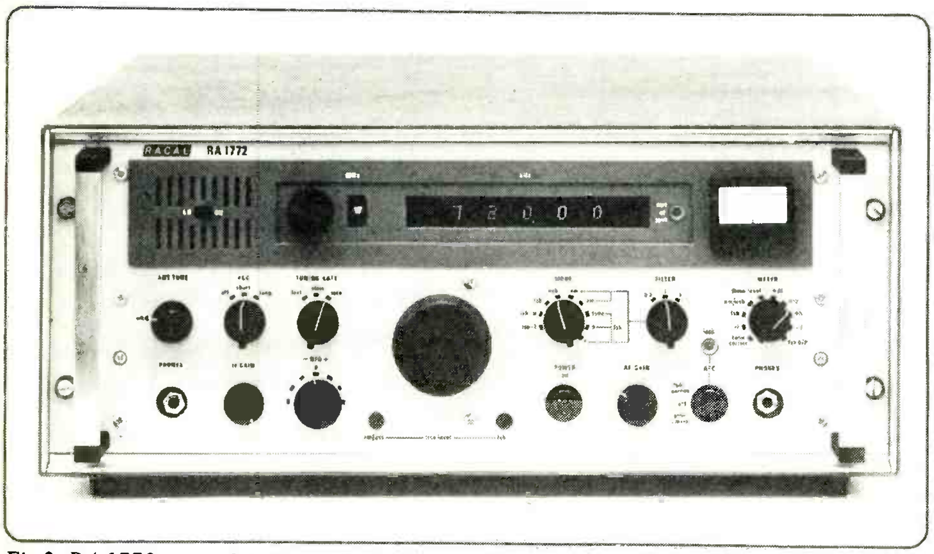


Fig 2. RA 1772 general purpose synthesized receiver.

signal strength requirement to overcome various effects and give a 10dB signal to noise ratio in a 3kHz bandwidth. The most obvious conclusion is that the 70dBµV i.p. receiver could not be used wideband on such a big antenna, (curve 4), even with 12% tuning, (curve 5), a mean signal of above 300µV must be arranged at around 11MHz. If an improvement in linearity to 90dBµV i.ps can be achieved then both curves 4 and 5 drop by 60dB to reduce the level to that of atmospheric noise. Curve 6 is that due to reciprocal mixing, a reduction in level of 30dB can be achieved so that, again, atmospheric noise becomes dominant. A common control in most h.f. receivers is the antenna attenuator. This control which reduces the level of all signals into the receiver is used since the intermodulation products fall faster than the wanted signal. It is, however, of little use if the wanted signal is already weak and near noise level. Fortunately at the level of performance achieved this can be dispensed with completely. A more detailed analysis with results are given in ref. 1.

It is not always evident that the receiver's limitations are preventing reception; as stated earlier, the effects are often disguised. One example is when a large unwanted signal intermodulates with a noisy signal or with atmospheric noise itself to give a noise-like signal on-tune. It is only the very experienced user who can determine that this is due to the receiver and not merely interference.

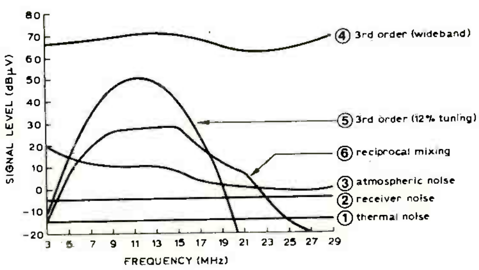


Fig. 3. Mean signal strength required for 10dB s/n ratio, showing effect of 70dB third order i.ps and reciprocal mixing with large rhombic antenna.

Receiver design

It is worth examining some of the ways in which the receiver design can be improved to the point of immunity from the problems mentioned. The h.f. superhet receiver has as its final i.f. a frequency convenient for large amounts of stable and variable amplification, typically up to 100dB. The frequency must also be one for which it is possible to construct narrow filters of defined characteristics. It is common to use crystal filters since these are stable and need no adjustment during the life-time of the equipment. No single frequency is standard but 1.4MHz is a good compromise because at this frequency the crystals are relatively compact and four to eight pole filters can be obtained in a package of 76 × 28 × 31mm. Single superhet receivers are constructed using a 1.4MHz i.f. but there is a problem of removing the image frequency at 2.8MHz off-tune and narrow r.f. filters become a necessity. It is often easier and more flexible to build a double superhet with a high first i.f. to remove the image from the h.f. band entirely. A first i.f. of 35.4MHz means an image frequency of 70.8MHz off-tune with the intermediate frequency also out of the h.f. band. A single low-pass filter before the first mixer which cuts above 30MHz is then all that is required to attenuate image and i.f. breakthrough to the specified levels, typically 90dB down (see Fig. 4).

Although it is sometimes beneficial to frequency selection it is never advantageous to the receiver performance if the first i.f. bandwidth is wider than the final output bandwidth. The highest possible amount of single-signal and dynamic selectivity are required both of which are obtained if the bandwidth is made narrow as soon as possible. It can be arranged for all frequency selection processes to be made in the first mixer, with fixed frequency injection in the subsequent mixer(s), so that a narrow first i.f. filter can be used. This filter can also be a crystal type so that its bandwidth need only be wide enough to pass the widest i.f. bandwidth envisaged, normally ±6kHz. This allows protection to subsequent stages against signals farther off-tune than 10kHz and considerable protection at 20kHz off-tune. Having such protection we may concentrate on providing a very high linearity in the stages which are wide-band, particularly the first mixer and r.f. amplifier.

The front-end. The first mixer is the section where the greatest amount of development effort has been concentrated in recent years. The problem is to achieve mixing and maintain linearity to signals at the input in a function that is basically non-linear. The mixer must be non-linear to signals on two inputs but linear to signals on the same input. A solution lies with the switching type of balanced mixer in which the input signals are switched through to the output in-phase and out-of-phase alternately at the local oscillator repetition frequency. It is important to maintain this linear switching even at input voltages of several hundred millivolts which requires several volts for switching. All parts of the mixer are important when designing for the order of linearity described. The mixer transformers must be carefully balanced and non-linear ferrites avoided. If the frequency band to be covered is wide, then transmission line transformers are useful to maintain inductance whilst keeping core and self capacitance losses low—ref. 2. Balance is important not only to reduce the level of direct i.f. noise from the local oscillator but also to reduce the level of the oscillator appearing at the antenna input. The level of this "re-radiation" has to be kept very low in a communications centre (C.C.I.R. recommendation 10µV max.) particularly if several receivers share a common antenna

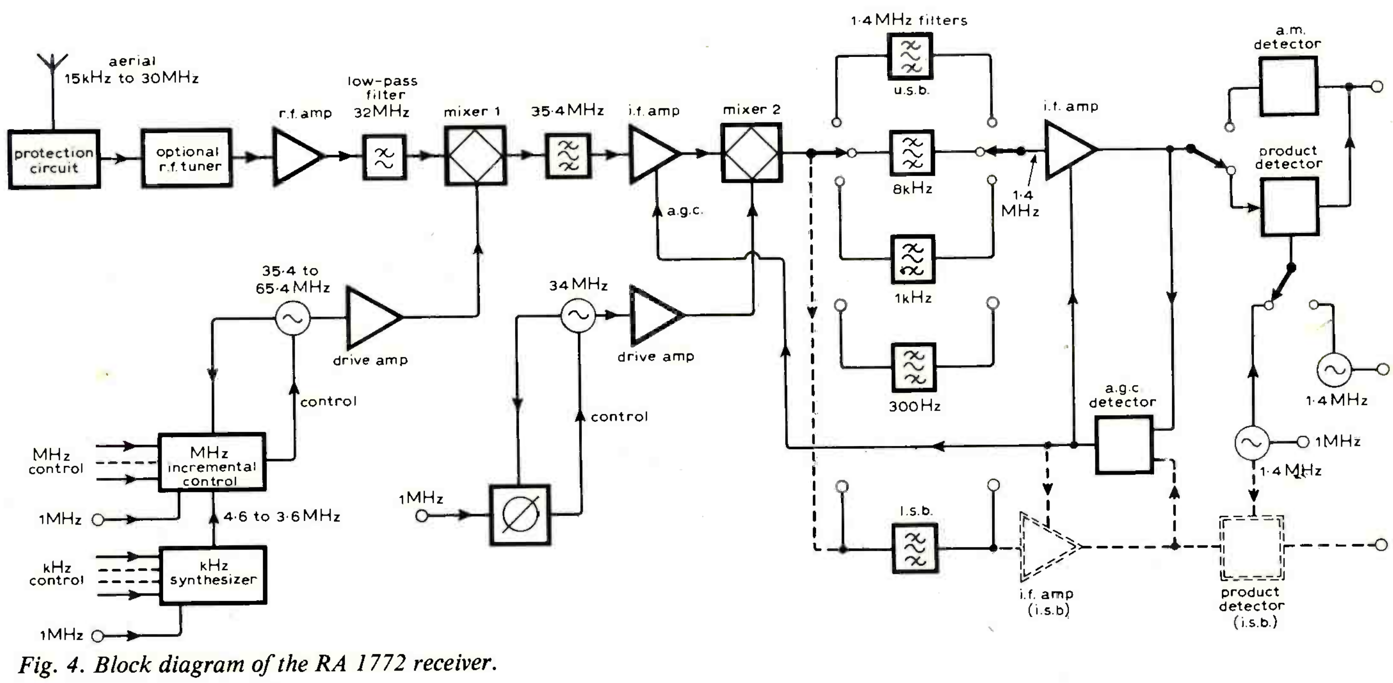
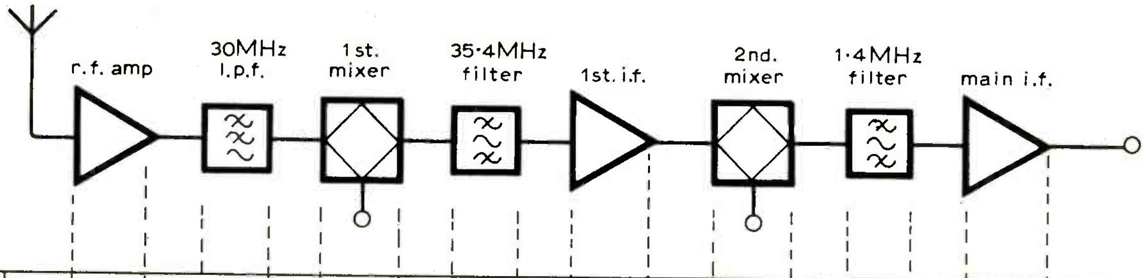


Fig. 4. Block diagram of the RA 1772 receiver.



		r.f. amp		30MHz l.p.f.		1st. mixer		35·4MHz filter		1st. i.f.		2nd. mixer		1·4MHz filter		main i.f.
noise figure of block (dB)		5		1		8		2		4		13		6		15
power gain (dB)		10		−1		−8		−2		17		5		−6		
accumulative noise figure (dB)	9		17		16		8		6		18		21		15	

Fig 5. Typical level chart.

distribution network. Another advantage of the high i.f. is that the input l.p.f. gives a high rejection to all feedback of local oscillator frequencies, these frequencies being outside the h.f. band.

Designing for high linearity means attention to all parts of the system including those which normally do not give rise to i.ps. The first i.f. crystal filter for example; it might be thought that since this contains purely passive components no problems could arise. This has proved to be far from the case in the RA 1772. Not only have all ferrite transformers had to be removed in favour of iron-dust but the crystals need to be manufactured very carefully to avoid any minute metalization to quartz discontinuities. Care must also be taken to ensure that the characteristics of the mixer are known from l.f. to u.h.f. because many mixer products up to frequencies of 1000MHz and beyond are produced of which only one is required. A noise figure around 15dB would be acceptable in most cases where the receiver is directly coupled to a receiving antenna, certainly up to 20MHz, because here the system would be atmospheric or man-made noise limited. If it is not directly coupled then a lower receiver noise figure is desirable. To achieve a worst-case noise figure of 10dB an r.f. amplifier is necessary which again needs a high linearity and signal handling capacity. In our case the gain as shown in Fig. 5 is 10dB so that the first mixer must provide third order i.ps of better than 90 for two 100mV signals.

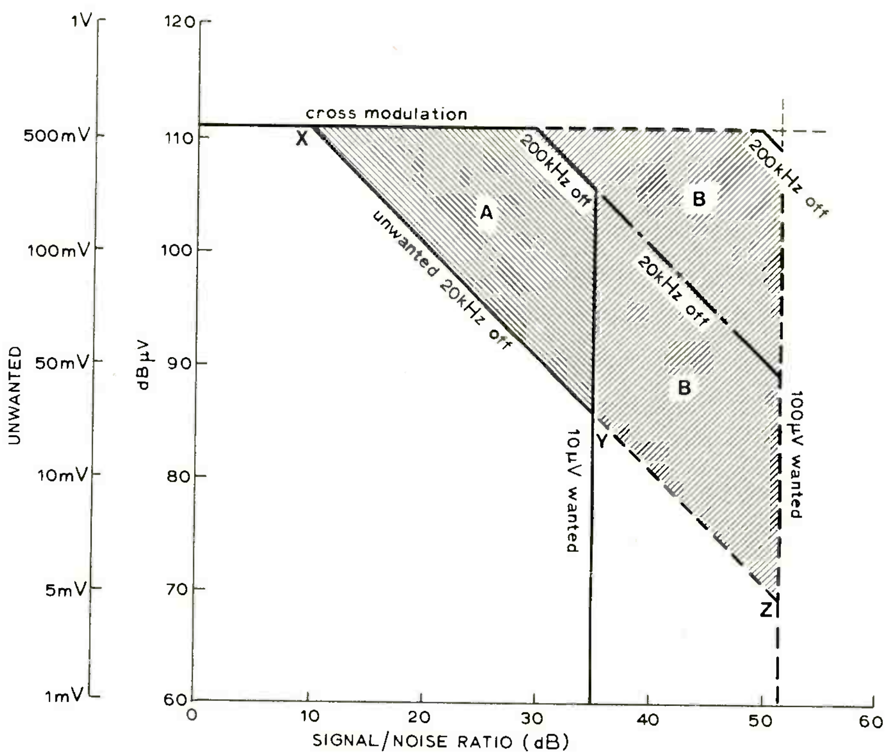


Fig. 6. Signal-to-noise ratio showing effect of reciprocal mixing and cross-modulation.

I.F. stages. Stages subsequent to the first i.f. filter are protected against signals off-tune but have to be capable of providing linear amplification to signals inside the passband. One measure of linearity is percentage distortion to the audio output after detection. The product detector as used for s.s.b. demodulation is capable of a higher linearity than the envelope detector and overall figures of 1 to 2% can be maintained. A.m. is thus often received using the sideband filters and product detector with, as a further bonus, the choice of sideband to minimize interference. Another measure of distortion is the in-band i.ps where the accepted minimum requirement is −40dB. This limit arises because in a multichannel v.f.t. system unwanted products spread into the tone frequencies of another channel and cause errors. Large range a.g.c. is a requirement and, whilst it is agreed that the output level change should be as small as possible, there is disagreement over time-constants. For a.m. and f.s.k. signals both attack and decay times should be short, in the order of a few tens of milliseconds, whereas for c.w. and s.s.b. signals the decay time should be long. Therefore a choice of time constant is usual, "short" and "long". Ideally in "long" there should be no a.g.c. decay when receiving s.s.b. until the transmission ceases, because otherwise an annoying increase in background noise returns between syllables of speech. A solution is to incorporate a "hold" period or decay time which lasts for two seconds, followed by a fairly fast decay of one second. The "hold" is readily achieved by storing the a.g.c. voltage on a capacitor which is fed to a high input impedance f.e.t. or m.o.s.f.e.t. until the end of the "hold" period when a discharge resistor is switched in. No a.g.c. is applied to the first i.f. amplifier until the signal reaches 300μV. This ensures that the signal-to-noise ratio increases with a signal strength as fast as possible until 50dB is achieved. Further requirements are a voltage/gain characteristic which is reasonably linear and defined, so that a.g.c. stability is maintained even with narrow filter bandwidths, and so that when using two receivers in diversity their two a.g.c. lines can be connected ensuring control of the higher signal strength receiver.

R.F. attenuation. No a.g.c. or attenuation is applied before the mixer, because with the linearity achieved in the mixer it is not necessary. This means that the small wanted signal is never attenuated. A method of extending the cross-modulation specification of a receiver is by using front end

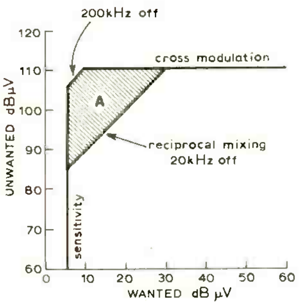


Fig. 7. Maximum unwanted signal level for 20dB s/n ratio.

attenuation determined by the level of the nearby unwanted signal. This is necessary if the natural cross-modulation level is lower than that of the anticipated signals but the result is of necessity a compromise. Shown in Fig. 6 is the s/n ratio achieved for two wanted signal levels against unwanted signals of different offsets. The diagonal limits are due to reciprocal mixing, the front-end attenuation would have to be arranged to follow the 20kHz line if the cross-modulation level was naturally lower than 300mV and specified at 20kHz. The disadvantage would be that unwanted signals further off-tune than 20kHz would also have the effect of causing the attenuator to operate and the extra signal to noise obtained in area A would not be obtained. Furthermore unless the attenuator was also coupled to the wanted level, line XY would extend to 2 and area B would also be lost. A more conventional representation, Fig. 7, shows the maximum level of unwanted signal for 20dB s/n ratio as a function of wanted signal. The same effect is illustrated as in the previous figure, i.e. there is no real substitute for a very high real crossmodulation level to match a very low reciprocal mixing level.

The author wishes to thank the directors of Racal Communications Ltd for permission to publish this paper and credit is due to the members of the engineering laboratories who have contributed to the successful development of the receivers.

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1. Winn, R. F. E. Effect of Receiver Design in Communication Systems, I.E.R.E. Proceedings of the Conference on Radio Receivers and Associated Systems, 4th–6th July 1972, pp. 193–204.
2. Ruthroff, C. L., Some Broad-Band Transformers, *Proceedings of the I.R.E.*, August 1959, pp. 1337–1342.

Receiver for modulation studies

Facilities for s.s.b. and i.s.b.

The radio receiver in the picture looks quite conventional but is in fact rather special. It is designed for studies of the possibilities of new methods of modulation in the m.f./l.f. sound broadcasting bands—notably single-sideband and independent-sideband. Re-planning exercises for the European medium- and long-wave broadcasting bands (see August issue, pp. 266–271) have the unenviable task of attempting to maintain the present service, in which there are invested millions of broadcast receivers and associated transmitting stations, yet pave the way towards better spectrum utilisation and accommodating more radio channels. At present two technical expedients appear to go some way towards a solution of the above conflicting requirements. These are: (a) Place all the channels on a regular frequency spacing of 8kHz, with nominal carrier frequencies being an integral multiple of the carrier spacing. (This has the effect of reducing intermodulation and TV interference, making receiver design easier and allowing more channels.) (b) Consider the gradual introduction of independent single-sideband transmissions. (This makes possible stereo broadcasting compatible with a.m., later on two language channels, or ultimately double the number of channels.)

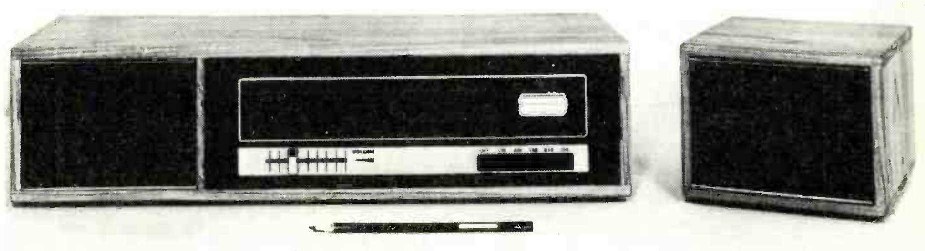
Incremental tuning

The receiver in fact contains battery powered circuits which respond to the two factors just described, but at the same time operates nearly conventionally on the existing m.f. sound radio transmissions. The differences introduced are as follows. First, the receiver tuning only settles down at 1kHz increments, even though controlled with a conventional continuous scale. The present channel frequency spacings are 8, 9 or 10 kHz, so the receiver can "capture" all existing stations. If the beneficial change to 8kHz comes about (by slightly retuning the existing transmitters) a simple change in the receiver's c.m.o.s. logic will make the receiver only settle on every channel—a very much easier thing to achieve, by the way, than on every 1kHz. Secondly, the push-buttons give listening mode options of a.m., lower sideband, upper sideband or independent sideband. Two loudspeakers are provided, as in unit audio, but in this equipment the lower sideband comes from the left-hand speaker and the upper sideband from the right-hand speaker. Sideband separation is accomplished by the phasing method of demodulation, with the receiver carrier phase locked to the incoming transmitted carrier.

Bi-aural listening

The overall sideband response is flat from 300Hz to 3000Hz, which compares well with a normal a.m. receiver. On present broadcasts one can listen bi-aurally, with a.m., or as i.s.b., or one sideband at a time in one speaker (if there is interference in the other). Apart from the fact that one soon recognises the potential of, say, two independent sideband broadcasts (expedient (b) above), the improvement in the quality of night-time broadcasts as received on the sideband method is a fact which has been recognised for some considerable time.

A single dual output amplifier i.c. provides a total power of 1W, controlled by the single dual volume control. The front end of the receiver is conventional, with its tuned ferrite rod aerial housed in the receiver cabinet together with all the other circuits. A full description of the receiver is to be found in the June 1974 issue of the *EBU Review* (Technical), No. 145. The development of the receiver, in the Electrical and Electronic Engineering department of the University College of Swansea, was supported by a grant from the UK Science Research Council.



The experimental receiver, showing the two loudspeakers.

New Products

H.f. receiver

Plessey Avionics have announced the introduction of a new solid-state ten-channel h.f. radio receiver for applications such as ground-to-air services, point-to-point links, and net operation. Designated PRD 535/1, the receiver provides reception of up to ten selected frequencies within the 1.6 to 22MHz range with all channels independently located over the band. The standard mode of reception is s.s.b. (u.s.b. and l.s.b. switchable) with optional facilities to provide double sideband (a.m.) and independent sideband (i.s.b.) reception. A further option is also available for the reception of f.s.k. transmissions which uses an additional plug-in module and an external converter/keyer. Audio output into an internal loudspeaker or headphone jack, together with a separate output for a 600 ohm balanced line connexion, is standard. A crystal oven is employed, which gives a frequency stability of 1 part in 10^6. A built-in front panel meter gives an indication of the signal strength or the audio output level at the 600-ohm outlet. Plessey Avionics and Communications, Martin Road, West Leigh, Havant, Hants.

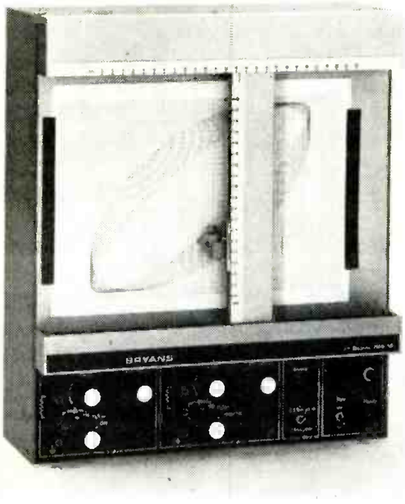
WW309 for further details

WW309

X-Y recorder

The 2500 XY/t recorder from Bryans is an A4 size instrument featuring a writing speed of 35cm/sec on both axes. The acceleration is 935cm/sec^2 on both axes and a timebase is built into the x axis, with a sweep range of 0.1 to 10sec/cm. A range of transducers for measuring pressure, force, acceleration or load is available for connexion to the recorder. Bryans Southern Instruments Ltd, 1 Willow Lane, Mitcham, Surrey CR4 4UL.

WW317 for further details



WW317

Mains disturbance monitor

Mains-supply switching transients and surges can be investigated by using the DLO19 power line disturbance monitor, now available from Datalab. It is intended for use with a digital-memory waveform recorder to detect and record disturbances up to 2000V peak-to-peak. Connexion is made via a high-voltage fixed plug, and front panel switching allows the selection of phase-to-phase or phase-to-neutral voltages. A 50/60Hz filter removes the fundamental frequency, and a direct or filtered output can be connected to the recorder. Triggering can be selected from positive going transients, negative going transients, or both. A trigger level control is also provided. Data Laboratories Ltd, Wates Way, Mitcham, Surrey.

WW327 for further details

WW327

V.h.f./u.h.f. display

The Eddystone 1061B/1 panoramic display will monitor a band of frequencies on a continuous basis and provide a visual display. The unit, which has been designed for use with receivers having appropriate i.f. outputs, is suitable for an i.f. of 10.7MHz, but other i.f. outputs can be accommodated to meet special requirements. The display provides an independently-variable sweep width from 20kHz/cm to 1MHz/cm and a continuously-variable sweep speed. A 6kHz resolution enables mobile radio signals of 12.5kHz channel spacing to be separated on the switchable 40dB logarithmic or 26dB linear display.

The sensitivity of 10μV/cm can be controlled over 0 to 40dB with a switched attenuator in 10dB steps and a separate, continuously-variable adjustment of 20dB. The screen measures 10 × 6cm and the complete unit is suitable for rack mounting or can be supplied in cabinet form. Eddystone Radio Ltd, Marconi House, Chelmsford, Essex CM1 1PL.

WW328 for further details

WW328

Rechargeable batteries

A range of rechargeable batteries suitable for use in emergency lighting and similar applications is available from Hakuto. These batteries are totally enclosed in styrene cases and the manufacturers claim that no electrolyte leakage is possible, regardless of the working position. The range, which is known as Hisealed, is rechargeable 200 times when the rated capacity is exhausted and 1000 times when the full capacity is partially discharged. A safety valve protects the batteries by lowering the internal voltage if an overcharge condition is detected. Hakuto International Ltd, 557–563 Rayleigh Road, Leigh-on-Sea, Essex SS9 5HP.

WW313 for further details

Microwave source

The model 524, first in a new range of compact microwave sources, has up to six programmable crystal-controlled frequencies and covers the 8.5 to 9.6GHz band. The long-term stability is 1 part in 10^6 per month and the frequency stability is 0.005% over the temperature range 0 to +70°C. A spurious harmonic level of better than −50dB is claimed and a f.m. noise of 95dB at 2kHz off carrier with an a.m. noise of −125dB also at 2kHz. G. & E. Bradley Ltd, Electral House, Neasden Lane, London N.W.10.

WW300 for further details

Harness-tying gun

A harness-tying tool designated TR-300 will tie cables at the rate of one per second. The instrument, which is pneumatically operated, can be counterbalanced to minimize fatigue. Tension of the tie can be preset and the tool automatically adjusts to the harness diameter from $\frac{1}{16}$ to $\frac{5}{8}$in. The installed ties are approved to MIL-S 23190 under MS 3367-4 type 1 class 2. Thomas & Betts Ltd, 90–93 Cowcross Street, London EC1M 6JR.

WW302 for further details

WW300

WW302

WW305

Accelerometers

The SA series of accelerometers is constructed using a spring plate, one end of which forms the sensing element, on to which semiconductor strain gauges are bonded. A small seismic mass is also fixed to the spring plate. The whole element is in a gasproof light metal case filled with oil to provide the necessary damping. The SA108 device features a frequency response from 0 to 600Hz with a linearity/hysteresis of ±1%. A nominal output of 200mV is available from a supply of up to 10V d.c. Vibro-Meter Ltd, Newby Road, Hazel Grove, Stockport, SK7 5EE.

WW305 for further details

High-frequency oscilloscope

Hewlett-Packard have introduced a 257MHz oscilloscope called the 1720A. This instrument has a sensitivity of 10mV/cm on each channel, and a sweep speed up to 1ns/cm. The *y* attenuator accuracy is 2% on all ranges (10mV/cm to 5V/cm) and the input impedance is selectable from 50Ω or 1MΩ with an 11pF shunt capacitance. Triggering is claimed to be stable for all displays requiring only 1cm of vertical deflection to 300MHz. The graticule can be illuminated by a flood gun, providing even exposure for photography. Focus is automatic and the oscilloscope retains all the performance characteristics over the temperature range 0° to 55°C. The UK price is £1,928 including accessories. Hewlett-Packard Ltd, 224 Bath Road, Slough.

WW316 for further details

Coaxial-line attenuator

Flann Microwave have introduced a continuously variable, coaxial-line attenuator providing an attenuation range from 0 to 40dB when calibrated at 2.5GHz and from 0 to 60dB when calibrated at 10GHz. The insertion loss is 0.5dB maximum and the v.s.w.r. is less than 1.35. The attenuator is direct reading and special models are available for narrow frequency bands within the 1 to 2.5GHz range. Flann Microwave Instruments Ltd, Dunmere Road, Bodmin, Cornwall PL31 2QL.

WW314 for further details

Delay timer

An electronic timer, type ETA, will provide delay times from three seconds to 20 minutes with a choice of four time ranges. Repeat accuracy on continuous cycling is around 1%, and a change of 5% in the supply voltage will only alter the timing by about 1.5% The unit is available with an inbuilt or remote potentiometer for adjustment of the delay. The output relay has double pole changeover contacts rated at 3A 250V a.c. with a 5A option available. Appliance Components Ltd, Cordwallis Street, Maidenhead, Berks, SL6 7BQ.

WW329 for further details

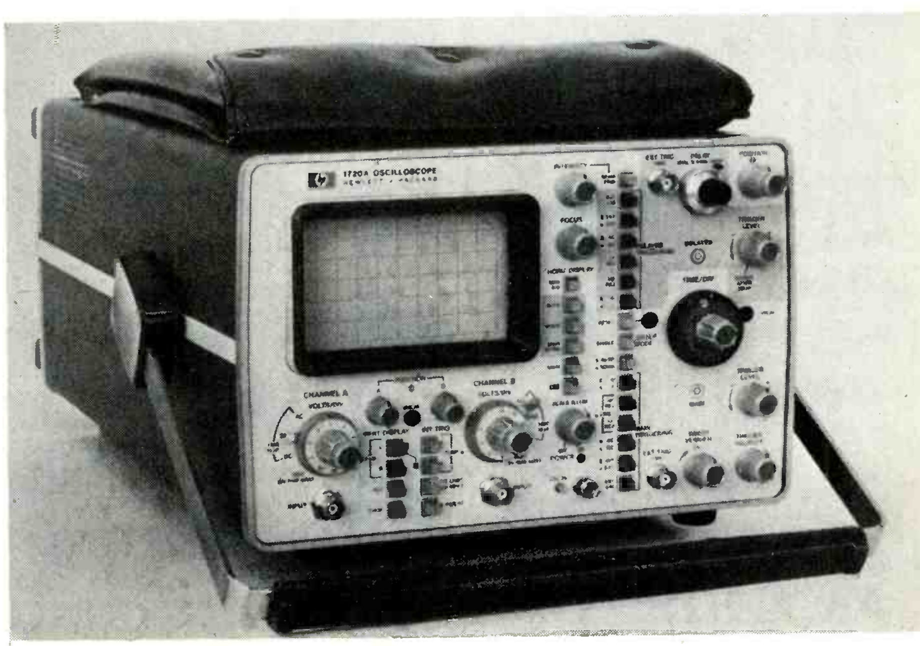
High-voltage probe

A hand-held probe designed for measuring up to 30kV has been introduced by Brandenburg Ltd. The probe is constructed from moulded polypropylene with a nylon insulated tip and a brass contact point. A safety feature incorporated in the design is the arrangement of the e.h.t. cable, which is brought out of the probe in front of the hand shield. The probe measures 260mm with an 85mm diameter shield, and weighs 75 grams. The price, including 2 metres of e.h.t. cable, is £5 plus v.a.t. Brandenburg Ltd, 939 London Road, Thornton Heath, Surrey CR4 6JE.

WW312 for further details

Drop-proof multimeter

The latest addition to the Daystrom-Schlumberger range of drop-proof multimeters is the 666. This model has been designed with semiconductor-circuit trouble-



WW316

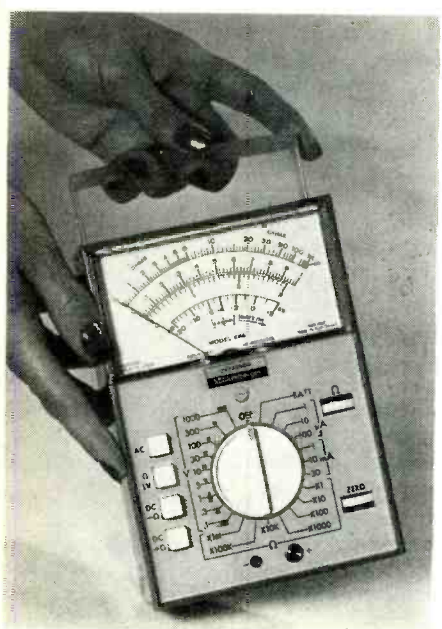
shooting in mind. The instrument has a 10MΩ input impedance and ohms-range with low voltage-drops. Plug-in circuit boards are used for easy maintenance and they can be calibrated without removing the instrument from its case. Compensation against temperature effects and a diode protected mechanism are provided in the meter which measures 7 × 5 × 2½in and costs around £33. Daystrom-Schlumberger, Bristol Road, Gloucester GL2 6EE.
WW307 for further details

Tunable quadrature oscillators

Now available from Lyons Instruments is the Frequency Devices Inc. range of precision sinewave oscillators. The 440 series of resistive tunable oscillators offer a distortion of 0.08% and two buffered outputs 90° ±0.1° out of phase, with a claimed amplitude tracking of better than 100 p.p.m/°C. Tuning over a 1000:1 range is possible with two equal resistors. The three models, 440, 442 and 444, cover the ranges 0.05 to 50Hz, 0.5 to 500Hz and 20Hz to 20kHz respectively. The units are priced at £39.50 plus v.a.t. (100 off). Lyons Instruments Ltd, Hoddesdon, Herts.
WW301 for further details

Laser power meter

A meter called the model 504 provides direct power read out at any wavelength from 440nm to 680nm in 1nm steps. The wavelength to be monitored is dialled on the front panel and the power range is selected from seven scales between 10mW and 10W. The unit is suitable for use with any type of visible c.w. laser from the sub-milliwatt devices through to the 10W argon lasers. The instrument, which is battery powered, incorporates a 0 to 50mV socket for recording purposes and is priced at $495 including the attenuators for operation up to the 3W range. The optional attenuator required for the 10W range is priced at $75. Lexel Corporation, 928 East Meadow Drive, Palo Alto, California, USA.
WW315 for further details



WW307

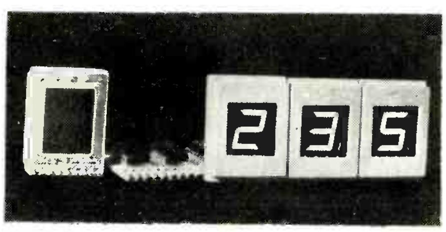
Liquid crystal displays

A range of l.c. digital displays are available in either the transparent or reflective mode. The digits, which come in different sizes, are encapsulated in bezels ready for mounting. The voltages range from 18 to 35V a.c. with a frequency from 50 to 300Hz. Consumption is 3nA per segment, and the rise time is 4–9ms with a decay time of 100–150ms. The contrast ratio for the transparent type is 80:1 and 20:1 for the reflective type. An average life of 25,000 hours is claimed in an operating temperature range from −20 to +80°C. Nimrod Electronics Ltd, Vann Lane, Chiddingfold, Surrey GU8 4TP.
WW311 for further details

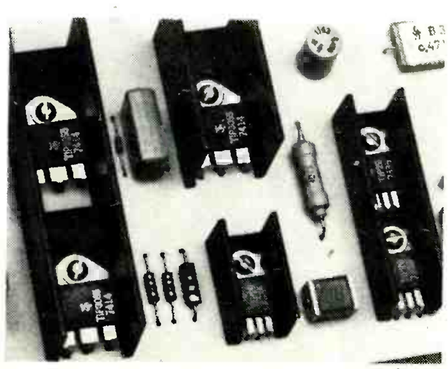
Heat sinks

The latest range of heat sinks from Jermyn is the ACH and BCH series for plastic TO66 and TO3 devices respectively. Each of the series is available in two versions for mounting either one or two devices. Thermal resistance figures for single and double ACH types are 28°C/W-12.5°C/W respectively, and 15.5°C/W–10°C/W for the BCH type. Jermyn Manufacturing, Sevenoaks, Kent.
WW304 for further details

WW315



WW311



WW304

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.

Time-base generator

A recent addition to the Motorola c.m.o.s. family is the MC14566 time-base generator. This device consists of two pulse shapers, a divide-by-ten ripple counter, a divide-by-five (or six) ripple counter and a monostable multivibrator. A single MC14566 can be arranged to divide by 50 or 60 to produce one pulse per second from a 50 or 60Hz input. In addition, a b.c.d. output indicating tenths of a second is available.

A second device can be connected in cascade with the first to provide one pulse per minute and a b.c.d. output of up to 59 seconds. With a third chip a complete digital clock can be constructed.
WW350 for further details **Motorola**

Switch debouncer

National have introduced an i.c. called the DM8544 which performs switch-debounce functions for four switches. The device consists of four RS flip-flops with internal pull-up resistors. A strobe control is provided which allows the switch state information to be sampled at a predetermined time. All control inputs/outputs are t.t.l. compatible for the device which operates in a temperature range from 0 to +70°C.
WW351 for further details
National Semiconductor

A.g.c. attenuator diode

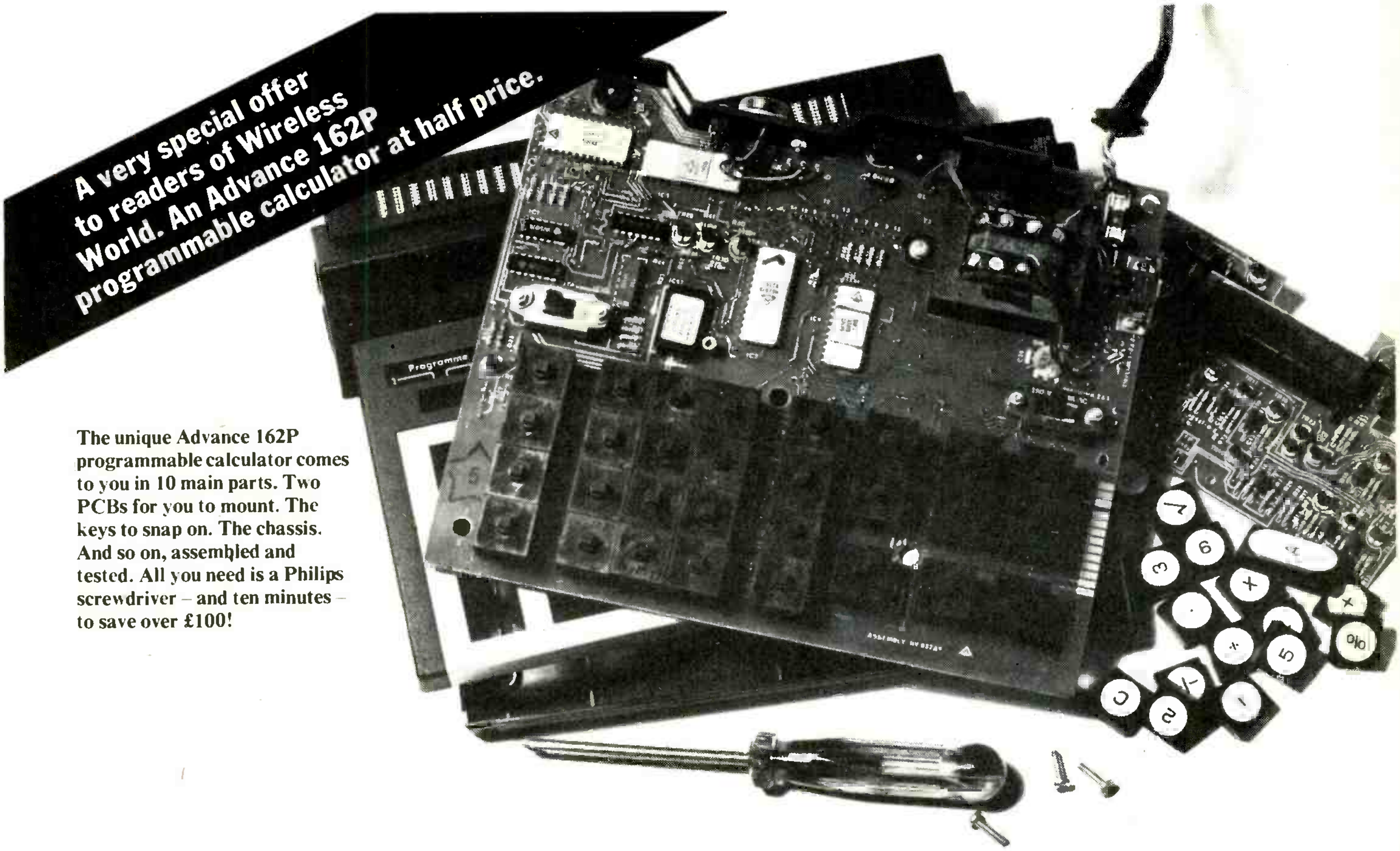
The 1N 5957 PIN diode has been designed as a current-controlled variable-resistance element suitable for a.g.c. circuits. The diode has a resistance range of four decades in a temperature range from −195 to +300°C. A carrier lifetime of 1.5 to 2μs is claimed for the device, with a leakage current of 10μA and a total capacitance of 0.4pF.
WW352 for further details G.E. Electronics

L.e.d. incorporating logic

A complex i.c. from SDS combines a seven-segment l.e.d. display with a b.c.d. counter, display storage latches, a b.c.d. to seven-segment decoder and constant current display drives. The device counts input pulses at up to 18MHz and displays the result. Using this chip it is possible to construct a high-speed multi-digit fully synchronous counter system without any external logic.
WW353 for further details **SDS**

Suppliers

Motorola Inc., Semiconductor Products Division, PO Box 8, 16 Chemin de la Voie-Creuse, 1211 Geneva 20, Switzerland.
National Semiconductor UK Ltd, The Precinct, Broxbourne, Herts EN10 7HY.
G.E. Electronics (London) Ltd, Eardley House, 182/184 Campden Hill Road, Kensington, London W8 7AS.
SDS Components Ltd, Hilsea Trading Estate, Portsmouth, Hants PO3 5JW.



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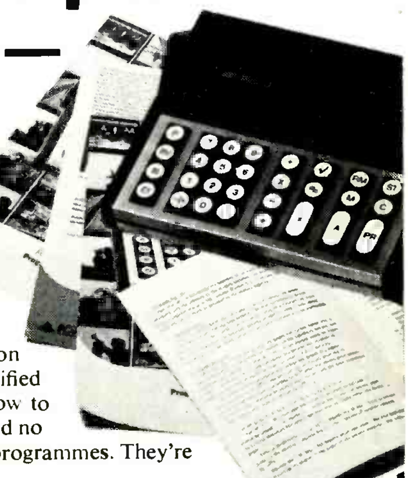

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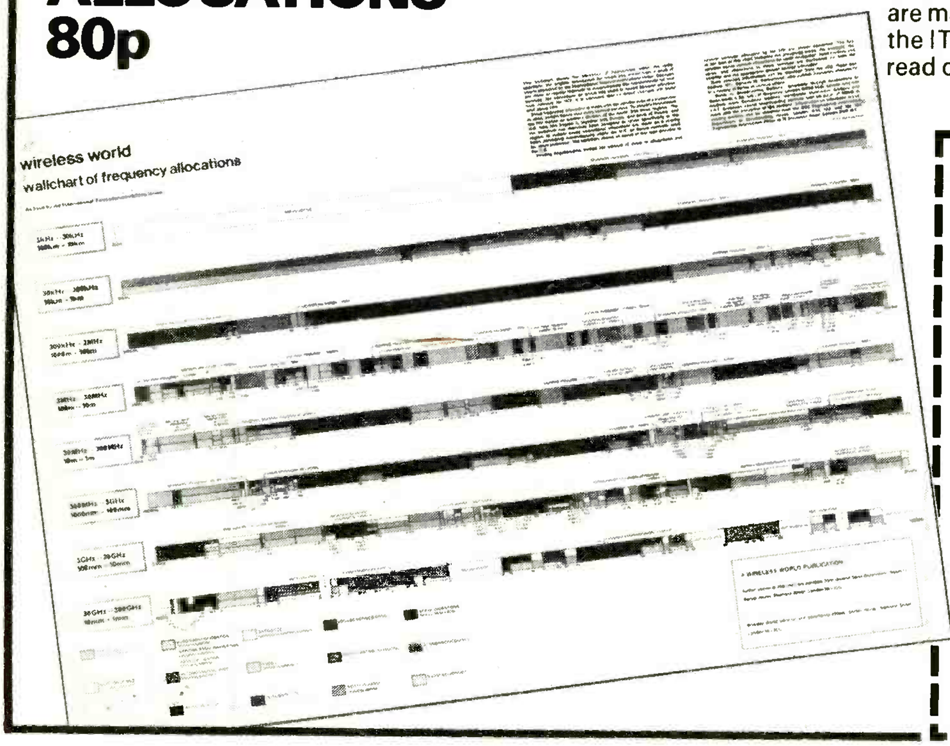

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AUTO TRANSFORMERS
Partridge. Tapped 0-220-230-240-250v 500 watts unshrouded table top connections **£2·50**, carr. 40p. Lemark tapped 0-240 115v 500 watts unshrouded table top connections **£5·00**, carr. 60p. 300 watts **£3·50**, carr. 50p.

12 volt 2 amp TRANSFORMER enclosed in metal case. Size 5×4¼×3 ins. with fitted input and output fuses. On/off switch. Output sockets and 4 ft. 240v. mains lead. **£2·75** p.p. 35p.

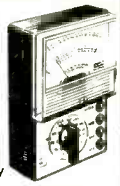
DRAKE L.T. TRANSFORMERS
Pri. 240v. E.S. Sec. 26v. 10A and 12v. 0·1A, open frame, table top connections, **£5·50**, carr. 50p. Pri. 200-220-240v., Sec. 1, 37v. 6A, Sec. 2, 37v. 2A, 21v. 11A, open frame table top connections, **£9·50**, carr. £1.

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.

ASK LASKYS and make no mistake

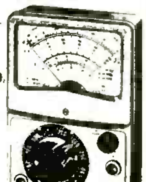
AUDIOTRONIC Model ATM1

Top value 1,000 opv pocket multimeter. Ranges:– 0/10/50/250/1,000 volt AC and DC. DC current 0-1mA/100mA. Resistence: 0/150k ohms. Decibels: –10 to +22dB. Size 90 x 60 x 28mm. Complete with test leads.
OUR PRICE £3.25 P&P 15p

AUDIOTRONIC Model ATM5

Jewel movement, attractively moulded case with edgwise ohms adjustment. Ranges: 0-3/15/150/300/1200V AC, (2500 opv). 0-6/30/300/600V DC, (5000 opv). 0-300 uA/0-300mA DC. Resistance: x 10 & x 100. –10 to +16dB. Supplied with battery test leads and data booklet. Size: 121 x 73 x 29mm.
OUR PRICE £3.95 P & P 20p

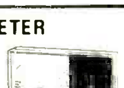
MODEL TH12

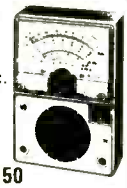
20,000 opv. Overload protection. Slide switch selector. 0/0.25/2.5/10/50/150/1000V DC. 0/10/50/250/1000V AC. 0/50uA/25/250mA DC. 0/3k/30k/300k/3 Megohms. –20 to +50dB.
OUR PRICE £5.95 P&P30p

HIOKI 720X VOM

A versatile, accurate measuring instrument. 20,000 opv. 0/5/25/100/500/1000V DC. 0/10/50/250/1000V AC. 0–50uA/250mA. 0–20k/2 Megohms.
OUR PRICE £5.97 P&P 30p

MODEL PL436

20,000 opv DC. 8000 opv AC. Mirror scale 6/3/12/30/120/600V DC. 3/30/120/600V DC. 50/600μA/60/600mA. 10/100K/1 Meg/10 Meg Ohm. –20 to +46dB.
OUR PRICE £6.97 P&P 30p.

U4323 MULTIMETER

20,000opv. Simple unit with audio/IF oscillator. Suitable for general receiver tuning. Ranges: 0.5/2.5/10/50/250/500/1000V DC. 2.5/10/15/250/500/1000V AC. 0.05/0.5/5/50/500mA DC. Resistance x 10, x 100, x 1,000, x 10,000 (50Ω, 500Ω, 5kΩ, 50kΩ centre scale) Battery operated. Size: 160 x 97 x 40mm. Supplied in carrying case complete with test leads.
OUR PRICE £7.70 P&P30p

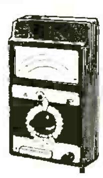
HIOKI 730X

30,000 opv. Overload protection. 6/30/60/300/600/1200V DC. 12/60/120/600/1200V AC. 60/μA/30mA/300mA. 2K/200K/2 Meg Ohm. –10 to +63dB.
OUR PRICE £7.50 P&P 30p

U4324 MULTIMETER

High sensitivity, overload protected. 20,000opv. Ranges: 0.6/1.2/3/12/30/60/120/600/1200V DC. 3/6/15/60/150/300/600/900V AC. Current: 0.06/0.6/6/60/600mA/3A DC. 0.3/3/30/300mA/3A AC. Resistence: 25/500 ohms/0.5/5/50/500k ohms/5 Mohms. Decibels: –10 to +12dB. Size 167 x 98 x 63mm. Supplied complete with test leads, spare diode and instructions.
OUR PRICE £9.25 P&P 30p

U435 MULTIMETER

20,000opv. Ranges: 75mV/2.5/10/25/100/250/500/1000V DC. 2.5/10/25/100/250/500/1000V AC. Current: 50uA/1/5/25/100mA/0.5/2.5A DC. 5/25/100mA/0.5/2.5A AC. Resistance: 0.3/3/30/300k ohms. Size: 205 x 110 x 84mm. Supplied complete with leads, crocodile clips and steel carrying case.
OUR PRICE £8.75 P&P 30p

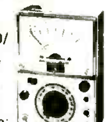
U4312 MULTIMETER

extremely sturdy instrument for general electrical use. 667opv. 0/0.3/1.5/7.5/30/60/150/300/600/900V DC & 75mV. 0/0.3/1.5/7.5/30/60/150/300/600/900V AC. 0/300uA/1.5/6/15/150/60/600mA/1/1.5/6A DC. 0/1.5/6/15/60/150/600mA/1.5/6A AC. 0/200/3k/30k ohms. DC accuracy 1%. AC 1.5%. Knife edge pointer, mirror scale. Complete with sturdy metal carrying case, leads and instructions.
OUR PRICE £10.25 P&P 50p

U91 Clamp VOLT AMMETER

For measuring AC voltage and current without breaking circuit. Ranges: 300/600V AC. Current: 10/25/100/250/500A. Accuracy 4%. Size 283 x 94 x 36mm. Complete with carrying case, leads and fuses.
OUR PRICE £13.50 P&P 30p

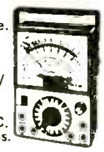
MODEL 500

30,000 opv with overload protection. Mirror scale. 0/0.5/2.5/10/25/100/250/500/1000V DC. 0/2.5/10/25/100/250/500/1000V AC. 0/50uA/5/50/500mA. 12A DC. 0/60k/6 meg/60 megohms.
OUR PRICE £13.95 Carr. paid
Leather case for above £1.75

HIOKI 750X VOLT-OHM-MILLIAMETER

43 ranges: 0–0.3/0.6/1.5/3/6/12/30/60/150/300/600/1,200V DC. 0–3/6/15/30/60/120/300/600/1,200V AC. Current: 0–30/60uA/1.5/3/15/30/150/300 mA/6/12A. Resistence: 0–3/300k/3/30Mohms. Decibels: –10 to +17dB. Output:– 0–3/6/15/30/60/120/300V. Accuracy ± 3% DC, ± 4% AC. Sensitivity: 50,000 opv DC, 5,000 opv AC. 4 inch meter. Built in protection. Size: 57 x 102 x 153mm.
OUR PRICE £11.95 P&P 40p

TMK MODEL TW50K

46 ranges, mirror scale. 50k/V DC 50k/V AC. DC Volts: 0.125/0.25/1.25/2.5/5/10/25/50/125/250/500/1000. AC Volts 1.5/3/5/10/25/50/125/250/500/1000. DC current 25/50uA/2.5/5/25/50/250/500mA/5/10A. Resistence: 10k/100k/1 Meg/10 Meg ohms. –20 to +81.5dB.
OUR PRICE £12.50 P&P 20p

HIOKI MODEL 700X

100,000opv. Overload protection. Mirror scale. 0.3/0.6/1.2/1.5/3/6/12/30/60/120/300/600/1200V DC. 1.5/3/6/12/30/60/150/300/600/1200V AC. 15/30uA/3/6/30/60/150/500mA/6/12A DC. 2k/200k/2M/20MOhms. –20 to +63dB.
OUR PRICE £14.95 P&P30p

Model HT100B4 MULTIMETER

Overload protected, shock proof circuits. 9.5uA Meter with mirror scale. Sensitivity 100kV. Polarity change switch. Ranges: 0.5/2.5/1-/50/250/500/1,000 Volts DC. 2.5/10/50/250/1,000 Volts AC. DC resistence' 0–20/200k/2/20 Meg. ohms. DC current:– 10/250uA/2.5/25/250 mA/10A. AC current:–0–10A. –20 to +62dB. Operates from 2 x 1.5V batteries. Size: 180 x 134 x 79mm.
OUR PRICE £17.50 P&P 40p

MODEL AS.100D VOM

100,000 opv. Mirror scale. Built-in meter protection. 0.3/12/60/120/300/600/1200V DC. 0/6/30/120/300/600V AC. 0/10μA/6/60/300mA/12 Amp. 0/2K/200K/2M/200 Meg Ohm. –20 to +17dB.
OUR PRICE £17.50 P&P 30p.

MODEL C7202EN

20,000 o.p.v. DC. 10,000 o.p.v. AC Mirror Scale. 5/25/50/250/500/1000/2500 V. DC. 10/50/100/500/1000 V. AC. DC Resistance x10, x1000 (30Ω centre scale) DC Current 50uA/2.5mA/250mA. –20 to +68 dB.
OUR PRICE £6.50 P & P 30p

KAMODEN 360 MULTIMETER

High sensitivity. DC 100kohm/V AC 10kohm/V 5" mirror scale, overload protected. Ranges: 0.5/2.5/10/50/250/1000V DC. 5/10/50/250/1000V AC. Current: 0.01mA/0,5/5/50/500mA/10A. Resistance: 0.1/1/10/100 ohms/1/10/100k ohms/10/100M ohms. Decibels –20 to +62dB. Battery operated. Size: 180 x 140 x 80mm. Supplied complete with, test leads etc.
OUR PRICE £17.50 P & P 40p

TMK MODEL 117 FET ELECTRONIC VOLTMETER

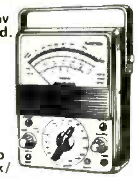
Battery operated. 11 Meg input, 26 ranges. Large 4¾" mirror scale. Size: 149 x 117 x 60mm. 0.3–12000V DC. 3–300V RMS AC. 8–800V P-P. DC current 0.12–12mA. Resistence up to 2000MOhms. Decibels: –20 to +51dB. Supplied complete with leads and instructions.
OUR PRICE £18.50 P&P 20p

TMK 100K LAB TESTER

100,000opv. 6½" scale. Buzzer short circuit check. Sensitivity 100,000 opv DC. 5k/V AC DC Volts: 0.5/2.5/10/50/250/1000V AC. 3/10/50/250/500/1000V DC. current 10/100uA/10/100/2.5/10A. Resistence: 1k/10k/100k/10 Meg/100 Meg ohms. Decibels: –10 to +49dB. Plastic case with carrying handle. Size: 190 x 172 x 99mm.
OUR PRICE £19.95 P&P 30p

370WTR MULTIMETER

Features AC current ranges. 20,000opv. 0/0.5/2.5/10/50/250/500/1000V DC. 0/2.5/10/50/250/500/1000V AC. 0/50uA/1/10/100 mA/1/10A DC. 0/100mA/1/10A AC. 0/5k/50k/500k/5 Meg/50 Meg. Decibels: –20 to +62dB.
OUR PRICE £19.95 P&P 30p

KAMODEN 72.200 Multitester

High sensitivity tester. 200,000 opv Overload protected. Mirror scale. Ranges:–0/.06/.3/3/30/120/600/1200V DC. 0/3/12/60/300/11200 V AC. 0/6uA/1.2mA/120mA/600mA/12A DC 0/12A AC. –20 to +63dB. 0/2k/200k/2 Meg/200 Megohms.
OUR PRICE £22.50 P&P 30p

U4317 MULTIMETER

High sensitivity instrument for field and laboratory work. Knife edge pointer, 86mm. mirror scale. Overload protection. Ranges: 100mV/0.5/2.5/10/25/50/100/250/500/1000 V DC. 0.5/2.5/10/25/50/100/250/500/1000V AC. Current: 50uA/0.5/1/5/10/50/250mA/1/5A DC. 0.25/0.5/1/5/10/50/250mA/1/5A AC. Resistance: 0.5/10/100/200 ohms/1/3/30/300k ohms. Decibels: –5 to +10dB Battery operated. Size: 210 x 115 x 90mm. Supplied in carrying case complete with leads.
OUR PRICE £16.50 P&P 40p

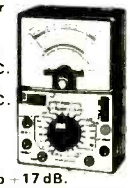
MODEL U4311 Sub-standard Multi-range Volt-Ammeter

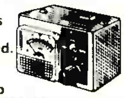
Sensitivity 330 Ohms/Volt AC and DC. Accuracy 0.5% DC. 1% AC. Scale length: 165mm. 0/300/750uA/1.5/3/7.5/15/30/75/150/300/750mA/1.5/3/7.5A DC. 0/3/7.5/15/30/75/150/300/750mA/1.5/3/7.5A AC. 0/75/150/300/750mV/1.5/3/7.5/15/30/75/150/300/750V DC. 0/750mV/1.5/3/7.5/15/30/75/150/300/750V AC. Automatic cut out device. Supplied complete with test leads, manual and test certificates.
OUR PRICE £52.00 P&P 50p

ALL PRICES EXCLUDE VAT

MODEL C7208FM

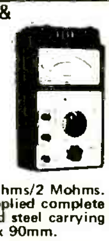
30,000 opv DC. 15,000 opv AC. 6/3/15/60/300/600/1200 V. DC. 6/30/120/600/1200 V. AC. DC Resistance x 1, x 10, x 100, x 1000 (50Ω centre scale) DC Current 30uA/3/30/600mA. –20 to +63dB.
OUR PRICE £8.95 P & P 30p

MODEL AF.105 VOM

50,000 opv. Mirror scale. Meter protection. 0/3/3/12/60/120/300/600/1200V DC. 0/6/30/120/300/600/1200V DC. 0/30μA/6/60/300 mA/12 Amp. 0/10K/1m/10m/100 Meg Ohms. –20 to +17 dB.
OUR PRICE £12.50 P&P 30p.

LB3 TRANSISTOR TESTER

Tests ICO and B. PNP/NPN. Operates from 9V battery. Instructions supplied.
OUR PRICE £3.95 P&P 20p

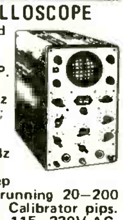
LB4 TRANSISTOR TESTER

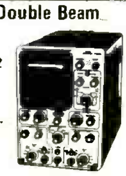
Tests PNP or NPN transistors. Audio indication. Operates on two 1.5V batteries. Complete with instructions etc.
OUR PRICE £4.50 P&P 20p

U4341 Multimeter & Transistor Tester

27 ranges. 16,700opv. Overload protected. Ranges: 0.3/1.5/6/30/60/150/300/900V DC. 1.5/7.5/30/150/300/750V AC. Current: 0.06/0.6/6/60/600mA DC. 0.3/3/30/300mA AC. Resistance: 0.06/0.6/2/6/20/60/200k ohms/2 Mohms. Battery operated. Supplied complete with probes, leads and steel carrying case. Size: 115 x 215 x 90mm.
OUR PRICE £10.50 P&P 30p

S100TR MULTIMETER TRANSISTOR TESTER

100,000opv. Mirror scale. Overload protection. 0/0.12/0.6/3/12/30/120/600V DC. 0/6/30/120/600V AC. 0/12/600uA/12/300mA/6/12A DC 0/10k/1 Meg/100 Meg. –20 to +50dB. 0.01–0.2 MFD Transistor tester measures Alpha, Beta and ICO. Complete with instructions, batteries and leads.
OUR PRICE £19.95 P&P 25p

C15 PULSE OSCILLOSCOPE

For display of pulsed and periodic waveforms in electronic circuits. VERT. AMP. Bandwidth: 10MHz. Sensitivity at 100kHz VRMS/mm: 0.1–25; HOR. AMP. Bandwidth: 500kHz. Sensitivity ay 100kHz VRMS/mm: 0.3–25 Preset triggered sweep 1–3000usec. Free running 20–200 kHz in nine ranges. Calibrator pips. 220 x 360 x 430mm. 115–230V AC.
OUR PRICE £43.00 Carr. paid

RUSSIAN CI16 Double Beam OSCILLOSCOPE

5 MHz pass band. Separate Y1 and Y2 amplifiers. Rectangular 5" x 4" CRT. Calibrated triggered sweep from 0.2usec. to 100 milli-sec/cm. Free running time base, 50Hz–1MHz. Built-in time base Calibrator and amplitude Calibrator. Supplied complete with all accessories and instruction manual.
OUR PRICE £87.00 Carr. paid

SWR METER Model SWR3

Handy SWR meter for transmitter antenna alignment, with built-in field strength meter. Accuracy 5%, Impedence 52' Indicator 100uA DC. Full scale 5 section collapsible antenna. Size 145 x 50 x 60mm.
OUR PRICE £4.25 P&P 30p

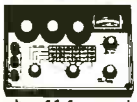
Also see following pages

MODEL TE15 GRID DIP METER

Transistorised. Operates as Grid Dip, Oscillator, Absorbtion Wave Meter and Oscillating Detector. Frequency range 440kHz–280MHz in six coils. 500uA meter. 9V battery operation. Size: 180 x 80 x 40mm.

OUR PRICE £19.95 P&P 30p

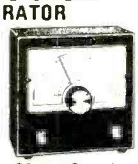
TRANSISTORISED L.C.R. A.C. BR/8 MEASURING BRIDGE



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 7⅜" x 5" x 2"

OUR PRICE £25.00 P&P 30p

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 30p

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 50p

TE22 SINE SQUARE WAVE AUDIO GENERATOR

Sine 20cps to 200kHz on 4 bands. Square 20 cps to 30 kHz. Output impedence 5000 Ohms. 200/250V AC operation. Supplied brand new guaranteed, with instruction manual and leads.

OUR PRICE £24.95 P&P 50p

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.

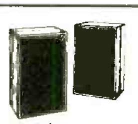
OUR PRICE £37.50 P&P 50p

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 50p

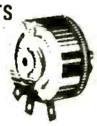
SPECIAL BARGAIN! FERGUSON 3406 HI-FI SPEAKERS



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 £22.50 PR. P&P £1

POWER RHEOSTATS



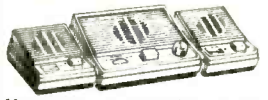
High quality ceramic construction. Windings embedded in vitreous enamel. Heavy duty brush wiper. Continuous rating. Single hole fixing. ¼" diameter shafts. Bulk quantities available.

25 WATT 10/25/50/100/500/1000/2500 ohms. £1.15 P&P 10p

50 WATT 10/50/100/250/500/1500/5000 ohms. £1.62 P&P 10p

100 WATT 1/5/10/25/50/250/500/2500 ohms.500 Ohms £2.34 P&P 15p

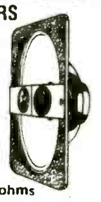
KE630 3 Station INTERCOM



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

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

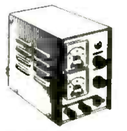
OUR PRICE £3.62 each P&P 35p

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

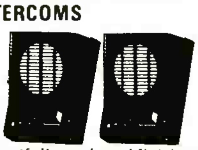
PS200 Regulated POWER SUPPLY UNIT



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&P 50p

AUDIOTRONIC LE-102A INTERCOMS



Beautifully made and finished in two tone ivory/buff, the LE-102A is useful in the home, office or shop and is suitable for use as baby alarm. Wall or desk mounting 57mm speaker/mic gives clear 2-way communication with on/off and volume control on master unit. Operates on 9V batt. Approx. 60ft lead.

OUR PRICE £3.95 P & P 30p

TRITON 4318 PORTABLE 8 TRACK CARTRIDGE PLAYER WITH MW/LW RADIO

Will play 8 track stereo cartridge monaurally. Channel selector switch. Covers medium and long wave bands. Volume and tone controls. Earphone socket. Battery/Mains operation.

OUR PRICE £11.95 P & P 50p

EA41 REVERBERATION AMPLIFIER

Self contained, transistorised, battery operated. Simply plug in microphone, guitar etc. and output to your amplifier. Volume control and depth of reverberation control. Beautiful walnut cabinet. 184 x 77 x 108mm.

OUR PRICE £7.50 P&P 30p

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

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 £2.25 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

SDH8V MONO/STEREO HEADPHONES

Volume control for each channel. 4/16 ohms impedence. Frequency response 20Hz–18kHz. Complete with 10ft. coiled lead and jack plug.

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BH001 HEADSET and Boom Microphone

Moving coil. Ideal for language teaching, communications etc. Headphone impedence 16 ohms. Microphone impedence 200 ohms.

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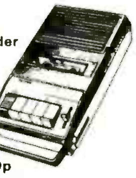
HANIMEX HRC 3075 CASSETTE RADIO

Covers Medium and FM wavebands. Slider volume and tone controls. Battery/Mains operation. Will record direct from radio or through built in condenser microphone. Complete with batteries, earphone, and cassette.

OUR PRICE £24·30 P & P 50p

TRITON CT.555 CASSETTE RECORDER



Battery/Mains. Piano key and slider controls. Automatic level control. Complete with mike and earphone.

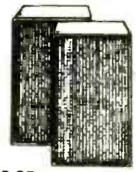
OUR PRICE £10.50 P & P 50p

ZEPHYR TC1500B CASSETTE RECORDER

Battery/Mains. Complete with mike, cassette, earphone.

OUR PRICE £9.95 P & P 50p

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 PAIR P&P 50p

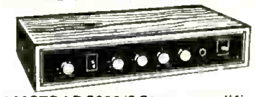
FM TUNER CHASSIS

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 £8.95 P&P 20p

Stereo Multiplex Adaptor £5.95 extra

SPECIAL OFFER! SAVE OVER 50%



AMSTRAD 8000/2 Stereo amplifier 7 watts per channel rms. Inputs for tuner tape, phono. Headphone socket. List price £29.95.

OUR PRICE £12.95 P & P 60p

SPECIAL OFFER! CONVERT YOUR STEREO SYSTEM TO 4D SOUND FOR UNDER £16.

Exclusive offer of GOODWIN 4-CHANNEL CONVERTER and a pair of AD15 10 watt 8 ohm bookshelf speakers enables you to add 4D sound to your existing system. Complete with simple connection details. Normal retail value £25.50.

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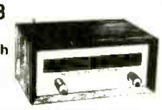
GOODWIN CONVERTER available separately £3.95 P & P 50p.

Model A1018 FM TUNER

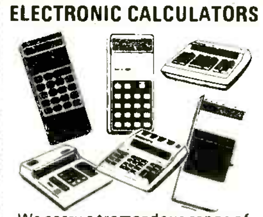


6 transistor high quality unit– 3 IF stages and double tuned discriminator. For use with most amplifiers. Covers 88–108MHz. Powered by 9V battery.

OUR PRICE £13.50 P&P 30p

Stereo multiplex adapter £5.95 extra.

ELECTRONIC CALCULATORS



We carry a tremendous range of both pocket and desk calculators from as little as £9. Owing to the demand it is not possible to include them in this advertisement, so send for our latest price list or call into any branch.

SINCLAIR SYSTEM 2000 STEREO AMPLIFIER AND TUNER

AMPLIFIER

Amplifier output 8 watts per channel RMS. Distortion less than 0·06%. Silicon transistors. Two pick-up plus radio and tape inputs, tape output and scratch filter. Excellent Value.

OUR PRICE £27.50 P & P 60p.

FM TUNER

Excellent selectivity and sensitivity. Twin dual-varicap tuning. 4 pole ceramic filter. 19 transistor stereo demodulator giving 40 dB separation. Distortion 0·2% output. Fantastic Value.

OUR PRICE £27.50 P & P 60p.

SINCLAIR IC12 INTEGRATED CIRCUIT AMPLIFIER

complete with printed circuit mounting board.

OUR PRICE £1.50 P & P 15p.

SINCLAIR Project 80 Modules

Z40 Power Amp	£5.45	P & P 15p
Z60 Power Amp	£6.95	P & P 15p
Stereo 80 Pre-Amp	£11.95	P & P 15p
Active Filter Unit	£6.95	P & P 15p
Project 805	£26.95	P & P 50p
PZ5 Power Supply	£4.98	P & P 30p
PZ6 Power Supply	£7.98	P & P 30p
PZ8 Power Supply	£7.98	P & P 30p
Transformer for PZ8	£4.05	P & P 50p

SINCLAIR Project 80 Packages

2 x Z40/Stereo 80/PZ5	£25.00
2 x Z40/Stereo 80/PZ6	£27.75
2 x Z60/Stereo 80/PZ8	£30.45

POST & PACKING 35p each.

TE1021 Stereo Listening Station

For balancing and gain selection of loudspeakers with additional facility for stereo headphone switching. Two gain controls, speakers on–off slide switch, stereo headphone socket.

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AUDIOTRONIC LOW NOISE CASSETTES

TYPE	5	10	25
C60	£1.57	£3.00	£7.08
C90	£2.24	£4.25	£10.00
C120	£2.73	£5.17	£12.24

AUDIOTRONIC 8 TRACK CARTRIDGES

TYPE	Each	5	10
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80M	£1.15	£5.40	£10.25

P&P Cassettes 3p, Cartridges 5p each OVER 10 of either POST FREE!

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5 Microphone inputs each with individual gain controls enabling complete mixing facilities. Battery operated. Size: 235 x 127 x 76mm. Inputs: Mics. 3 x 3mV 50k; 2 x 3mV 600 ohms. Phono. Mag. 4mV 50k; Phono Ceramic 100mV 1 Meg. Output 250mV 100k.

OUR PRICE £8.97 P&P 20p

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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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 listed below.

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AE1 100mW output stage	£1.55
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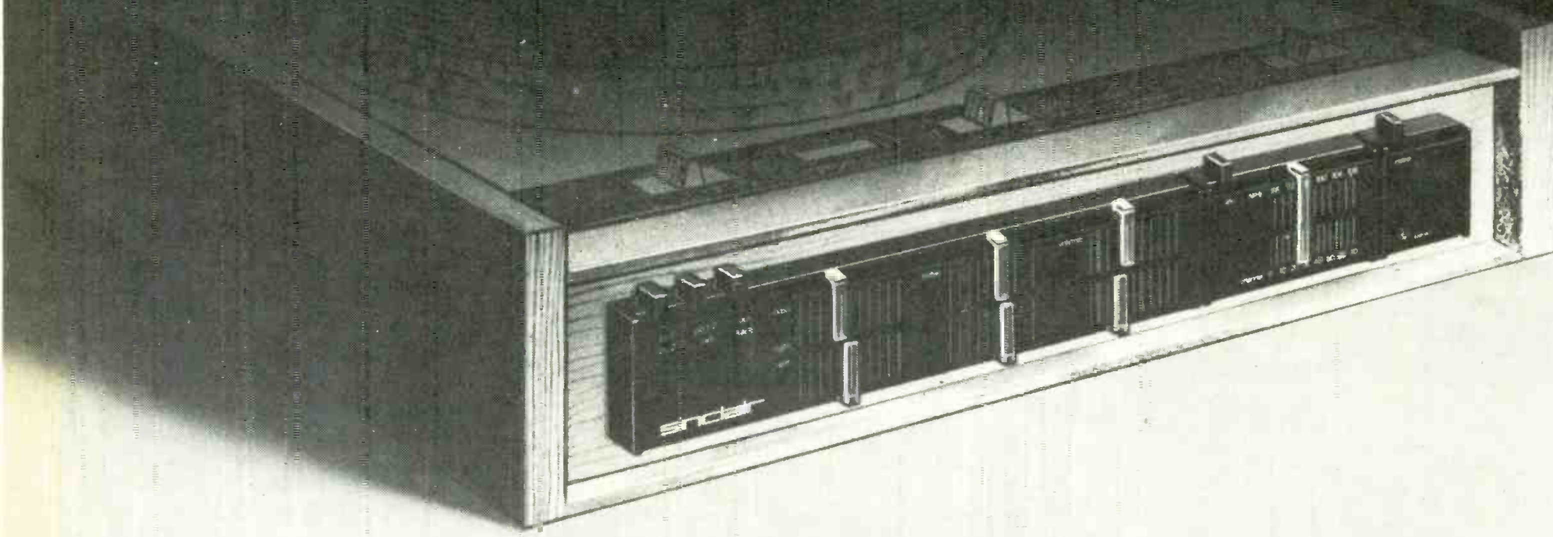
AE6 Monostable multi-vibrator	£1.11
AE7 RC generator	£1.08
AE8 Bass filter	£1.05
AE9 Treble filter	£1.05
AE10 CCIR filter	£1.05

Also see previous page

ALL PRICES EXCLUDE VAT

Project 80

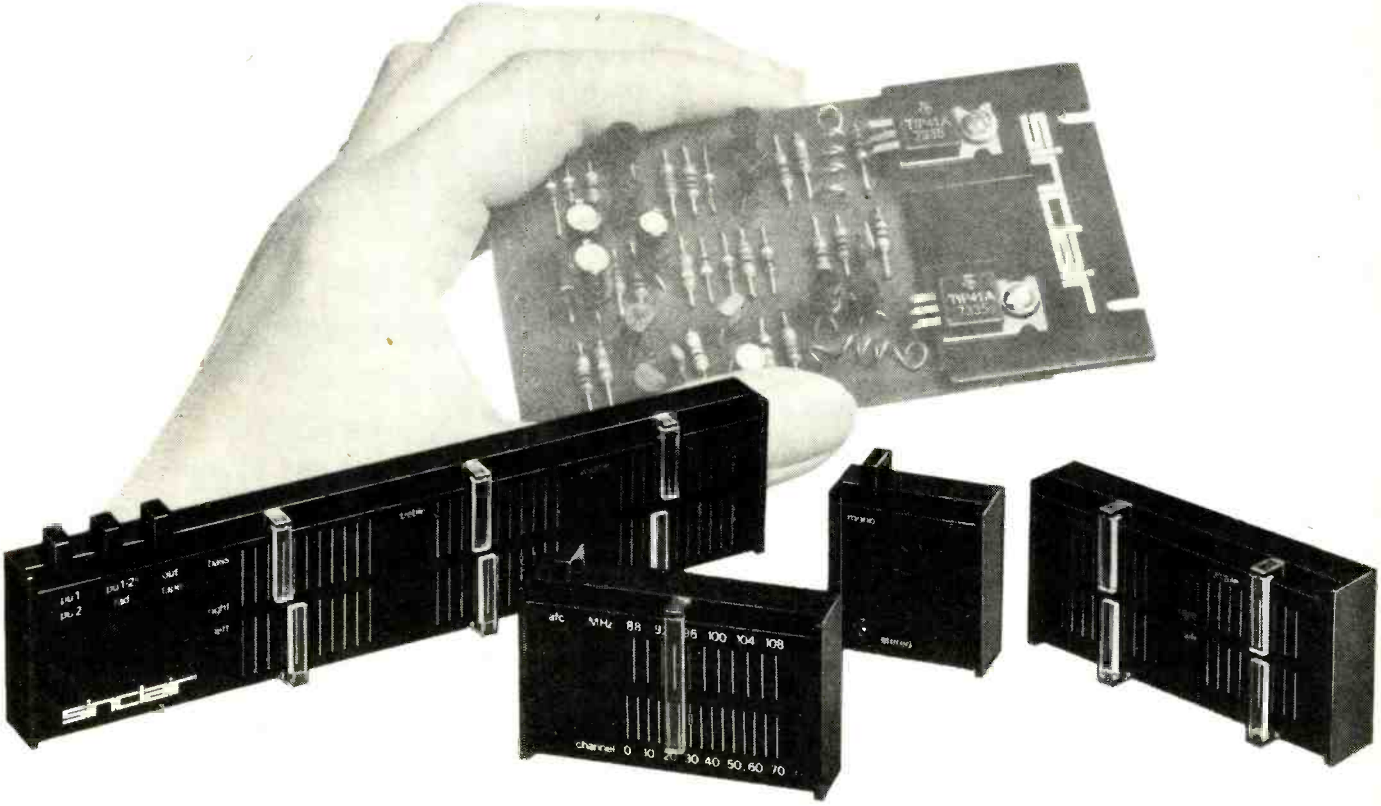
a brilliant new concept in modular hi·fi



Project 80 is going to be the ultimate in modular hi-fi construction for a very long time to come. It combines the qualities most demanded of any modern domestic system – good circuitry, reliability and fine performance – with other features to be found nowhere else in the world. For example, *compactness* – Project 80 control units are $\frac{3}{4}$" deep × 2" high, and each one is completely self-contained. *Elegance* – all of Sinclair's design leadership has been concentrated on producing designs of outstanding functional elegance unsurpassed for styling and simplicity. *Flexibility* – the size and styling of Project 80 modules makes them the most versatile units ever. Combine them how you will, where you will, the Project 80 System of your choice gives you the best.

sinclair

Sinclair Project 80



technically the world's most advanced

Project 80 gives you choice from a range of 9 different modules for combining in a variety of ways to suit your requirements. The Stereo 80 is a versatile pre-amp control unit designed to meet all domestic hi-fi requirements including tape monitoring, high sensitivity magnetic cartridge input, and of course, individual slide controls on each channel for precise output matching. By separating the F.M. tuner and stereo decoder, useful economies can be effected where stereo radio reception is not needed. Two power amplifiers – Z.40 (18 watts RMS continuous into 4 ohms using 35V) and Z.60 (25 watts RMS continuous into 8 ohms using 50V) are available with choice of 3 different power supply units. The PZ.8 with its virtually indestructible circuitry is particularly recommended. For the final word in system building, the Active Filter Unit puts the finishing touch of quality to what are easily the world's most technically advanced hi-fi modules. Any further units likely to be added to Project 80 range will be compatible with those already available.

Stereo 80 Control Unit 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 350mV Radio 100mV; 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 tape radio and P.U. Sliders on each channel for volume bass treble R.R.P. (add £1·19 V.A.T.) **£11.95**

Project 80 FM Tuner Size – 85 × 50 × 20mm (3½ × 2 × ¾ins) Tuning range Dual varicap – 87·5 to 108MHz Detector – I.C. balanced coincidence One I.C. equal to 26 transistors Distortion – 0·2% at 1KHz for 30% modulation 4 pole ceramic filter in I.F. section Aerial impedance – 75 Ω or 240-300 Ω Sensitivity – 5 microvolts for 30dB S/N ratio Output – 300mV for 30% modulation Power requirements – 25 to 35 volts R.R.P. (add £1·19 V.A.T.) **£11.95**

Project 80 Stereo Decoder Size – 47 × 50 × 20mm (1⅞ × 2 × ¾ins) One 19 transistor I.C. Channel separation greater than 30dB Power requirements – 25V Output 150mV per channel R.R.P. (add 74p V.A.T.) **£7.45**

Active Filter Unit Separate controls on each channel. Size – 108 × 50 × 20mm (4¼ × 2 × ¾ins) Voltage gain – minus 0·2dB Frequency response – 40Hz to 22KHz controls minimum Distortion – at 1KHz – 0·03% using 30V supply H.F. cut off (scratch) – 22 KHz to 5·5KHz. 12dB/oct. slope L.F. cut off (rumble) – 28dB at 20Hz. 9dB/oct. slope R.R.P. (add 69p V.A.T.) **£6.95**

Z.40 Power Amplifier Size – 55 × 80 × 20mm (2⅛ × 3⅛ × ¾ins) 9 transistors Input sensitivity – 100mV Output 18 watts RMS continuous into 4 Ω (35V) Frequency response – 30Hz-100KHz ±3dB S/N ratio – 64dB Distortion – at 10 watts into 8 Ω less than 0·1% Power requirements – 12 to 35 volts; built-in protection against overload. R.R.P. (add 54p V.A.T.) **£5.40**

Z.60 Power Amplifier Size – 55 × 98 × 15mm (2⅛ × 3¾ × ¾ins) 12 transistors Input sensitivity – 100-250mV Output – 25 watts RMS continuous into 8 Ω (50V). Distortion – typically 0·03% Frequency response – 15Hz to more than 200KHz ±3dB S/N ratio – better than 70dB Built-in protection against transient overload and short circuiting Load impedance – 4 Ω min. safe on open circuit R.R.P. (add 69p V.A.T.) **£6.95**

Power Supply Units PZ.8 Stabilised. Re-entrant current limiting makes damage from overload or even direct shorting impossible. Normal working voltage (adjustable) 50V. R.R.P. £7·98 + 79p V.A.T. Without mains transformer PZ.6 35V. stabilised R.R.P. £7·98 + 79p V.A.T. PZ.5 30V un-stabilised R.R.P. £4·98 + 49p V.A.T.

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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.

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WW—061 FOR FURTHER DETAILS

AMPLIFIER KITS OF *Distinction*

DESIGNER-APPROVED KIT

In Hi-Fi News there was published by Mr Linsley-Hood a series of four articles (November 1972–February 1973) and a subsequent follow-up article (April 1974) on a design for an amplifier of exceptional performance which has as its principal feature an ability to supply from a direct coupled fully protected output stage, power in excess of 75 watts whilst maintaining distortion at less than 0.01% even at very low power levels. The power amplifier is complemented by a pre-amplifier based on a discrete component operational amplifier referred to as the Liniac which is employed in the two most critical points of the system, namely the equalization stage and tone control stage, positions where most conventional designs run out of gain at the extremes of the frequency spectrum. Unusual features of the design are the variable transition frequencies of the tone controls and the variable slope of the scratch filter. There is a choice of four inputs, two equalized and two linear, each having independently adjustable signal level. The attractive slimline unit pictured has been made practical by highly compact PCBs and a specially designed Toroidal transformer.

Hi-Fi News Linsley-Hood 75 W Amplifier Mk III Version (modifications as per Hi-Fi News April 1974)

Full circuit description in handbook (pack 15—price 30p)

FREE TEAK CASE WITH FULL KITS

KIT PRICE only **£62.40** post free (U.K.)

Pack		Price
1	Fibreglass printed-circuit board for power amp.	£0.85
2	Set of resistors, capacitors, pre-sets for power amp.	£1.70
3	Set of semiconductors for power amp. (now using 8DY56, BD529, BD530)	£6.50
4	Pair of 2 drilled, finned heat sinks	£0.80
5	Fibreglass printed-circuit board for pre-amp.	£1.30
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, 25-0-25 V.	£9.15
11	Fibreglass 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	
	Total cost of individually purchased packs	£69.75

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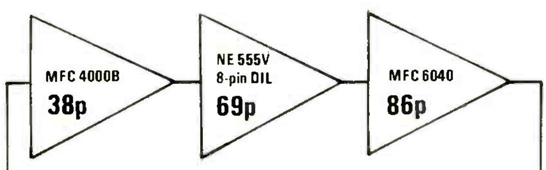
LINEAR I.C.s



CA3046 14-pin DIL 69p	SG1495D 14-pin DIL £2.70
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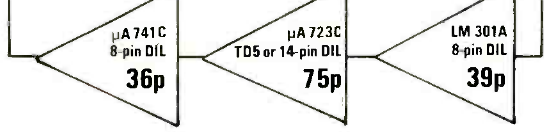

ORGAN BUILDERS

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THE DMO2

13 Master Frequencies on ONE tiny circuit board.
LOOK AT THESE AMAZING ADVANTAGES
★ 13 frequencies from C8 to C9. ★ Each frequency digitally derived from a SINGLE h.f. master oscillator. ★ Initial tuning for the WHOLE ORGAN: ONE SIMPLE ADJUSTMENT. ★ Relative tuning NEVER DRIFTS! ★ External control allows instant tune-up to other musicians. ★ Outputs will directly drive most types of dividers including the SAJ110. ★ And each output can also be used as a direct tone source. ★ Variable DEPTH AND RATE tremulant optional extra. ★ Gold-plated plug-in edge connexion. ★ Complete fibreglass board (including tremulant if required) ONLY 3.7in. × 4.5in. ★ Very low power consumption.

★ EXTREMELY ECONOMICAL PRICE. ★ Ready-built, tested and fully guaranteed.
DMO2T (with tremulant) ONLY £14.25.
DMO2 (without tremulant) £12.25.

★ S.a.e. please for full technical details.

Trade enquiries welcome.

SAJ110 7-stage frequency dividers in one 14-pin DIL package. Sine or square wave input allows operation from almost any type of master oscillator including the DMO2 (when 97 notes are available). Square wave outputs may be modified to saw-tooth by the addition of a few components. SAJ110: £2.63 each OR special price for pack of 12: £25.00. S.a.e. please for data sheet.

Model 120

Centurion

PROFESSIONAL QUALITY

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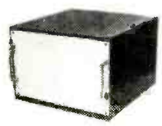
4 Models



Model 120 all-aluminium two-part constructioo. Top and sides, blue hammer finish, front, rear and base: white. Others: mild steel three-part construction.
Top, base, sides and detachable rear panel, blue hammer. Detachable aluminium front panel finished in white.

Dimensions in inches.

Model	W	H	D	Price
120	8	2½	6	£2.87
220	8	6	3½	£3.78
221	8	6	6	£4.07
320	120	8	12	£8.42

Chassis for model 320 £2.34 extra.

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We stock all the parts for the "Electronics Today International" synthesiser including all the P.C.B.s required and all the metalwork including a drilled and printed front panel for a truly professional finish.
Some of the circuits in this brilliant design are entirely original. Independent authoritative opinions agree, the E.T.I. International Synthesiser is technically superior to practically all synthesisers available today. S.a.e. please for our detailed price lists.

WW—025 FOR FURTHER DETAILS

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Pk. 2 Resistors, capacitors, pots	£1.75
Pk. 3 Semiconductor set	£4.70

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Pk. 1 F/Glass PCB	£0.85
Pk. 2 Resistors, capacitors, pots	£2.15
Pk. 3 Semiconductor set	£5.60

20W LINSLEY-HOOD

Pk. 1 F/Glass PCB	£0.85
Pk. 2 Resistors, capacitors, pots	£2.40
Pk. 3 Semiconductor set	£3.35

60V REGULATED POWER SUPPLY

Pk. 1 F/Glass PCB	£0.75
Pk. 2 Resistors, capacitors, pots	£1.40
Pk. 3 Semiconductor set	£3.10

BAILEY-BURROWS PRE-AMP

Pk. 1 F/Glass PCB	£2.05
Pk. 2 Resistors, capacitors, pre-sets, transistors	£4.95
Pk. 3R Rotary potentiometer set	£1.60
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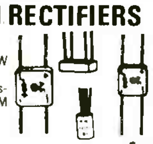

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125	Stereo control unit	6.61	835	Guitar preamp.	4.99
127	Noise reduction unit	9.55	840	Delay car alarm	6.99
130	Mono control unit	4.16	875	CAP. Discharge ignition for car engine (–Ve Earth)	13.19
157	Private TV loop trans	4.95			
605	Power supply for 115	5.31	80	Scope Calibrator	2.65
610	Power supply for 120	5.31	255	Level indicator	6.98
615	Power supply for 2 X 120	6.64	525	120–160mHz VHF timer	11.31
230	AM/FM aerial amplifier	3.29	715	Photo cell switch	8.07
240	Auto packing light	6.90	795	Electronic continuity tester	4.97
275	Mic. preamplifier	6.98	860	Photo timer	15.51
525C	120–160MHz VHF tuner	11.31	235	Acoustic Alarm for driver	8.61
570S	LF generator 10Hz–1mHz	21.45	465	Quartz XTAL checker	9.90
575S	Sq. wave generator 20Hz–20kHz	19.77	220	Signal Injector	2.65
		9.47	390	VOX	£13.62
590	SWR meter		432	Testakit	21.83
630	STAB Power supply 6–12v 0.25–0.1A	9.24	670	Buffer Battery Charger	7.59
690	DC motor speed Gov.	3.31	850	Electronic Keyer	16.37

ALL TYPES OFFERED SUBJECT TO AVAILABILITY. PRICES CORRECT AT TIME OF PRESS. E & OE. 8% VAT TO BE ADDED TO ALL ORDERS.

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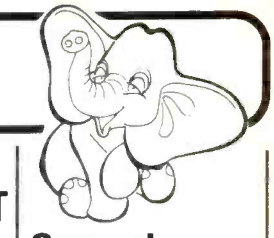


You can build the Texan and Stereo FM Tuner

TEXAN 20 + 20 WATT IC STEREO AMPLIFIERS

Features glass-fibre PC board. Gardners low field transformer, 6-IC's, 10 transistors plug diodes etc. Designed by Texas Instruments engineers for Henry's ad. P.W. 1972. Supplied with full chassis work, detailed construction handbook and all necessary parts. Full input and control facilities. Stabilised supply, overall size 15¼in × 2¾in × 6⅜in mains operated. Free teak sleeve with every kit. **£28.50** (GB post paid).

STEREO FM TUNER

Features capacity diode tuning, led and tuning meter indicators, stabilized power supply—mains operated. High performance and sensitivity with unique station indication IC stereo decoder. Overall size in teak sleeve 8in × 2¾in × 6⅝in.
Complete kit with teak sleeve **£21.00** (GB post paid). Join the large band of happy constructors!

TRANSISTORISED MODULES

Tuners—Power Suppliers—Amplifiers

Amplifiers (All single channel unless stated)

4-300	9 volt	300 MW	o/p 3–8 ohm, 1–10mVi/p	Special offer	£1.75
2004	9 volt	250 MW	o/p 3–8 ohm, 10–10mVi/p	Special offer	£2.70
104	9 volt	1 watt	o/p 8–10 ohm, 10mVi/p		£3.10
304	9 volt	3 watt	o/p 1–8 ohm, 10mVi/p		£3.95
555	12 volt	3 watt	o/p 8–16 ohm, 150mVi/p		£4.10
555ST	12 volt	1½ × 1½ watt	o/p 8 ohm, 150mVi/p	Stereo module	£5.95
E1208	12 volt	5 watt	o/p 4–16 ohm, 25–60mVi/p		£5.10
608	24 volt	10 watt	o/p 4–8 ohm, 30–50mVi/p		£4.95
410	28 volt	10 watt	o/p 8 ohm, 160mVi/p		£4.95
620	45 volt	30 watt	o/p 1–8 ohm, 150mVi/p		£9.95
Z40	30/35 volt	15 watt	o/p 1–8 ohm, 100mVi/p		£5.45
Z60	45/50 volt	25 watt	o/p 1–8 ohm, 100–250mVi/p		£6.95
SA6817	24 volt	6 + 6 watt	o/p 8 ohm, 100mVi/p	Stereo module	£10.20

Amplifiers with controls

E1210	12 volt 2½ + 2½ watts 8 ohms	Stereo	£8.25
R500	Mains 5 watts 4–16 ohms	Mono	£6.30
SAC14	Mains 7 + 7 watts 8 ohms	Stereo	£11.75
SAC30	Mains 15 + 15 watts 8 ohms	Stereo	£14.95
CAO38	9 volt 1½ + 1½ watts 8 ohms	Stereo	£6.95
CAO68	12 volt 3 + 3 watts 8 ohms	Stereo	£10.50

FM Modules

Mullard LP 1186 FM tuner (front end) with data 10.7MHz o/p	£4.85
Mullard LP 1185 10.7MHz IF unit	£4.50
Gorler Permability FM tuner (front end) 10.7MHz o/p	£4.20

FM and AM tuners and decoders

(All models fitted dials supplied with instructions)

FM 5231 (tu 2) 6 volt FM tuner	£7.95
TU3 12 volt version (FM use with decoder)	£7.95
SD4912 Stereo Decoder for Tu 3.12 volt	£7.95
SP62H 6 volt stereo FM tuner	£14.95
A1007 9 volt MW–AM tuner	£4.80
Sinclair 12/45 volt FM tuner stereo recorder for above	£7.45
A1018 9 volt FM tuner in cabinet	£13.95
A1005M (S) 9–12 volt stereo decoder FM for above	£7.50
106Z 12 volt stereo decoder. General purpose	£6.50

Preamplifiers

Sinclair	Stereo 60 Preamplifier	With Controls	£6.75
E1300	CART/TAPE/MIC INPUTS 9 volt	Module	£2.85
E1310	Stereo 3–30mV mal cart 9 volt		£4.75
FF3	Stereo 3mV tape head 9 volt		£4.95
3042	Stereo 5–20mV Mag. cart. mains		£5.95
EQ25	Mono 3–250mV Tape/cart/flat. 9 volt		£1.95

Power Supplies—Mains input (*chassis-rest cased)

470C 6/7½/gear 300mA with adaptors	£2.25
P500 9 volt 500mA	£3.20
HC244R 3/6/7½/9 volt 400mA stabilised	£5.50
*P11 24 volt ½ amp 3.30 *P15 28 volt ½ amp	£3.30
*P1080 12 volt 1A 4.70. *P1081 45 volt 0.9A	£7.80
P12 4½–12 volt 0.4–1 amp	£7.15
SK01A 3/6/8/12 volt 1 amp stabilised	£12.75
P1076 3/4½/6/7½/9/12 volt ½ amp	£4.20
Sk800A 1–15 volt 0–½A stabilised	£17.50

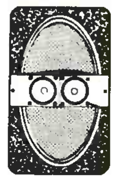
QUALITY CASSETTE TAPES

"Living Sound" made specially for Henry's by EMP Tapes Ltd.
5 screw type with library case. Post paid (GB)

	3 for	6 for	10 for	25 for
C60	£1.10	£2.00	£3.15	£7.50
C90	£1.47	£2.85	£4.65	£11.37
C120	£1.83	£3.54	£5.60	£14.00

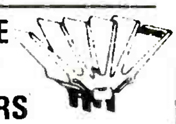
EMI SPEAKERS

Special Purchase



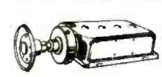
13×8 chassis speakers (carr/packing 30p each or 50p pr)
★150 TC 10 watt 8 ohm twin cone **£2.20**
★450 10 watt 4, 8, 15 ohm with twin tweeters and crossover **£3.85** each
FW 15 watt 8 ohm with tweeter **£5.25**
350 20 watt 8, 15 ohm with tweeter **£7.80** each
*Polished wood cabinet **£4.80** carr., etc., 35p each or 50p pair

EXCLUSIVE 5 WATT IC AMPLIFIERS



Special purchase 5 watt output 8–16 ohm load. 30 volt max DC operation complete with data.
Price **£1.50** ea.
or 2 for **£2.85.**

UHF TV TUNERS



625-line receiver UHF transistorised tuners FM. UK operation. Brand new.
(Post/packing 25p each)
TYPE A Geared variable as illustrated **£2.50**
TYPE B 4-button push-button (adjustable) **£3.50**

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Brand new ex-WD portable radiation detectors 0–10r complete with power unit, haversack and probe (CV2247) PRICE **£9.97** carr/packing £1.00.
Brand new seal photo multiplier units (designed FM fuel tank fire detective) **£3.50.**

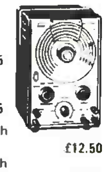
SPECIAL OFFER Cassette Storage

Rotating unit up to 32 cassettes stackable **£3.60** pp 15p
Car unit with bracket for 10 cassettes **£2.80** pp 10p

TEST EQUIPMENT

MULTIMETERS

(carr/packing 35p)



U4324 20KV with case	£9.25
U435 20KV with steel case	£8.75
U4313 20KV with steel case	£12.50
U4317 20KV with case	£16.50
U4341 33KV plus transistor tester steel case	£10.00
U4323 20KV plus IKHzd 465KHz OSC with case	£7.70
ITI-2 20KV slim type	£5.95
THL33D (L33DX) 2KV robust	£7.50
TP5SN 10KV (Case £2.00)	£8.25
AF105 50KV De-luxe (Case £1.90)	£12.50
S100TR 100KV plus transistor tester	£22.50

General Test Equipment

(* carr/packing 30p † carr/packing 50p) unless stated

† 3100 IMA strip chart recorder	£44.00
† Tk40 AC multivoltmeter	£19.75
† Tk15 Grid dip meter 440KHz–28MHz	£16.50
† Tk65 28 range valve voltmeeter	£22.50
† Tk20D RF generator 120KHz–500MHz	£18.95
† Tk220 AF generator 20Hz–200KHz	£19.95
* HM350 In circuit transistor tester	£19.50
* C3025 Compact transistor tester	£6.95
* TT145 De-luxe meter 1–300 MHz	£14.75
† G3-36 R/C osc. 20Hz–200KHz	£19.75
* C3042 SWR Meter	£5.75
* SE350A De-luxe signal tracer	£12.95
* SE400 Mini-lab all in one tester	£15.50
C1–5 Scope 500.000KHz (carr £1.00)	£43.00
* C3043 5 CH F/A meter 1–300MHz	£5.75
Resistance sub box (Post etc 20p)	£2.40
Capacitator (Post etc 20p)	£2.10
2 amp variable transformers (carr £1)	£6.55
Radio activity counter 0–10r (carr £1)	£9.97
Mains unit for above (carr 50p)	£3.75

JOSTY KITS IN STOCK

JOSTY KIT

(Post, etc., 15p each)

AF20	Mono transistor amplifier	£4.80
AF25	Mixer	£3.60
AF30	Mono transistor pre-amp	£2.81
AF35	Emmiter amplifier	£2.27
AF80	Small 0.5W amplifier for mic.	£4.22
AF305	Intercom	£9.52
AF310/2	Mono amplifier (for stereo use two)	£6.87
M160	Multivibrator	£1.71
M1302	Transistor tester	£8.45
M191	Vu-Meter	£4.56
M192	Stereo balance meter	£4.97
LF380	Quadrophonic device	£11.36
AT60	Psychedelic light control, single channel	£7.80
AT65	Psychedelic light control, 3 channel	£14.55
AT25	Window wiper robot	£5.82
AT30	Photo cell switching unit	£5.70
AT50	400w Triac light dimmer speed control	£4.80
AT56	2.200w Triac light dimmer speed control	£6.90
AT5	Automatic light control	£2.58
GU330	Tremelo unit for guitars, etc.	£7.50
HF61	Diode detector	£3.32
HF65	Frequency modulated FM transmitter	£2.70
HF75	FM transistor receivar	£2.87
HF310	FM tuner unit	£15.81
HF325	De-luxe FM tuner unit	£24.12
HF330	Stereo decoder for use with HF310/325	£9.96
GP310	Stereo pre-amp for use with 2. AF 310	£21.27
GP312	Basis circuit board	£11.45
GP304	Basis circuit board	£4.94
HF380	Aerial amplifier for LW to VHF	£4.94
HF395	Broadband aerial amplifier	£1.77
NT10	Power supply 100m/a 9v stab and 12v unstab	£6.15
NT300	Professional stab. power supply	£12.51
NT310	Power pack 2 × 15 volt 2A	£5.71
NT305	Voltage converter	£4.50
NT330	Power pack AF310/GP304	£6.07
NT315	P/S 240v a.c. to 4.5 – 15v d.c. 500m/a	£9.57
AE1	Output stage 100mW	£1.50
AE2	Pre-amplifier	£1.15
AE3	Diode-receiver	£1.82
AE4	Flasher	£0.99
AE5	A stable multivibretor	£0.95
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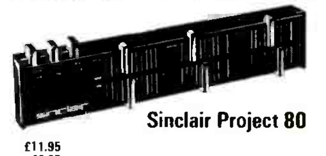
AE7	RC generator	£0.97
AE8	Bassfilter	£0.90
AE9	Treblefilter	£0.90
AE10	CCIR—filter	£0.90

AMATEUR ELECTRONICS by Josty Kit, the professional book for this amateur—covers the subject from basic principals to advanced electronic techniques. Complete with circuit board for AE1 to AE10 (see above). PRICE £3.30 (no VAT).

SINCLAIR MODULES AND KITS



Sinclair Project 80

ST80 stereo pre-amplifier	£11.95
Audio filter unit	£6.95
Z40 15 watt amplifier	£5.45
Z60 25 watt amplifier	£6.95
PZ5 power supplies for 1 or 2 Z40	£4.98
PZ6 power supplies (S. Tab) for 1 or 2 Z40	£7.98
PZ8 power supplies (S. Tab) for 1 or 2 Z60	£7.98
Transformer for PZ8	£3.95
FM tuner	£11.95
Stereo decoder	£7.45

All above post paid (GB only).

PACKAGE DEALS (Carriage/packing 35p)

2 × Z40, S780, PZ5	£25.00
2 × Z60, S780, PZ6	£27.75
2 × Z60, S780, PZ8 + Trans.	£34.40

Sinclair Special Purchases
* Project 60 stereo preamplifier **£6.75** post 20p
* Project 605 kit **£19.95** post 25p
* Cambridge calculator kit **£13.59** post 15p

SINCLAIR CALCULATOR KIT

Complete kit NOW **£13.59** + VAT

Also built **£19.95** + VAT

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ROTARY, CARBON TRACK. *Double wipers for good contact and long working life*

P.20 SINGLE linear 100ohms to 2·2megohms ea. **14p**
P.20 SINGLE log. 4·7Kohms to 2·2megohms ea. **14p**
JP.20 DUAL GANG lin. 4·7Kohms to 2·2megohms ea. **48p**
JP.20 DUAL GANG log. 4·7Kohms to 2·2megohms ea. **48p**
JP.20 DUAL GANG Log/antilog 10K, 22K, 47K, 1 megohm only ea. **48p**
JP.20 DUAL GANG antilog 10K only **48p**
2A DP mains switch for any of above **14p** extra.
Decades of 10, 22 and 47 only available in ranges above.
Skeleton Carbon Presets Type PR, horizontal or vertical **6p** each.

SLIDER

NEW STEREO SLIDERS

Matched tracks. Type PG58ST. Lin of log from 47K to 1 meg **60p**
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**

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**

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0·1, 0·22, 0·47, 1·0 mF/35V, 1·5/20V ea. **14p**
2·2/16V, 2·2/35V, 4·7/16V, 10/6·3V ea. **14p**
4·7/35V, 10/16V, 22/6·3V ea. **18p**
10/25V, 22/16V, 47/6·3V, 100/3V, 6·8/25V, 15/25V ea. **20p**

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**

CERAMIC PLATE

In a range of 26 values from 22 to 6800pF/50V d.c., each **2p**

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, **67p** each. 20W 7·5V to 75V **94p**. Clip to increase 1·5W rating to 3 watts (type 266F), **5p**.
20W 7·5V to 75V **69p** each

VEROBOARD

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**.
0·052 pins (for 0·15 matrix) per 100—**35p**.

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**
3015G showing + or − & 1 & dec. pt. **£1·20**

LEDS (Light Emitting Diodes) **25p**
Photo Cells, each **40p**

THE BEST 100 TRANSISTORS

Taken from our catalogue 7

2N1307	47p	AF200U	70p	BD135	37p		
2N2646	51p	AF239	60p	BD136	39p		
2N3053	26p	B1906	36p	BDY20	83p		
2N3054	60p	BA138	31p	BF194	15p		
2N3055	60p	BB103	24p	BFR39	23p		
2N3702	11p	BB105	34p	BFR79	23p		
2N3703	10p	BB109	18p	BFX29	33p		
2N3704	11p	BC107A	15p	BFX84	27p		
2N3705	10p	BC107B	15p	BFY51	23p		
2N3794	18p	BC108B	14p	BRY39	45p		
2N3819	25p	BC108C	14p	BY164	51p		
2N4062	11p	BC109B	18p	C106B1	42p		
2N4443	93p	BC109C	18p	C106D1	62p		
2N5062	42p	BC147A	12p	C1406	78p		
2N5163	20p	BC147B	13p	MJ481	£1·20		
2N5459	32p	BC148B	12p	MJ491	£1·35		
40361	48p	BC149C	14p	MJ2955	80p		
40362	44p	BC158B	15p	MJE371	89p		
406C2	46p	BC159	15p	MJE521	81p		
40636	£1·36	BC167B	13p	MJE2955	£1·12		
40669	£1·10	BC168B	12p	MJE3055	68p		
AC128	17p	BC169B	12p	OA91	6p		
AC151R	23p	BC169C	13p	SD4	8p		
AC153	27p	BC179B	26p	TIP31A	70p		
AC153K	37p	BC182L	26p	TIP32A	80p		
AC176	24p	BC184L	26p	TIP41A	80p		
AC176K	38p	BC212L	12p	TIP42A	£1·00		
AC187K	31p	BC214L	14p	WO2	30p		
AC188K	29p	BC257A	14p	ZTX300	14p		
AD133	£1·92	BC259B	14p	ZTX304	23p		
AD136	£1·11	BC758	30p	ZTX500	14p		
AD149	65p	BD130	90p	ZTX504	45p		
AD161	42p	BD131	48p				
AD162	40p	BD132	52p				

HUNDREDS MORE IN CATALOGUE 7

RESISTORS

Code	Watts	Ohms	1 to 9	10 to 99 (see note below)	100 up
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	0·97 nett
C	1	4·7–10M	3·2	2·5	1·92 nett
MO	1/2	10–1M	4	3·3	2·3 nett
WW	1	0·22–3·9Ω	11	10	8
WW	3	1–10K	9	8	6
WW	7	1–10K	11	10	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 ⅓W, C ¾W, and MO ½W.
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 ½W 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.

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	—	—	—
10,000	42p	46p	—	—	—	—	—	—

ALUMINIUM BOXES

5 sided + lid (or base)
2¾″ × 5¼″ × 1½″ high, 4″ × 4″ × 1½″ high, 4″ × 2¾″ × 1½″ high, 4″ × 2½″ × 2″ high, each **43p**.
3″ × 3″ × 1″ high **38p**; 4″ × 5¼″ × 1½″ high **48p**;
6″ × 4″ × 2″ high **60p**; 5″ × 3½″ × 2½″ high **52p**

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**

S-DEC

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

For more advanced work with 208 contacts in 38 rows. Will take one 16 lead carrier. **£3·63.** (Carriers supplied separately.)

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Many types including:
T03 Transistor cover, clip-on **7p**
HEATSINK
Type 6WI Extruded aluminium 1° C/W, undrilled **60p**
drilled 2 × T03 **78p**

ANTEX soldering irons

CN340 **£1·95** Spare bits **32p**
CCN240 **£2·30** Spare bits **40p**

DESOLDER BRAID

6 ft strip **66p**

WAVECHANGE SWITCHES

1 pole 12 way; 2 pole 6 way
3 pole 4 way; 4 pole 3 way each **29p**
TAG STRIP 28 way **11p**

NUTS, SCREWS, ETC.

In lots of 100 each
4BA NUTS **28p**; 6BA NUTS **28p**
½″ 4B Screws **28p**; ½″ 6BA Screws **24p**
Threaded pillars 6BA, ½″ hexagonal **£1·68**
Plain spacers ½″ round **£1·12**
Other sizes available

ENAMEL COPPER WIRE in 2 ounce reels

16, 18, 20, 22 SWG **34p**; 24, 26, 28, 30 SWG **40p**
32, 34 **46p**; 36, 38, 40 **5p**

MAGNETO RESISTORS ● FERRITES ● LIQUID CRYSTAL DISPLAYS ● TOUCH SWITCHES ● SPECIAL I.Cs

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KODAK RESIST COATED PRINTED CIRCUIT BOARD

BOARD SIZE	FIBRE GLASS												PAPER	
	1/32"—1 oz				1/32"—2 oz				1/16"—1 oz				1/16"—1 oz	
	Single Sided		Double Sided		Single Sided		Double Sided		Single Sided		Double Sided		Single Sided	
	Positive	Negative	Positive	Negative	Positive	Negative	Positive	Negative	Positive	Negative	Positive	Negative	Positive	Negative
75mm × 100mm	14p	12p	15p	13p	8p	8p	8p	8p	16p	15p	14p	13p	8p	8p
100mm × 150mm	27p	24p	29p	26p	15p	14p	19p	15p	33p	30p	29p	26p	15p	14p
150mm × 200mm	53p	48p	56p	51p	30p	27p	37p	30p	66p	60p	60p	54p	30p	27p
200mm × 250mm	88p	80p	92p	84p	51p	45p	63p	51p	£1·10	£1·00	£1.02	92p	51p	45p
250mm × 250mm	£1·10	£1·00	£1·15	£1·05	65p	55p	80p	65p	£1·38	£1·25	£1·30	£1·15	65p	55p
12" × 6"	80p	70p	85p	75p	55p	45p	65p	55p	£1·00	90p	£1·10	£1·00	55p	45p
12" × 12"	£1·60	£1·40	£1·65	£1·45	£1·05	85p	£1·25	£1·05	£1·95	£1·75	£2·10	£1·90	£1·05	85p

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IF ABOVE SIZES DO NOT MATCH YOUR REQUIREMENTS, ASK FOR QUOTE—CUT TO YOUR SIZE.
THIS IS AN OFFER THAT YOU CANNOT AFFORD TO MISS! ACT NOW!

SMALL ELECTROLYTICS

Ref. No.	Capacity	Voltage	Price	Ref. No.	Capacity	Voltage	Price
H8/2	2·5μF	16V	4p	H7/5	80μF	16V	4p
H8/3	3μF	50V	4p	H7/7	100μF	10V	4p
H8/3A	4μF	50V	4p	H7/7A	150μF	16V	5p
H8/5	5μF	10V	4p	H7/9A	125μF	4V	4p
H8/6A	10μF	10V	4p	H7/10A	160μF	25V	3p
H8/8A	16μF	16V	4p	H7/11	160μF	25V	6p
H8/9A	20uF	70V	4p	H7/11A	150μF	10V	5p
H8/10	22μF	50V	4p	H7/13A	200μF	25V	8p
H8/11	25μF	12V	4p	H7/14	220μF	50V	10p
H8/12	32μF	15V	4p	H7/14A	220μF	16V	6p
H8/12A	30μF	10V	4p	H7/15	220μF	25V	5p
H8/13A	32μF	50V	4p	H7/15A	220μF	35V	10p
H8/14	40μF	25V	5p	H6/1A	250μF	4V	3p
H8/14A	40μF	16V	4p	H6/3A	320μF	2·5V	3p
H8/15A	40μF	35V	4p	H6/4	320μF	10V	4p
H7/1A	50μF	10V	4p	H6/4A	330μF	16V	5p
H7/2A	64μF	2·5V	2p	H6/5	330μF	25V	10p
H7/4	64μF	15V	4p	H6/5A	330μF	35V	15p

NEW! NEW! NEW! NEW!

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

MULLARD ELECTROLYTIC CAPACITORS

071 and 072 series

Type No.	Working Voltage Vdc.	Capacitance μF	Max. Ripple Current at 50°C	Weight	Price
071 16332	25	3300	3·7 amps	1oz	17p
071 15472	16	4700	3·9 amps	1oz	17p
071 15682	16	6800	5·8 amps	1½oz	22p
072 15752	16	7500 + 7500	10·5 amps	3oz	37p
072 15113	16	11000 + 11000	13·8 amps	4½oz	49p
072 14113	10	11000 + 1000	10·6 amps	3½oz	37p
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	16p
072 14173	10	16500 + 16500	13·4 amps	4½oz	49d
106 and 107 series					
106 16223	25	22000	17 amps	10oz	£1·12
107 10222	100	2200	10 amps	5½oz	74p

Type No.	Voltage	Capacitance	Weight	Price
102 15163	16	16000	8oz	40p
104 90003	20	39000	16oz	50p
102 16802	25	8000	7oz	50p
104 90002	40	21000	16oz	£1

A further 10% discount on lots of 100 of any one type.

Please calculate the weight of your order and include appropriate postage.

Not over	Ordinary Parcels	Not over	Ordinary Parcels
		12lb	53p
2lb	23p	14lb	58p
4lb	30p	16lb	63p
6lb	36p	18lb	68p
8lb	42p	20lb	73p
10lb	48p	22lb	78p

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TEST SET FREQUENCY RESPONSE CT381
Frequency range:
10kc/s–33Mc/s in nine directly calibrated ranges. Accuracy ±3% of the indicated centre frequency.
F.M. deviation: (nominal)
0–500kc/s above—4Mc/s
0–400kc/s at 1.5Mc/s—4Mc/s
0–165kc/s at 600kc/s—1.5Mc/s
falling to 3kc/s at 10kc/s.
Output impedance:
75 ohms resistive.
Power supplies:
Mains 100–120V and 180–250V. Frequency 50–500c/s. Consumption 340W (nominal).
Belling Lee radio frequency interference filter type Y2005S. 100 Amps, 400W, 440V, Single wave **£15.**

HEWLETT PACKARD

430C	Microwave power meter.	£60
H01-8401A	Leveller amplifier.	£39
8709A	Synchronizer.	£120
8707A	RF unit holder.	£185
8734B	Pin modulator 7.0–12.4GC.	£95
8732A	Pin Modulator 1.8–4.5 GC.	£65
8431A	Bandpass filter 2–4GC.	£40
797D	Directional Coupler 1.9–4.1GHz.	£30
8436A	Bandpass filter 8–12.4GC.	£95
185A	800MHz Sampling oscilloscope.	
185B	Sampling oscilloscope.	

TINSLEY TYPE 4363E AUTO VERNIER POTENTIOMETER.
PYE Precision vernier potentiometer 7568. 1µV to 1.90100V in two ranges. Accuracy 0.002%.
SULLIVAN T2100 PRECISION POTENTIAL DIVIDER.
Range:
Input: 1, 2, 5, 10, 20, 50, 100, 200, 500, 1000V. Output: 1V, 200 ohms/V. Accuracy of Ratio: 0.001% or better.
CROPICO TYPE P10 PRECISION D.C. POTENTIOMETER.
Main Dial: 17 steps of 0.1 or 0.01V according to the range selected; incorporating a double pole switch which has ⅜" dia. copper studs faced with a 10% gold silver alloy, the multileaf phosphor-bronze brushes are self cleaning. Accuracy ±0.001%.
L30047 CAMBRIDGE UNIVERSAL BRIDGE.
Voltmeter Valve CT54 (Micovac), with mains power supply (power supply not available separately). In strong metal case with full operating instructions. 2.4V–480V AC or DC in 6 ranges, 1 ohm to 10 Megohm in 5 ranges. Indicated on 4 in. scale meter. Complete with probe, **£12.50** including p. and p. (Leads extra.)

TEKTRONIX
NON-PLUG-IN UNIT OSCILLOSCOPE.
515A. DC–15MHz. **£150.**
524AD. DC–10MHz. **£100.**
MAIN FRAME OSCILLOSCOPES:
543. DC–30MHz. 547. DC–50MHz.
545. DC–30MHz. 545A. DC–30MHz.
545B. DC–33MHz. 551. DC–27MHz.
PLUG-IN UNITS.
Type 1A 1.50mV/cm to 20V/cm5mV/cm. Type 1A 2.50mV/cm to 20V/cm. } Not available separately.
Type B. 0.005V/cm to 20V/cm. 0.05V/cm to 20V/cm.
Type CA. 0.05V/cm to 20V/cm.
Type D. 1mV/cm to 50V/cm. Type G. 0.05V/cm to 20V/cm.
Type L. 5mV/cm to 2V/cm. 0.05V/cm to 20V/cm.
Type M. 0.02V/cm to 10V/cm.
230 DIGITAL UNIT.
Digital readout parameters. Pulse amplitude, pulse risetime and falltime, pulse width, time interval.
R116. 10-NS PROGRAMMABLE PULSE GENERATOR
with Delay.
PASSIVE PROBE P6006 with 10X attenuation, designed for oscilloscopes having an input resistance of 1 megohm and input capacitance of up to 55pf. Price **£10.**
PROBE P6065 10X. 10 megohm, 12.5pf, 500V D.C. max. Length 6ft. Price **£15.**

MUIRHEAD FREQUENCY ANALYSER TYPE D-669-B.
Frequency range 30c/s–30kc/s. Accuracy better than 1.5%. Input voltage 300µV–100V for full scale deflexion. Smallest indication 15µV. Maximum input voltage 300V r.m.s. Price **£95.** Full spec. on request.
MUIRHEAD 2-PH. L.F. DECADE OSCILLATOR Type D880.
Frequency range 0.01c/s–11.2kc/s (continuously variable above 0.1c/s).
V.L.F. 0.01c/s–0.1c/s in steps of 0.01c/s. Hourly frequency stability.
Ranges X1, X10, X100 ±0.05% } After
Ranges X0, 1, V.L.F. ±0.1 } 3 hours.
T.F.801D/1/S A.M. SIGNAL GENERATOR.
Freq. range: 10 MHz to 485 MHz. Built-in crystal calibrator. Internal and external sine a.m. External pulse modulation. Calibration Accuracy: Using crystal calibrator, within ±0.2% over entire frequency range. R.F. output level 0.1µV to 1V source e.m.f. **£249.**
OA.1094A/3 H.F. SPECTRUM ANALYSER
with L.F. extension unit type TM6448. Freq. range: 100 Hz to 30 MHz. Measures relative amplitudes up to 60 dB. Spectrum width 0-30 KHz. Sweep duration: 0·1, 0·3, 1, 3, 10, 30 sec. and manual. Full spec on request. **£695.**
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T.111 ROBAND TRANSISTORIZED SUPPLY. Mains input 110V or 230V, output 0–50V at 5 Amperes cont. variable, overload cut-out. **£49.**
REMSCOPE SO1/740 STORAGE OSCILLOSCOPE.
Fluorescence: Yellow, resolution: 40 lines/cm E.H.T.: 8kV, display time: 10 mins–1 hr approx., storage time: 1 week approx. **£128.**
CD 1212 WIDE-BAND GENERAL-PURPOSE OSCILLOSCOPE.
Employing plug-in pre-amplifiers for single or dual trace displays.
Wide-band pre-amplifier CX 1251. Bandwidth: DC –40Mc/s (–3dB ± 1dB); 2.5c/s–40Mc/s AC coupled (–3dB ± 1dB). Rise time 8 nanosec approx. Sensitivity: 50mV/cm–50V/cm in nine calibrated ranges with fine gain control.
Dual trace pre-amplifier CX 1252. Bandwidth: DC –24Mc/s (–3dB ± 1dB) AC coupled. Rise time: 14 nanosec approx. Sensitivity: 50mV/cm–50V/cm in nine calibrated ranges with fine gain control. Full specification on request. **£128.**
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Freq. range: 12 MHz to 485 MHz in five bands. Built-in crystal calibrator. Full spec. on request. **£220.**
CT. 373 TEST SET. Oscillator: 17c/s–170kc/s ±1%, ±1c/s at ambient temp. 0°C–45°C. Distortion Meter: Freq. range: 20c/s to 20kc/s. distortion range: 10%, 30%, 100% f.s.d. 0.5% readable. Signal input: approx. 500mV to 130V basic range, 250mV to 1300V extreme limits. Full spec. on request. **£98.**
AVO MODEL 3 VALVE TESTER. Enables comprehensive characteristics to be plotted or measures valves on a simple good/bad basis. **£55.**
AVO CT 160 VALVE TESTER. As above but in portable valise form. **£65.**
Viewing by appointment only.

JOHN FLUKE
821A VOLTMETER: ±0.01% absolute accuracy, infinite input resistance at nil over entire 0–500V range, standard cell reference, polarity switch, taut-band suspension meter, in-line readout with automatic lighted decimal, no zero controls.
803. DIFFERENTIAL DC/AC VOLTMETER. AC voltage 0–500V in 3 ranges, DC voltage 0–500V in 4 ranges. Full spec. on request.

TF.937 F.M./A.M. SIGNAL GENERATOR.
Freq. range 85 KHz to 30 MHz. The carrier freq. can be standardized against a built-in dual freq. crystal calibrator, which is complete with miniature loudspeaker as an aural beat detector. **£87.**
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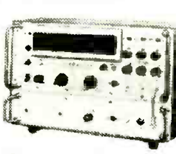
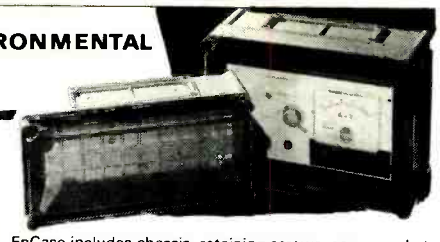
TEST SET DEVIATION FM No 2. The carrier frequency range extends from 2.5Mc/s to 10Mc/s and from 20Mc/s to 100Mc/s in a total of eight bands: the deviation ranges are 0 to 5kc/s, 0 to 25kc/s and 0 to 75kc/s. **£48.**

RACAL UNIVERSAL COUNTER/TIMER SA550 (CT488)



8 digit in-line read-out. Facilities include: direct frequency measurement up to 100 MHz; pulse, period, ratio, time interval and totalising measurements. Input sensitivity variable from 300MV to 9V, three independent inputs, self-check etc. Full spec. on request. **£145.**



EnCase ENVIRONMENTAL HOUSING

A cleverly designed protected polycarbonate enclosure; weatherproof, hoseproof and damp and dust protecting. Its high impact strength will withstand rough handling. The seven sizes can interconnect and any case will extend vertically or horizontally or both, while maintaining full protection. Send for new catalogue.

EnCase includes chassis, retaining screws, cover, gasket and cover-retaining screws; also includes P. & P. and 8% VAT. Many extras available, incl. hinges, etc.

ENA	7½" × 7½" × 5"	£4.90
ENB	11" × 7½" × 5"	£6.28
ENC	15" × 7½" × 5"	£8.39
END	11" × 11" × 5"	£8.58
ENE	15" × 11" × 5"	£10.97
ENF	22" × 11" × 5"	£15.14
ENG	22" × 15" × 7"	£20.91

Prices correct August 1974.

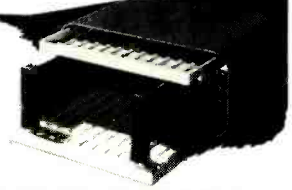
CONTIL SAMOS miniature cases

in easy-to-work blue and white PVC/steel. Assemble in the lower half; complete before springing cover into place—four Pozidrives, two to hinge it, two to fasten it. Carries four P.C. boards horizontally, or two vertically; four required for each case (for one vertical board, two each case).

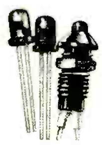
		1 off
S1	100 × 50 × 50mm	87p
S2	100 × 100 × 50mm	99p
S3	100 × 150 × 50mm	£1.12
S4	125 × 50 × 75mm	£1.24
S5	125 × 100 × 75mm	£1.42
S6	125 × 150 × 75mm	£1.67
S7	125 × 200 × 75mm	£1.86

much less for quantity. Prices include P. & P, 8% VAT, four feet and four plated screws.
Special feet to carry Printed Circuit Boards sold separately. Price, incl. 8% VAT, 25p for four PC feet. Prices correct August 1974.

WH Printed Circuit System



is simple, inexpensive, and fits into low-cost West Hyde cases. The System comprises six cards (two styles, three sizes), connectors and five types of board guide. Connectors are double-sided and all contacts gold-plated. Shown: Mod-301 case with boards 421, guides 311, 21-way connectors. Prices: Mod-301 (including chassis) **£3.95**; Connector 21-way **77p**; Boards 421 & 422 **£1** (up to eight DILs on each board); Card guide pairs 311 **£2.26**. Prices include P. & P. and 8% VAT. Much less for quantities.



LEDs with chromium-plated screwed case suitable for 5.5mm. hole or unmounted LEDs 3.2mm. dia.

1 off inc. P & P and 8% VAT

Cased red	**59p**	w/o case	**30p**
Cased green	**70p**	w/o case	**48p**

Much less for quantities. Send for catalogue. Prices correct August 1974.

CONTIL MOD·2

The design of these cases permits the instrument to be built or serviced within their external panels. 48 shapes. Low cost. Blue PVC/steel with white PVC-coated aluminium panels.

	Width	Height	Depth	1 off		Width	Height	Depth	1 off
A	4.5"	3"	6.5"	**£3.59**	M	4.5"	3"	13"	**£4.41**
B	4.5"	7"	6.5"	**£4.41**	N	4.5"	7"	13"	**£5.40**
C	4.5"	10"	6.5"	**£4.88**	O	4.5"	10"	13"	**£6.84**
D	9"	3"	6.5"	**£4.88**	P	9"	3"	13"	**£5.40**
E	9"	7"	6.5"	**£5.40**	Q	9"	7"	13"	**£6.84**
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AC122	0·13	AF116	0·27	BC154	0·33	BD136	0·44
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AC126	0·19	AF118	0·39	BC158	0·13	BD138	0·55
AC127	0·20	AF124	0·33	BC159	0·13	BD139	0·61
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AD130	0·42	BC142	0·33	BCZ10	0·22	BF173	0·24
AD140	0·53	BC143	0·33	BCZ11	0·28	BF176	0·39
AD142	0·53	BC145	0·50	BCZ12	0·28	BF177	0·39
AD143	0·42	BC147	0·11	BD115	0·68	BF178	0·33
AD149	0·55	BC148	0·11	BD116	0·88	BF179	0·33
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BF185	0·33	MPF104	0·41	2G339A	0·18
BF187	0·30	MPF105	0·41	2G344	0·20
BF188	0·44	OC19	0·39	2G345	0·18
BF194	0·13	OC20	0·70	2G371	0·18
BF195	0·13	OC22	0·52	2G371B	0·13
BF196	0·16	OC23	0·54	2G373	0·19
BF197	0·16	OC24	0·62	2G374	0·19
BF200	0·50	OC25	0·42	2G377	0·33
BF222	1·05	OC26	0·32	2G378	0·18
BF257	0·50	OC28	0·55	2G381	0·18
BF258	0·66	OC29	0·55	2G382	0·18
BF259	0·94	OC35	0·46	2G401	0·33
BF262	0·61	OC36	0·55	2G414	0·33
BF263	0·61	OC41	0·22	2G417	0·28
BF270	0·39	OC42	0·27	2N388	0·39
BF271	0·33	OC44	0·17	2N388A	0·61
BF272	0·88	OC45	0·14	2N404	0·22
BF273	0·39	OC70	0·11	2N404A	0·31
BF274	0·39	OC71	0·11	2N524	0·46
BFW10	0·66	OC72	0·16	2N527	0·54
BFX29	0·30	OC74	0·16	2N598	0·46
BFX84	0·24	OC75	0·17	2N599	0·50
BFX85	0·33	OC76	0·17	2N696	0·14
BFX86	0·24	OC77	0·28	2N697	0·15
BFX87	0·27	OC81	0·17	2N698	0·27
BFX88	0·24	OC81D	0·17	2N699	0·39
BFY50	0·22	OC82	0·17	2N706	0·09
BFY51	0·22	OC82D	0·17	2N706A	0·10
BFY52	0·22	OC83	0·22	2N708	0·13
BFY53	0·19	OC139	0·22	2N711	0·33
BSX19	0·17	OC140	0·22	2N717	0·39
BSX20	0·17	OC169	0·28	2N718	0·27
BSY25	0·17	OC170	0·28	2N718A	0·55
BSY26	0·17	OC171	0·28	2N726	0·31
BSY27	0·17	OC200	0·28	2N727	0·31
BSY28	0·17	OC201	0·31	2N743	0·22
BSY29	0·17	OC202	0·31	2N744	0·22
BSY38	0·20	OC203	0·28	2N914	0·16
BSY39	0·20	OC204	0·28	2N918	0·33
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C442	0·33	ZN414	1·20	2N1711	0·22
C444	0·39	2G301	0·21	2N1889	0·35
C450	0·24	2G302	0·21	2N1890	0·50
MAT100	0·21	2G303	0·21	2N1893	0·41
MAT101	0·22	2G304	0·27	2N2147	0·79
MAT120	0·21	2G306	0·44	2N2148	0·63
MAT121	0·22	2G308	0·39	2N2160	0·66
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2N2217	0·24	2N3054	0·51	2N4059	0·11
2N2218	0·22	2N3055	0·55	2N4060	0·13
2N2219	0·22	2N3391	0·16	2N4061	0·13
2N2220	0·24	2N3391A	0·18	2N4062	0·13
2N2221	0·22	2N3392	0·16	2N4284	0·19
2N2222	0·22	2N3393	0·16	2N4285	0·19
2N2368	0·19	2N3394	0·16	2N4286	0·19
2N2369	0·16	2N3395	0·19	2N4287	0·19
2N2369A	0·16	2N3402	0·23	2N4288	0·19
2N2411	0·27	2N3403	0·23	2N4289	0·19
2N2412	0·27	2N3404	0·31	2N4290	0·19
2N2646	0·52	2N3405	0·46	2N4291	0·19
2N2711	0·23	2N3414	0·17	2N4292	0·19
2N2712	0·23	2N3415	0·17	2N4293	0·19
2N2714	0·23	2N3416	0·31	2N5172	0·13
2N2904	0·19	2N3417	0·31	2N5294	0·60
2N2904A	0·23	2N3525	0·83	2N5457	0·35
2N2905	0·23	2N3614	0·74	2N5458	0·35
2N2905A	0·23	2N3615	0·82	2N5459	0·44
2N2906	0·17	2N3616	0·82	2N6121	0·75
2N2906A	0·20	2N3646	0·10	28301	0·55
2N2907	0·22	2N3702	0·13	28302A	0·46
2N2907A	0·24	2N3703	0·13	28302	0·46
2N2923	0·16	2N3704	0·14	28303	0·61
2N2924	0·16	2N3705	0·13	28304	0·77
2N2925	0·16	2N3706	0·13	28305	0·86
2N2926(G)	0·14	2N3707	0·14	28306	0·86
2N2926(Y)	0·12	2N3708	0·09	28307	0·86
2N2926(O)	0·11	2N3709	0·10	28321	0·62
2N2926(R)	0·11	2N3710	0·10	28322	0·46
2N2926(B)	0·11	2N3711	0·10	28322A	0·46
2N3010	0·77	2N3819	0·31	28323	0·62
2N3011	0·16	2N3820	0·55	28324	0·77
		2N3821	0·39	28325	0·77
		2N3823	0·31	28326	0·77
		2N3903	0·31	28327	0·77
		2N3904	0·33	28701	0·46
		2N3905	0·31	40361	0·44
		2N3906	0·30	40362	0·50

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Type	Price	Type	Price	Type	Price
AA119	0·09	BY130	0·18	OA10	0·15
AA120	0·09	BY133	0·23	OA47	0·08
AA129	0·09	BY164	0·55	OA70	0·08
AAY30	0·10	BYX38/30	0·46	OA79	0·08
AAZ13	0·11	BYZ10	0·39	OA81	0·08
BA100	0·11	BYZ11	0·33	OA85	0·10
BA116	0·23	BYZ12	0·33	OA90	0·07
BA126	0·24	BYZ13	0·28	OA91	0·07
BA148	0·16	BYZ16	0·44	OA95	0·08
BA154	0·13	BYZ17	0·39	OA200	0·07
BA155	0·16	BYZ18	0·39	OA202	0·08
BA156	0·15	BYZ19	0·31	SD10	0·06
BA173	0·16	CG62 (OA91 Eq.)	0·06	SD19	0·06
BY100	0·17	CG651 (OA70-OA79)	0·07	1N34	0·08
BY101	0·13	OA5	0·39	1N34A	0·08
BY105	0·19	OA5SL	0·23	1N914	0·06
BY114	0·13			1N916	0·06
BY124	0·13			1N4148	0·06
BY126	0·16			18021	0·11
BY127	0·17			18951	0·07
BY128	0·17				

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Q43	5 BC 107 NPN transistors	0·55
Q44	5 NPN transistors 3 × BC 108, 2 × BC 109	0·55
Q45	3 BC 113 NPN TO-18 transistors	0·55
Q46	3 BC 115 NPN TO-5 transistors	0·55
Q47	4 NPN high gain transistors 2 × BC167, 2 × BC168	0·55
Q48	3 BCY 70 PNP transistors TO-18	0·55
Q49	3 NPN transistors 2 × BFY51, 1 × BFY52	0·55
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100	0·27	0·27	0·52	0·52	0·55	0·63	0·62	1·54
200	0·27	0·32	0·54	0·54	0·62	0·67	0·67	1·76
400	0·32	0·42	0·59	0·62	0·67	0·83	0·77	1·93
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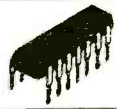

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SN7412	0·30	0·29	0·28
SN7413	0·32	0·31	0·30
SN7416	0·40	0·39	0·38
SN7417	0·40	0·39	0·38
SN7420	0·18	0·17	0·16
SN7422	0·30	0·29	0·28
SN7423	0·40	0·39	0·38
SN7425	0·40	0·39	0·38
SN7426	0·40	0·38	0·36
SN7427	0·40	0·38	0·36
SN7428	0·45	0·42	0·40
SN7430	0·18	0·17	0·16
SN7432	0·40	0·38	0·36
SN7433	0·42	0·40	0·38
SN7437	0·45	0·42	0·40
SN7438	0·45	0·42	0·40
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UIC30 = 12 × 7430	0·55
UIC40 = 12 × 7440	0·55
UIC41 = 5 × 7441	0·55
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UIC43 = 5 × 7443	0·55
UIC44 = 5 × 7444	0·55
UIC45 = 5 × 7445	0·55
UIC46 = 5 × 7446	0·55
UIC48 = 5 × 7448	0·55
UIC50 = 12 × 7450	0·55
UI351 = 12 × 7451	0·55
UIC53 = 12 × 7453	0·55
UIC54 = 12 × 7454	0·55
UIC60 = 12 × 7460	0·55
UIC70 = 8 × 7470	0·55
UIC72 = 8 × 7472	0·55
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UIC74 = 8 × 7474	0·55
UIC76 = 8 × 7476	0·55
UIC80 = 5 × 7480	0·55
UIC81 = 5 × 7481	0·55
UIC82 = 5 × 7482	0·55
UIC83 = 5 × 7483	0·55
UIC86 = 5 × 7486	0·55
UIC90 = 5 × 7490	0·55
UIC91 = 5 × 7491	0·55
UIC92 = 5 × 7492	0·55
UIC93 = 5 × 7493	0·55
UIC94 = 5 × 7494	0·55
UIC95 = 5 × 7495	0·55
UIC96 = 5 × 7496	0·55
UIC100 = 5 × 74100	0·55
UIC121 = 5 × 74121	0·55
UIC141 = 5 × 74141	0·55
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UIC154 = 5 × 74154	0·55
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72709P	DIL	8	0·33	0·31	0·29
72709	DIL	14	0·35	0·33	0·30
72710	DIL	14	0·45	0·43	0·40
72741	DIL	14	0·40	0·38	0·35
72741C	TO-5	8	0·45	0·43	0·40
72741P	DIL	8	0·38	0·36	0·34
72748P	DIL	8	0·38	0·36	0·34
SL201C	TO-5	8	0·50	0·45	0·40
SL701C	TO-5	8	0·50	0·45	0·40
SL702C	TO-5	8	0·50	0·45	0·40
TAA263	TO-72	4	0·80	0·70	0·60
TAA293	TO-74	10	£1·00	0·95	0·90
TAA350A	TO-5	10	£1·85	£1·80	£1·70
µA703C	TO-5	6	0·28	0·26	0·24
µA709C	TO-5	8	0·35	0·33	0·30
µA711	TO-5	10	0·45	0·43	0·40
ZN414	TO-18	4	£1·20	—	—
TBA800	DIL	14	£1·50	—	—

DTL 930 SERIES LOGIC I.C's

Type	1	25	100+
BP930	0·15	0·14	0·13
BP932	0·16	0·15	0·14
BP933	0·16	0·15	0·14
BP935	0·16	0·15	0·14
BP936	0·16	0·15	0·14
BP944	0·16	0·15	0·14
BP945	0·30	0·28	0·25
BP946	0·15	0·14	0·13
BP948	0·30	0·28	0·25
BP951	0·70	0·65	0·60
BP962	0·15	0·14	0·13
BP9093	0·45	0·43	0·40
BP9094	0·45	0·43	0·40
BP9097	0·45	0·43	0·40
BP9099	0·45	0·43	0·40

DUAL-IN-LINE SOCKETS

14 & 16 Lead Sockets for use with DUAL-IN-LINE I.C's. TWO Ranges PROFESSIONAL & NEW LOW COST.

PROF. TYPE No.	1–24	25–99	100up
TSO 14 pin type	33p	30p	27p
TSO 16 ,, ,,	38p	35p	32p
LOW COST No.			
BPS 14 ,, ,,	16p	14p	12p
BPS 16 ,, ,,	17p	15p	13p
BPS 8 pin type	15p	13p	11p

NUMERICAL INDICATOR TUBES

Type	Description	
3015F	Minitron 7 Segment Indicator	£1·50
MAN 3M	L.E.D. 7 Segment Display 0.127" High Characters	£1·90
CD 66	Side Viewing 'Nixie Type' Tube 16 mm.	£1·87
GR 116	Side Viewing 'Nixie Type' Tube 13 mm.	£1·70

3 TERMINAL POSITIVE VOLTAGE REGULATORS

TO.3 Plastic Encapsulation
µA7805/L129 5V (Equv. to MVR5) £1·76
µA7812/L130 12V (Equv. to MVR12V) £1·76
µA7815/L131 15V (Equv. to MVR15V) £1·76

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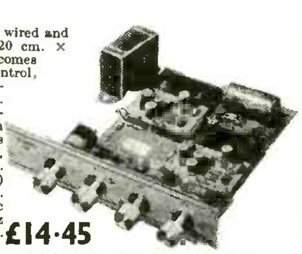
EDSR 3166 TRIPLE 66 BIT DYNAMIC SHIFT REGISTER TTL Compatible. Low Clock Capacitance, High Speed Diode Protected Inputs Wired 'OR' Capability SPECIFICATION SHEET AVAILABLE £2.50

TEAK VENEERED CABINET for: STEREO 20
TC 20. £3.95 p&p 30p

E.M.I. LEK 350 Loudspeaker System Enclosure kit in teak veneer, including speakers. Rec. retail price £45.50 per pr. OUR SPECIAL PRICE £30 per pair P.& P. £1. ONLY WHILE STOCKS LAST!

The STEREO 20

The 'Stereo 20' amplifier is mounted, ready wired and tested on a one-piece chassis measuring 20 cm. × 14 cm. × 5·5 cm. This compact unit comes complete with on/off switch volume control, balance, bass and treble controls, Transformer, Power supply and Power amps. Attractively printed front panel and matching control knobs. The 'Stereo 20 has been designed to fit into most turntable plinths without interfering with the mechanism or, alternatively, into a separate cabinet. Output power 20w peak. Input 1 (Cer.) 300mV into 1M. Freq. res. 25Hz-25kHz. Input 2 (Aux.) 4mV into 30K. Harmonic distortion. Bass control ±12dB at 60Hz typically 0·25% at 1 watt. Treble con. ±14dB at 14kHz.



£14·45

SHP80 STEREO HEADPHONES, 4-16 ohms impedance. Frequency response 20 to 20,000 Hz Stereo/mono switch and volume controls £4.95

TRANSFORMERS

T461 (Use with AL10) £1·60 P. & P. 15p.
T538 (Use with AL20 & AL30) £2·30 P. & P. 15p.
BMT80 (Use with AL60) £2·75 P. & P. 25p

POWER SUPPLIES

PS 12. (Use with AL10, AL20 & AL30) 88p
SPM 80. (Use with AL60) £3·25

PA 12. PRE-AMPLIFIER SPECIFICATION

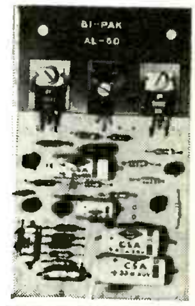
The PA 12 pre-amplifier has been designed to match into most budget stereo systems. It is compatible with the AL 10, AL 20 and AL 30 audio power amplifiers and it can be supplied from their associated power supplies. There are two stereo inputs, one has been designed for use with *Ceramic cartridge while the auxiliary input will suit most †Magnetic cartridges. Full details are given in the specification table. The four controls are, from left to right: Volume and on/off switch, balance, bass and treble. Size 152mm × 84mm × 35mm

PRICE £4·35

Frequency response—20Hz–50KHz (—3dB
Bass control—± 12dB at 60H
Treble control—±14dB at 14KHz
*Input 1. Impedance 1 Meg. ohm Sensitivity 300mV
†Input 2. Impedance 30 K ohms Sensitivity 4mV

FRONT PANELS FP12 50p

NOW WE GIVE YOU 50w PEAK (25w R.M.S.) *PLUS* THERMAL PROTECTION! The NEW AL60 Hi-Fi Audio Amplifier FOR ONLY £3.95

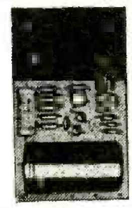


- Max Heat Sink temp. 90°C.
- Frequency Response 20Hz to 100KHz
- Distortion better than 0.1% at 1KHz
- Supply voltage 15-50 volts
- Thermal Feedback
- Latest Design Improvements
- Load—3, 4, 8 or 16 ohms
- Signal to noise ratio 80dB
- Overall size 63mm × 105mm .. 13mm

Especially designed to a strict specification. Only the finest components have been used and the latest solid state circuitry incorporated in this powerful little amplifier which should satisfy the most critical A.F. enthusiast.

FULLY BUILT—TESTED and GUARANTEED

STABILISED POWER MODULE SPM80 £3·25



SPm80 is especially designed to power 2 of the AL60 Amplifiers, up to 15 watt (r.m.s.) per channel simultaneously. This module embodies the latest components and circuit techniques incorporating complete short circuit protection. With the addition of the Mains Transformer BmT80, the unit will provide outputs of up to 1·5 amps at 35 volts. Size: 63 mm × 105 mm × 20 mm. These units enable you to build Audio Systems of the highest quality at a hitherto unobtainable price. Also ideal for many other applications including: Disco Systems, Public Address, Intercom Units, etc. Handbook available, 10p.

TRANSFORMER BMT80 £2·15 p. & p. 25p

STEREO PRE-AMPLIFIER TYPE PA100

Built to a specification and NOT a price, and yet still the greatest value on the market, the PA100 stereo pre-amplifier has been conceived from the latest circuit techniques. Designed for use with the AL60 power amplifier system, this quality made unit incorporates no less than eight silicon planar transistors, two of these are specially selected low noise NPN devices for use in the input stages.
Three switched stereo inputs, and rumble and scratch filters are features of the PA100, which also has a STEREO/MONO switch, volume, balance and continuously variable bass and treble controls.

SPECIFICATION:

Frequency response	20Hz—20kHz ±1dB
Harmonic distortion	better than 0·1%
Inputs: 1. Tape head	3·25mV into 50KΩ
2. Radio, Tuner	75mV into 50KΩ
3. Magnetic P.U.	3mV into 50KΩ
Bass control	±15dB at 20Hz
Treble control	±15dB at 20kHz
Filters: Rumble (high pass)	100 Hz
Scratch (low pass)	8kHz
Signal/noise ratio	better than +65dB
Input overload	+26dB
Supply	+35 volts at 20mA
Dimensions	292 × 82 × 35 mm

All input voltages are for an output of 250mV. Tape and P.U. inputs equalised to RIAA curve within ±1dB from 20Hz to 20kHz.

only £13·15

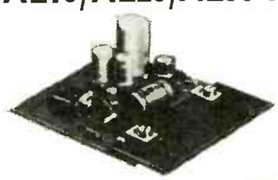
MK 60 AUDIO KIT

Comprising: 2 × AL60, 1 × SPM80, 1 × BTM80, 1 × PA 100, 1 front panel, 1 kit of parts to include on-off switch, neon indicator, stereo headphone sockets plus instruction booklets. Complete Prices: £28·75 plus 30p postage.

TEAK 60 AUDIO KIT

Comprising: Teak veneered cabinet size 16½" × 11¾" × 3¾", other parts include aluminium chassis, heatsink and front panel bracket, plus back panel and appropriate sockets etc. Kit price: £9·95 plus 30p postage.

AL10/AL20/AL30 AUDIO AMPLIFIER MODULES



The AL10, AL20 and AL30 units are similar in their appearance and in their general specification. However, careful selection of the plastic power device has resulted in a range of output powers from 3 to 10 watts R.M.S.
The versatility of their design makes them ideal for use in record players, tape recorders, stereo amplifiers and cassette and cartridge tape players in the car and at home.

Parameter	Conditions	Performance
HARMONIC DISTORTION	Po = 3 WATTS f = 1KHz	0·25%
LOAD IMPEDANCE	—	8–16Ω
INPUT IMPEDANCE	f = 1KHz	100 kΩ
FREQUENCY RESPONSE ± 3dB	Po = 2 WATTS	50 Hz–25KHz
SENSITIVITY for RATED O/P	Vs = 25V. Rl = 8Ω f = 1KHz	75mV. RMS·
DIMENSIONS	—	3" × 2½" × 1"

The above table relates to the AL10, AL20 and AL30 modules. The following table outlines the differences in their working conditions.

Parameter	AL10	AL20	AL30
Maximum Supply Voltage	25	30	30
Power output for 2% T.H.D. (RL = 8Ω f = 1 KHz)	3 watts RMS Min.	5 watts RMS Min.	10 watts RMS Min.
PRICE	£2·20	£2·59	£3·3

All prices inclusive of V.A.T. Giro No. 388 - 7006
Please send all orders direct to warehouse and despatch department

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Beautifully finished in executive case, also available as easy-build kit .... **£29.50 + £2.36 VAT**

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Small, attractively-styled, up-to-the-minute design, 10Hz–30MHz 6-digit .... **£55 + £4.40 VAT**

LED display, also available as easy-build kit .... **£45 + £3.60 VAT**

High-frequency model 10Hz–220MHz minimum, still a full 6-digits and LED display .... **£97 + £7.76 VAT**

Also available as easy-build kit .... **£75 + £6.00 VAT**

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CALCULATORS

All prices VAT inclusive until 1st October, 1974. British made by Advance

162P 40-step programme desk top **£199**

162R as 162 but includes √ **£175**

161R. 1 memory, %, 16-digit √ **£108**

88 2 memory % √, hand-held, with rechargeable batteries, charger, case & desk stand **£99**

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Latest—We have CBS–SQ Logic ICs in stock now! Full logic kit available .... **£27.00 + £2.16 VAT**

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WW10/74

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TRANSFORMERS

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SAFETY ISOLATING

Prim. 120/240V. Sec. 120/240V. Centre Tap with screen

VA (WATTS)	REF. No.	PRICE Cased £	PRICE Plugs 2 Pin + 1 Earth £	PRICE Open £	Post £
60	149	7·35	0·80	4.00	0·38
100	150	8·22	0·80	4·60	0·52
200	151	10·20	0·80	7·40	0·52
250	152	11·68	0·80	8·88	0.65
350	153	14·10	0·80	10·80	0·80
500	154	15·68	0·80	12·38	1·00
750	155	24·63	1·00	18·72	1·20
1000	156	32·19	1·00	26·50	1·20
1500	157	38·18	1·00	30·34	0.A
2000	158	45·20	2·40	34·68	0.A.
3000	159	66·50	2·40	53·35	0.A.

MINIATURE & EQUIPMENT

Primary 240V with Screen

VOLTS Sec. 1	VOLTS Sec. 2	MILLIAMPS Sec. 1	MILLIAMPS Sec. 2	TYPE No.	PRICE £	Post £
3-0-3	—	200	—	238	1·23	0·10
0-6	0-6	500	500	234	1·30	0·10
0-6	0-6	1000	1000	212	1·95	0·22
9-0-9	—	100	—	13	1·23	0·10
0-9	0-9	330	330	235	1·43	0·10
0-8-9	0-8-9	500	500	207	1·75	0·22
0-8-9	0-8-9	1000	1000	208	2·30	0·30
15-0-15	—	40	—	240	1·23	0·10
0-15	0-15	200	200	236	1·30	0·10
20-0-20	—	30	—	241	1·23	0·10
0-20	0-20	150	150	237	1·30	0·10
0-15-20	0-15-20	500	500	205	2·47	0·38
0-20	0-20	300	300	214	1·72	0·22
0-20	—	3500	No Screen	1116	3·00	0·40
20-12-0-12-20	—	700 (D.C.)	—	221	2·31	0·30
0-15-20	0-15-20	1000	1000	206	3·22	0·38
0-15-27	0-15-27	500	500	203	2·73	0·38
0-15-27	0-15-27	1000	1000	204	3·52	0·38

12 and 24 VOLTS PRIMARY 200-240 Volts.

AMPS 12V	AMPS 24V	TYPE No.	PRICE £	Post £
0·3	0·15	242	1·34	0·22
0·5	0·25	111	1·38	0·22
1	0·5	213	1·58	0·22
2	1	71	2·09	0·22
4	2	18	2·58	0·38
6	3	70	3·80	0·42
8	4	108	4·20	0·52
10	5	72	4·80	0·52
12	6	116	5·01	0·52
16	8	17	6·22	0·52
20	10	115	9·47	0·69
30	15	187	11·95	0·97
40	20	232	13·26	1·00
60	30	226	15·30	1·10

30 VOLTS

PRIMARY 200/240V. SECONDARY 12, 15, 20, 24, 30V.

AMPS	Ref. No.	Price £	Post £
0.5	112	1·72	0·22
1	79	2·21	0·38
2	3	3·26	0·38
3	20	4·10	0·42
4	21	4·68	0·52
5	51	5·80	0·52
6	117	6·50	0·52
8	88	8·50	0·67
10	89	8·47	0·67

50 VOLTS

PRIMARY 200/240V. SECONDARY 24, 30, 48, 60V.

AMPS	Ref. No.	Price £	Post £
0·5	124	2·08	0·38
1	126	2·96	0·38
2	127	4·63	0·42
3	125	6·84	0·52
4	123	7·94	0·67
5	40	8·86	0·67
6	120	10·15	0·82
8	121	13·58	1·00
10	122	18·15	1·00
12	189	16·00	1·10

60 VOLTS

PRIMARY 200/240V. SECONDARY 19, 25, 33, 40, 50V.

AMPS	Ref. No.	Price £	Post £
0·5	102	2·33	0·30
1	103	3·00	0·38
2	104	4·57	0·42
3	105	5·20	0·52
4	106	6·89	0·52
6	107	11·17	0·67
8	118	14·19	0·97
10	119	15·47	0·97

BRIDGE RECTIFIERS

	Price
ONE AMP	
50 P.I.V.	0·25
100 P.I.V.	0·25
200 P.I.V.	0·28
600 P.I.V.	0·30
FOUR AMP	
100 P.I.V.	0·55
200 P.I.V.	0·59
400 P.I.V.	0·65
600 P.I.V.	0·75
TWO AMP	
50 P.I.V.	0·35
100 P.I.V.	0·40
200 P.I.V.	0·45
400 P.I.V.	0·50
SIX AMP	
50 P.I.V.	0·65
100 P.I.V.	0·70
200 P.I.V.	0·08
400 P.I.V.	0·90

POWER UNIT TYPE CC12–05

Output switched 3, 4·5, 6, 7·5, 9 and 12 Volts at 500 mA D.C. Operates from 240 V mains, suitable for Radios, Tape Recorders, Record Players etc. Size 7·5 × 5·0 × 14·0 cm. Price £3·95. Post 25p.

AUTO TRANSFORMERS

VA (Watts)	Ref No.	PRICE Cased £	PRICE Plugs 2 & 3 pin £	PRICE Open £	Post £
Tapped at 115, 220, 240 Volts					
20	113	3·00	0·15	1·55	0·30
Tapped at 115, 200, 220, 240 Volts					
150	4	5·80	0·15	3·98	0·39
200	65	6·40	0·15	4·50	0·40
300	66	7·27	0·15	5·28	0·52
500	67	9·99	0·15	8·29	0·67
750	83	12·56	0·75	9·76	0·82
1000	84	15·70	0·75	12·40	0·82
1500	93	19·88	0·75	16·58	1·50
2000	95	30·10	1·44	22·05	1·50
3000	73	43·58	1·90	32·00	1·90

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4″ SIZE: 110mm Wide × 82mm High × 43mm Deep.

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0–50 micro A.	1250	0–50 micro A.	1400
0–100 micro A	580	0–100 micro A.	730
0–500 micro A	170	0–500 micro A.	200
0–1 mA	170	0–1 mA	200
0–5 mA	170	0–5 mA	200
0–10 mA	6	0–10 mA	6
0–50 mA	0·5	0–50 mA	0·5
0–100 mA	0·5	0–100 mA	0·5
0–500 mA	0·5	0–500 mA	0·5
0–1 AMP	0·5	0–1 AMP	0·5
0–2 AMP	0·5	0–2 AMP	0·5
0–25 Volt	15K	0–25 Volt	15K
0–50 Volt	50K	0–50 Volt	50K
0–300 Volt	300K	0–300 Volt	300K
"g" Meter	170	"g" Meter	200
VU Meter	5250	VU Meter	5250

VU Meters are complete with detectors. Modem wide view. Price 2″ £2·95 Post 10p. Price 4″ £3·95 Post 10p. Lamps **55p** per set.

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A reliable unit ideal for timing Bathroom/Toilet Ventilators, Stairway/Cloakroom Lighting etc. Gives up to 30 mins. delay before switching off. Delay: 1–30 mins. adjustable. Max Load: 400 VA or 1000 Watts resistive. Ivory Case: $3\frac{3}{8}$in. × $3\frac{3}{8}$in. × 2in. Fitting Instructions included. Trade Price: £5·80. Post 20p.

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POWER SUPPLY UNIT PN-12A: 230V a.c. input 50-60c/s, 513V and 1025V at 420m/A o/put. With 2 smoothing chokes 9H, 2 Capacitors, 10Mfd 1500V and 10Mfd 600V. Filament transformer 230V a.c. input. 4 Rectifying valves type 5Z3. 2 × 5V windings at 3Amps each and 5V at 6Amp and 4V at 0·25Amps. Mounted on steel base 19in. W × 11in. H × 14in. D. (All connections at the rear.) Excellent cond. **£8·50** each, Carr. £2.
MODULATOR UNIT: 50 watt, part of BC-640, complete with 2 × 811 valves, microphone and modulator transformers etc. **£7·50** each, Carr. £2·00.
CATHODE RAY TUBE UNIT: With 3in. tube, Type 3EG1 (CV1526) colour green, medium persistence complete with nu-metal screen, **£3·50** each, post 50p.
APN-1 INDICATOR METER, 270° Movement. Ideal for making rev. counter. **£1·25**, post 30p.
AIRCRAFT SOLENOID UNIT S.P.S.T.: 24V, 200 Amps, **£2** each, 30p post.
VARIAC TRANSFORMERS: Input 115V, output 0-135V at 2 Amps. **£3** each. 75p post.
RACK CABINETS: (totally enclosed) for Std. 19 in. Panels. Size 6 ft. high × 21 in. wide × 16 in. deep, with rear door. **£12** each, Carr. £2·50.
CLASS "D" WAVEMETER NO. 1 MK. II: Crystal controlled heterodyne frequency meter covering 2-8MHz. Power supply 6V d.c. Good secondhand cond. **£7·50** each. Post 60p.
ROTARY INVERTERS: TYPE PE.218E—input 24-28V d.c., 80 Amps. 4,800 rpm. Output 115V a.c. 13 Amp 400 c/s. 1 Ph. P.F.9. **£17·50** each. Carr. £2·00.
REDIFON TELEPRINTER RELAY UNIT NO. 12: ZA-41196 and power supply 200-250V a.c. Polarised relay type 3SEITR. 80-0-80V 25mA. Two stabilised valves CV 286. Centre Zero Meter 10-0-10. Size 8in. × 8in. × 8in. New condition **£7·50**, Carr. 75p.
TS 15C/AP FLUXMETER: Used to provide qualitative measurements of flux densities between pole faces of magnets. Range 1200-9600 gausses. ±2%. S/hand good cond. **£25** + 60p post.
AUTO TRANSFORMER: 230V 50c/s, 1000 watts. Mounted in strong steel case 5in. × 6½in. × 7in. Bitumen impregnated. **£10** each, Carr. £1.
UHF ASSEMBLY: (suitable for 1000MHz conversion) incl. UHF valves; 2C42, 2C46, 1B40. Complete with associated capacitors and screening; 3 manual counters 0-999. Valves 6AL5 and 8 × 6AK5. **£10** each, 60p post.
TELEPRINTER TYPE 7B; Pageprinter 24V d.c. power supply, speed 50 bauds per min. 'as new' cond. in original packing case, **£25** each; or second hand cond. (excellent order) no parts broken, **£15** each. Carriage either type £3·00.
INSULATION TEST SET: 0-10 kV negative, earth with amplifier provision for checking ionisation. 110/230V a.c. input. S/hand good cond. **£30** + £1 carr.
AUTOMATIC VIBRATION EXCITER CONTROL UNIT TYPE 1016: Manufactured by Bruel & Kjoer. 5-5000c/s per sec. S/hand V. good cond. **£90**, Carr. £2.
VRC 19X MOBILE TRANS/REC: 152-174 mc F.M. Power o/put 25 watts. Input voltage 24v. d.c. Weight 80lbs. **£35·00** each, carr. £3·00.
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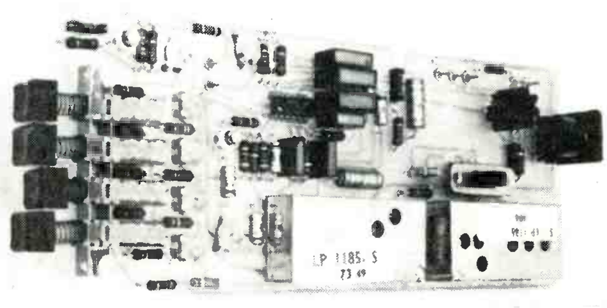

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BC159	14p
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BC171	12p
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BC178	17p
BC179	18p
BC182	10p
BC183	10p
BC184	11p
BC212	11p
BC213	10p
BC214	12p
BC237	12p
BC238	11p
BC239	12p
BC307	11p
BC308	11p
BC309	12p
BC478	
BCY70	18p
BCY71	22p
BD115	55p
BD121	100p
BD123	100p

BD124	65p
BD131	40p
BD132	45p
BD153	65p
BD156	60p
BDY60	75p
BDY61	165p
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BF167	23p
BF170	23p
BF173	25p
BF177	26p
BF178	28p
BF179	33p
BF180	33p
BF181	33p
BF182	33p
BF184	22p
BF185	22p
BF194	11p
BF195	12p
BF196	14p
BF197	15p
BF200	32p
BF257	32p
BFR39	30p
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BFR79	30p
BFR80	30p
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BFX29	30p
BFX30	30p
BFX84	26p
BFX87	20p

BFX88	24p
BFY50	18p
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BSX19	16p
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MJ490	95p
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OC45	11p
OC70	11p
OC71	11p
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0.5A	—	—	—
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4A	55p	65p	75p
6A	65p	90p	100p

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0.5A	—	—	—
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7408	20p	7441	75p	7483	120p
7409	28p	7442	76p	7485	187p
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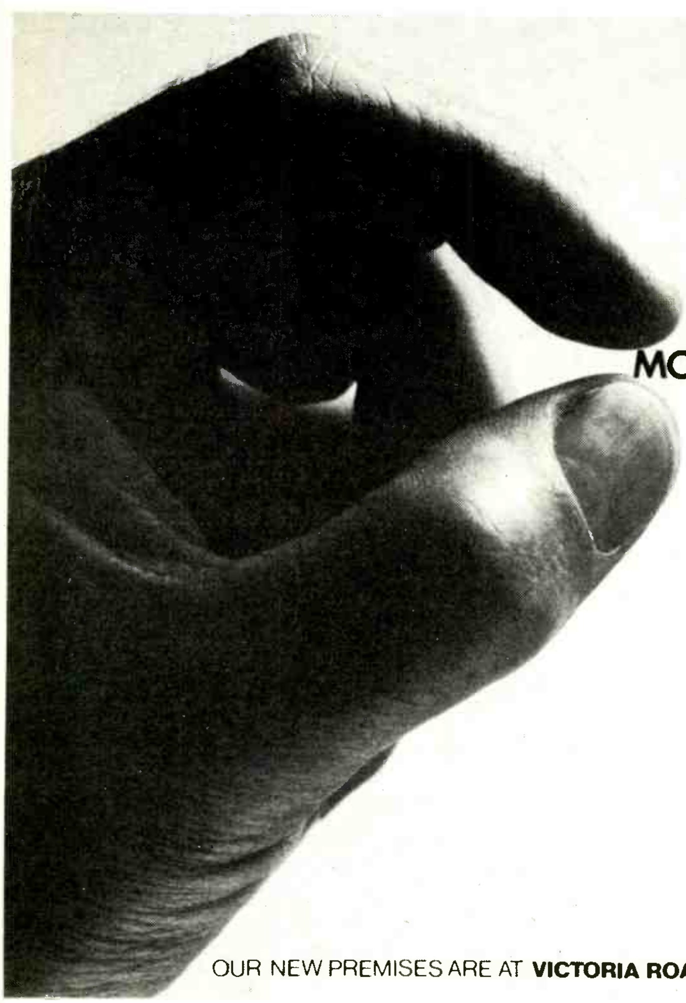

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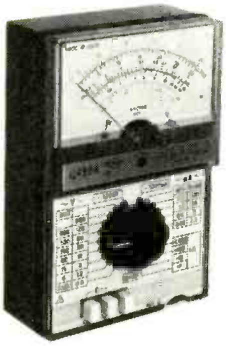

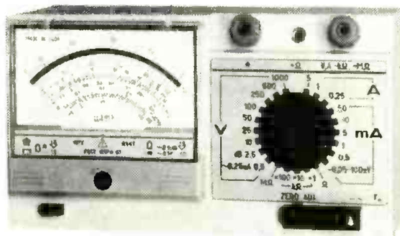

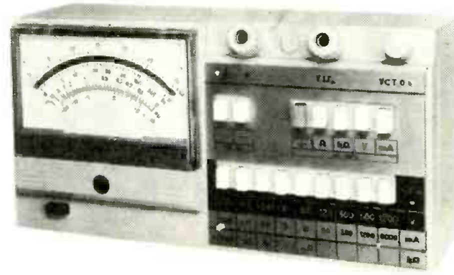

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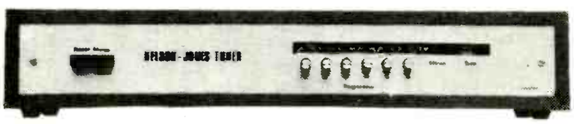

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('WW' JUNE '73)

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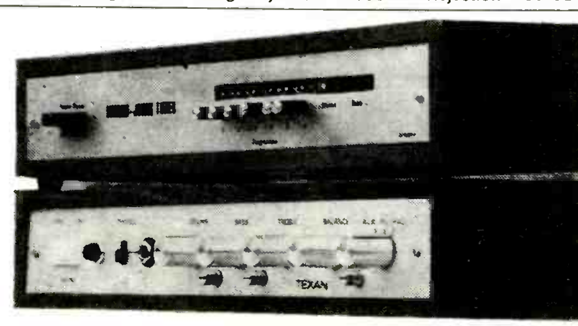

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EZ40	0.70
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EZ80	0.30
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GY501	0.75
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PCF80	0.40
PCF82	0.40
PCF84	0.60
PCF86	0.60
PCF200	0.75
PCF201	0.75
PCF801	0.55
PCF802	0.50
PCF805	0.90
PCF806	0.75
PCF808	0.90
PCH200	0.80
PCL81	0.55
PCL82	0.40
PCL83	0.65
PCL84	0.45
PCL86	0.50
PCL805	0.60
PFL200	0.70
PFL200	0.70
PL36	0.60
PL81	0.50
PL82	0.45
PL83	0.45
PL84	0.45
PL504	0.80
PL508	1.00

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PL509	1.35
PL802	0.95
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PY80	0.40
PY81	0.40
PY82	0.40
PY83	0.40
PY88	0.45
PY500	1.00
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UBF89	0.40
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UBL21	0.70
UCC85	0.45
UCF80	0.75
UCH42	0.75
UCH81	0.45
UCL82	0.45
UCL83	0.65
UF41	0.70
UF80	0.35
UF85	0.45
UF89	0.50
UL41	0.70
UL84	0.40
UY41	0.45
UY85	0.40
VR105/30	0.45

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VR150/30	0.45
X66	0.65
Z800U	2.70
Z801U	2.70
Z900T	1.20
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3D6	0.40
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5Y3GT	0.55
5Z3	0.80
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5Z4TG	0.55
6AB7	0.60
6AC7	0.60
6AH6	0.70

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6AK5	0.40
6AK8	0.40
6AL5	0.25
6AL5 W	0.55
6AM6	0.45
6AN8	0.45
6AQ5	0.45
6AQ5W	0.70
6AS6	0.80
6AT6	0.45
6AU6	0.40
6AV6	0.45
6AX4GT	0.75
6AX5GT	1.00
6B7	0.70
6BA6	0.30
6BE6	0.35
6BG6G	0.90
6BJ6	0.65
6BQ7A	0.60
6BR7	1.20
6BW6	1.00
6BW7	1.00
6C4	0.40

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6C6	0.50
6CB6	0.50
6CH6	1.45
6CL6	0.75
6D6	0.55
6EA8	0.85
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6F23	0.90
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6F33	3.50
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6J4WA	1.25
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6J5GT	0.50
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6J7	0.60
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6K6GT	0.80
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6K7G	0.30
6K8GT	0.50
6K25	1.00
6L6	1.25

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6L6G	0.40
6L7G	0.40
6SA7	0.50
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6SC7GT	0.40
6SG7	0.50
6SJ7	0.55
6SJ7GT	0.35
6SK7	0.55
6SL7GT	0.50
6SN7GT	0.55
6SQ7	0.55
6V6G	0.15
6V6GT	0.50
6X4	0.40
6X5G	0.40
6X5GT	0.50
6Y6G	0.90
6Z4	0.65
6-3OL2	0.90
7B7	0.80
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9D6	0.40
9D2	6.00
12AG	0.55
12AT6	0.45
12AT7	0.40
12AU7	0.33
12AV6	0.50
12AX7	0.33
12BA6	0.45
12BE6	0.50
12BH7	0.50
12C8	0.55
12E1	3.50
12K5	1.10
12K7GT	0.50
12K8GT	0.70
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12SA7GT	0.70
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14S7	1.00
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725A	23.00

A lot of these valves are imported and prices vary for each delivery, so we reserve the right to change prices for new stock when unavoidable.

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Please write or phone for current price of any of the transistors, diodes shown below.

AC113, AC126, AC127, AC128, AC176, ACY18, ACY19, ACY20, ACY28, ACY39, ACY40, AD149, AD161, AD162, ADZ11, ADZ12, AF114, AF115, AF116, AF117, AF118, AF124, AF125, AF126, AF127, AF139

AF178, AF186, AFZ12, ASY26, ASY27, ASY28, BC108, BC118, BC119, BC136, BC137, BC148A, BC172, BC172A, BC212A, BCY31, BCY33, BCY72, BF115

BF167, BF185, BFY51, BFY52, BFY90, BSY27, BSY38, BSY95A, BYZ16, CRS1/10, CRS1/20, CRS1/30, CRS1/40, CRS3/10, CRS3/20, CRS3/30, CRS3/40, CRS25/025, GET115

GET116, GEX66, NKT222, OA5, OA47, OA70, OA71, OA73, OA79, OA91, OA200, OA202, OAZ200, OC22, OC22, OC26, OC28, OC29, OC39

OC36, OC42, OC44, OC45, OC70, OC73, OC78, OC78D, OC81, OC82, OC82D, OC82DM, OC83, OC139, OC140, OC170, OC172, OC200, OC206

SX754, ZR11, ZR21, 1N23A, 1N25, 1N32A, 1N38A, 1N43, 1N70, 1N277, 1N415C, 1N4148, 2N456A, 2N708, 2N918, 2N1304, 2N1305, 2N1307, 2N1309

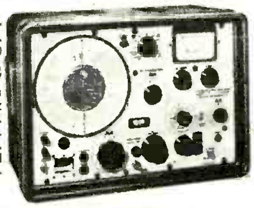
2N2062, 2N2147, 2N2411, 2N2989, 2N3053, 2N3054, 2N3055, 2N3390, 2N3391, 2N3730, 2N3731, 2N3819, 2N4038, 2N4058, 2N4061, 2N4785, 2N5295, 3N128, 3N154, 3N159, 2S303, 404, 2082, 40250, 40251, 40668

VALVES AND TRANSISTORS

Telephone enquiries for valves, transistors, etc., retail 749 3934; trade and export 743 0899.

OTHERS IN STOCK inc. Integrated circuits, CRT & special valves. Min. Mail Order £1. U.K. Postage £1-£2, 17p, £2-3, 22p, over £3 free. C.O.D. 25p extra.

BEST PRICES PAID FOR TEST AND COMMUNICATION EQUIPMENT. Single items or quantities. Private or Industrial.



TF144H SIG-NAL GEN. Freq. range 10 KHz-72 MHz, R.F. output 2µV to 2V at 50 ohms 400 and 1000 Hz internal mod. Limited qty. only available. Full spec. and price on request.

TEXTRONIC 585 OSCILLOSCOPE
DC to 100MHz. Separate time bases with delay and 5X magnifier. Time base A: 0·05 microsecs to 2 sec/cm in 24 stages also continuously variable between steps. Time base B: 2 microsecs to 10 sec in 18 stages. Delay 1 microsec to 10 sec. Complete with type 81 adaptor enabling use of all letter series plug ins. Type 80 plug-in (less probe) also available.

MARCONI TF 1060 SIGNAL GENERATOR. Freq. range 450-1250MHz in one directly calibrated band. Output piston attenuator 0·15 microvolts—445mV at 50 ohms. Modulation: internal signal 1000Xz at 30%. External pulse 1 microsec or longer at 30v min.

SOLOTRON CD 1400 OSCILLOSCOPE SYSTEM
Available with a choice of "Y" or "X" plug-ins: wide band 15MHz, high gain differential, standard time base, slow speed, delayed sweep. Prices on application depending on combination selected.

500/250W MEDIUM WAVE BROADCAST TRANSMITTERS. Price and details on application.

M.O. for ET 4336 TX (see description in previous issues) £8·50, P. & P. £1·50.

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SPRAGUE 20,000 MFD 55VDC £1·30.
MALLORY 20,000 MFD 30V (45VDC surge) £1·15.
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SIGNAL GENERATOR TF 801B as for TF 801D/1/3 except for minor circuit changes, e.g. 1 and 2 MHz switched calibrator, £175.00.

SCHLUMBERGER 6 500a SYNC. OSCILLATOR 200-500MHz. £95·00

PLESSEY PR 524 DUAL DIVERSITY RECEIVER. Freq. 2-30 MHz. Solid state, six pre-selected channels with motorised tuning, automatic receiver selection and indication. Complete with FSK terminal unit and spare coils for turret tuners. All housed in table top cabinet. £100·00

ROHDE & SCHWARTZ MICROWAVE POWER METER. 3200MHz, built-in calibration, 50Ω. £120·00

TF 1102 AMPLITUDE MODULATOR Amplitude modulates at up to 80% the C.W. or F.M. output of any signal generator with a frequency range of 100kHz to 500MHz. Input waveforms to the modulator may be: sine, square, pulse or picture at any level up to H1 impedance, Mod level monitored on panel meter. £40·00

★ **Open 9-12.30, 1.30-5.30 p.m. except Thursday 9-1 p.m.** ★

TF1041C VTVM A.C. voltage range 300 MV to 300V in 7 ranges, 20 Hz-1500 MHz. D.C. voltage ranges 300 MV 1000V in 8 ranges. D.C. resistance 50 ohms to 500 ohms. Price £62·50.
TF 1041B. Spec. as for 1041C. £52·50.

HEWLETT—PACKARD
185A 800 MHz SAMPLING OSCILLOSCOPE WITH 188A DUAL TRACE PLUG-IN. Full spec. and P.O.A.
175A 50MHz Oscilloscope.
5248 COUNTER FREQUENCY MEASUREMENT: 10Hz to 10,1MH2. Accuracy : 1 count. Automatic positioning of decimal point. Period measurement: 0-10kHz, reads in seconds, milliseconds or microseconds, decimal point automatically positioned. Display on 6 neon lamp decades and 2 meters. Complete with manual and following plug-ins: **525A** 10 to 100MHz, **525B** 100 to 220MHz, **526A** video amplifier. Price on application.
200CD WIDE RANGE OSCILLATOR 5Hz to 600kHz £60.00.
616B SHF SIGNAL GENERATOR. Freq. range 1,75GHz-4,2GHz. Mod.: F.M., C.W. Pulse and Ext. A.M., output 0,1uV-200mW. Price on application.

TF 1258A VHF SPECTRUM ANALYSER for analysis and measurement of Radar Equipment. Frequency range 190 to 230MHz with crystal check points. Sweep width 0·5 to 5MHz, output pulse delay (*a*) 85-175 µSec, (*b*) 0·7-1·4 mSec with ×1 and ×2 multiplier and ÷2, ×1, ×2 multiplier. Output 2µV to 20mV with ×10 multiplier. £200.

TF 1370 R-C OSCILLATOR, SQUARE AND SINE WAVE. Freq. Sinewave 10Hz-10MHz, squarewave 10Hz-100kHz. Direct output: sinewave: 0-31.6V rms., 10Hz-1MHz, squarewave: 0-73.2pp 10Hz-100kHz. Attenuator range: −50dB to +10dB. Impedance: 75, 100, 600Ω. Price upon application

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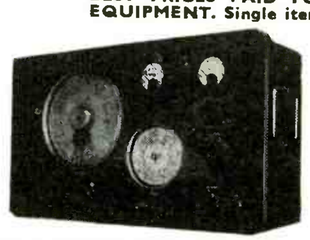
THYRISTOR TEST SET, complete untested £50.

TEST EQUIPMENT
for direct line for all enquiries regarding test equipment only, phone 01-748 5496.



TF 801D/1/S SIGNAL GENERATOR. Range 10-485 MHz in five ranges. R.F. output 0·1 µV-IV source e.m.f. Dial calibrated in volts, decibels and power relative to thermal noise. Piston type attenuator. 50Ω output impedance. Internal modulation at 1 kHz at up to 90% depth, also external sine and pulse modulation. Built-in 5MHz crystal calibrator. Separate R.F. and mod. meters. P.O.A.

TEKTRONIX OSCILLOSCOPES
571A-600MHz, separate P.S.U. £150 complete.
561A-10MHz, solid state, complete with 3A1 dual trace vert. and 3B3 delay time base plug-ins P.O.A.
541A-33MHz. Choice of plug-ins. P.O.A.
LA265A(545A)-33MHz, separate time bases with delay. P.O.A.
545-15MHz. Separate time bases with delay. Price on application.
PLUG-IN UNITS
CA—24 MHz dual trace 50MV-20V.
G—20 MHz differential 50MV-20V.
L—30 MHz fast rise time 5MV-20V.
D—High gain differential 1MV-50V.
N 600MHz sampling 10MV-cm.
53/54C. Dual trace 33MHz, 60MHz, 0.05-20v.

3 PHASE AUTO TRANSFORMER, wye input 400v, wye output 241.5/230/218.5v 50c 18kVA. Made by Westinghouse of USA. Brand new in original cases £60,00 including UK transport.

PLEASE ADD 8% VAT

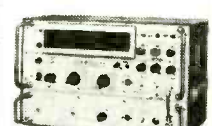
894 TF AUDIO TESTER. Combined A.F. Generator (0-25kHz), Output meter (up to 2W. at 600, 15 and 3Ω,) and valve voltmeter (0-800V.), with stepped and variable attenuators. £60.

TF 1400S DOUBLE PULSE GENERATOR WITH TM 6600/S SECONDARY PULSE UNIT. For testing radar, nucleonics, 'scopes, counters, filters etc. **SPEC. TF 1400S.** Rep. freq. 10Hz to 100kHz, pulse width 0·1 to 100µ sec., delay −1·5 to +3000µ sec., rise time 30N sec. **SPEC. TM 6600/S.** As for TF1400S except pulse width 0·5 to 25µ sec., delay 0 to +300µ sec. £230.

TF 526B OSCILLATOR AND DETECTOR UNIT £50·00.

TF 1226B, TF1225A, TF 577A. WHITE NOISE TEST SET £185·00. Full spec. on request.

RACAL UNIVERSAL COUNTER/TIMER SA550 (CT488)



8 digit in-line read-out. Facilities include: direct frequency measurement up to 100MHz; pulse, period, ratio, time interval and totalising measurements. Input sensitivity variable from 300MV to 9V, three independent inputs, self-check etc. Full spec. on request. £145.

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PLEASE NOTE

Unless offered as "as seen"

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RCA ET 4336 also modified version of increased output to 700w.
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C-13 TRANSMITTERS
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FABULOUS Marconi

MARCONI Type TF144H STANDARD SIGNAL GENERATOR

Frequency range: 10kHz–72MHz. Crystal Check: 400kHz and 2MHz crystals. Stability: 0.002% in 10 minute interval.

Full specification available on request

£245

MARCONI TF867 STANDARD SIGNAL GENERATOR

Carrier Frequency. Range: 15Kc/s—30Mc/s in 11 bands. Calibration Accuracy: ± 1%. Output Voltage: 0.4µV–4V. Impedance: 75 ohms nominal for outputs from 2–4V 75 ohms for outputs from 4µV–2V. 13 ohms for outputs from 0.4µV–0.4V. Accuracy: below 3Mc/s ± 0.25dB to ± 0.1µV, 3–10Mc/s ± 0.5dB or 00.2µV. 10–30Mc/s ± 1.0dB or ± 0.5µV. Power Supply: 100–125V, 200–250V, 40–100c/s. Dimensions: 18 in. high x 21in. wide x 14½in. deep.

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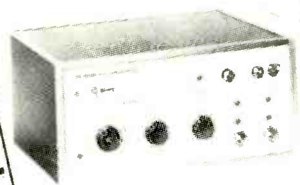
ADD 8% VAT TO ALL PRICES

ADVANCE SQUARE WAVE GENERATOR SG21

Frequency Range 9Kc/s to 100Mc/s. Rise time less than 1nS Ex-Demonstration. New condition in manufacturer's original carton.



9Kc/s to 100Mc/s continuously variable.
Accuracy ± 4%. ± 1% F.S.
MAIN OUTPUT 20mV–1V into 50 ohm external termination continuously variable.
Accuracy ± 5%.
Maximum output on open circuit 2V.
RISE TIME less than 1nS up to 500mV.
TRIGGER OUTPUT
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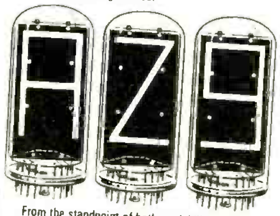
Rise time nominally 1.5nS.
Fall time nominally 3.5nS
Size: 11inW. 5½inH. 9inD.
Wt. 7.1 lb.
LAST LISTED PRICE £95

OUR PRICE £35 P/P £1.50
Also available SG21A 100Kc/s–30Mc/s.

ALPHANUMERIC NIXIE TUBES B7971

The Alphanumeric NIXIE tube has the ability to display all the letters of the alphabet, numerals 0 thru 9 and special characters in a single tube.



From the standpoint of both readability and electrical characteristics, the Alphanumeric NIXIE tube provides many unique benefits including ★ All DC operation ★ Uniform, continuous line characters of equal height ★ Memory with simple solid state drive circuits ★ Readability in high ambient light ... 200 footlamberts brightness ★ Long life with no loss of brightness ★ Character height 2½ins.

Price only 99p each plus 16p

JUST ARRIVED NIXIE TUBES NUMERIC ONLY. PHONE FOR DETAILS LARGE QUANTITIES

HERE! NOW! FOR IMMEDIATE DELIVERY!

AVO 7 £19.50

Fully tested and checked, guaranteed 12 months with one free calibration.

AVO MODEL 7X £24

Leads and batteries extra. Leather cases for above £3.50. Ever-ready case enables the meter to be used while in its case £5.

***Please note: X stands for fully tropicalised, splash-proof and mu-metal shield.**

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SAVE OVER 50% ON ORIGINAL COST

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* Complete with electronics for interfacing to DEC PDP8

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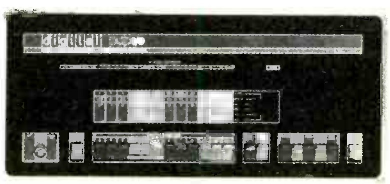

PDP8E 12K Processor complete with
Facit 4001 High Speed Reader (500 cps)
Data Dynamics BRPE 114 Punch (110 cps)
ASR33 Teletype
Sperry J101 8 megabit Memory Drum
Line Printer
Rack-mounted in double cabinet

PDP8E 4K Processor complete with
Facit 4001 High Speed Reader (500 cps)
Data Dynamics BRPE 114 Punch (110 cps)
ASR33 Teletype
Complete in cabinet

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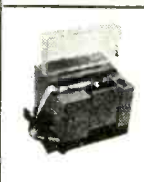
Selective Level Oscillator 10KHz-14MHz TFPS 42. **£349.**

TELETYPE PUNCH

BRPE High-speed punch. Self-contained, consists of punch unit, base, motor unit. For use in many data communication systems. Operating speeds up to 100 characters per second (1100 words per minute). Available for punching 5, 6, 7, or 8, level codes, into 11/16", 7/8" tape. Synchronous, parallel-wire input. **£145**



WELMEC 7 & 8 HOLE ELECTRO-MECHANICAL PUNCHES & READER

Models S110 and R82C, 17 char. per sec. Rebuilt, available from stock. **£45.**

ICT KEYBOARDS

In original packing—Numerical from **£4·50.**

ICT KEYBOARDS

In original packing—Alpha-numeric. Prices from **£15·00.**

Magnetic Tape Transporters AMPEX TM4, TM2, TM7, FR300 IBM 7330, POTTER. From **£89.00.**

TAPE READERS

Photo-electric Readers for all colour paper tapes up to 1 in.
1CL Type 2640 (250 cps). Elliott T2/94 (250 cps). Elliott D4/42 (500–1,000 cps).
Available with full warranty.
Prices from **£220.**

HEWLETT PACKARD DIGITAL RECORDER MODEL 565A

Data Entry, parallel to 11 columns. Print speed 5 lines per second. **PRICE £85·00.**

Stop Press

VERY LATEST TEKTRONIX 100MHz Dual Trace Oscilloscope 465.
Listed at over £1000. **Our Price £775.**
TEKTRONIX 453A Listed at over £1300.
Special Offer this month £795.

BONANZA!

LIMITED QUANTITY
Made to meet the most stringent Government Service Standards

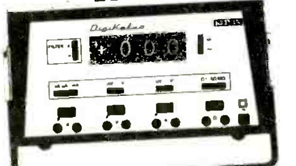
DC–40MHz DUAL TRACE

Solartron C.T.484 oscilloscope. 3% accuracy. Dual Trace Displays.

DUAL TRACE Y AMPLIFIER. Bandwidth: D.C.–24 Mc/s. Rise Time: 14 nanosecs. Sensitivity: 50 mV/cm. Input Impedance: 1 M.ohm 26pF. Measuring Accuracy: ±5% direct, ±3% with calibrator.
TIME BASE. 100 nanosecs/cm–5 secs/cm or continuously variable up to 12 secs/cm. Sweep expansion X 5. Accuracy: ±3%.
X AMPLIFIER. Bandwidth: D.C.–150 Kc/s. Input Sensitivity: 200 mV/cm and 1 V/cm. Input Impedance: 1 M.ohm 40 pF.
INTERNAL CALIBRATOR. Accuracy: ±3%.
WIDE BAND Y AMPLIFIER PLUG ALSO AVAILABLE: Bandwidth: D.C.–40 Mc/s. Rise Time: 8 nanosecs. Sensitivity: 50 mV/cm. Input Impedance: 1M.ohm 22pF Measuring Accuracy: ±5% direct, ±3% with calibrator.
P.O.A.

£149.50

SPECIAL OFFER
Brand New Digital Volt Meter
NEW LOW, LOW PRICE £37.50



★ With 4 independent inputs ★ 3 digits plus polarity ★ range switching without breaking current measuring circuit ★ High input impedance on voltage ★ low input impedance on current.
Frequency Range 300Hz–500Hz on volts. Measures 0.01mV–600VDC. 1nA–999mA current. 1mV–500VAC. 100nA–999mA.
NEW CONDITION IN MANUFACTURER'S ORIGINAL PACKING

PRECISION A.C. MILLIVOLTMETER VF 252 BY SOLARTRON

£75

* 1% Accuracy on all ranges
* 0.5% Long Term Stability
* 1.5mV–150V f.s.d. Sensitivity Range
* < 20μV Internal Noise
* 6in. Linear Scale calibrated in volts and dB
* > 30MΩ Input Resistance
* Isolated or Balanced Input

DIGITAL MAGNETIC TAPE DECK

These machines, originally ex-computer, are multi-track recording units, ideal for data storage. Record and Replay Heads encased in one common unit. Low resistance heads. Bit density 557 b.p.i. ½ in., 10¼ in. spools. 230V to 380V. Capstan motor speed 1,500 r.p.m. 48V DC rewind motors. Finished in brush aluminium and matt black. Size 27 in. X 26 in. X 8 in. Weight 90 lbs.

NEW LOW PRICE £49.50
Vacuum Assembly £15 extra.
Tape £1.50 extra.

6V 25A Power Supplies

10% VARIABLE VOLTAGE HIGH CURRENT HIGH STABILITY HIGH RELIABILITY

These power supplies were designed for continuous operation in computer equipment. Manufactured to highest engineering standard for long-term reliability and stability. Independent voltage and current meters. C Core Transformer.
Manufacturer's price probably in excess of £200.

£25

OSCILLOSCOPE CT 436
Commercial Designation Solartron CD1014

General Purpose Dual Beam DC-6MHz flat faced double gun cathode ray tube operating at 1.6kV. The time base velocity is continuously variable between 1cm/usec. and 1cm/sec.
TIME BASE Free running or triggered from positive or negative pulses. Sweep speed 1cm/usec to 1cm/sec.
Synchronisation: positive or negative going internal from either channel or external continuous waves.
Internal 3mm P/P.
External 100mVP/P.
Sensitivity 100mV/cm, maximum on Y2 amplifier 1mV/cm.
Size 9½" X 11½" X 15". Wt. 25 lb.
PRICE: **£69.50.**

RCA 301 TAPE DECK MODEL 381

PRICE **£29.50**

Technical Data. ½" wide Magnetic Tape. Power supplies: Input 208-230V AC 60 c/s. Single phase Magnetic recording head. read/write and erase. Seven channels each head. Speed 30"/sec. forward or reverse. 90"/sec. during rewind. The recording density of 333 characters per inch is maintained, thus giving the nominal read and write rate of 10,000 characters per second. Maximum diameter of 8" tape reel. Accommodates 1200ft. of Magnetic Tape, which gives a minimum of 1,150ft. available for recording.

MINITRON

K.G.M. Type 3015F 7 Segment display showing figures 0–9 plus decimal point. Character of 9mm height. In 16 DIL case.
NEW LOW PRICE £1·25
SN7447N BCD
Decoder Driver **£1·00.**

Potentiometers

TEN TURN 3600° ROTATION

Res Ohms	Linearity Per cent	Manufacturers	Model	Price
100	0.5	Beckman	A.S.	£2·00
200	0.5	Beckman	A.	£2·00
500	0.1	Beckman	S.	£2·50
500	1·0	Relcon	HEL107-10	£2·25
1K		Relcon	HEL0710	£2·25
2K	0·5	Beckman	SA1101	£3·00
2K	0·25	Beckman	7216	£3·00
2K		Reliance	GPM15	£2·00
2K		General Controls	GPA15/4	£2·00
5K		Relcon	07–10	£2·50
5K		Colvern	CLR2503	£3·00
10K	0·1	Beckman X	A	£3·50
15K		Colvern	CLR2402	£3·00
25K	0·5	Helipot	SAJ337	£3·00
29K	0·05	Beckman	SA1244	£4·50
30K	0·1	Beckman	A.88	£3·50
30K	0·5	Beckman	SA1692	£3·00
50K		Reliance	07·10	£2·25
50K			07·5	£2·25
50K	0·5	Beckman	A	£3·00
100K	0·1	Beckman	A	£3·50
100K		Colvern	2501	£2·25
298K	0·1	Beckman	8A3902	£3·50
300K	0·1	Beckman	A.	£3·50

THREE TURN 780° ROTATION

Res Ohms	Linearity Per cent	Manufacturers	Model	Price
25Ω		Beckman	Type C	£2·25
100/100		Beckman	Type C	£3·00
300		Beckman	9303	£2·25
1K		Fox	PX2/H3	£2·25
10K	0·5	Beckman	C.ss.	£2·25
20K/20K	0·1	Beckman	C.S.	£3·00
10K/10K	0·1	Beckman	C.	£3·00
50K	0·5	Beckman	C.S.	£1·75

FIFTEEN TURN 5400° ROTATION

Res Ohms	Linearity Per cent	Manufacturers	Model	Price
25K/25K		Beckman B	10 watts	£6·50
46K/46K		Beckman B	10 watts	£6·50

AC CLAMP VOLTAMMETER

Clamp-on Voltammeter is used for measurements of AC voltages and currents without breaking circuits.
Specification
Measurement ranges:—Current 10–25–100–250–500 Amps. Voltage 300, 600 V. Accuracy 4%. Scale length 60mm. Overall dimensions 283 X 94 X 36mm. Weight 1.5 lbs.

£10·50

SPECIAL PURCHASE OF ADVANCE EX-DEMONSTRATION TEST EQUIPMENT

Advance PG56 Double Pulse Generator
Independently variable. 2Hz–3MHz Pulse Width. Delay 70nS–0.2 secs. in 19 steps. Rise Time better than 10nS. External trigger and internal rate generator. **£120**

Advance PG52 Pulse Generator
Repetition frequency up to 20MHz and output pulses up to 20V into 5 ohms with rise and fall times of 5nS. Also produces complex ramp wave forms not obtainable from conventional pulse generators. Fully protected against short circuit. **£275**

Advance T.V. Dot and Cross Hatch Generator SG73
Output in form of modulated signal at VHF and UHF at level suitable for aerial sockets of receiver.
Two Ranges
Band III on fundamental (MOD)
Band IV & V On Harmonics (–MOD)
Modulation 405 Lines or 625 Lines
£49.50 EX-DEMONSTRATION BRAND NEW

Carriage and packing charge extra on all items unless otherwise stated.

Please note: all instruments offered are second-hand and tested and guaranteed 12 months unless otherwise stated.

ADD 8% VAT TO ALL PRICES

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49–53 Pancras Road, London NW1 2QB. Telephone 01-837 7781

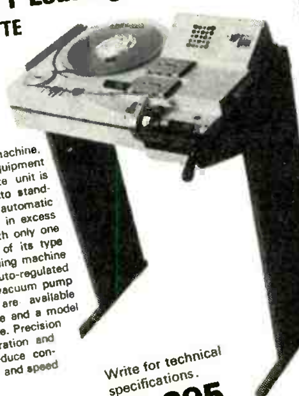
PROMPT DESPATCH MAIL ORDER. CALLERS WELCOME MON–FRI 9 A.M. to 5.30 P.M.

ELECTRONIC

ALL ITEMS BRAND NEW AND

Duplison Series 211 Loading Machine

NEW ALL-IN-ONE CASSETTE LOADING AND WINDING MACHINE



World's first and fastest integral unit

New tape loading and winding machine, which combines three items of equipment into one integral unit. The desk size unit is designed to wind tape pancakes into standard C—0 cassettes, and semi-automatic operation allows a production rate in excess of 1,400 tapes every 8 hours, with only one operator—said to be the fastest of its type in the world. The loading and winding machine has all TTL logic controls, with an auto-regulated tape tension control, and built-in vacuum pump and splicer. Several models are available for pre-recorded tape, blank tape and a model compatible for both types of tape. Precision alignment of the splicing operation and tape control is designed to reduce considerably the number of rejects and speed up the entire operation.

Write for technical specifications.

£1,295

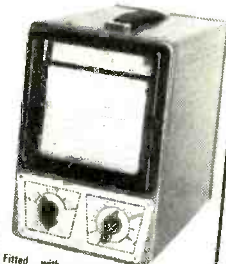
A BOON TO ANY LABORATORY

MINIATURE PEN RECORDER AT A MINIATURE PRICE

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 120x 120x285mm. Weight 7.7 lbs. (3.5 Kg). Price complete with accessories

£39.00

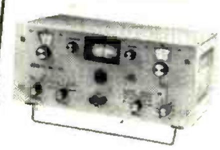
FULLY COMPREHENSIVE AC/DC PEN RECORDER COMPLETELY SELF-CONTAINED & FULLY PORTABLE



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

IDEAL FOR TESTING SMALL PRODUCTION BATCHES



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

UNIQUE 10 CHANNEL RECORDER

Up to 10 different recording operations at lowest cost yet.

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

SPECIAL OFFER

The Sinclair Scientific. Logs, trig and arithmetic. All at the touch of a button. At last there's a pocket calculator which gives you log and trig functions instantly.

Full 12-function machine

With the functions available on the scientific keyboard, you can handle directly $\log_{10}$ antilog$_{10}$ sin and arcsin, cos and arccos, tan and arctan, automatic squaring, automatic doubling, x^y (including square and other roots), plus, of course, addition, subtraction, multiplication, division and any calculations based on them.

7-digit scientific notation, 200-decade range. Reverse Polish logic and 25-hour battery life. Send for further information. **£27.50**

At last! A Signal Generator covering 140KHz to 110MHz

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 48 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 0–60% adjust. Frequency modulation: 1000 Hz adjust. Deviation from 0 – +/– 50 KHz. External modulation: AM; FM: from 30 Hz to 15 KHz.

£259.00

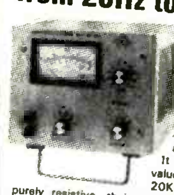
NEW "Strobette" STROBOSCOPE–TACHOMETER

What is "Strobette"? "Strobette" is a complete combined Stroboscope–Tachometer available at a remarkable price. It's a stroboscope because it is capable of optically stopping, or slowing, any moving object while the object is in motion. And it's a tachometer since it can measure the speed, or rate of motion, of a rotating or moving object. "Strobette" is a tool, analyser, measuring device, fault detector for engineers, technicians, inspectors, teachers.

WIDE RANGE: Stroboscope—200 to 6,000 flashes per minute, Tachometer—200 to 6,000 RPM. **ACCURACY:** 3% or better. **CIRCUITRY:** 100% solid state. **BEAM ANGLE:** 80°. **CALIBRATION:** At 3,600 FPM against any known synchronous speed—7200, 3600, 1800, etc. **FLASH DURATION:** Approximately 10 to 25 microseconds. **LIGHT COLOUR:** Xenon white 500°K. **COMPACT, LIGHTWEIGHT:** Can be carried in tool box, weighs only 27 oz. **EASY TO USE:** One on-off switch and one dial.

ONLY £49.50

Full transistorised output power meter covering 1mW to 10W from 20Hz to 50KHz



OUTPUT POWER METER TYPE MU 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 20KOhm. 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 10W
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 8% VAT TO ALL PRICES

Carriage and packing charge extra on all items, unless otherwise stated.

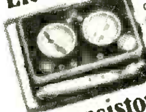
BONANZA!

GUARANTEED FOR 12 MONTHS

THESE ACCESSORIES CAN BE USED IN CONJUNCTION WITH THE SUPERTESTER 680R, ALSO IN MANY CASES WITH POPULAR MAKES OF TEST METERS.

Signal Injector Producing 1KHz and 500 KHz signals for circuit testing. £5.95

Gauss Meter For measuring magnetic field strengths. £11.95



Electronic Voltmeter Input resistance of 11Mohms for d.c. and 1.6Mohms shunted by 10pF for a.c. £22.00

Transistor Tester For transistors and diodes. £11.95

Amperclamp For measuring a.c. currents from 250mA to 500 amps. £11.95

Temperature Probe Covering the range −50 to +200°C £11.95

Phase Sequence Indicator To indicate the phase sequence of a 3 phase supply. £5.95

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-2.5 mA-25 mA-250 mA-2.5 Amp 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

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 100mA. A 10-to-1 current transformer 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.

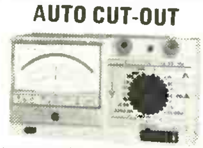
£39.50 inc. leather case

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. 3-6-15-60-150-1300-600-9·)0 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 **£8.50**

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.

£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. Resistanca 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 × 97 × 40mm. in carrying case, complete with test leads.

AMAZING VALUE £7.70

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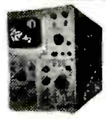
Phone 01-723 8753

SIGNAL GENERATORS

MARCONI TF801D/1S. 10-480 mHz P.O.A.
MARCONI TF801B/2S. 10-480 mHz **£225.**
MARCONI TF144H 10kHz—72 mHz P.O.A.
MARCONI TF1370 RC Oscillator 10kHz-10mHz. Sine/Square.
ROHDE & SCHWARZ SMAF (illustrated) AM/FM 4-300 mHz.
ROHDE & SCHWARZ SMLR 15-30mHz power generator. P.O.A.
RACAL/AIRMEC 201A. 30kHz-30mHz. As new. P.O.A.
ADVANCE SG21 VHF Square-wave generator 9kHz-100mHz. **£25.**

OSCILLOSCOPES



TEKTRONIX 555 (Late model) with two 'L' plug-ins and '21A' and '22A' plug-ins.
TEKTRONIX 545A with CA unit. DC-30mHz. Price only **£295·00.**
TETRONIX 531 DC-15mHz with L type plug-in
TETRONIX 535 DC-15mHz with L typa plug-in
ITT METRIX miniature portable scope. DC-10mHz. Brand new. **£50.**
NB: Due to the fragile nature of CRTs we regret that these oscilloscopes cannot be despatched by post. Collection only or delivery could be arranged.

MISCELLANEOUS TEST EQUIPMENT

MARCONI TF1400S double pulse generator with TM6600/S secondary pulse unit. **£105.**
MARCONI TF791D deviation meter. 4-1024mHz. 0-100kHz deviation.
MARCONI TF1342 low-capacitance bridge 0·002pf-1,111pf. Resistance 1-1000M.ohm. **£85.**
ROHDE & SCHWARZ USVD calibrated receiver 280-4, 600mHz.
ROHDE & SCHWARZ A.F. Wave Analyser type FTA 0-20kHz plus log/lin AF meter incorporated. Excellent condition.
ROHDE & SCHWARZ URV milli-voltmeter BN10913 (late type) 1mV-10V. With 'T' type insertion unit, free probe and attenuator heads. 1kHz-1,600mHz. **£175.**
COSSOR 1453 True RMS milli-voltmeter. Excellent. **£75.**
ADVANCE PG54 Pulse generator. AS NEW.
SOLARTRON EM1006 production-line resistance tolerance check-set. 0-15Mohm digital read-out.
AIRMEC TYPE 210 modulation meter. Excellent condition.
WAYNE KERR B521 LCR Bridge. Excellent condition. **£55.**
EDDYSTONE 770R VHF Receiver covering 19-165mHz. As mew. **£125**

MUFFIN INSTRUMENT FANS
Dimensions 4·5 x 4·5 x 1·5 ins. Very quiet running, precision fan specially designed for cooling electronic equipment, amplifiers etc. For 110V. AC operation—(practise is to run from split primary of mains transformer or use suitable mains dropper). CC only 11 Watts. List price over £10 each. Our price, in brand new condition, is **£3·50.**

POLARAD Model SA84WA SPECTRUM ANALYSER
10MHz-63GHz. I.F. Markers. Spectrum calibrator. Log/Lin scale. NB. This is not the instrument with the expensive TWT to replace. Supplied in full working, excellent condition. Guarantee.

MANY TYPES of RF plugs and sockets in stock:—
BNC plugs 50Ω. **30p.** BNC sockets 50Ω. **25p.** N. Type plugs 50Ω. **50p.** Burndept plugs. **40p.** Burndept sockets. **40p.** Miniature PYE. **20p.** Miniature sockets. **20p.**
All connectors are brand new. Immediate delivery. Please add appropriate postage.

DURATRAK VARIACS type 100L. 230V. AC Input. 0-230V. AC Output, at 8 amps. Brand new units, less control knobs. Price only **£15·00.** Carriage £1.

MINI HELIPOTS
500 Ω Beckman Linearity Tolerance 0.075% (10 Turn). 1K Ω Beckman Linearity Tolerance 0.25% (10 Turn). 20 Ω Colvern CLR 26/6310/9S (3 Turn). 5K Ω Colvern (10 Turn).

AVO VALVE TESTERS
Brief-case type 160. Full working condition throughout. **£65.**

AERIAL CHANGE/OVER RELAYS
of current manufacture designed especially for mobile equipments, coil voltage 12v., frequency up to 250 MHz at 50 watts. Small size only, 2 in. × ⅞ in. Offered brand new, boxed. Price **£1·50,** inc. P.&P.

RACAL/AIRMEC VHF/UHF Millivoltmeter type 301A. Frequency range 50Hz-900mHz. Voltage range 300μV-3V in eight ranges. Co-axial input 50 and 75 ohms BNC connectors. DC Ranges 100μV-10V in ten ranges. Light-weight mains operated instrument in as new condition with handbooks. Other makes of voltmeter also available from stock.

HEWLETT-PACKARD RF POWER METER
Type 432A. Power range 1μW-10mW in 7 ranges. Frequency range 10mHz-10GHz. Automatic zeroing. With 478A co-ax mounts and carrying case. In excellent condition.

HEWLETT PACKARD/ BOONTON TYPE 8900B
Peak-power calibrator. Measures true peak power ±.6 db absolute. Frequency range 50-2000Mhz. RF power range 200mW peak, full-scale. RF Impedance 50 ohms. P.O.A.

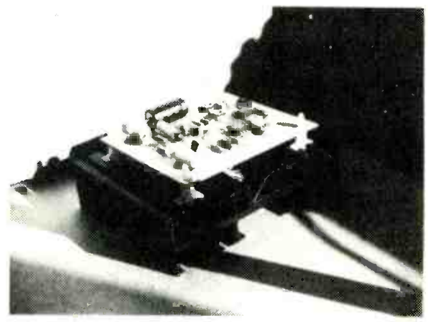
POLARAD MICROWAVE RECEIVER
Model 'R' with tuning unit type RMT. Frequency range 4.2GHz-7.65GHz. AM/FM. In working condition. Price £75.

PLEASE ADD 8% V.A.T. TO THE TOTAL AMOUNT WHEN ORDERING. INCORRECT AMOUNTS WILL CAUSE DELAY IN DESPATCH. THANK YOU.

hurst ELECTRONICS

92 Warwick Road, Ealing, London W5 5PT
Telephone: 01-567 0424

HE 100
100 WATT POWER AMP MODULE



- ★ Includes large black anodised heatsink—no further heatsinks required.
- ★ Top grade glass-fibre P.C.B.
- ★ Uses high quality components.
- ★ Fully protected—short/open circuit proof.
- ★ Only 5 external connections.
- ★ Fully guaranteed.

TECHNICAL SPECIFICATIONS

★ Power output	: 106W. R.M.S. into 8Ω
★ Distortion	: 0.8% at full O/P. Typ. 0.4%
★ Signal to noise	: Better than −96dB.
★ Input sensitivity	: 0dB (0.775V.)
★ Supply volts	: 45–0–45V.

Price **£15.12** inc. VAT. (ready built)
OR
Complete kit (including P.C.B. and all components) **£11.88** inc. VAT. Enclose 50p postage & packing.

Power supply for HE100 (including transformer, capacitors, rectifier) **£8.95** inc. VAT. Postage & packing 85p.

Pre-amps etc., also available.
SAE for details.

CALLERS WELCOME

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PHONE: Allan Petters on 01-261 8508 or 01-261 8423.
Classified Advertisement Rates are currently zero rated for the purpose of V.A.T.

Advertisements accepted up to 12 noon Tuesday, October 8th for the November issue subject to space being available.

Our Telecommunications programme will make the best of your skills and ambition

TXE4 is the new British Telephone Switching System currently being manufactured and installed. Designed by STC, it will satisfy the requirements of high traffic density and lead into fully electronic computer-controlled digital switching systems. A further joint development programme with the British Post Office enables STC to make appointments at varying levels of seniority which offer considerable potential technically and in terms of reponsibility.

Tomorrow's Telephone Exchange Today

System Development Engineering

The TXE4 System will be further developed to meet traffic demands beyond the end of the century.

This will involve extension of the current TXE4 technology to meet traffic density, system security and compatibility with Switching Systems abroad.

The appropriate background for this work is in depth experience of Telephone Switching development and System design.

System Integration Engineering

The design of the TXE4 System is such that it can be widely applied in various networks, and Integration Engineering interfaces with, and provides a bridge between, system design and application engineering.

Principal duties involve translation of design options into practical choices for application engineering and the specification of rules for exchange lay-outs taking account of transmission and power requirements.

Integration Engineering also contributes in large measure to new developments within the system.

Thorough knowledge of Switching Systems, together with practical experience of large scale installation, commissioning or job engineering, is essential for the work described.

Senior Customer Liaison Engineering

This refers to work on the more advanced version of TXE4 which is being developed. It involves negotiating with the Post Office and overseas telephone authorities on the facilities to be provided and preparing tenders from the customers' specifications.

Each tender preparation will be a design and development exercise in itself. It will include work on space division switching, line and inter-register signalling, exchange sub-systems, exchange and network facilities, exchange loading and traffic analysis.

Qualifications for this post are a degree or City and Guilds Final Certificate in Telecommunications and between five and ten years' experience in the design of Switching Systems. Knowledge of Post Office facilities would be an advantage.

Salaries and conditions of employment are competitive.

For an application form, please telephone Diana Hunt on 01-368 1200 Ext 3141 or write to her at Department 32211 Electronic Switching Division, Standard Telephones and Cables Limited, Oakleigh Road South, New Southgate, London, N11 1HB.

Standard Telephones and Cables Limited

A British Company of ITT

RF Engineers

Interested in the future of Cable TV?

Our latest contracts call for an expansion of our development teams working on new programmes in this field of community communications.

As one of Europe's largest suppliers of cable television products we can offer you a stimulating career in a Company noted for it's technology in the field of television.

Competitive salaries will be offered – up to £3,000 or higher for those Engineers who can make a significant contribution. A threshold supplement is also being paid. There are good fringe benefits including a contributory Pension Scheme and assistance with removal expenses where appropriate.

If you are qualified to degree/HNC level with a minimum of two years experience in VHF/UHF circuit design, preferably in the field of television, we would like to hear from you.

There are also vacancies for technicians qualified to ONC level for work in this field.

Please write giving brief details of qualifications and experience to:
K. E. Goodman,
Personnel Department,
EMI Limited, 135 Blyth Road,
Hayes, Middlesex.

TELECOMMUNICATIONS DIVISION
EMI SOUND & VISION EQUIPMENT LTD

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The international music, electronics and leisure Group.

4058

RADIO OFFICERS

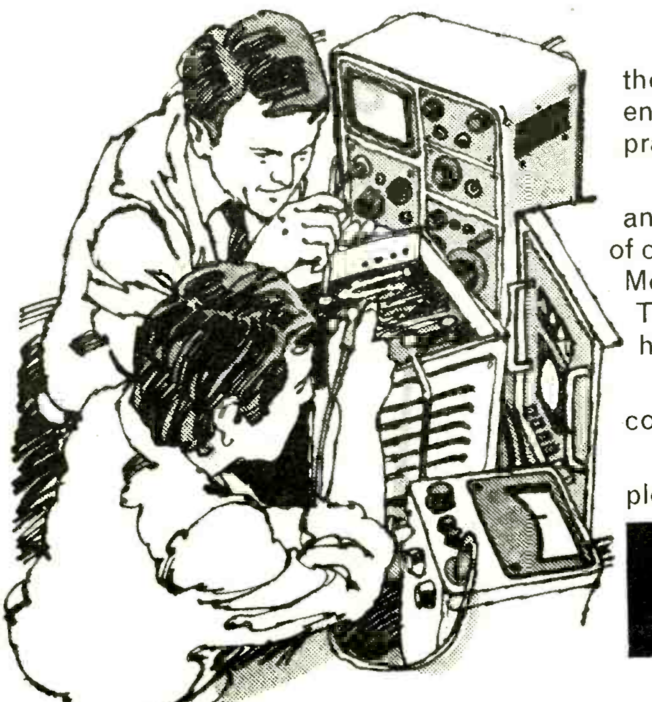
Here is your invitation to apply to join the Diplomatic Service

Qualifications:

1. MPT/PMG 1 (or equivalent City & Guilds Certificate)
2. Skill in the operation of H.F. radio communications equipment.
3. Competence in sending and receiving morse.

Further particulars can be obtained from:
Communications Administration Department,
Foreign and Commonwealth Office,
Hanslope Park,
Hanslope,
Milton Keynes MK19 7BH.

14074



NATIONAL PHYSICAL LABORATORY, DIVISION OF MARITIME SCIENCE

vacancies at

TEDDINGTON, MIDDLESEX

and

HYTHE, HAMPSHIRE.

ELECTRONIC DEVELOPMENT

A number of interesting posts with a wide range of duties are available at the above locations.

We use analogue and digital circuits, audio and radio frequencies, land and sea based equipment, together with computers to handle our results.

Assistant Scientific Officers, with an interest in electronics, are required to join small teams at both sites to help us maintain and develop our systems, and to assist in trials on ships and offshore structures.

Excellent opportunities exist to obtain broad practical experience and to study for higher qualifications leading to a worthwhile career.

The minimum qualifications are 4 GCE or CSE Grade 1 subjects, to include Maths, Science and English Language. Salary ranges from £887 (at age 16) to £1,547 (at age 25) rising to £1,899.

If you would like further details you may telephone Mr. R. F. Johnson or Mr. R. W. Cuffe at the numbers shown.

Mr. R. F. JOHNSON: 01-977 3222 Ext. 4165 during working hours or Woking 65942 evenings and weekends.

MR. R. W. CUFFE: Hythe, (Hants) 3065 (STD 042-14) in working hours, or Hythe 6804 evenings and weekends.

Alternatively, write to Mr. H. B. Boyle, Officer-in-Charge, Department of Industry, National Physical Laboratory, Division of Maritime Science, St John's Street, Hythe, Southampton, Hampshire, SO4 6YS, quoting Reference MS/INST.

[4072

ZAMBIA

Challenge and reward go hand-in-hand in the perpetual sunshine of this new and fast-developing nation. 3-year contracts bring attractive salaries, lower rates of tax, minimal-cost furnished accommodation, free air passages for you and your immediate family, baggage allowance, car loans and 25% terminal gratuity—normally tax free.

Radio Specialists to become Police Inspectors

These positions are in the Signals Section of Zambia's Police Force, and location may be anywhere within Zambia. Essential requirements are: at least 5 years' practical, post-training experience in low and medium-power HF, VHF and UHF radio equipment; advanced knowledge of Multiplex equipment and crossbar telephone exchanges and a working knowledge of diesel and petrol-driven generators. In addition, Final or Full Technological C & G Certificate will be needed. Upper age limit is 40.

Salary: K2,688–K3,624 (c. £1,800–c. £2,420). Supplement: approx. £1,000.
Salary Scales: Entry point on salary scale shown will be related to experience.
Note on Supplements:— British citizens are normally eligible for the Overseas Supplement which is shown against each post. Details of this Annual Supplement, including eligibility, will be sent on request. The supplement is paid into the Officer's own bank account in Britain or Ireland and is normally tax free.

Please apply by sending full personal and professional details to:
Recruitment Officer,
Zambia High Commission,
7–11 Cavendish Place,
London W1.

[4118

Radio Operators. How to see more of your wife without losing sight of the sea.

Join the Post Office Maritime Service. We have openings for Radio Operators at several of our coastal stations.

The work is just as interesting, just as rewarding as aboard ship, but you get home to see your wife and family more often. You need a United Kingdom General or First Class Certificate in Radiocommunications, or an equivalent certificate issued by a Commonwealth Administration or the Irish Republic.

Starting pay for a man of 25 or over is £2,270, plus cost of living allowance with further annual increases after that. Though we're happy to take people from 19 up.

In addition to your basic salary, you'll get an average allowance of £450 a year for shift duties and there are opportunities for overtime.

Other benefits include a good pension scheme, sick pay and prospects of promotion to Senior Management.

For more information, write to: ETE Maritime Radio Services Division (L527), ET 17.1.1.2., Room 643, Union House, St. Martins-le-Grand, London, EC1A 1AS.

Post Office Telecommunications

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Electronics Technician Engineers

do you like to get about the country?

TELECOMMUNICATION TEST AND SYSTEM COMMISSIONING TECHNICIANS

We have vacancies for staff in the following categories to commission telephone, telegraph, data and television transmission systems within the UK and Eire.

Immediately, we are seeking suitable men for our Coaxial Line and Multiplex Commissioning Teams.

Installation Technicians

To take charge of Commissioning Teams in the field for Coaxial Line and Multiplex systems. For these posts we need people between the ages of 25 and 35 with a full City and Guilds Certificate or equivalent qualification in telecommunications and with at least 3 years field experience.

Applicants with previous supervisory experience are preferred but we will provide opportunities for the right men to develop this capacity.

Testers

To work as members of the Commissioning Team. We are looking for people educated to City and Guilds Intermediate Certificate standard in telecommunications between the ages of 20 to 30 years.

Previous similar experience, possibly obtained in H.M. Services, will be an advantage.

Applicants for all these positions must hold a current Driving Licence.

We offer attractive salaries, a contributory pension scheme and other big-company fringe benefits. There are good career prospects with this internationally renowned telecommunications company.

Please telephone or write for an application form to:— Mrs. S. Hughes, (Ref: WW 10/74), Personnel Department, Standard Telephones and Cables Ltd., Chester Hall Lane, Basildon, Essex SS14 3BW. Basildon 3040 Ext. 261.

Standard Telephones and Cables Limited

A British Company of ITT

4059

ROYAL FREE HOSPITAL HAMPSTEAD

MEDICAL PHYSICS TECHNICIANS (ELECTRONICS)

Two vacancies—**one permanent and one locum (6 months from 1st November, 1974)** exist in the Electronics Workshop of this brand new major Teaching Hospital. Applicants should hold the Final City and Guilds or an equivalent qualification. Some knowledge of analogue and digital circuit techniques desirable.

Salary on a scale £1,899 to £2,589 dependent on qualifications and experience.

Application forms (to be returned by 5th November) from **Personnel Dept., Royal Free Hospital, 21 Pond Street, London, NW3. Tel: 01-794 0431.**

[4097

AVON AREA HEALTH AUTHORITY (TEACHING)

BASIC GRADE PHYSICIST

Required for a two year research post at Frenchay Hospital, Bristol, aimed at improving prosthetic devices fitted following the removal of the larynx. Experience of physiological pressure monitoring or allied fields would be an advantage. Salary scale £2,160-£2,565. Applications should be sent to Miss H. Inman, Personnel Officer, 10 Marlborough Street, Bristol BS1 3NU to arrive by 7th October.

[4088

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 7-month specialist training course, successful applicants are paid on a scale rising to £3,096 pa; commencing salary according to age—25 years and over £2,276 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

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RADIO TECHNICIAN

NEW ZEALAND

Vacancies exist at our Wanganui, Hastings and New Plymouth service departments for competent Radio Technicians to repair and maintain land mobile, marine and aircraft radio telephone equipment. A thorough practical knowledge of V.H.F., H.F. (D.S.B. and S.S.B.) equipment is essential.

If you are planning emigrating to New Zealand in the near future, then please write airmail, with full personal and career details to:

Barlows Radio Telephone Service Ltd.,
P.O. Box 611,
WANGANUI,
NEW ZEALAND.

4069

AUDIO-VISUAL ENGINEERS

The Heathrow Hotel features Europe's most sophisticated conference complex, complementing the hotel's fine restaurants, bars and first-class accommodation.
The finest audio-visual facilities are available to clients using our conference facilities and due to increased business the following vacancies are now available:

SENIOR AUDIO-VISUAL ENGINEER £2,800–£3,200

To operate and maintain a wide range of CCTV and colour studio equipment including broadcast cameras and one inch helical scan VTR's. Applicants should be between 25–35, have several years' experience of studio work in broadcasting or education and possess relevant technical qualifications.

AUDIO-VISUAL ENGINEER £1,800–£2,400

To operate and maintain a wide range of audio-visual equipment including CCTV.
Applicants should preferably be between 20–25, have several years' experience of CCTV maintenance and possess relevant technical qualifications.
Excellent company benefits include 17 days' holiday, non-contributory pension scheme and free life insurance.
Please apply with relevaht details to The Personnel Department, The Heathrow Hotel, Bath Road, Heathrow, Hounslow, Middlesex or telephone 01-897 2419 for application form.

The Heathrow

A Lex Hotel

|4066

UNIVERSITY OF EDINBURGH

TELEVISION ENGINEER

Required by the DEPARTMENT OF AUDIO VISUAL SERVICES to be responsible for the day-to-day operation and maintenance of the television studio, mobile recording, all University television facilities, and the deployment of five technical staff. Experience in educational closed circuit or broadcast television studios is essential, with a sound knowledge of helical scan video tape recorders. If necessary, assistance with relocation expenses will be given.
Salary will be on the scale £2,817–£3,201 p.a. (under review), plus threshold payment. Holidays: 4 weeks and 4 days.
Applications, quoting the post reference no. A051, and including the names and addresses of two referees familiar with applicant's technical background, should be addressed to the Personnel Officer, University of Edinburgh, 63 South Bridge, Edinburgh EH1 1LS. Telephone 031-667 1011, ext. 4446. |4065

MAKE MONEY FROM YOUR HOBBY

Sell a range of nationally advertised Hi-Fi speakers from home and make some real money fast. The range has already become well-known and very favourable reviews have been carried out. You sell only a brand-new fully guaranteed product with full support from the manufacturer. Your mark up is 67% and maximum investment is £140. This is a direct selling opportunity and not part of any pyramid scheme.
Write for full details to:

ELBAR INDUSTRIES,
Dept. 6,
2 Greystones Close,
Kemsing, Sevenoaks, Kent

[4098

SMITHS INDUSTRIES LIMITED
AVIATION DIVISION

Vacancies exist in our Quality Branch for

CALIBRATION ENGINEERS

TEST EQUIPMENT

The duties involved will be the performance certification, quality assessment, fault diagnosis and repair of a wide variety of analogue form electronic test equipment.
For this post an engineering apprenticeship and preferably an O.N.C. or equivalent or alternatively H.M. Forces Tech Training, together with experience of several years on the calibration and maintenance of Electronic Test Equipment, is desired.

Write to: H. Upson,
Assistant Personnel Manager,

SMITHS INDUSTRIES LIMITED

AVIATION DIVISION

Bishops Cleeve, Cheltenham, Glos. GL52 4SF

4063

ELECTRONICS TECHNICIAN

GELLER BUSINESS EQUIPMENT LTD.,

distributors of electronic calculating and dictating equipment, require a young man 17 plus as a trainee electronics technician. A well paid interesting career for an intelligent person prepared to work and study.

Write or phone to:

GELLER BUSINESS EQUIPMENT LTD.
15 PERCY STREET, LONDON, W1
Tel: 01-580 1614

[4125

THE UNIVERSITY OF LEEDS
DEPARTMENT OF PHYSIOLOGY
CARDIOVASCULAR UNIT

Applications are invited for the post of **EXPERIMENTAL OFFICER** in Electronics. A degree is required. Responsibilities include PDP12 and PDP8 computers, electronic equipment in three physiological laboratories and three hospital catheter laboratories, and the supervision of four electronics technicians. Salary scale £1,752 to £2,376. Preliminary enquiries may be made to the Director of the Cardiovascular Unit, Department of Physiology, The University, Leeds LS2 9JT.

Forms of application and further particulars from the Registrar, The University, Leeds LS2 9JT (please quote 43/13/Cl), to whom applications should be returned as soon as possible.

INTERNATIONAL MANAGEMENT CONSULTANTS LIMITED
TECHNOLOGY AND SCIENCE CENTRE

ELECTRONICS TECHNICIAN/STUDENT TECHNICIAN

PA Technology and Science Centre at present located in Cambridge, but shortly moving to Melbourn, has vacancies for Technicians to do varied and responsible work within the Electronics Engineering Group.

TECHNICIAN

Applicants should be familiar with wiring and construction techniques for electronic equipment, and be capable of working to the highest standards with minimum supervision. Duties will include prototype circuit wiring and testing, in close cooperation with the Group's Engineers.

STUDENT TECHNICIAN

A unique opportunity for a student with some practical experience in the Industry. Age group 18–21 years with some further education targets, eg: O.N.C./H.N.C., City and Guilds F.T.C. Day release for further education would be supplemented by personal training from professional Engineers and Technicians.

Working conditions are good, and sensible salaries will be offered, subject to regular review.
If you are interested in either of these positions, telephone Cambridge 66661, Extension 21, or write to:

Dr D. G. Buchanan,
PA Technology and Science Centre,
Winship Road, Milton,
Cambridge CB4 4BE—*marking your envelope 'Confidential'*

[4067

T.V. Engineers for New Zealand

Are you dissatisfied with your present position, feeling like a change of scene? Do something about it now! Be our guest—come down under and join the Tisco Team, N.Z.'s largest service organisation.
We are in service only and our engineers are all important people, every one of our 30 managers is an ex engineer.
We are now selecting staff to sponsor under the Immigration Scheme to arrive in N.Z. mid 1975.

If you,

- Have 5 years experience, preferably some in colour.
- Single or married with 3 children or less.

write now enclosing a photograph and details of past experience to:-
The Technical Staff Supervisor, Tisco Ltd, Private Bag, Royal Oak, AUCKLAND, NEW ZEALAND.

[4070

ELECTRONIC ENGINEER OR PHYSICIST

required for a Hospital department concerned with the investigation of brain functions. The successful applicant, who would work under the direction of the Principal Physicist, will be expected to develop electronic apparatus for research purposes. Supervision of the maintenance of existing apparatus would also be necessary. A good knowledge of electronics is required together with the ability to produce prototype apparatus. Our interests are high gain amplifiers for low frequencies and digital timing apparatus. The appointment can be as a Physicist (salary range £1,623-£2,385) or as a Medical Physics Technician (salary range £2,727-£3,516) depending upon qualifications and experience. Applications, together with the names of two referees, to Geoffrey A. Robinson, Secretary to the Board of Governors, The National Hospitals for Nervous Diseases, Queen Square, London WC1N 3BG. [4089

FREELANCE ENGINEER

wanted to rebuild a limited number of ITEL paper tape Word Processing machines. £50.00 paid per machine.

Apply Box WW4071

EAST SUSSEX COUNTY COUNCIL — BRIGHTON TECHNICAL COLLEGE

Senior C.C.T.V. Technician

Required as soon as possible to head a team responsible for the maintenance of closed circuit television equipment and other audio-visual aids.

Applicants should possess a City and Guilds Final Certificate in Radio and Television Servicing and have had relevant practical experience.

Salary payable within grade T4 (£1,644 to £1,926). These scales are currently under review. An additional payment may be made in accordance with the local authorities Threshold Agreement.

Application form and details available from Chief Administrative Officer, Brighton Technical College, Pelham Street, Brighton, BN1 4FA (Tel: 685971).

[4091

HUMBERSIDE AREA HEALTH AUTHORITY
HULL DISTRICT

ELECTRONICS TECHNICIAN

Salary range **£2,190** to **£2,817** p.a.

Candidates should possess H.N.C. or equivalent qualifications, but consideration will be given to suitably qualified and experienced candidates in these fields.
Successful candidate will be a member of a new and expanding department, servicing a wide range of electronic/bio-medical and diagnostic X-ray equipment.
Application forms and job description can be obtained from the **Personnel Officer, Humberside Area Health Authority, Hull District, Victoria House, Park Street, Hull. Tel: 223961.**
[4103

Devon Area
Health Authority

Medical Physics Technician IV

(£1,773-£2,463 per annum)
Plus threshold agreement.

Applications are invited for the above post in the Electronics Division of the Physics Service based at the new District Hospital at Wonford, Exeter. Duties under the direction of a graduate electronics specialist will include the planned maintenance and servicing of patient orientated electronic equipment in the area. Some modification and construction of instruments will also be required.

For further information ring 0392/72261. Ext. 27 (Mr. E. D. James). Application form and job description obtainable from Personnel Officer, Royal Devon and Exeter Hospital (Wonford), Barrack Road, Exeter, EX2 5DW.

[4087

AUDIO-TELEVISION TECHNICIAN

Required by Communication Media Unit (a University service). Duties include operating and maintaining Audio and Video recording system, closed-circuit television, synchronized sound for film production, tape-slide systems, and public address. On occasions when the film projectionists are overloaded, the Audio-Television Technician may be called upon to help them. A sound theoretical and practical knowledge of electronics is called for. Salary within the scale £1,848–£2,163 p.a.

Application forms from the Establishment Officer, The University of Aston in Birmingham, Gosta Green, Birmingham B4 7PT quoting reference L/693/W.

[4102

THE UNIVERSITY OF ASTON IN BIRMINGHAM

ELECTROSONIC
SE LONDON

TEST/SERVICE ENGINEERS

£2,000—£2,800

Electrosonic Ltd. A leading company in the rapidly expanding fields of audio, audio-visual and lighting control systems, require test/service engineers. Applicants should have a sound knowledge of basic electronics and some years' experience of test and service work. An academic training to ONC level or equivalent qualification is desirable. The post is based in S.E. London but some travelling is required.
The company offers an attractive working environment and excellent conditions of employment.
Applications should be made in writing to:
Mr. R. D. Naisbitt, Personnel Director,
ELECTROSONIC LTD
815 Woolwich Road, Charlton, London SE7 8LT
Telephone 01-855 1101

[4126

Laboratory Technician

For the Scientific Services Department

A Technician is required for the workshop of a Research and Development Department based initially at Cockfosters. The workshop staff are to be rebased at Gravesend during the next two to three years.
Applicants should have served a Craft Apprenticeship and hold an ONC or equivalent qualifications. The work is concerned with the manufacture of experiment rigs and apparatus and some experience of this type of work is desirable.
Salary is within a range which rises to £3238 per annum.

Applications, quoting vacancy No. 1283/74WW and giving age, details of experience and qualifications, should be forwarded to the Personnel Officer (Recruitment), CEGB, Bankside House, Sumner Street, London SE1, to arrive by October 9, 1974.

Central Electricity Generating Board
South Eastern Region

4124

COURSES

Skilled in T.V. Electronics?

Here's a job to put you to the test

With the coming of colour TV, there has been a tremendous upsurge of opportunities for electronics people. It's an industry which is growing fast and at ITT in Hastings, this growth has been particularly apparent. Production is increasing rapidly to keep pace with the continuing demand for our sets throughout Europe.

Here in Hastings, we're looking for top-notch senior engineers to join our Test Engineering team. It's a job calling for formal electronics training followed by extensive practical experience of TV test as a Service Engineer, in the Forces or in industry.

If you'd like to put your ability to the test with ITT, we'd like to hear from you. It's an opportunity which, if you have the expertise we are looking for, could take you into the training areas of the Company. Generous additional benefits include pension and sickness schemes and assistance with re-location expenses where appropriate.

Write now with full details of your qualifications and experience to: David Harris, Personnel Officer, ITT Consumer Products (UK) Ltd., Theaklen Drive, Hastings, Sussex TN34 1YL.

[4128

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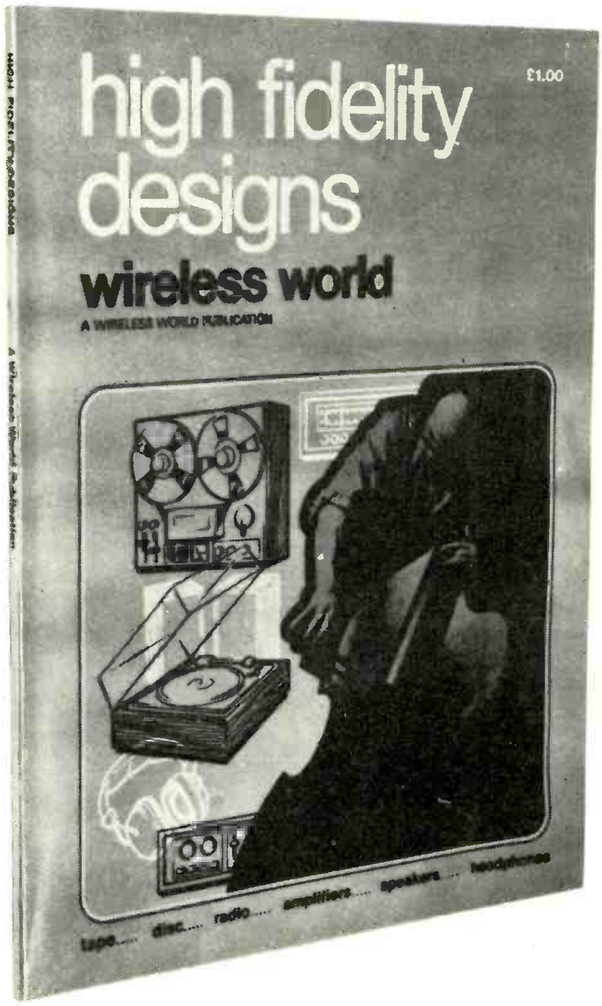

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PLEASE WRITE IN BLOCK LETTERS. CLASSIFICATION.................................. NUMBER OF INSERTIONS.................

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Printed in Great Britain by Hazells Offset Ltd., Leigh Road, Slough, Bucks., and Published by the Proprietors I.P.C. Electrical-Electronic Press Ltd., Dorset House, Stamford St., London, SE1 9LU telephone 01-261 8000. *Wireless World* can be obtained abroad from the following: Australia and New Zealand: Gordon & Gotch Ltd. India: A. H. Wheeler & Co. Canada: The Wm. Dawson Subscription Service, Ltd. Gordon & Gotch Ltd. South Africa: Central News Agency Ltd.: William Dawson & Sons (S.A.) Ltd. United States: Eastern News Distributors Inc. 155 West 15th Street, New York, N.Y. 10011.

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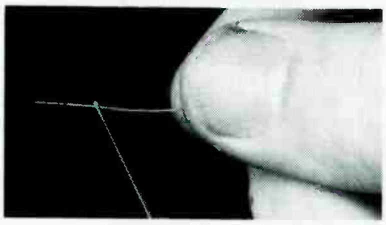
Ersin Multicore 5-Core Solder

The proved superiority of ERSIN Multicore Solder for over thirty years is due to many factors. We have specialised throughout this period in the manufacture of cored solders. Consequently our research and manufacturing staff have been able to devote all their energies to the development of Multicore Solders. All alloys are of highest purity, carefully formulated and checked.

Our unsurpassed ERSIN flux is rigorously tested before and after it is incorporated in the solder wire. Our five separate cores of flux ensure flux continuity, leave only an ultra-thin layer of solder separating flux from work for instant wetting and provide a more accurate ratio of flux to solder. It is therefore possible to use less solder and obtain greater reliability.

Our Quality Control at all stages of manufacture is guaranteed and recorded by the batch number on every reel.

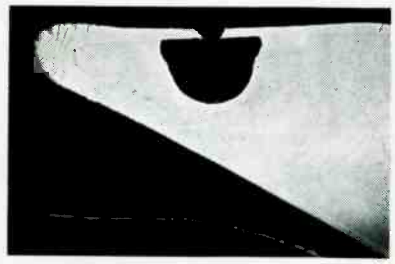
Needle fine gauges



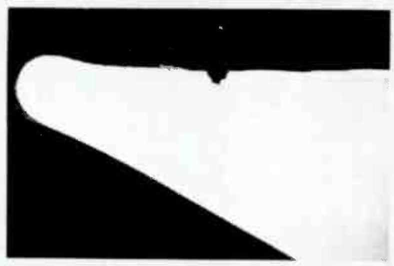
In addition to our standard range of wire diameters (10-22 swg: 3.2-0.7 mm) supplied on 2½ kg and ½ kg reels we also mass-produce needle-fine gauges (24-34 swg: 0.56-0.23 mm) on 250 g reels for microminiature soldering applications—still with 5 Cores of flux.

Savbit Solder

One of our most popular special ERSIN Multicore Solder alloys is SAVBIT alloy. Compared with ordinary tin/lead solders it dramatically reduces the erosion of soldering iron bits, copper wires and printed circuit conductors. It also saves costs and increases reliability. SAVBIT alloy containing 5-Cores ERSIN 362 flux has received special Ministry approval—under DTD. 900/4535 for Military applications.



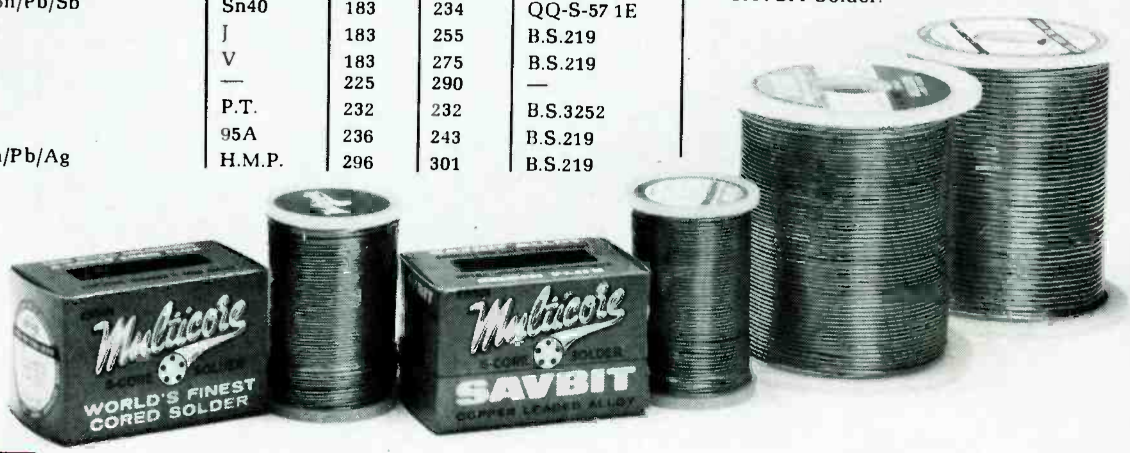
Sectioned iron-plated bit, after 40,000 simulated operations using 60/40 Solder.



Sectioned iron-plated bit, after 40,000 simulated operations using SAVBIT Solder.

ALLOY

Composition (nominal major elements)	Grade	Melting Temperature Solidus °C	Melting Temperature Liquidus °C	Specification
50/33/17 Sn/Pb/Cd	TLC	145	145	DIN 1707
62/36/2 Sn/Pb/Ag	LMP	179	179	DIN 1707
62/35.7/2/0.3 Sn/Pb/Ag/Sb	Sn62	179	179	QQ-S-57 1E
63/36.7/0.3 Sn/Pb/Sb	Sn63	183	183	QQ-S-57 1E
60/40 Sn/Pb	K	183	188	B.S. 219
60/39.7/0.3Sn/Pb/Sb	Sn60	183	188	QQ-S-57 1E
50/50 Sn/Pb	F	183	212	B.S.219
50/49.7/0.3 Sn/Pb/Sb	Sn50	183	212	QQ-S-57 1E
50/48.5/1.5 Sn/Pb/Cu	Savbit 1	183	215	DTD 900/4535 DIN 1707
45/55 Sn/Pb	R	183	224	B.S.219
40/60 Sn/Pb	G	183	234	B.S.219
40/59.7/0.3 Sn/Pb/Sb	Sn40	183	234	QQ-S-57 1E
30/70 Sn/Pb	J	183	255	B.S.219
20/80 Sn/Pb	V	183	275	B.S.219
15/85 Sn/Pb	—	225	290	—
Pure Tin	P.T.	232	232	B.S.3252
95/5 Sn/Sb	95A	236	243	B.S.219
5/93.5/1.5 Sn/Pb/Ag	H.M.P.	296	301	B.S.219



For full information on these and a Selector Guide to other MULTICORE products please write on your Company's letterhead direct to:

Multicore Solders Limited, Maylands Avenue, Hemel Hempstead, Hertfordshire HP2 7EP.
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