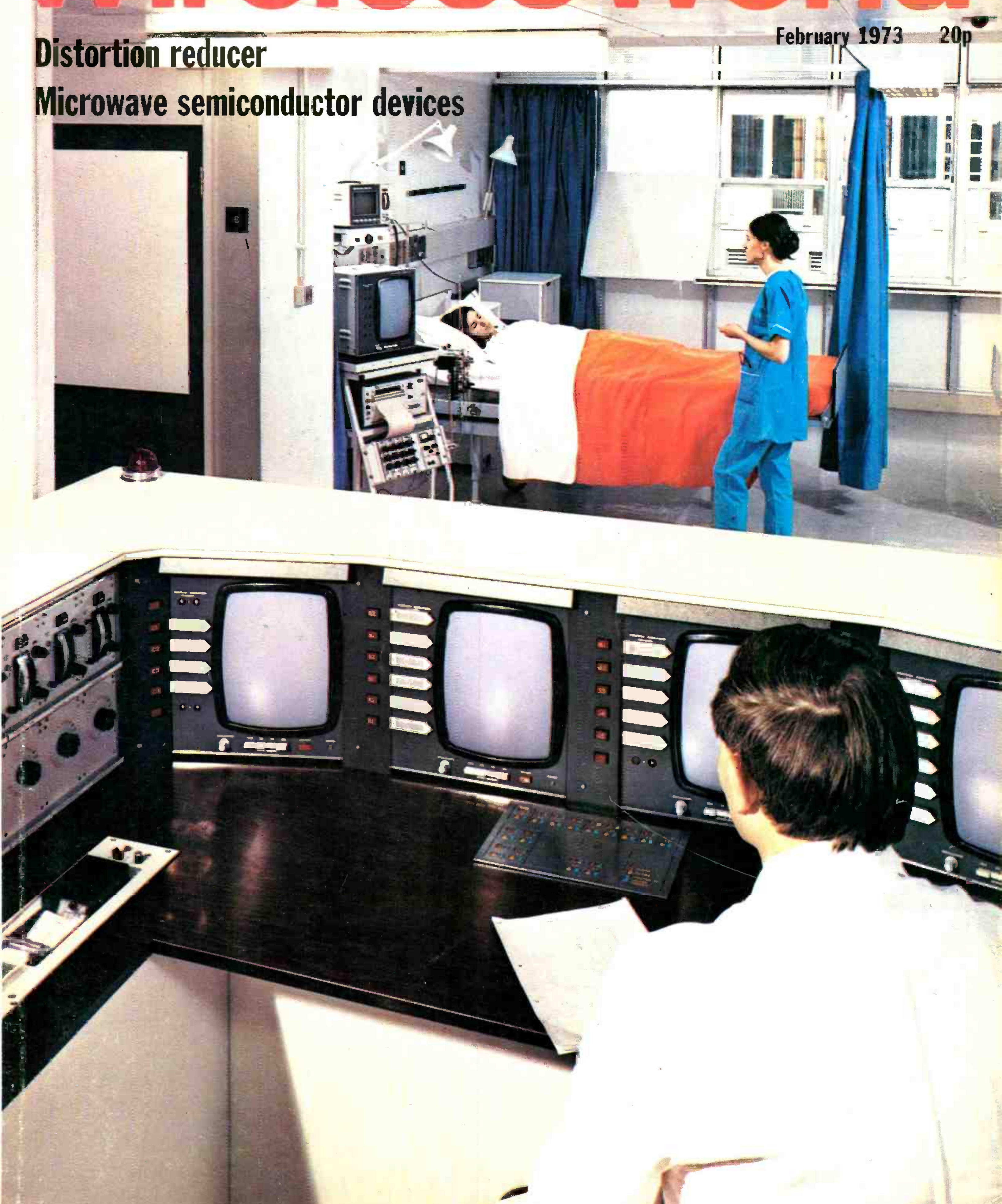
Wireless World

February 1973 20p

Distortion reducer

Microwave semiconductor devices



The new Bradley 200 is a quality 100 MHz general purpose oscilloscope it costs just £595 (U.K. Price)

That's remarkable value for money. Considerably less than you could pay for the same performance, accuracy, sensitivity and versatility. Not that we set out to undercut the competition.

All we wanted to do was to produce the best 100 MHz general purpose oscilloscope on the market. But because we started from scratch, we were able to use the latest engineering techniques and advanced circuitry (including many i.c.'s). And this meant we could price the 200 very competitively.

The 200 incorporates all the features you would expect in a first-class modular instrument plus several new ideas. To find out about these, please telephone Ashley Stokes on 01-450 7811, Extension 113. Or write to him at this address:

G. & E. BRADLEY LIMITED,
Electral House, Neasden Lane,
London NW10 1RR
Telex: 25583

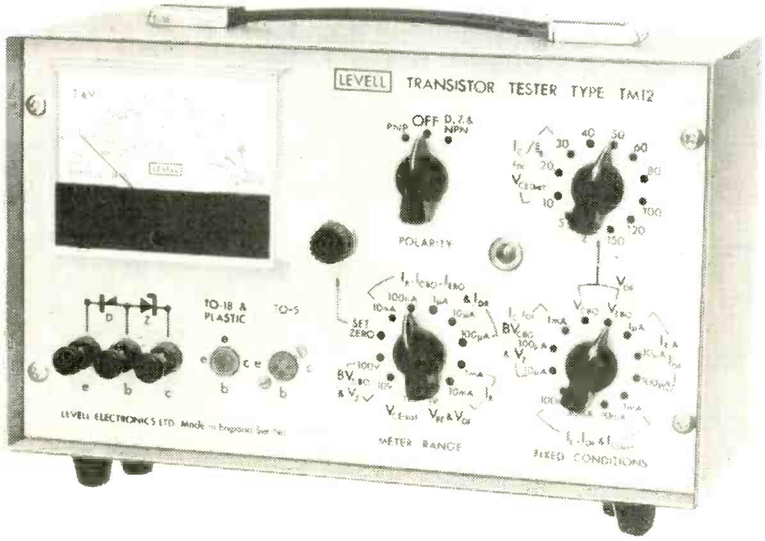
A Lucas Company

BRADLEY electronics

WW—001 FOR FURTHER DETAILS

LOW COST TRANSISTOR TESTERS

LEVELL
PORTABLE INSTRUMENTS



VOLTAGE UP TO 150V. LEAKAGE DOWN TO 0·5nA.

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 and 30. The instrument is powered by a 9V battery and a transistor D.C. to D.C. converter to produce 150V.

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. Short circuit current limit 1mA.
BV_{CBO}:	10V or 100V f.s.d. acc ± 2% f.s.d. ±1% at currents of 10μA, 100μA and 1mA ± 20%. Open circuit voltage limit 150V.
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%. V_{CE}=2V approx.
h_{FE}:	3 inverse scales of 2000 to 100, 400 to 30 and 100 to 10 convert I_B into h_{FE} readings. Acc. is ±(2+200÷% of f.s.d.)% i.e. ±4% at f.s.d.
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 acc. ±1%.

POWER SUPPLY
One type PP9 battery, or A.C. mains when a LEVELL Power Unit is fitted.

SIZE & WEIGHT
7″ x 10¼″ x 5½″. 8 lbs

type TM12 £65

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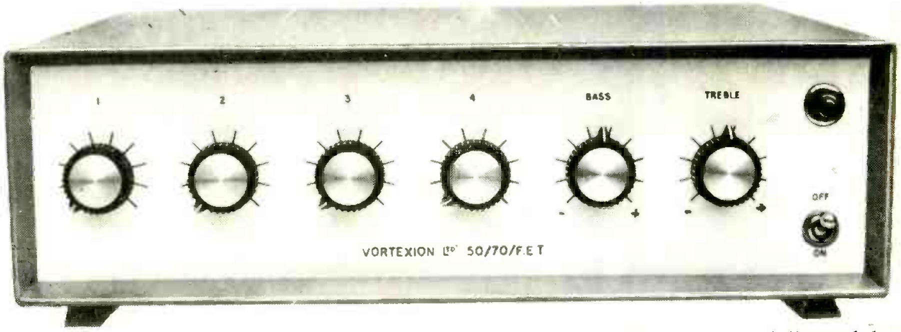
Tel: 01-449 5028/440 8686

WW—004 FOR FURTHER DETAILS

Vortexion

50/70 WATT ALL SILICON AMPLIFIER WITH BUILT-IN 4-WAY MIXER USING F.E.T.s.



This is a high fidelity amplifier (0.3% intermodulation distortion) using the circuit of our 100% reliable 100 Watt Amplifier with its elaborate protection against short and overload, etc. To this is allied our latest development of F.E.T. Mixer Amplifier, again fully protected against overload and completely free from radio breakthrough.

The mixer is arranged for 2-30/60Ω balanced line microphones, 1-HiZ gram input and 1-auxiliary input followed by bass and treble controls. 100 volt balanced line output or 5/15Ω and 100 volt line.

50/70 WATT ALL SILICON AMPLIFIER WITH BUILT-IN 5-WAY MIXER USING F.E.T.s
This is similar to the 4-way version but with 5 inputs and bass cut controls on each of the three low impedance balanced line microphone stages, and a high impedance (10 meg) gram stage with bass and treble controls plus the usual line or tape input. All the input stages are protected against overload by back to back low noise, low intermodulation distortion and freedom from radio breakthrough. A voltage stabilised supply is used for the pre-amplifiers making it independent of mains supply fluctuations and another stabilised supply for the driver stages is arranged to cut off when the output is overloaded or over temperature. The output is 75% efficient and 100V balanced line or 8-16Ω output are selected by means of a rear panel switch which has a locking plate indicating the output impedance selected. The Mixer section has an additional emitter follower output for driving a slave amplifier, phones or tape recorder, output .3V out on 600 ohms upwards.

100 WATT ALL SILICON AMPLIFIER. A high quality amplifier with 8 ohms-15 ohms or 100 volt line output for A.C. Mains. Protection is given for short and open circuit output over driving and over temperature. Input 0.4V on 100K ohms.

THE 100 WATT MIXER AMPLIFIER with specification as above is here combined with a 4-channel F.E.T. mixer, 2-30/60Ω balanced microphone inputs.1-HiZ gram input and 1-auxiliary input with tone controls and mounted in a standard robust stove enamelled steel case. A stabilised voitage supply feeds the tone controls and pre amps, compensating for a mains voltage drop of over 25% and the output transistor biasing compensates for a wide range of voltage and temperature. Also available in rack panel form.

CP50 AMPLIFIER. An all silicon transistor 50 watt amplifier for mains and 12 volt battery operation, charging its own battery and automatically going to battery if mains fail. Protected inputs, and overload and short circuit protected outputs for 8 ohms-15 ohms and 100 volt line. Bass and treble controls fitted.
Models available with 1 gram and 2 low mic. inputs, 1 gram and 3 low mic. inputs or 4 low mic. inputs.

200 WATT AMPLIFIER. Can deliver its full audio power at any frequency in the range of 30 c/s-20 Kc/s ± 1 dB. Less than 0.2% distortion at 1 Kc/s. Can be used to drive mechanical devices for which power is over 120 watt on continuous sine wave. Input 1 mW 600 ohms. Output 100-120V or 200-240V. Additional matching transformers for other impedances are available.

20/30 WATT MIXER AMPLIFIER. High fidelity all silicon model with F.E.T. input stages to reduce intermodulation distortion to a fraction of normal transistor input circuits. The response is level 20 to 20,000 cps within 2 dB and over 30 times damping factor. At 20 watts output there is less than 0.2% intermodulation even over the microphone stage at full gain with the treble and bass controls set level. Standard model 1-low mic. balanced and 1 auxiliary input.

VORTEXION LIMITED, 257-263 The Broadway, Wimbledon, S.W.19 1SF

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WW—005 FOR FURTHER DETAILS

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AKG D190
Professional dynamic microphone.
Directional characteristic.
Smooth frequency response.
Frequency range; 30 – 16,000 Hz.
No wonder this is one of the top selling professional mikes in this country.
RRP £20.50 to £24.90 according to type.

AKG K 60.
Another widely used product both professionally and by thousands of hi-fi enthusiasts all over the country.
Lightweight – double headband – soft – detachable ear cushions.
Excellent noise excluding properties.
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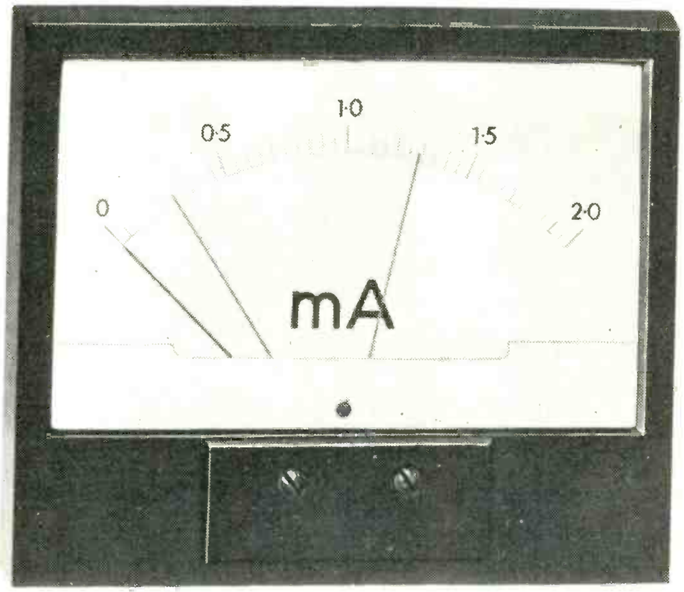
ANDERS MEANS METERS...

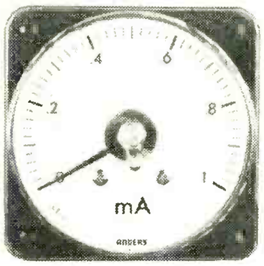


SOLICONTROLLER 36 MOVING COIL RELAY

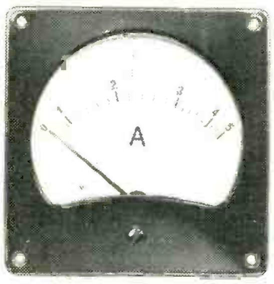
- Indication/control of volts and amps at preset levels.
- Dial can be scaled in watts, frequency, RPM liquid level, etc.
- Changeover relay or voltage output at each alarm position
- Restyled model of instrument proved in the field over many years
- High and/or low adjustable control pointers
- Reliable and accurate photo-electric system utilised

Anders provide what is probably the largest range of meters available from a single source in Europe: MC/MI, dynamometer, vibrating reed, electrostatic, etc. in over 100 case styles and sizes, a few of which are shown below.

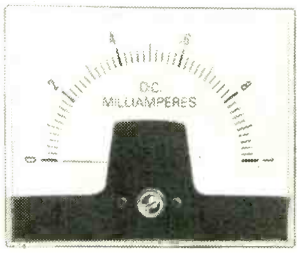
Popular models and ranges are stocked in depth while a specially equipped instrument department enables swift production of non-standard ranges and scales, to suit individual customer requirements, in large or small quantities.



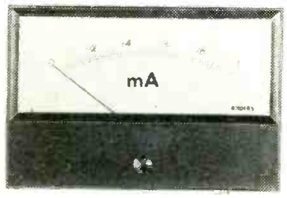
Oxford Long Scale 240°. 2 models, 5·5″, 8″ scales. DC moving coil and AC moving coil rectified.



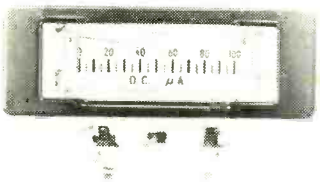
Vulcan Moving Iron. 4 models, 1·5″, 1·8″, 2·7″, 3·7″ scales. Voltmeters, ammeters and motor starting meters.



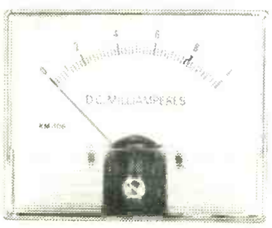
Crescent Long Scale 180°. 3 models, 4″, 5″, 6·25″ scales. DC moving coil and AC moving coil rectified. Clear plastic.



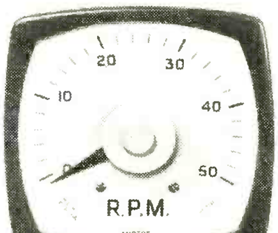
Regal Range 100° flattened arc. 2 models 2.5″ and 3.2″ scales. Taut band. DC moving coil and AC moving coil rectified.



Profile Miniature Edgewise Meters. 3 models, 1″, 1·2″, 2″ scales. DC moving coil and AC moving coil rectified.



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



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

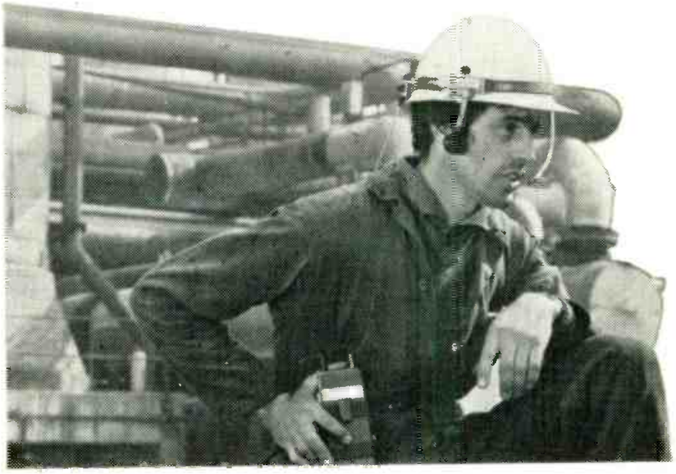
Lancaster Long Scale 240°. 2 models, 4″, 5·5″ scales. DC moving coil and AC moving coil rectified.

ANDERS ELECTRONICS LIMITED 48/56 Bayham Place, Bayham Street, London, N.W.1. Telephone 01-387 9092.

Manufacturers and distributors of Electrical Measuring Instruments. Sole U.K. distributors of FRAHM Resonant Reed Frequency Meters and Tachometers. Manufacturers of purpose built electrical and electronic equipment to customers requirements.

WW—008 FOR FURTHER DETAILS

BURNDEPT HAVE PLANS TO SPEED UP A BUSINESS ON THE MOVE



Burndept communication systems will give any business a move on.

Firstly, Burndept have the planning skill.

With 50 years' experience in radio communications, they'll plan a system according to your needs.

Secondly, Burndept has the equipment.

Burndept's new Personal Radio-telephone is the most versatile unit yet designed. It's small and light, and has a wide range of accessories. So it can be used simply by anybody anywhere – airline mechanics, construction workers, oil refinery men – all find a use for it. The Burndept Mobile Radio-telephone is a complete UHF transmitter/receiver suitable for lorries, cars, cranes and fork lift trucks.

But Burndept go one better.

They back up their systems planning with a most efficient after-sales service.

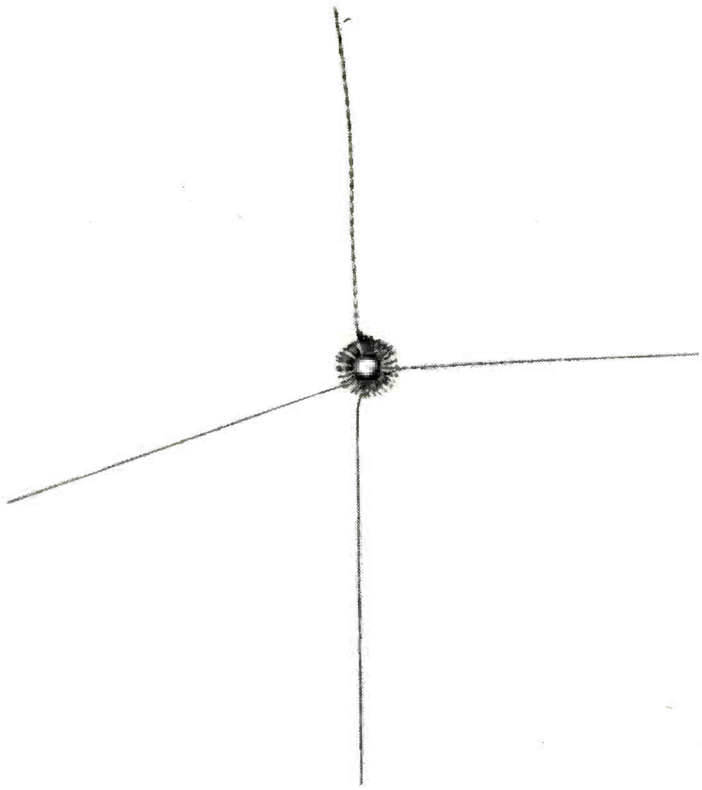
So you'll always get the best out of Burndept – and speed up your business on the move.

BURNDEPT

With us, service comes first.
Burndept Electronics (E.R.) Ltd.
St. Fidelis Road, Erith, Kent. Tel. Erith 39121.

WW—009 FOR FURTHER DETAILS

The smaller we get the bigger we grow



From miniature to standard, simple to complex, prototype to production, Gardners have the expertise the electronics industry demands.

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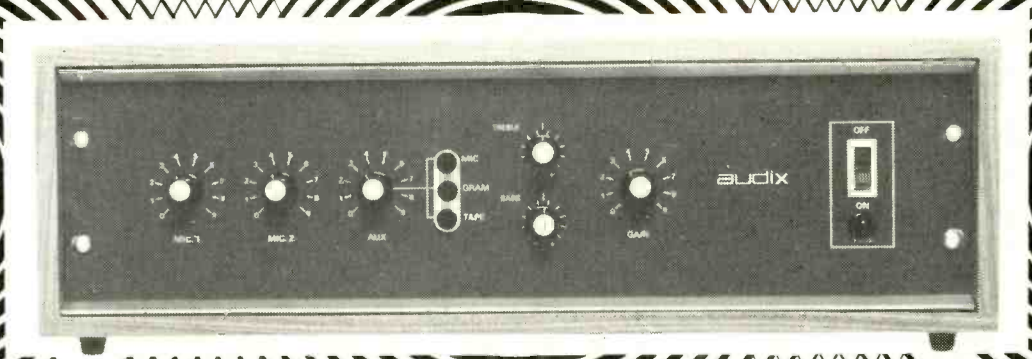
WW—010 FOR FURTHER DETAILS

audix
SOUND SYSTEMS AND ELECTRONICS

AUDIO AMPLIFIERS



MODELS A80, A25, A18

The Model A80 Audio Amplifier illustrated is representative of the range of integrated amplifiers designed and manufactured by Audix for commercial applications such as factories, hotels, conference centres etc. Facilities for two low impedance balanced microphones and one switchable input for medium impedance microphone, tape recorder or gramophone are incorporated in this 60 watt r.m.s. amplifier. Outputs at 100V and 8 ohms are provided and are protected electrically against damage by short circuit, open circuit, inductive and capacative loads.

Power amplifiers having continuous r.m.s. ratings of 15, 30, 60, 120 and 175 watts are also available and can incorporate a wide variety of input mixing modules to satisfy the different requirements of individual clients.

audix

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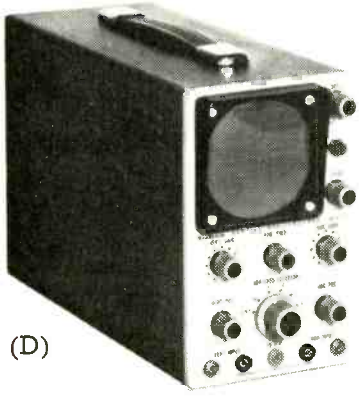
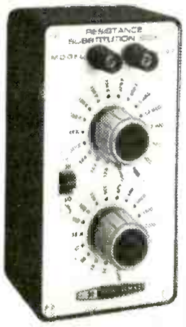
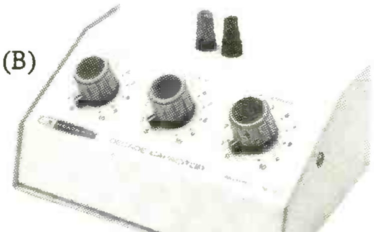


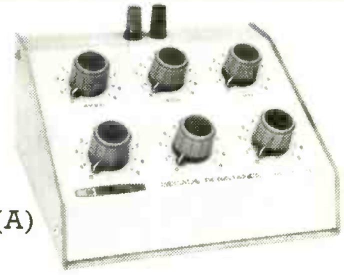
(D)



(C)

(B)





(A)

(A) Decade Resistance Box
1 ohm to 999,999 ohms in 1 ohm steps. 1/2% accuracy, 1 watt.
Kit K/IN-17 £14.80 Carr. 40p

(B) Decade Capacitor Box
100 pF to 0.111 μF in 100 pF Increments @ 350 VDC continuous, 500 VDC intermittent.
Kit K/IN-27 £9.80 Carr. 40p

(C) Resistance Substitution Box
15 ohms to 10 megohms in common values. Accuracy ±10%. Rating 1 watt all values.
Kit K/IN-37 £4.80 Carr. 30p

(D) Service Oscilloscope
2 Hz to 3 M Hz vertical band width. 250 mV pk-to-pk. Sensitivity T/Base 20 Hz to 200 kHz in four ranges.
Kit K/OS-2 £29.50 Carr. 80p

(E) Popular VVM
0–1.5, 5, 15, 50, 150, 500, 1500 V DC and AC (RMS) Full Scale. Resistance 10 ohm centre scale ×1, ×10, ×100, ×1000, ×10k, ×100k, ×1 MEG.
Kit K/IM-18D £15.80 Carr. 40p

(F) Capacitor Substitution Box
18 position switch selects any of 18 standard values. Range 0.0001 μF through 0.22 μF.
Kit K/IN-47 £3.90 Carr. 30p

(G) Portable Solid-State VVM
4 DC, 4 AC, 4 ohm ranges. 11 Mohm input DC, 1 Mohm input AC. Large 4½" 200 μA Meter. Battery powered. Rugged polypropylene case. Test leads supplied.
Kit K/IM-17U £13.80 Carr. 40p

(H) In-Circuit Transistor Tester
Tests DC gain, in or out of circuit. Iceo or Icbo leakage. Identifies NPN/PNP types. Large 4½" 200 μA Meter. Portable, battery powered. Rugged polypropylene case.
Kit K/IT-18 £13.80 Carr. 40p

(I) RF Signal Generator
Covers 100 kHz to 200 M Hz in 6 bands. Modulated or unmodulated RF output. Factory wired/aligned coil and band switch assembly. Large accurately-calibrated dial scales.
Kit K/RFIU £19.50 Carr. 40p

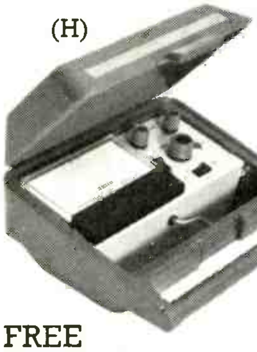
(J) Portable Transistor/Diode Checker
Checks high low power transistors. PNP/NPN types. Shorts, leakage, open element and current gain. Checks forward, reverse current. Operates on internal 1.5 volt cells.
Kit K/IT-27 £3.90 Carr. 30p

(E)

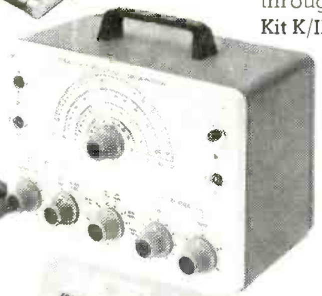
(F)

(G)

(H)



(I)



(J)

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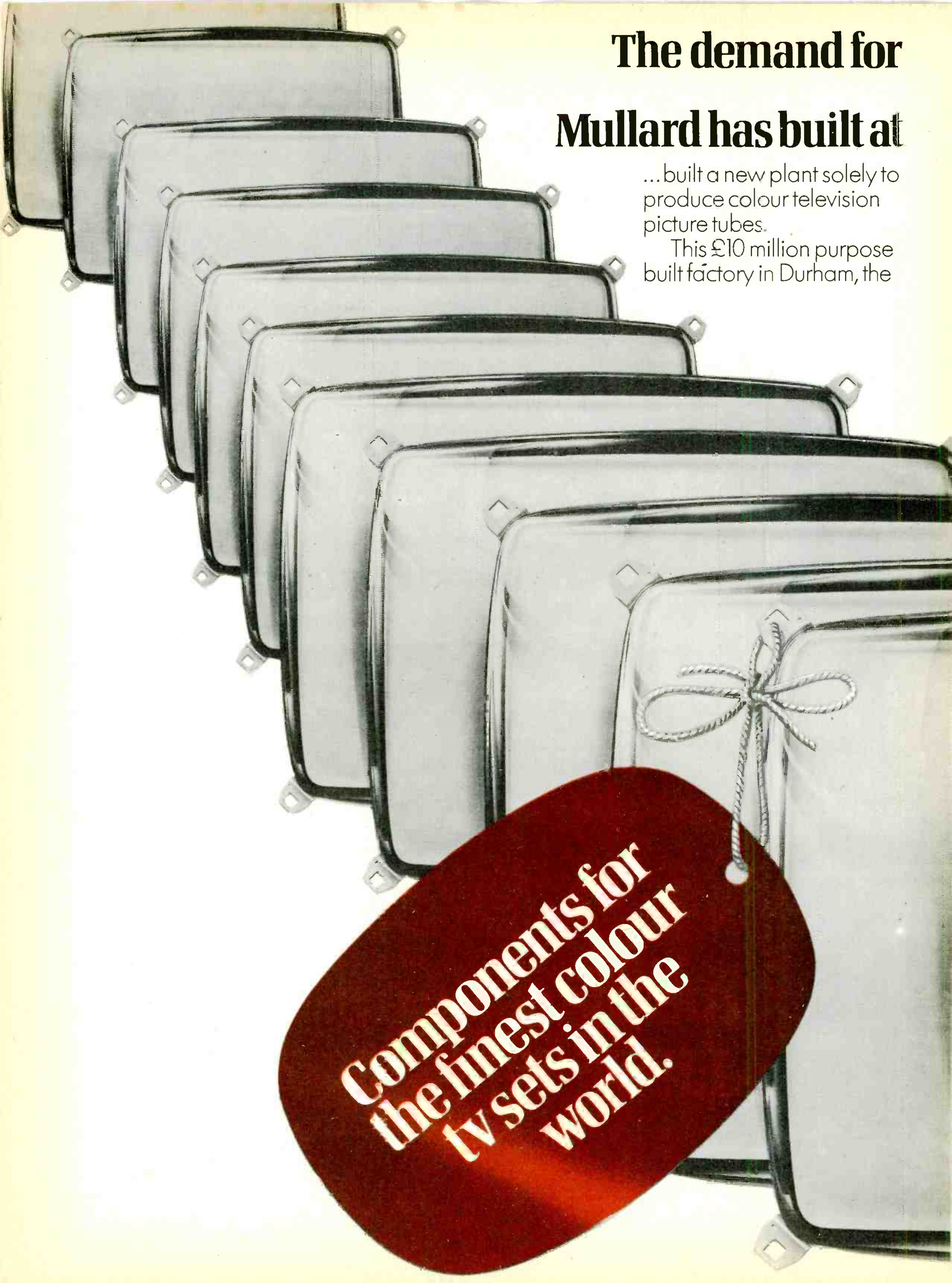

The demand for
Mullard has built at
...built a new plant solely to produce colour television picture tubes.
This £10 million purpose built factory in Durham, the
Components for the finest colour tv sets in the world.

colour TV goes on growing

Durham to help you meet it...

most modern in the world, performs all the stages in the manufacture of colour tubes, from the delicate assembly of tube guns to the laying of over one million phosphor dots on the screen, making use of glass from Mullard's own glass factory at Simonstone.

Mullard ColourScreen tubes are designed for British transmission standards, helping setmakers to offer viewers a superb picture from the finest sets.

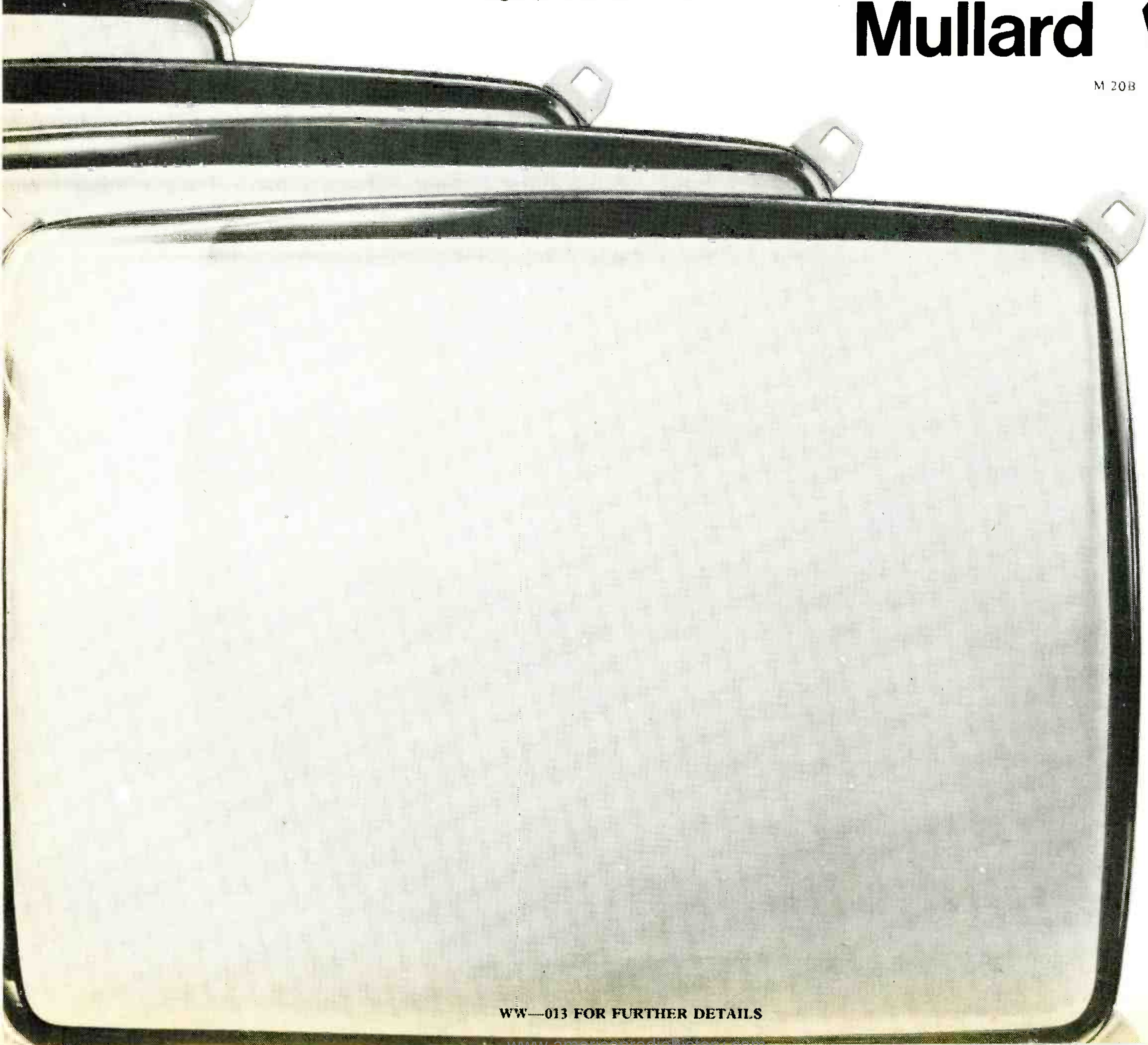
With its square corners, flat faceplate, constant colour registration and high light output, ColourScreen is not only the best, but will continue to be the biggest selling home produced tube. With investments like Durham supplementing the huge production at Simonstone, and also enabling Mullard to increase its already impressive export performance.

Mullard Durham started volume production of ColourScreen tubes ahead of schedule and will further increase its output in the months to come.

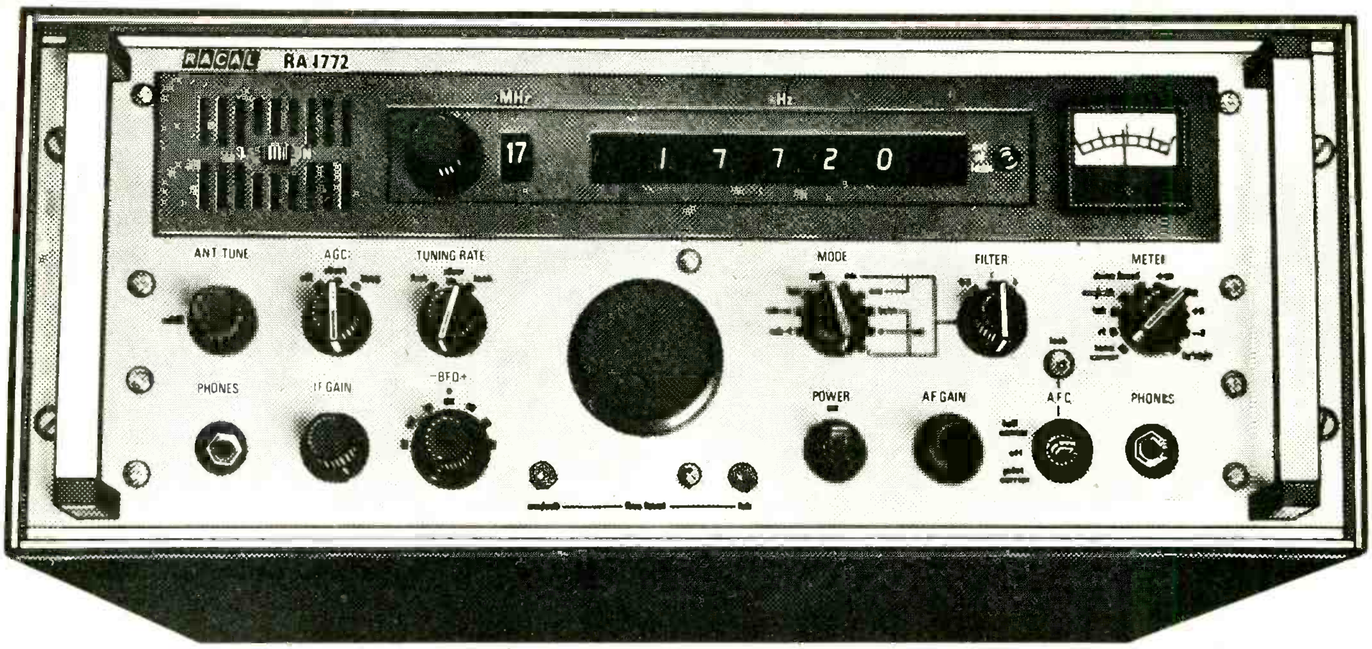
Helping you meet the huge demand for the finest colour TV sets in the world.

Mullard

M 20B



WW—013 FOR FURTHER DETAILS



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The RA. 1770 series of solid-state synthesized Communications Receivers combines the company's internationally recognized reputation and experience with the most advanced design and production techniques.

The RA. 1772 is a synthesized tunable receiver designed for operator control and suitable for all forms of reception and monitoring over the wide frequency range 15kHz–30MHz. The unique system of single knob frequency control allows rapid tuning across a complete 1 MHz band in 10 Hz increments with the "feel" and smoothness of a VFO but the accuracy and stability of the frequency standard.

The RA. 1771 is designed for point-to-point operation where frequency selection is by in-line decadic controls.

The electrical design embodies the latest techniques in mixer and signal path development to produce a performance with respect to dynamic range, intermodulation products, reciprocal mixing, cross modulation, blocking and spurious responses far exceeding that found in any receiver of its type.

- RA. 1772–Single knob synthesizer control–LED display.
- RA. 1771–Decadic switch frequency selection.
- 15 kHz–30 MHz in 10 Hz increments.
- Intermodulation products better than –90 dB
- Unsurpassed signal path performance.
- Optional RF tuning–Choice of frequency standards.
- Operator proven control layout.
- High MTBF–Low MTTR.
- RA. 1772–Approved Nato No. 5820-99-624-5397.

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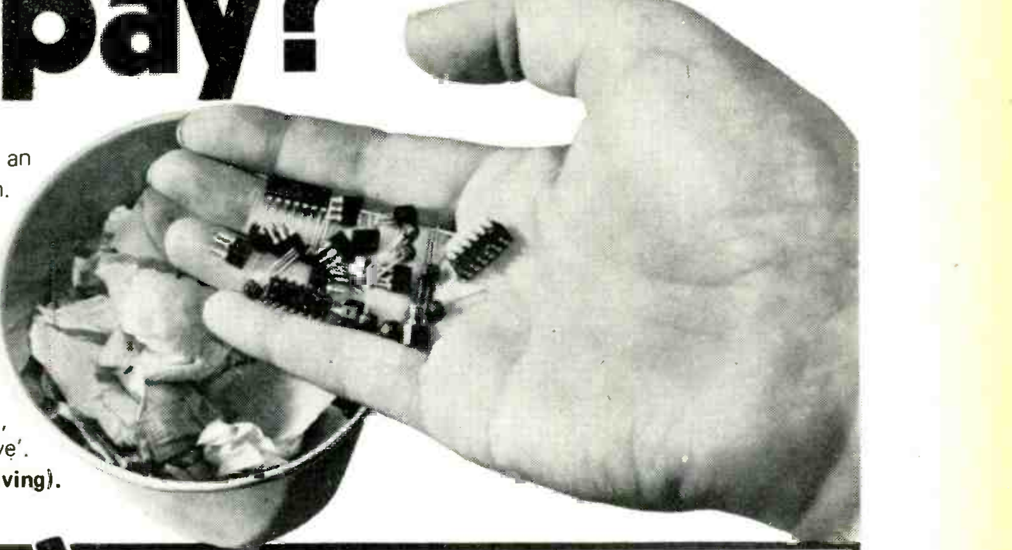
Racal...the communications people

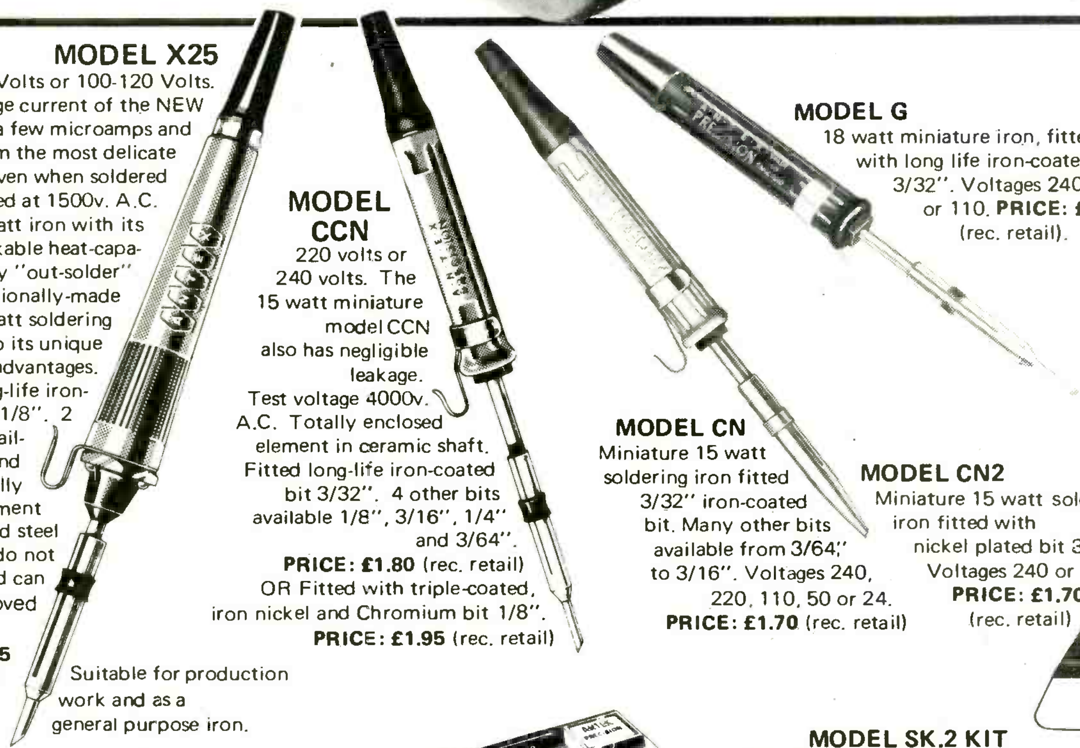
RACAL
The Electronics Group

WW—014 FOR FURTHER DETAIL

is this the price you pay?



Probably, if you're still using an ordinary soldering iron. Ordinary soldering irons can cause damage to transistors and integrated circuits – damage which wastes time and costs money. Now, with the unique ANTEX X25 and CCN low leakage soldering irons no harm can come to the most delicate equipment, even when soldered 'Live'.
(You could be making quite a saving).



MODEL X25

220-240 Volts or 100-120 Volts. The leakage current of the NEW X25 is only a few microamps and cannot harm the most delicate equipment even when soldered "live". Tested at 1500v. A.C. This 25 watt iron with its truly remarkable heat-capacity will easily "out-solder" any conventionally-made 40 and 60 watt soldering irons, due to its unique construction advantages. Fitted long-life iron-coated bit 1/8". 2 other bits available 3/32" and 3/16". Totally enclosed element ceramic and steel shaft. Bits do not "freeze" and can easily be removed

PRICE: £1.75
(rec. retail)

Suitable for production work and as a general purpose iron.

MODEL CCN

220 volts or 240 volts. The 15 watt miniature model CCN also has negligible leakage. Test voltage 4000v. A.C. Totally enclosed element in ceramic shaft. Fitted long-life iron-coated bit 3/32". 4 other bits available 1/8", 3/16", 1/4" and 3/64".
PRICE: £1.80 (rec. retail)
OR Fitted with triple-coated, iron nickel and Chromium bit 1/8".
PRICE: £1.95 (rec. retail)

MODEL G

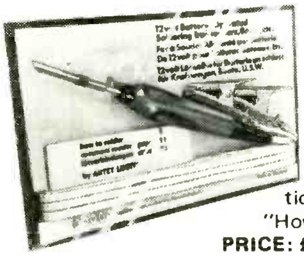
18 watt miniature iron, fitted with long life iron-coated bit 3/32". Voltages 240,220 or 110. **PRICE: £1.83** (rec. retail).

MODEL CN

Miniature 15 watt soldering iron fitted 3/32" iron-coated bit. Many other bits available from 3/64" to 3/16". Voltages 240, 220, 110, 50 or 24.
PRICE: £1.70 (rec. retail)

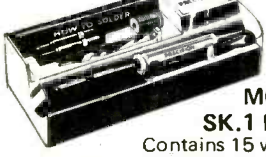
MODEL CN2

Miniature 15 watt soldering iron fitted with nickel plated bit 3/32". Voltages 240 or 220.
PRICE: £1.70
(rec. retail)



MODEL MES.KIT

Battery-operated 12v. 25 watt iron fitted with 15' lead and 2 heavy clips for connection to car battery. Packed in strong plastic wallet with booklet "How to Solder"
PRICE: £1.95 (rec. retail)



MODEL SK.1 KIT

Contains 15 watt miniature iron fitted with 3/16" bit, 2 spare bits 5/32" and 3/32", heat sink, solder, stand and "How to Solder" booklet.
PRICE: £2.75 (rec. retail)

MODEL SK.2 KIT

Contains 15 watt miniature iron fitted with 3/16" bit, 2 spare bits 5/32" and 3/32" heat sink, solder, stand and "How to Solder" booklet.
PRICE: £2.40
(rec. retail)

ANTEX

From radio or electrical dealers, car accessory shops or in case of difficulty direct from:–
ANTEX LTD. FREEPOST
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☐ Please send the ANTEX colour catalogue.
☐ Please send the following:
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ADDRESS ....
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Getting valves is getting tricky.

Ever spent hours trying to get a valve, only to find that putting it in circuit makes no difference?

Everybody has.

With VCM 163 you can check exactly which valves are OK and which aren't. And spend time getting only the valves that really need replacing.

As valve testers go – and let's face it, most of them have – Avo VCM 163 is a very sophisticated instrument. It even has a NATO stock number.

And what's more there's a new Avo Valve Data Manual (19th edition) free with each VCM 163. It includes obsolete types and 84 pages of equivalents, and could save a fortune in wasted time. The manual is also available separately at just £5.25 (U.K. Trade).

So write or telephone for more details of VCM 163 now. Send us a cheque for £5.25, and we'll send you a 19th edition Valve Data Manual too.

Trust Avo to look after you.

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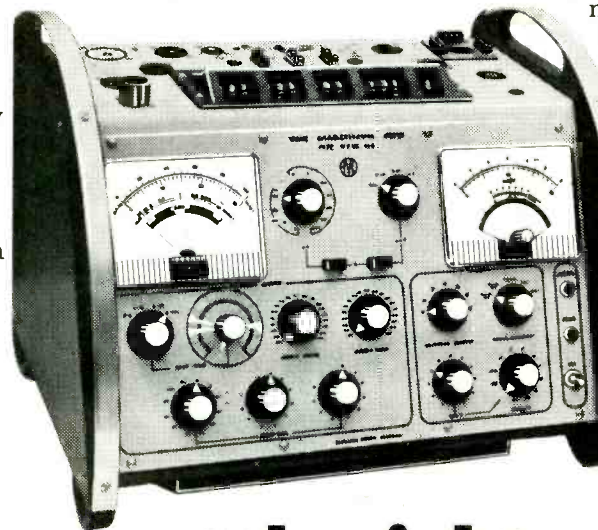
Telephone: Dover 2626.



Avo

So be sure you get the right valve. With an Avo VCM 163 valve tester.

Thorn Measurement Control and Automation Division. THORN

WW—016 FOR FURTHER DETAILS

NOW IT'S THE AMCRON DC 300

and as ever, still the best of its kind in the world

£360

AMCRON DC.300
TWO CHANNEL POWER AMPLIFIER

Eminently suitable for P.A. operation, laboratory and other precision controlled applications. There are other power amplifiers in the Amcron (formerly Crown International) range from two channel 60 watts RMS output to 1000 watts RMS single channel models as well as pre-amp I.C. 150.

Requests for fuller information invited

In the Amcron DC.300 you will recognise what was formerly the Crown International DC.300. No other power amplifier in the world has such remarkable specifications. The change to Amcron was simply to avoid possible confusion of name identification. Nothing else has been altered. It might be that the DC.300 you order still shows 'Crown' on the front. It is of no significance. The Amcron remains the same thoroughbred in electronic engineering. Only the name has been changed and if you value perfection, it won't take long to remember.

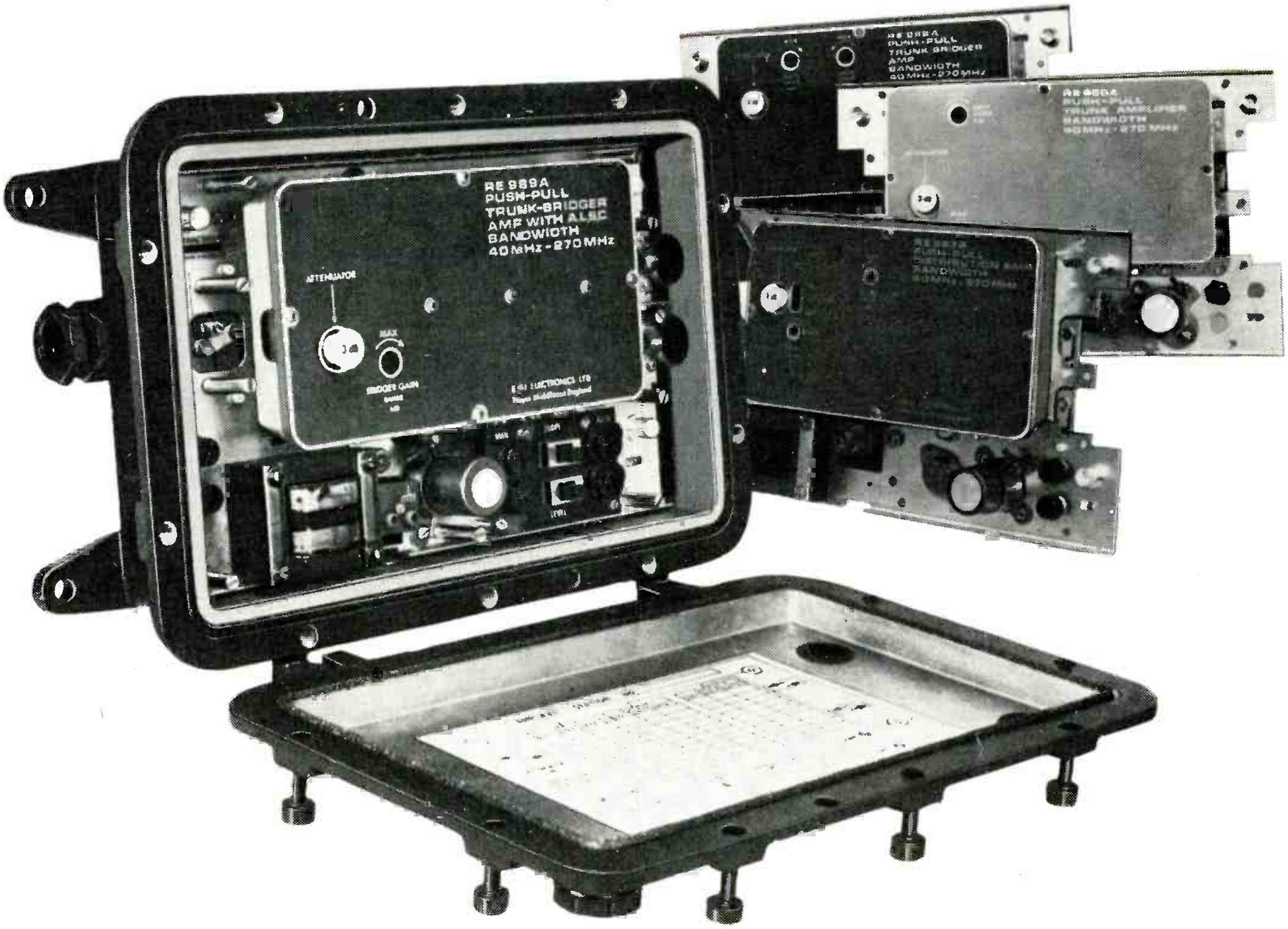
● BRIEF SPECIFICATIONS

POWER	At clip point 340 watts RMS per channel into 4 ohms. 190 watts into 8 ohms per ch. Mono — more than 500 watts RMS into 8 ohms.
POWER RESPONSE	± 1dB from zero to 20 KHz at 150 watts RMS into 8 ohms per ch.
THD	0.02% at 300 watts RMS per ch. into 4 ohms.
I.M. DISTORTION	less than 0.1% from 0.01 watts to 150 watts RMS into 8 ohms per ch.
HUM & NOISE	100 dB below 150 watts RMS into 8 ohms per ch.
DAMPING FACTOR	Greater than 200 up to 1KHz.
PROTECTION	against short or open circuit and mis-matching.
INPUT SENSITIVITY	1.7V ± 2% at 10 KHz for 150 watts RMS into 8 ohms.
SIZE	19" x 7" high x 9¾" deep with front panel, suitable for rack mounting.

LEAFLET WITH FULLER DETAILS ON APPLICATION

MACINNES LABORATORIES LTD. STONHAM, STOWMARKET. IP14 5LB
Telephone Stonham (044 971) 486.

WW—017 FOR FURTHER DETAILS



EMI Colorline CATV

The multi-channel VHF system with 40-270 MHz bandwidth, lower distortion · Increased Cascadeability

EMI Colorline Mark II Push-Pull CATV equipment offers full channel capacity, lower distortion and greater system reach.
The push-pull amplifiers and their associated passive units have a band-width of 40-270 MHz and are designed for systems distributing up to twenty channels, where single octave operation is not acceptable.
VHF bands, 1,11, and 111 and areas of the VHF spectrum outside the normal broadcast bands can be used.
Mark II Colorline permits the planning and installation of networks having extremely low cross-modulation, intermodulation and harmonic distortion. All amplifiers have full AC line power facilities.
Amplifier/power units are readily interchangeable without disturbing cable connections and are also mechanically compatible with EMI Mark I amplifiers. If you're planning a CATV system, you should know more about Colorline. Contact EMI today.

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EMI Telecommunications

Telecommunications Group,
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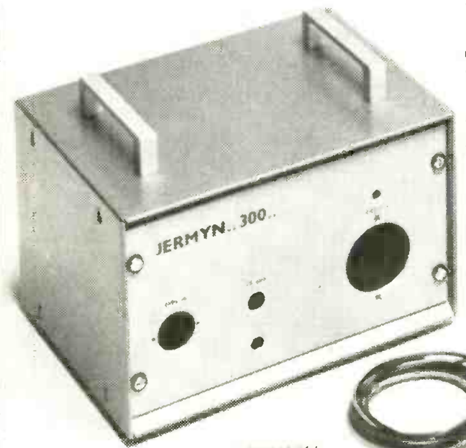
Telephone: 01-573 3888 Telex 22417
Cables: EMISOUND LONDON

WW—018 FOR FURTHER DETAILS

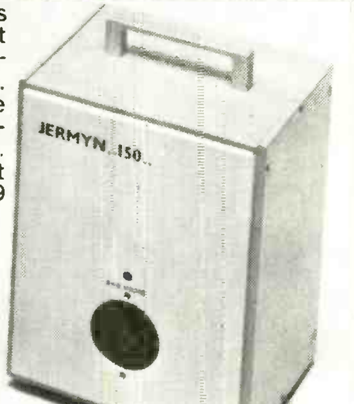
Candles are for Eskimos.

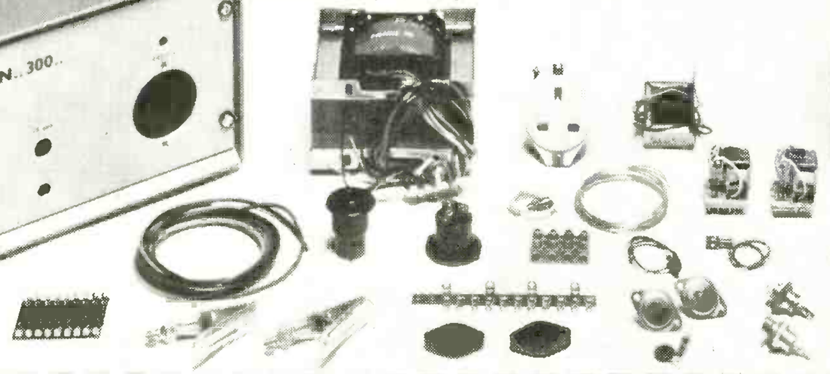
The 1973 answer to power cuts.
The Jermyn invertor.



When plugged into any 13 amp socket these units charge 12/24v car batteries (up to 10 amps). In the event of a power failure they automatically start inverting, providing a 240v 50Hz emergency supply at 150/300 watts. Enough for a couple of standard lamps and the TV or the central heating pump and the hi-fi. All this and full protection against overload and wrong battery lead connection.

A complete kit of parts costs £25 for the 150 watt unit or £34 for the 300 watt version (made up and tested) £29 and £39 respectively.





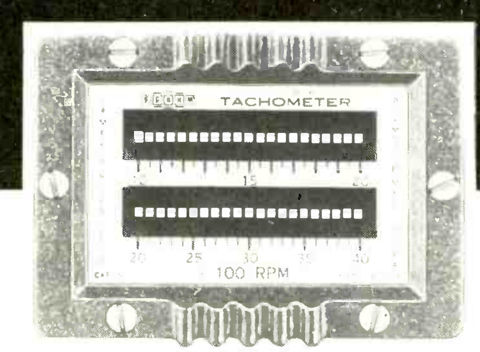
To Jermyn Industries Vestry Estate Sevenoaks Kent	Please rush me ☐ Kit(s), ☐ made up invertors. I enclose cheque/postal order for £	Name Address

WW1

Block Capitals Please

WW—020 FOR FURTHER DETAILS

Accurate and direct measurement of speed without coupling to moving parts



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for hand use or permanent mounting

Ranges and combinations of ranges from 900 to 100,000 r.p.m.

Descriptive Literature on Frahm Resonant Reed Tachometers and Frequency Meters available from the sole U.K. Distributors. 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—030 FOR FURTHER DETAILS

a handout from Hatfield

The Hatfield hand-held decibel meter is only 7¼" x 4½" and the other small thing about it is the unbeatable low price.

It's versatile, has a wide range and is very robust. Push-button operation prolongs the battery life which is in excess of 50 hours. The range is +21 to -60 bBm.

Price: £89.50 ex. works.

Send for full details of this remarkable instrument.

HATFIELD

forward thinking in electronics

HATFIELD INSTRUMENTS LIMITED
Burrington Way, Plymouth PL5 3LZ. Devon.
Tel. Plymouth (0752) 72773/4 Grams: Sigjen, Plymouth. Telex: 45592
South-East Asia: *for prompt service and deliveries, contact:*
Hatfield Instruments (NZ) Ltd., P.O. Box 561, Napier, New Zealand

WW—031 FOR FURTHER DETAILS

THREE APPROACHES TO DIGITAL MEASUREMENT

Whatever your electrical measurement problem, there's a Bradley instrument to solve it – instantly, accurately, compactly and at a realistic price.

For DC voltages, there's the Model 173B, a digital package that measures only 215mm x 110mm x 290mm; this means that you can mount two side by side on a standard 19in. rack. The 173B will tackle DC voltages of either polarity with a first-class resolution of 10µV. Its five full-scale ranges each having a 15,000 bit length, cover from 10µV to 1500.0 V with an accuracy of 0.01% of reading, ± 1 digit.

The Bradley 173B costs only £320 in the UK.

For a little more, you can buy the Model 188 which incorporates all the features and performance of the 173B on DC plus true high performance and accuracy for AC measurements. In the AC mode, it offers four ranges covering from 100µV to 1200.0 V r.m.s. with a mid-band accuracy of 0.1% of reading ± 1 digit. The frequency range is 20Hz to 100kHz. Five digit readout can be triggered internally or externally in either automatic or manual modes. In addition, 'Hold' or 'One-Shot' facilities are provided. And, as with the 173B, there's a calibration position on the range switch which brings an unsaturated standard cell into use as an internal reference. The Bradley 188 AC/DC DVM costs £405 in the UK.

Finally, there's the Model 196 Digital Multimeter. In addition to measuring AC/DC voltages with the same accuracy and high standards as the 173B and 188, the 196 will also tackle resistance measurements over the range 0.01 Ω to 15M Ω. The Bradley 196 costs £435 in the UK.

Our own BCS Certificate is available.

To find out more, please telephone Ashley Stokes on 01-450 7811, extension 113. Or write to him at the address below.

G. & E. BRADLEY LIMITED,
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BRADLEY electronics

A sound choice

This new and exciting range of speakers is the outcome of many years research and development into all aspects of drive unit and enclosure design.

Results include permanent sealing of enclosures but retaining ease of access, elimination of crossover networks and attendant problems, superb performance and distinctive styling at new, lower prices.

Power capacities range from 4 watts right up to 35 watts, with cabinet finishes in teak, walnut or white.

You must see and hear this exciting new range for yourself. But start by writing for further information to the following address.

Modern Engineering & Technology Ltd,
4 Station Road West, Canterbury, Kent. Tel: 0227 60431/2
Main distributors for Canterbury Audio.

WW—022 FOR FURTHER DETAILS

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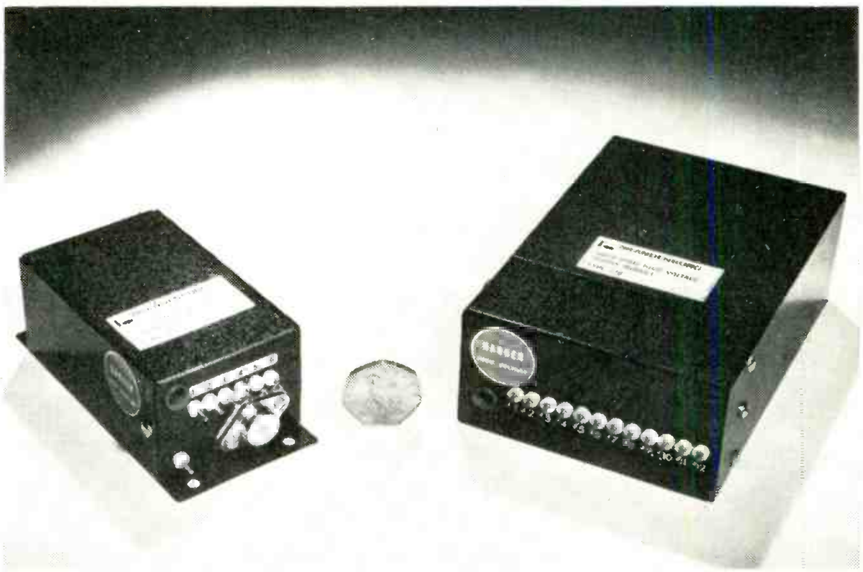
brandenburg
STABILISED HIGH VOLTAGE

solid state HV modules to power cathode ray tubes, etc.
—ready to connect



Many companies looking for HV supply modules have been driven to making their own – in spite of the cost and time involved. But now there is no need to. Brandenburg the British high voltage specialists, can supply standard, compact, reliable, fully tested modules with outputs up to 15kV at up to 500 μA to meet the most exacting demands at a very economical price. For requirements outside this range, Brandenburg are always prepared to quote for batch or quantity production of custom-engineered designs to meet particular applications.

★ Prototypes test proven under extreme electrical and environmental stress conditions.

★ Designed and packaged to operate in a wide range of environments.

★ Additional low voltage and output in the order of 500V suitable for various applications including focus supply.

★ Capable of withstanding overloads, flashovers and short circuit conditions.

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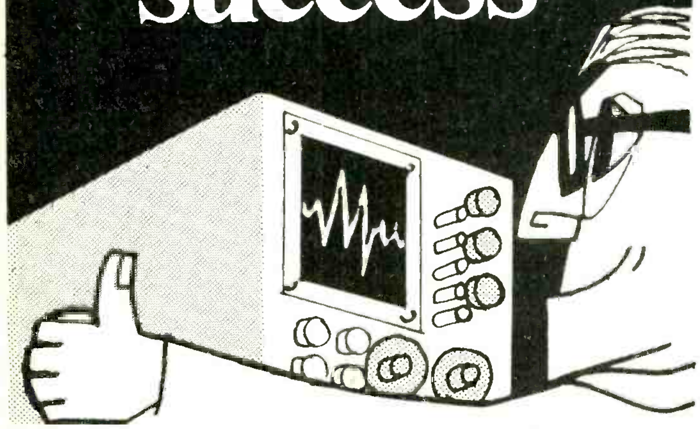
Germany: Herr. G. E. Wolfe (BRANDENBURG), 6 Frankfurt am Main-Niederrad, Hahnstr 46. Tel: 67-72-05
Agents or distributors in principal countries. P4129

WW—023 FOR FURTHER DETAILS

Our electronics are a signal success



Our manufacturing resources could contribute to *your* success, too! We've chalked up many years of service to ministries, government departments, armed forces, and a formidable list of significant names in industry. They all come to Whiteley for the specialist knowhow and resources we have developed. Can we help you?
We can build to your drawings and specification, or put our design departments at your service, as needed. From a small component to a complete system, in audio work, relay switching circuits, control systems, and many other spheres—our facilities are ready. The Whiteley organisation is self-contained. The manufacturing resources are backed by our own toolroom, sheet metal working and press shops, plating and finishing lines, coil and transformer winding shop, plastics moulding shop and a modern new cabinet factory. Capitalise on all these Whiteley facilities—call us in for a look at your next electronics need. You'll be in good company!

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London Office: 109 Kingsway, W.C.2. Tel. 01-405 3074

WW—025 FOR FURTHER DETAILS

What makes you think that we think you are thinking about edge connectors?

WE AREN'T YOU KNOW!

Actually, we *were* thinking that *you* might be thinking of Sub Miniatures or other Multi-way Connectors, or even Rocker Switches, Metal Pressings or Plastic Components. And we were thinking that, even if you only wanted a few of any or each of these, it would be a pleasure to do business with you.

And *you* might find it a pleasure to do business with *us*, especially as we can solve so many of your supply problems.

For instance, suppose you *did* want just a few of these or any other Cinch, Dot or FT components very quickly, we could, as stock holders, have them on the way to you the day we got your order.

Perhaps you'd like to put this promise to the test.

UNITED-CARR SUPPLIES

The single source that simplifies.

We have a remarkably comprehensive catalogue and if you can make good use of it, we shall be glad to send you one, but please state possible requirements.

Cinch DOT FT STOCKISTS

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WW—026 FOR FURTHER DETAILS

aerials by Aerialite for the soundest reasons

Aerialite aerials – products of intense scientific research and development – are about the best aerials of their kind available today. Made to last, the steel is rust-proof, the aluminium is of the finest quality. If you want really exceptional value for money, Aerialite makes sound sense.

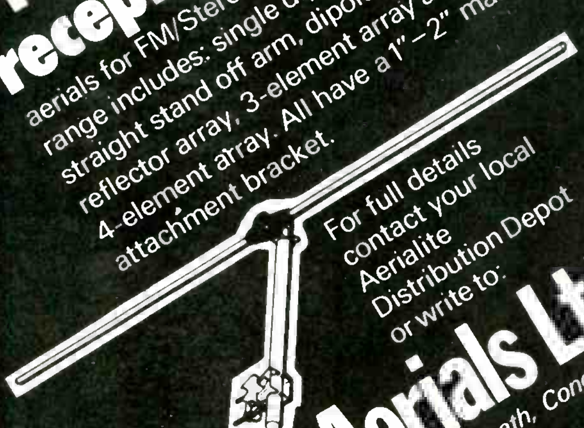
the Mastatic Aerial System, for LW, MW & SW radio reception

A vertical rod fixed clear of any electronic smog, the Mastatic picks up radio signals and passes them through two transformers comprising the Antistatic Downlead system. Static is reduced to one thousandth part of what it would be.

Available in 3 configurations, with choice of chimney lashing unit, wall mounting brackets or mast attachment brackets

the 900 range for FM/Stereo reception

Today's most sophisticated aerials for FM/Stereo reception – the range includes: single dipole with straight stand off arm, dipole and reflector array, 3-element array and 4-element array. All have a 1"–2" mast attachment bracket.



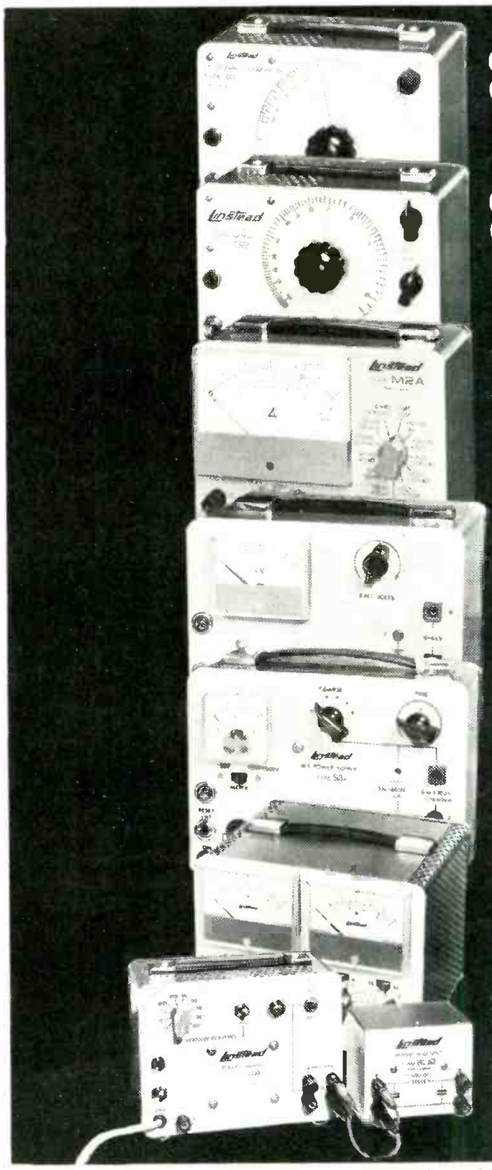
For full details contact your local Aerialite Distribution Depot or write to:

Aerialite Aerials Ltd
Radnor Park Trading Estate, West Heath, Congleton, Cheshire, CW12 4PX
Telephone: Congleton 3892/9
Telex: 669640

CW 21533

WW—028 FOR FURTHER DETAILS

The magnificent seven.



G1. L.F. Signal Generator £24

G2. L.F. Signal Generator £28

M2A. Voltmeter £32

S2. E.H.T. Supply £37

S3. HT/LT Supply £26.50

S7. Twin Stabilised Supply £69

S4A. High Current Variable Supply £21

SU2. Smoothing Unit £5.80

Linstead are the best British-made electronic instruments at their price on the market today.

G1. Nuffield Ref. 181. 10Hz to 100kHz. 0-6v. r.m.s. Sine wave. 0-9v. peak to peak Square wave. 0-1 watt into 3 ohms.

G2. Nuffield Ref. 181. 10Hz to 100kHz. Sine Wave 0-6v and 1 watt into low impedance. Square wave ½ microsecond rise time. Step attenuator

M2A. 12 A.C. ranges 100 microvolts to 400 volts. Frequency 10Hz-1MHz. 8 D.C. ranges 0 to 400v. Impedance 10 megohms.

S2. Nuffield Ref. 14. 0-6kv. 1 mA at 5kv. Metered. 6.3v at 3A. insulated for operation at E.H.T.

S3. Nuffield Ref. 15. 0 to +300v. at 0 to 60mA. 0 to −30v. at 0 to 60mA. 2 insulated outputs at 6.3v, 2A.

S7. 0-30V, 0-1A, per section. Fully protected against overload and short circuit. Outputs floating and can be series or parallel connected.

S4A. Nuffield Ref. 59. 0 to 25v. A.C. and D.C. 0 to 8A 1v. steps. Thermal-magnetic cut-out.

SU2. For use with S4A. Pi-filter 0-4A.

Please send for further details about the Magnificent Seven

Linstead means a good deal in electronics

Linstead Electronics, Roslyn Works, Roslyn Road, London N15 5JB
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WW—029 FOR FURTHER DETAILS

NEW
from Goodmans for constructors

Din 20 Kit

20 watt, high fidelity loudspeaker kit contains all parts necessary to complete the system, except timber and other material for the cabinet itself, with detailed, illustrated instructions.
Specification: 20 Watts DIN, 4 ohms impedance, 8 ins bass unit, dome HF radiator, crossover frequency 4,000 Hz.

Axent 100

Dome HF Radiator with integral crossover.
Capable of high frequency sound reproduction with negligible distortion in systems rated up to 30 Watts DIN, this 'state of the art' drive unit has an integral crossover which cuts frequencies below 3kHz at a rate of 12dB/Octave.

Audiom 100

12 inch high fidelity bass loudspeaker.
For use as a bass unit in two-way systems, the sensitivity and high frequency roll-off of the Audiom 100 has been tailored to match the Axent 100.

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Sound reasoning.

THORN A member of the Thorn Group

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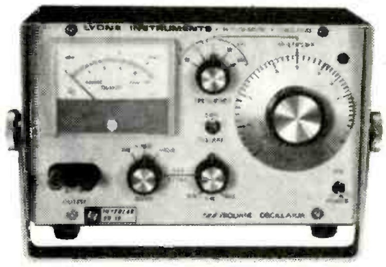
WW—019 FOR FURTHER DETAILS

INTRODUCING INTERLAB
from LYONS INSTRUMENTS

a new series of versatile, low cost, instruments for laboratory, test and education

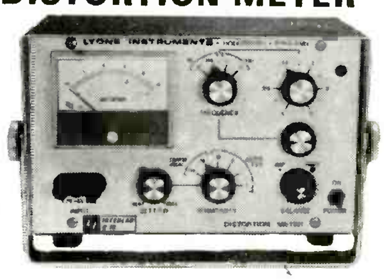
SINE/SQUARE OSCILLATOR



- 10 Hz – 1 MHz
- 10V p–p output
- 0·1% typical distortion
- 50Ω source impedance

TYPE SQ10 £57

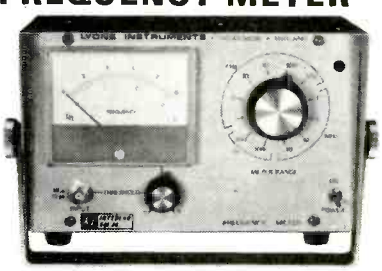
DISTORTION METER



- Range 0·1 – 10%
- 10 Hz – 100 kHz
- Intrinsic distortion less than 0·05%

TYPE D10 £68

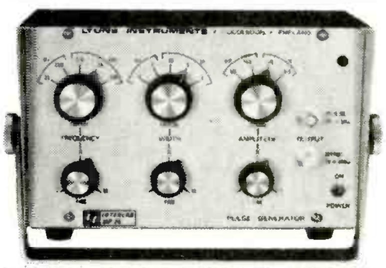
FREQUENCY METER



- 30 Hz – 30 MHz
- ± 3% accuracy
- 1 MΩ input
- DC ∝ f output

TYPE FM25 £57

and of course a PULSE GENERATOR



- 25 Hz – 2·5 MHz
- Width 100 ns–10 ms
- 50mV – 5V into 50Ω
- RT/FT 10 ns

TYPE MP25 £48

INTERLAB
series from LYONS INSTRUMENTS

LI

Lyons Instruments Limited, Hoddesdon, Herts.
Telephone Hoddesdon 67161 Telex 22724

A Claude Lyons Company

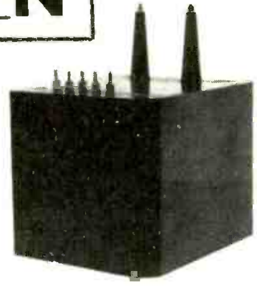
Also available from authorised distributors:—
ITT Electronic Services, Harlow; Electroplan, Royston (SQ10).

WW—032 FOR FURTHER DETAILS

10—12 Watts — 25 kVA

DRAKE TRANSFORMERS

INCORPORATING R. F. GILSON LTD. N



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Coils
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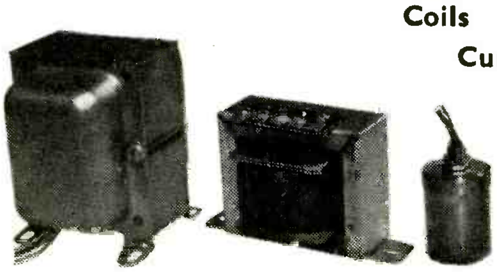
Transistor Transformers
Inverter Transformers
Screened Microphone Transformers
Wide Band R.F. Transformers
Resin Cast Transformers



DRAKE TRANSFORMERS LTD., BILLERICAY, ESSEX

Billericay 51155

WW—033 FOR FURTHER DETAILS

i.c. breadboards low cost, high performance units

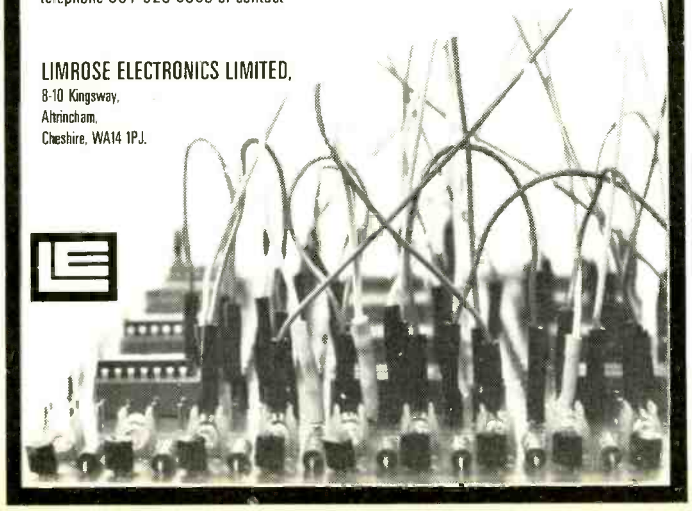
All our i.c. breadboarding units are now even better value for money.

Our second-generation CK2 0020 I.C. Patchboard unit, still selling for only £50, has been completely redesigned and now has many additional features. Light-emitting diodes are used as logic indicators and a manual pulse generator and busbars have been added to ease your patching a little.

A cheaper "extension" unit, selling at only £36, will accommodate a further eighteen integrated circuits or can be used on its own for linear work.

For further information on these and other breadboarding units from Limrose, please telephone 061-928 8063 or contact

LIMROSE ELECTRONICS LIMITED,
8-10 Kingsway,
Altrincham,
Cheshire, WA14 1PJ.



WW—034 FOR FURTHER DETAILS

Valradio

The Marine Valradio range of Transvertor are designed for operating low voltage DC battery equipment. Models are also available for AC equipment. Dual 110v and 220v DC available as standard as well as single voltage units.

Type	Input	Output	Price
CR110/220/60RT	110/220	12v 5A smoothed or 24v 2.5A DC	£66.00
CR110/220/12T	110/220	12v 10A Smoothed DC	£88.00
C110/220/60S	110/220	115 & 230v sine wave 60 watts	£70.40
C220/200S	220	115 & 230v sine wave 200 watts	£101.20

Other similar units available to operate from 12, 24, 32 & 50V DC and outputs of from 30W to 750W in square, sine wave or DC.

Send for information leaflet WC13.

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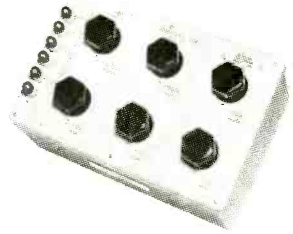
WW—035 FOR FURTHER DETAILS

VARIABLE AUTOTRANSFORMER LATR-2M

Bench mounted fully shrouded.
Input: 120, 220 and 250V.
Output: 0–260V.
Max. load 2 Amps.

£6.55

SIX-DECADE 0.01 CLASS RESISTANCE BOX TYPE P327



6 decades of 0.1-1-10-100-1000-10,000 steps. All decades and their respective wipers are brought out to separate terminals.
All-metal construction, fully screened.
Capacity: 0.3A for 0.1 and 1Ω decades; 0.1A for 10Ω decade, 0.03A for 100 decade; 0.01A for 1000 decade and 0.003A for 10,000 decade.

£65.00

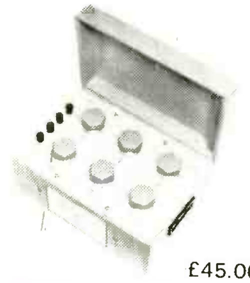
SUB-STANDARD MULTI-RANGE AC/DC VOLTMETER

Mirror scale 175mm long.
Knife edge pointer.
48 ranges from 75mV to 750V and from 300µA to 7.5A.
Accuracy 0.5% DC; 1% AC.
Transistorized relay protects movement and circuits.
Push button range selection.

£49

SIX DECADE 0.02 CLASS ACCURACY RESISTANCE BOX TYPE P236

6 decades 0.1-1-10-100-1000–10,000Ω.
Four terminals enable the box to be used also as a potential divider.
Rated power 0.25W per step with full accuracy or 1.00W per step with reduced accuracy.



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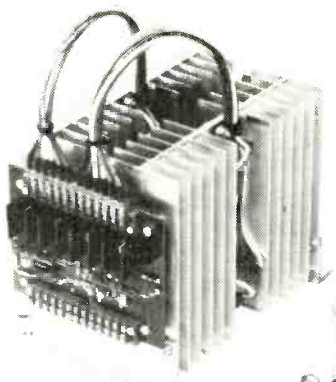
WW—036 FOR FURTHER DETAILS

200W DC SERVO SYSTEMS

Bi-directional. Designed around stock items. Immediate Delivery. Systems tailored to individual requirements.

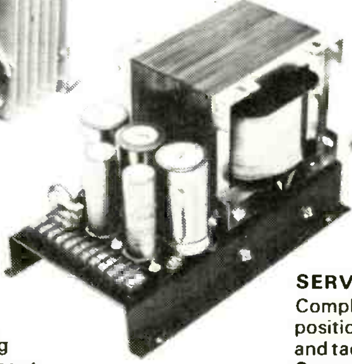
Accurate positioning and variable speed drive functions in the fractional horsepower range for industrial, medical and other professional applications can now be achieved by use of DC Servo Systems designed around stock items and available for immediate delivery.

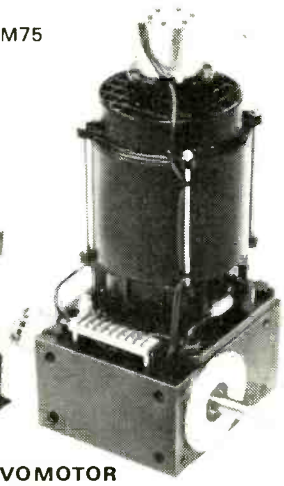
The well-known McLennan modular construction concept almost completely eliminates design time from servo-system production and yet systems can be supplied to exactly the degree of sophistication required for specific applications.



BI-DIRECTIONAL CONTROL AMPLIFIER TYPE EM73
Differential input.
Automatic current limiting
Automatic dynamic braking
Uses linear devices throughout.

POWER UNIT TYPE EM75
Will supply up to three servo units depending upon load factors.
Operates from 115V, 220V or 240V input.





SERVOMOTOR
Complete with reduction gearhead, positional feedback potentiometer and tachogenerator.
Several versions available.

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CONTROL SYSTEMS AND COMPONENTS
Kings Road Crowthorne Berkshire
Telephone: Crowthorne 5757/8

WW—037 FOR FURTHER DETAILS

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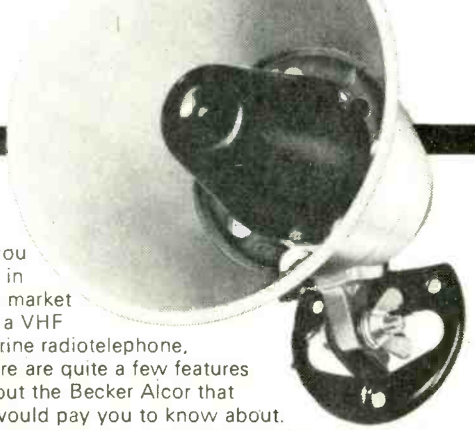
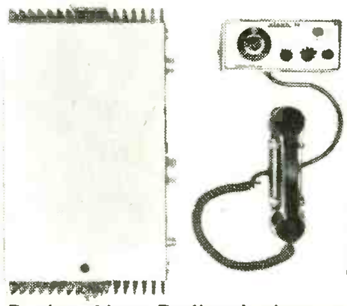


If you are in the market for a VHF marine radiotelephone, there are quite a few features about the Becker Alcor that it would pay you to know about.
For instance, the transmitter/receiver unit is remotely mounted, leaving the control unit free to fit into the most confined spaces. The loudspeaker and hand set can then be sited in the most convenient locations. Here are some more facts:—

- *Power output to aerial 20 watts*
- *Frequency 156-162 MHz*
- *Transmitter bandwidth 2 or 6 MHz*
- *Fully transistorized*
- *14 or 24 channels at choice out of all available VHF maritime channels*
- *Simplex, semi-duplex or full duplex*
- *Squelch sensitivity 0·2uV*
- *Reduced power switch (1watt O/P)*
- *25 KHz channel spacing*
- *Supply: 12/24, 110/220V DC and 110, 127 and 220V AC*
- *Approved by the British, Dutch and German authorities.*



Becker Alcor Radiotelephones and the Mizar Receiver manufactured in Holland are marketed throughout the U.K.

Hatfield Instruments (Radio Division) also manufacture 200 and 400 watt H.F. SSB Radiotelephones.

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forward thinking in electronics

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South-East Asia: *for prompt service and deliveries, contact*.
Hatfield Instruments (NZ) Ltd., PO Box 561, Napier, New Zealand.

WW—042 FOR FURTHER DETAILS

meet an AM-FM SIGNAL GENERATOR
with synthesised frequency coverage from 10 kHz (300Hz) to 100 MHz

A product of Schomandl KG, the decade Signal Generator Type MS 100m is a multi-purpose precision generator whose output frequency of 10kHz (300 Hz) to 100 Mhz is adjustable in least increments of 1 Hz.
This continuous frequency adjustment allows interpolation within decade Δf ranges from ± 5 Hz to ± 5 MHz which can be effected manually, either by an analogue DC signal or by sweeping.

The frequency generating system of the MS 100 M is provided with a synchronized oscillator in each frequency selection stage and produces output signals of high spectral purity whilst using only a minimum of frequency-dependent elements. Since the set is immune to RF leakage, even low output voltages can be accurately adjusted. The output level can be continuously adjusted over 10dB (meter indication in V and dB) and in least increments of 1 dB down to −130 dB.

MS 100 M

- **Four models offer frequency selection in steps of 1, 10, 100 Hz or 1 kHz and output can be swept from ±5 Hz to ±5 MHz.**
- **Frequency selection manual or remote control.**
- **1 volt output adjustable via stepped and variable attenuators to −130 dB (0.3μv).**
- **Quality signal (noise level −120 dB/Hz referred to signal output level).**
- Technical data with full specifications for the Rohde & Schwarz MS 100 M and its recommended extras, the Rohde & Schwarz Programmed Controller type PSM and Remote Controlled Attenuator Set type DPHP, will be sent in response to enquiries against this advertisement.

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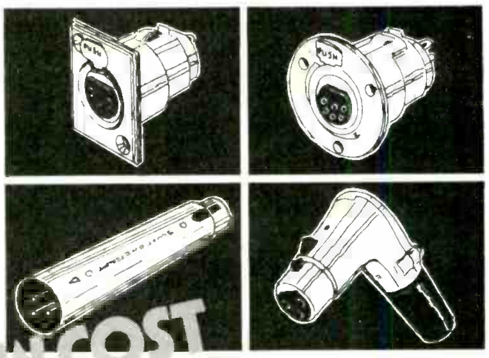

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Complete range of Switchcraft audio connectors now available for all studio and ancillary equipments.

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Safe — self-polarisation; captive insert screw provides rigid assembly and electrical continuity; pin and contact insulation eliminates hum and noise problems.

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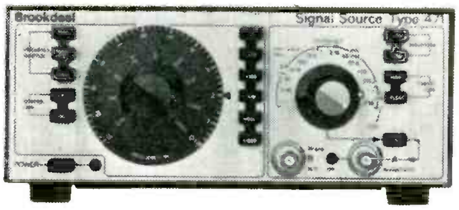
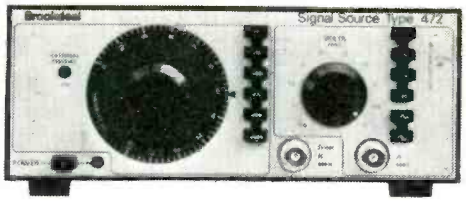
Choose your signal source!

I want the best low-distortion wide-band performance going...



It must be the Brookdeal 471 ! Radical new thinking in oscillator design gives extremely low harmonic distortion (typically 0·05% up to 10kHz) and total freedom from amplitude bounce. Six frequency ranges cover 0·001 Hz to 1·1 MHz, controlled manually or by an external voltage. Four decade continuous programming in log mode, two decade in linear. Output is sine or square wave from 3·16Vrms to 1 μVrms, calibrated to an accuracy of ± 1%. A second output gives 3Vp–p for triggering etc. Square wave risetime is typically 30ns. Output may be switched on or off by a front panel push button. Get the full data – you'll be even more convinced !

Give me a really good oscillator at a budget price...



The new Brookdeal 472 is your best buy. A sensibly priced oscillator that still offers outstanding performance in a soundly engineered instrument. Frequency control is linear, having a two decade sweep on each range, covering 0·1 Hz to 1·1 MHz with manual or external programming. The output has complete freedom from amplitude bounce and low harmonic distortion (typically 0·1%). Waveform may be either sine or square. Amplitude is continuously variable from 5Vrms to < 500 μVrms, calibrated to an accuracy of ± 1%. The second output gives a square wave of 3·5Vp–p for triggering etc.

Brookdeal

Brookdeal Electronics Ltd., Market Street, Bracknell, Berks.
Telephone Bracknell, (STD 0344) 23931 Telex 847164.

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DIXONS TECHNICAL ANNOUNCE THEIR MOST OLD-FASHIONED PRODUCT:

There are some very good reasons for going to Dixons Technical.

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In these take-it-or-leave-it days, Dixons Technical is a civilised oasis in a hard-sell desert.

For example, they have permanent technical staff who will take time to help you tailor your purchase to fit your needs, and to fit your pocket.

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Service: the most old-fashioned product to be found at Dixons Technical.

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Phone Mr. Frankfurt or Mr. Richards at 01-437 8811. Service starts with them. Ask them about any piece of equipment you're interested in.

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Portable Service Oscilloscope

TYPE 101
£80
DC—8MHz
50mV/Div.
(5mV/Div. with 155 Active Probe)
50 nS/Div.
Wt. 5 lb.

IDEAL FOR COLOUR TV SERVICING

113 DC/Battery version of 101 .... £90
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155 Active Probe (Gain X 10, x 1, ÷ 10 @ 10 M Ohms) £15
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Meteronic Ltd., 114/116 Shipbourne Road, Tonbridge, Kent. Tel: Tonbridge 61448

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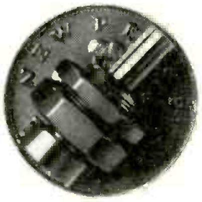

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The Jackson Friction Ball Drive Reduction Unit is unique. Simply because it's the only one of it's type and size available in the United Kingdom. It has sealed lubrication, with a hardened steel shaft and bearings to give it extra long life. And it's low in price. The unit has a 10:1 reduction ratio, with an output torque of 8 oz. ins. minimum.

Our skilled personnel can produce custom made components to suit your individual needs. And with 45 years of experience your guarantee is our reliability.

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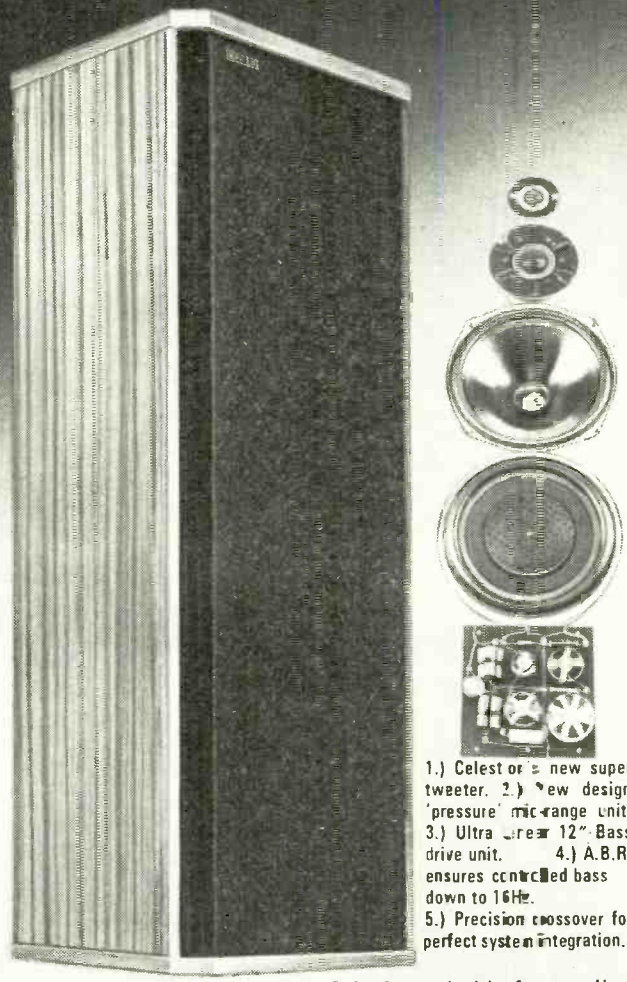
Celestion Loudspeaker Engineering advances the state of the art to a new plateau.

Ditton 66 Studio Monitor



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

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

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Loudspeakers for the Perfectionist
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RADFORD

AUDIO MEASURING INSTRUMENTS

Two instruments having a superior performance than any others of this type regardless of price. Now accepted as standard equipment by Broadcasting Authorities, recording studios, magazine equipment test laboratories, and audio research and development laboratories all over the world.

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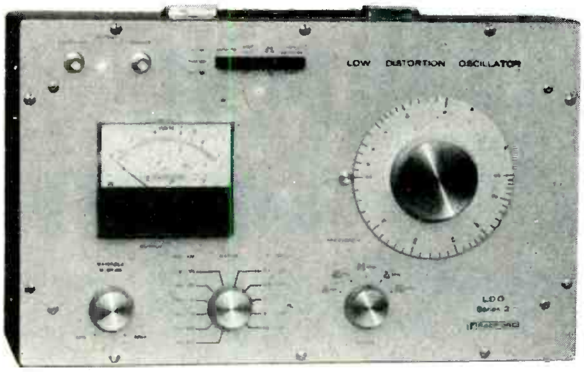
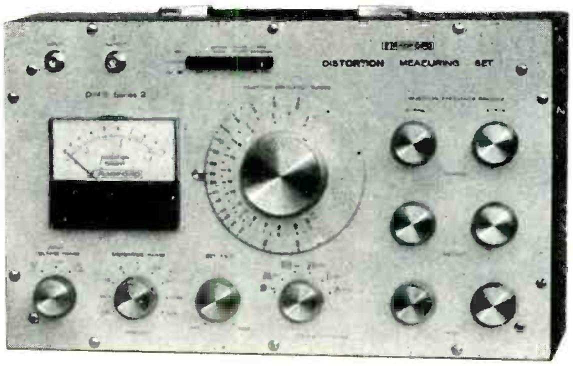


An instrument of high stability providing very pure sine waves, and square waves, in the range of 5 Hz to 500 kHz. Hybrid design using valves and semiconductors.

Specification

Frequency Range:	5 Hz-500 kHz (5 ranges)
Output Impedance:	600 Ohms.
Output Voltage:	10 Volts r.m.s. max.
Output Attenuation:	0-110 dB continuously variable.
Sine Wave Distortion:	0.005% from 200 Hz to 20 kHz increasing to 0.015% at 10 Hz and 100 kHz
Square Wave Rise Time:	Less than 0.1 microseconds.
Monitor Output Meter:	Scaled 0-3, 0-10, and dBm.
Mains Input:	100 V.-250 V. 50/60 Hz.
Size:	17¼ × 11 × 8 in
Weight:	25 lb.
Price:	£150

DISTORTION MEASURING SET



A sensitive instrument for the measurement of total harmonic distortion, designed for speedy and accurate use. Capable of measuring distortion products as low as 0.002%. Direct reading from calibrated meter scale.

Specification

Frequency Range:	20 Hz-20 kHz (6 ranges).
Distortion Range:	0.01%-100% f.s.d. (9 ranges)
Sensitivity:	100 mV.-100 V. (3 ranges).
Meter:	Square law r.m.s. reading.
Input Resistance:	100 kOhms.
High Pass Filter:	3 dB down at 350 Hz. 30 dB down at 45 Hz.
Frequency Response:	±1 dB from second harmonic of rejection frequency to 250 kHz.
Power Requirements:	Included battery.
Size:	17¼ × 11 × 8 in.
Weight:	15 lb.
Price:	£120.

Descriptive technical leaflets are available on request.

RADFORD LABORATORY INSTRUMENTS LTD.
BRISTOL BS3 2HZ
Telephone: 0272, 662301

WW—057 FOR FURTHER DETAILS

Need good r.f. test gear be expensive?

Not from Farnell. For example, the TM 6. A highly sensitive precision millivoltmeter for use at frequencies up to 1.5GHz. It displays with reliable accuracy, r.m.s. voltages from 1mV to 300V f.s.d., the readings on the lower ranges being about as near to true r.m.s. as you can get.

It's solid state with linear I/Cs, F.E.Ts, photo-choppers and full wave diode probe to ensure maximum reliability and freedom from microphony. It operates from mains or batteries and will also feed a pen recorder.

Supplied complete with probe, earthing clip, X100 multiplier and instruction manual it costs just £220. Accessories for optimum performance above 20MHz include a 'T' connector, £14; 'N' adaptor, £8; and 50Ω load, £5.

There's more. Our new modular **r.f. signal generator** is a brilliant conception and you're really missing out if you haven't studied this data. There's also a **100MHz frequency meter** and an **r.f. power meter** — all excellent instruments and inexpensive.

Farnell

Telecommunications Division

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WW—058 FOR FURTHER DETAILS

The P.E.Triffid Radio

A high quality low cost AM receiver based on the latest I.C. development-the Ferranti ZN414 radio chip

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IDENTI CHART

A 21" x 15½" wall chart detailing the major characteristics of the more important types of fixed capacitors used by constructors.

P.E. Sound Synthesiser

A fascinating and impressive instrument for the musician, composer, and all keen experimenters in sound and electronics. Comprehensive, yet easy to build due to modular design. The first part of this important series appears in this issue.

PRACTICAL ELECTRONICS

February issue out now 20p

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Our CCS2 beam tetrode is especially easy to design into co-axial circuits.

That's because we've designed a special beryllia ceramic flange which separates the heatsink from any active part of the envelope.

The alternative version, the CCS1, has an anode block, the face of which is bolted directly to the heatsink.

So, if you find air blowers an embarrassment to your design, get the facts on these conduction cooled beam tetrodes.

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Telex: 23435 Cables: Thermionic London
A member of The GEC Electronic Tube Co. Ltd., a management company which unites the activities of The M-O Valve Co. Ltd., and English Electric Valve Co. Ltd.

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Today's sophisticated communications equipment calls for crystals that meet the most exacting standards of the art. Standards that were acceptable a few years ago cannot meet the requirements of design engineers today. Today's tight tolerances demand quartz blanks with precision selected angles of cut, and Hy-Q use X-ray diffraction equipment to determine this most important factor.

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HQ66

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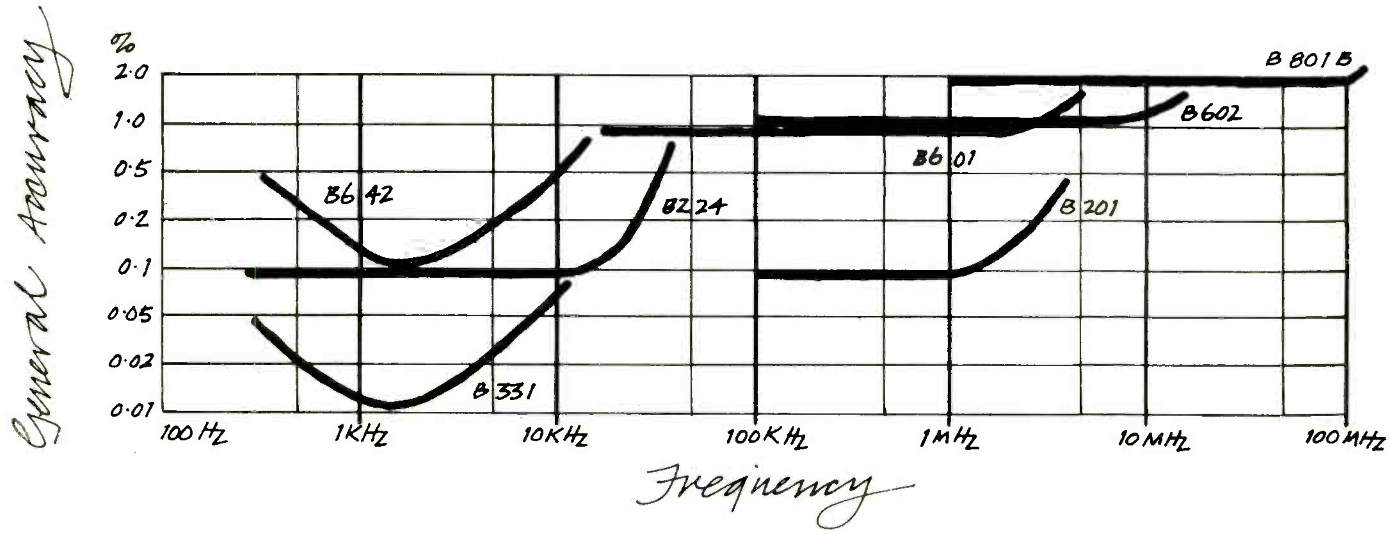
audio radio & vhf bridges

Each design is based on the transformer ratio-arm principle and enables accurate and highly stable impedance or admittance measurements to be made on both balanced and unbalanced systems.

At low frequencies small values of capacitance or high values of resistance can be measured at the end of very long cables.

At all frequencies three terminal measurements can be made using the guard facility of a transformer bridge to isolate one component from a complex network.

The complete range of WAYNE KERR bridges includes single frequency bridges designed for special purposes such as component batch selection and production process control.



Automatic Balancing Bridges

B421	1kHz	
B541C	1kHz	
B642	1591.6Hz	(Manual 200Hz to 20kHz)
B700	1kHz	
B331	1591.6Hz	(Manual 200Hz to 20kHz)

Manual Bridges

B500	2 x line freq and 1kHz
B224	200Hz to 50kHz
B201	100kHz to 5MHz
B601	15kHz to 5MHz
B602	100kHz to 10MHz
B801B	1MHz to 100MHz

For more information call Bognor Regis (02433) 4501 or write to the address below:

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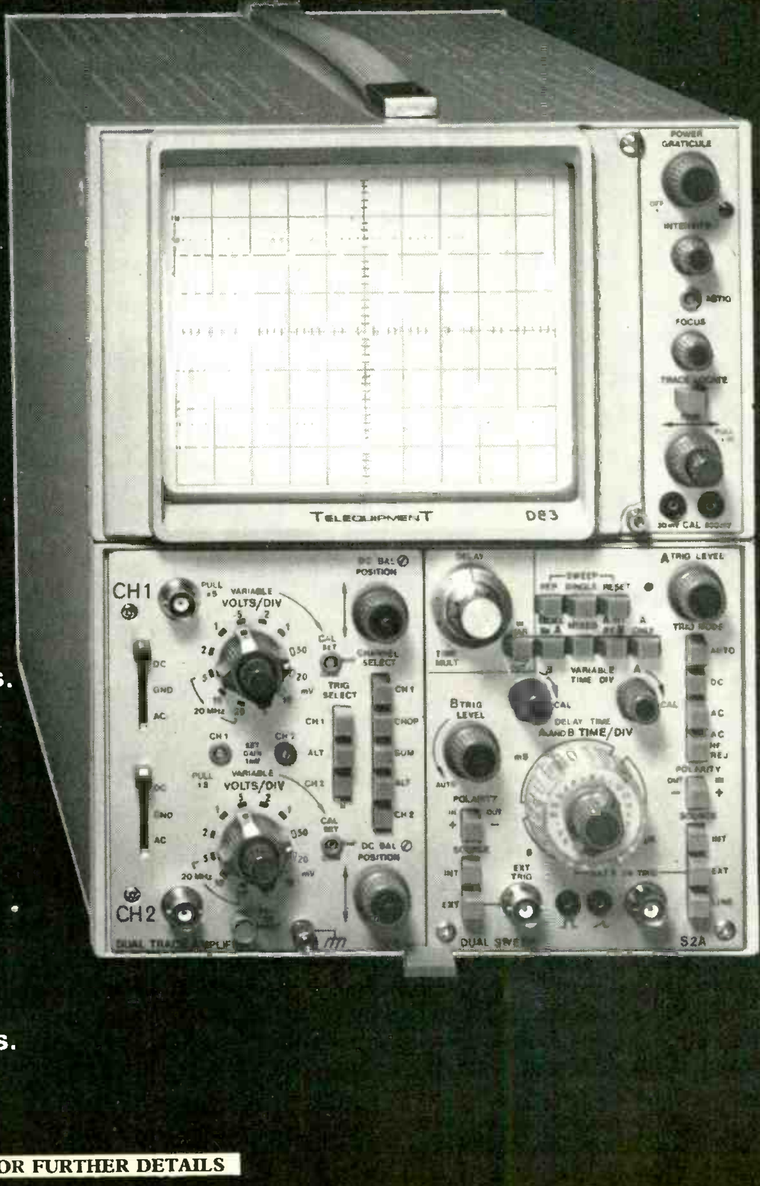
Durban Road, Bognor Regis, Sussex PO22 9RL

A member of the Wilmot Breeden group

a new 50MHz oscilloscope

Telequipment's D83
is not just another 50MHz scope.
It's a brilliant combination
of performance and plug-in versatility

at the incomparable price of £450



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A 6½ in CRT operating at 15kV which provides brighter traces and 50% more viewing area than 8 x 10cm CRT's.

Dual trace operation in alternate and chopped modes with 5mV/div sensitivity all the way up to 50MHz.

Choice of a High Gain Differential Amplifier operating down to 50μV/div sensitivity.

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Stability of a high order due to the adoption of the latest solid-state circuit technology, ensuring trouble-free operation over long periods.

These are only some of the advantages offered by the D83 – find out the rest by sending for full details now.

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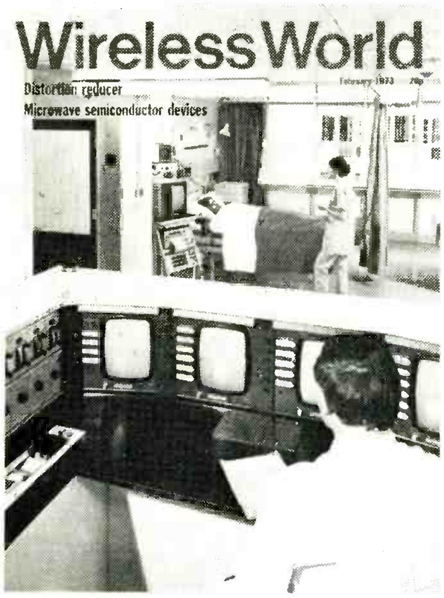
Wireless World

Electronics, Television, Radio, Audio

Sixty-third year of publication **February 1973** **Volume 79 Number 1448**



Continuous monitoring of vital life functions in the Intensive Care Unit of Northwich Park Hospital, Harrow, is the subject of **this month's front cover.** The system, installed by S.E. Laboratories, provides bedside monitoring and recording for each patient with a central monitoring console.

In our next issue

Digital multimeter project. The first part of a three-part article which describes the design and construction of a versatile digital multimeter using integrated circuits. Frequency, period, voltage, current, resistance and capacitance measurements are presented on a $3\frac{1}{2}$-digit, seven-segment display.

The design and production technology of modern **audio tape heads** will be outlined, against the background of increasing demands for higher fidelity.

Contents

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Wireless World

Broadcast and Cable Television

It was hoped that, coming after nearly two years' deliberations, the recently issued first report of the Television Advisory Committee would provide a workable premise on which the Minister of Posts and Telecommunications could formulate future plans. In fact it says little, if anything, that was not already known. The main conclusions, if such they can be called, are concerned with television frequencies, the continued use of dual standard receivers and the duplication of programmes, the redeployment of bands I and III, satellite broadcasting which "could become technically feasible on an experimental basis in the 1980s", distribution by wire and, finally, reproduction on domestic receivers of recorded material.

Despite the fact that some 20% of the 14 pages of the report is devoted to distribution by wire, its conclusions are strongly criticized by the Cable Television Association (formerly the Relay Services Association) for not taking a more positive attitude to the "contribution that cable can make in the immediate future, to the value and usefulness of the television set". The Association's outgoing chairman, Barry King, of British Relay, says it "limply concludes that the *status quo* must be maintained at least for 13 years". Indeed, *status quo* is writ large over the whole report. It may be unfair to judge this report in isolation for it does state that the five reports of the T.A.C.'s Technical Sub-committee will be published later and it may well be that these will give some worthwhile technical information on which the Minister can base his decisions.

We will confine ourselves in this leader to the question of cable television, variously called relay, wire broadcasting (a misnomer, if ever there was one) and telediffusion.

What is the present position in this £100M industry in this country? The franchise to operate the various relay services conducted mainly by four major groups will terminate in 1976 when the B.B.C. and I.B.A. licences come up for renewal. Until recently the relay companies were not allowed to originate material of any nature to feed into their networks and the television programmes relayed had to be those normally received on a domestic aerial in that locality. There was, however, a recent change of heart on the part of the Ministry and permission has been given for an experimental period until June 1976 for local programming. Pilot schemes are to be conducted in Sheffield (British Relay), Bristol (Rediffusion) and Swindon (Radio Rentals and EMI) in addition to the Greenwich scheme which has been operating for some months. The companies involved in these experiments are not allowed to operate them on a profit-making basis. Recalling the fiasco of the pay-television experiment of a few years ago in which British Relay (the only company which in the event took up the challenge) is thought to have lost nearly £1M, the companies feel that they are again being hamstrung by the Minister's terms of operation. Obviously, with such heavy capital investment the relay companies are anxious to know that the future holds. Will the cable systems eventually be taken over by the Post Office as part of a national cable information service? What part is cable likely to play in the extension of the television service? Perhaps a glimpse into the future was given recently in a paper at the I.E.E. by Charles Sowton (director of radio technology at the M.P.T.) who is chairman of the T.A.C.'s Technical Sub-committee. He said "While cable systems for the distribution of television and sound programmes have, so far, been provided separately from the telephone system, if we are to have a nation-wide cable television system in the future there would seem to be merit in considering whether there might not be advantages in combining it with other existing and future communication requirements. In the extreme one can envisage a wideband 2-way, switched communications network capable of meeting all requirements, including telephone and viewphone, meter reading, electronic mail delivery, facsimile reproduction of newspapers, information retrieval, and many others, besides television and sound programmes for entertainment and for educational purposes".

Incidentally, the hand of international bureaucracy is also meddling in this area. The Commission of the European Communities has asked the design office of Innovation, Communication Structures to carry out a study on cable TV. The Commission's bulletin "Industry Research and Technology" recently stressed the desirability of preventing this "*new* means of communication from developing on similar lines to TV and with similar consequences, i.e., on separate and insufficiently co-ordinated bases".

Distortion Reducer

Added to audio power amplifiers reduces t.h.d. and i.d. without loss of gain

by D. Bollen

Many audio power amplifiers in general use today have harmonic distortion levels of more than 0.5% somewhere in their useful frequency range or at maximum rated output, the chief offenders being those in the low price, i.c., and high power "pop" categories. This article describes an active feedback system which can be added to such amplifiers to clean up their sound by reducing total harmonic and intermodulation distortion without loss of gain. The principle employed is similar to an error feedback loop in a servo system. Valve amplifiers, transformer transistor amplifiers, and amplifiers prone to instability may not function satisfactorily with the reducer circuit.

Modern transistor audio power amplifiers of the transformerless type can offer a very flat gain characteristic and unvarying phase relationship between input and output over a wide frequency range, and this makes possible a straightforward method of extracting a distortion feedback signal without recourse to frequency dependent filters. Briefly, operational amplifier techniques are used to subtract the input signal from an attenuated version of the power amplifier output signal, thus leaving a difference signal consisting of distortion and noise. This difference signal can be fed back in anti-phase to the power amplifier input to reduce the unwanted error, with an attendant lowering of hum and output impedance, a slight decrease in stability, and some modification of frequency response due to phase differences between the power amplifier and reducer circuit.

In a typical case, t.h.d. and i.d. at 1kHz can be reduced by ten, or down to 0.1%, whichever is greater, and by about five at 30Hz and 20kHz, with comparable increases in damping factor. Hum is reduced about seven times. The reducer circuit contributes its own distortion and wideband noise while, at the same time, working to lower power amplifier distortion and noise, with the result that final noise level is maintained at a level of about -70dB. Frequency response can be within 2dB of the original from 20Hz–40kHz.

With the above amount of distortion reduction, and a resistive amplifier load with 2μF in parallel, overshoot or ringing on a 10kHz square wave will be increased approximately by a factor of five.

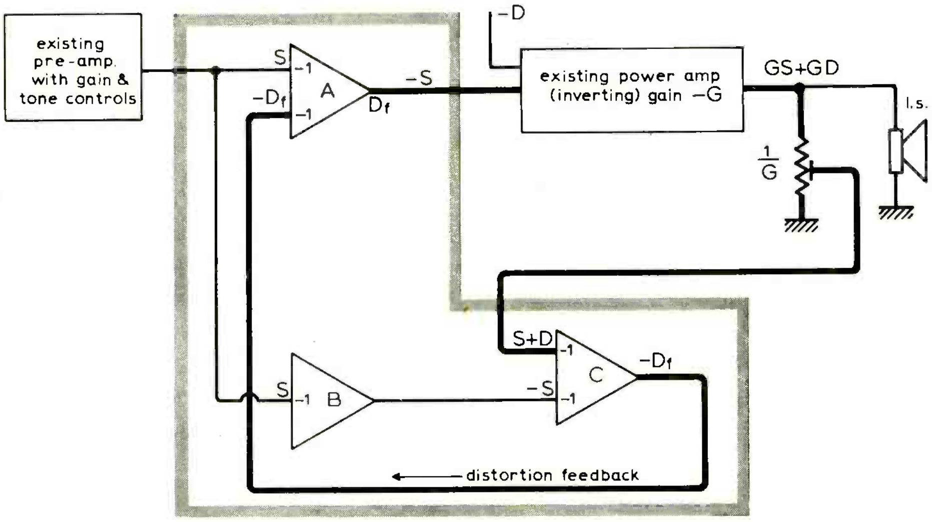


Fig. 1. Distortion reducer with inverting power amplifier. D, equivalent amplifier input distortion; GD, distortion at amplifier output; D_f, distortion feedback signal.

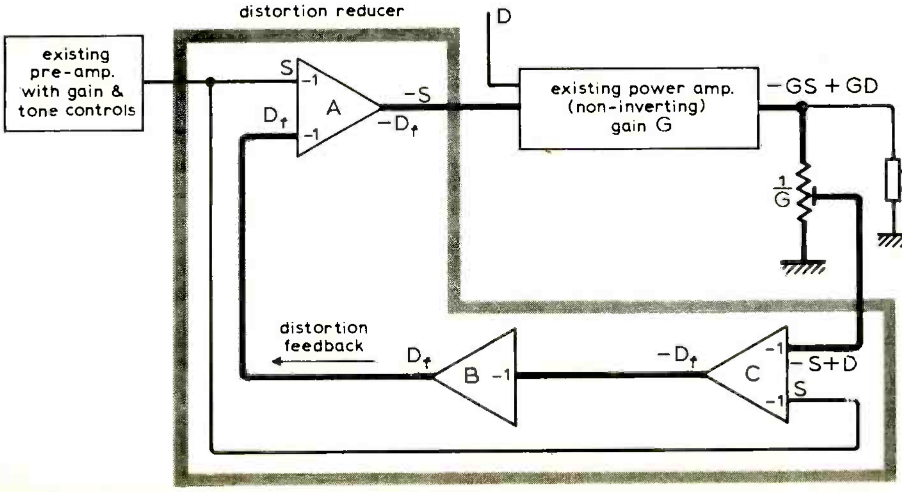


Fig. 2. Distortion reducer with non-inverting power amplifier.

In the block diagram of the reducer Fig. 1, op-amps *A*, *B*, and *C* form a distortion selective feedback loop shown by the thickened line. Each op-amp has unity gain inputs and is inverting (i.e. 180° phase difference between input and output, signified by a minus sign). The power amplifier also inverts and has a gain $-G$.

Distortion, in its several forms, is a complex function only loosely related to signal amplitude, and for this reason the description which follows is simplified for convenience. It is assumed, for example, that harmonic distortion can be considered as a constant equivalent input signal *D*—with a negative sign in the case of inverting power amplifiers—and that the measured distortion at the power amplifier output is *D* multiplied by amplifier gain *G*.

The operations performed upon signals by the circuit of Fig. 1 are as follows. Input *S* from the pre-amplifier is inverted by amplifier *A* and passed to the power amplifier as

$-S$. The power amplifier adds $-D$ to $-S$ and multiplies both terms by $-G$ to give an output $GS+GD$. A potentiometer set for a coefficient $1/G$ then cancels out G to leave $S+D$ at one of the summing inputs of amplifier C. At the other amplifier C input is $-S$, which has previously been taken from the pre-amplifier and inverted by amplifiers B. Functions $S+D$ and $-S$ are summed and inverted by amplifier C to leave $-D_f$, the distortion feedback signal. Finally, after inversion by amplifier A and summation with the original input signal, D_f is presented to the power amplifier input, clearly in anti-phase with the equivalent input distortion signal $-D$.

The net effect of the unity gain distortion feedback loop in Fig. 1 is to halve distortion while leaving the amplitude of the output signal GS unchanged. If now a gain G_2 is given to the D_f input of amplifier A the amount of distortion reduction obtained will be, ideally,

$$\frac{1}{1-\left(-G\times\frac{1}{G}\times G_2\right)}=\frac{1}{1+G_2}$$

but to this must be added any distortion contributed by the reducer circuit itself. Obviously, all forms of distortion and noise, in short anything which is not present in the input signal S, will tend to be reduced in the above manner.

In the case of a non-inverting power amplifier A, B, and C amplifiers are rearranged as shown in Fig. 2, to feed an appropriate anti-phase error signal back to the input. Bridge output power amplifiers consist of two separate amplifiers fed by a phase splitter, so this application will demand two reducers, one for each output terminal, with error signals fed back to the power amplifier halves after the phase splitter, as in Fig. 3.

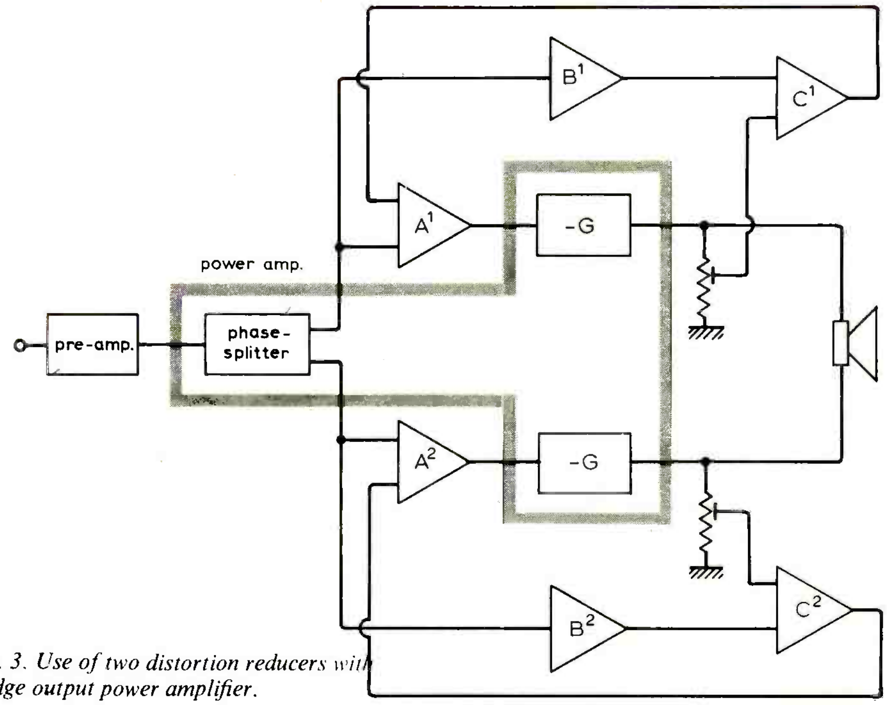


Fig. 3. Use of two distortion reducers with bridge output power amplifier.

Circuit considerations

When compared with the cost of replacing or redesigning a power amplifier and its power supply for lower distortion, the price of the reducer circuit is negligible. Nevertheless it was considered desirable to aim for simplicity and economy consistent with a useful amount of distortion reduction and reasonable noise level.

The op-amps used in the reducer circuit could hardly be simpler, based as they are on single transistors of the BC109 type. Power amplifier sensitivities of 100mV to 1V can be accommodated without modification or loss of gain, and unlimited power outputs by adjustment of a single resistor value. The complete circuit of Fig. 4, for use with inverting power amplifiers, is optimized for distortion versus noise at around 500mV input r.m.s. At high power amplifier sensitivities noise becomes a problem which can be solved by accepting some gain loss, while at low sensitivities minimum attainable distortion can rise to 0.2%.

Op-amp A in Fig. 4 has adder inputs R_1 and R_2, with R_1 handling the input signal at unity gain and R_2 adjusting distortion feedback loop gain starting at times three. Capacitor C_2 provides compensation to offset high frequency instability. Emitter

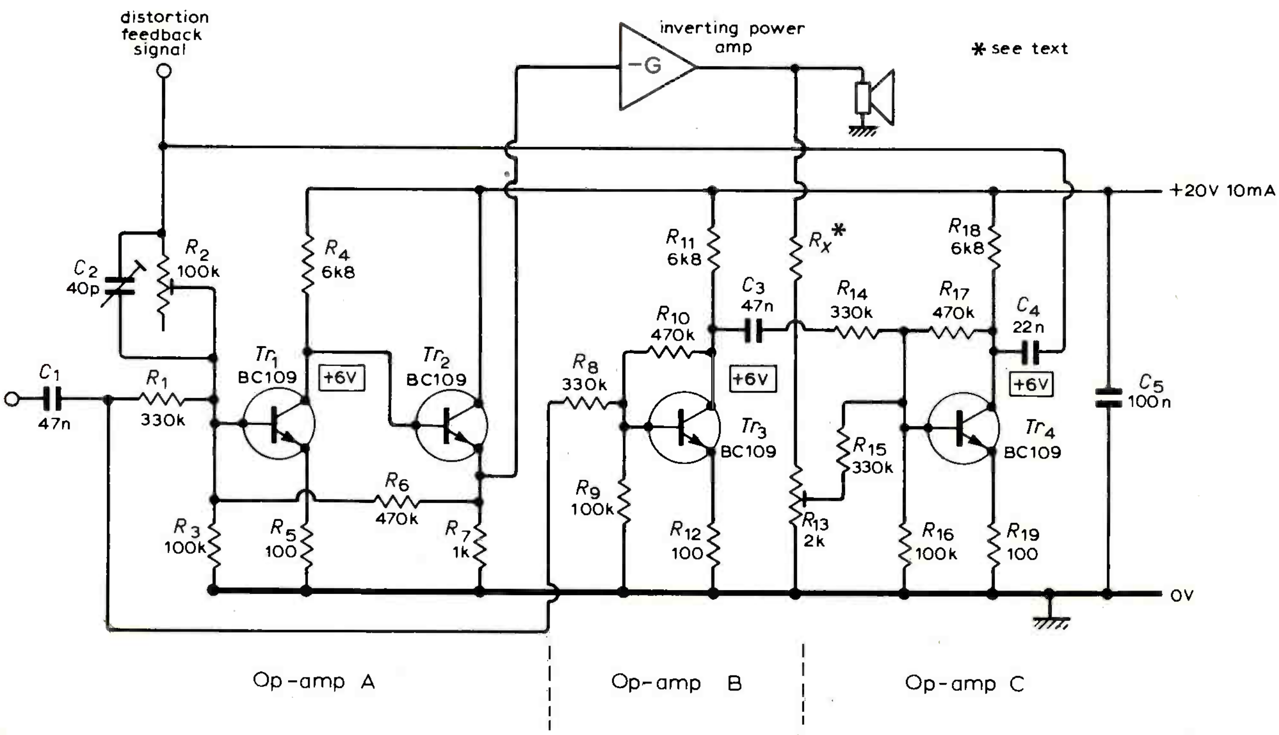


Fig. 4. Circuit of distortion reducer, for use with inverting power amplifiers.

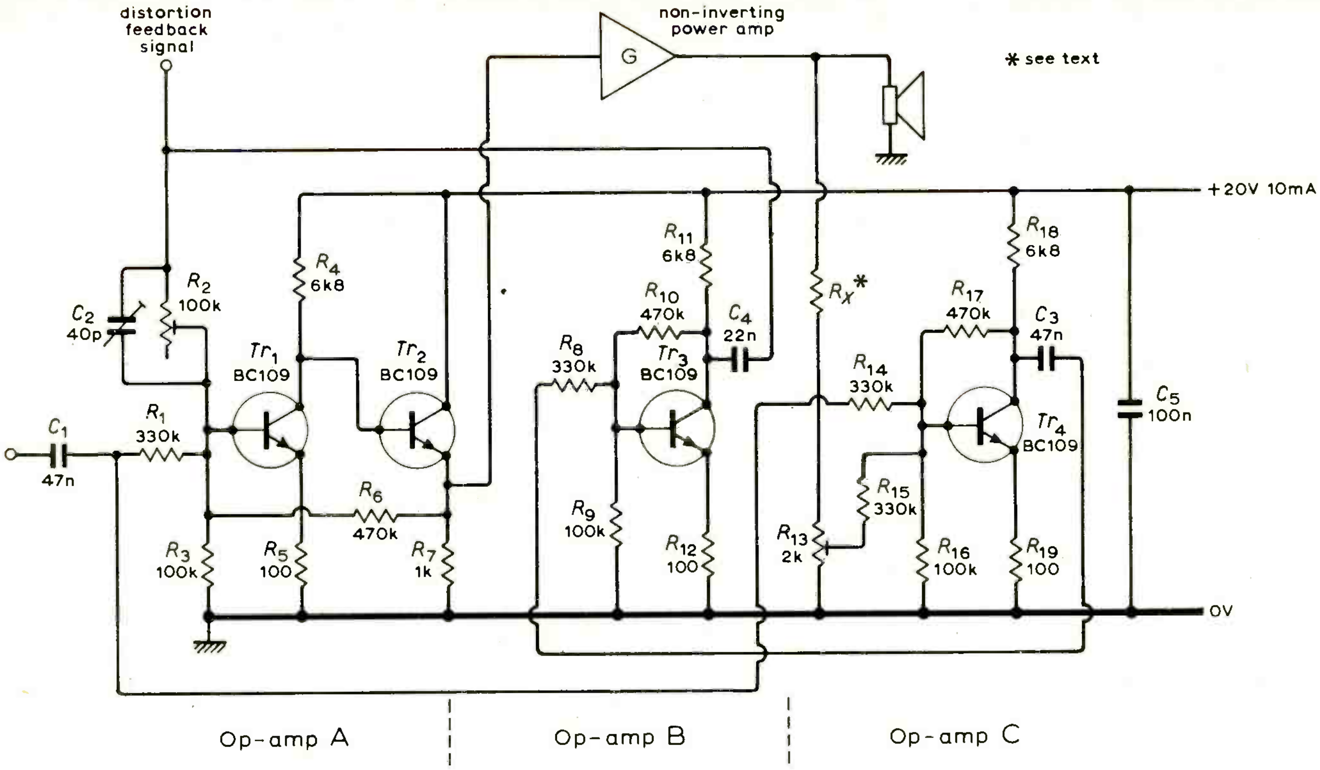


Fig. 5. Circuit of distortion reducer, for use with non-inverting power amplifiers.

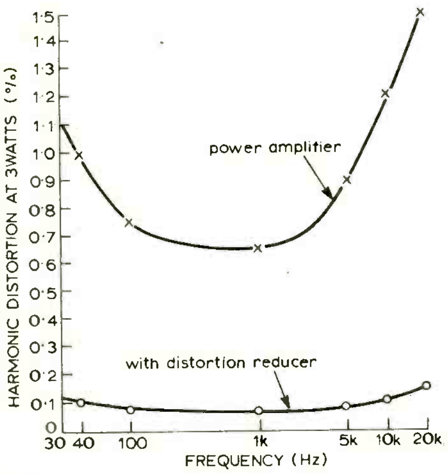


Fig. 6. Distortion/frequency curves of test amplifier.

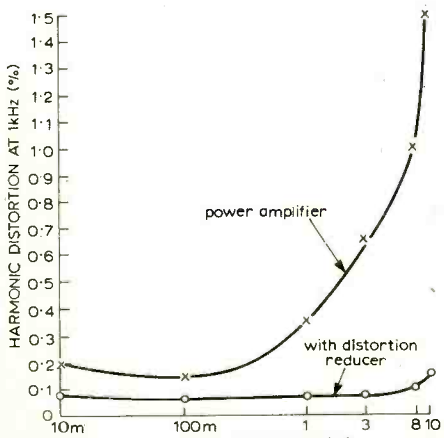


Fig. 7. Distortion/power curves of test amplifier.

follower Tr_2 is capable of driving power amplifier input impedances of down to 1kΩ at 500mV without increased distortion. Op-amp *B* is a simple unity gain inverter which feeds op-amp *C* input R_{14}. Resistors R_2 and R_{13} are adjusted for a null at the distortion product terminal.

In Fig. 4, an output taken from across the loudspeaker load is passed via R_X to R_{13}, and thence to op-amp *C* input R_{15}. Resistor R_X is selected on the following basis: $R_X = (\sqrt{WR/S}) - 2$, where R_X is in kilohms, *W* the power amplifier output in watts given by an input signal *S* in volts r.m.s., and *R* the loudspeaker impedance. There is sufficient latitude in the value of R_X for the above calculation to be based on manufacturer's power amplifier data.

Capacitors C_1, C_3, and C_4 in Fig. 4 are chosen to give a steep cut below 20Hz, and this discourages low frequency instability. If desired, the l.f. roll-off can be modified by adjusting the value of C_1 (see Fig. 8).

A second version of the distortion reducer circuit, for use with non-inverting power amplifiers, is shown in Fig. 5. The only differences between Fig. 4 and Fig. 5 are connections to op-amp inputs and outputs and the positions of C_3 and C_4.

Results

Apart from random checks with various amplifiers, a pair of low cost power amplifiers of 10 watt rating were built for detailed tests with the reducer, from an anonymous circuit which claimed "less than 1% distortion".

Alone, one power amplifier oscillated freely with a 2μF load, while the other showed one cycle of ringing on a 10kHz square wave. This disparity was thought to be due to gain variations in the transistors used, since the layouts were identical. Wideband noise, excluding hum, was −60dB for the unstable amplifier and a good −80dB for the other, which gave a "lop sided" hiss in stereo headphones. The distortion characteristics of the power amplifiers were similar, and not untypical, with claimed distortion being exceeded at 8 watts, and beyond the limits of 40Hz–8kHz at 3 watts. The lowest t.h.d. obtained was 0.15% at 100mW and 1kHz. With an unregulated power supply of generous 3A rating at 30V, and 10,000μF smoothing, power amplifier hum was an inaudible <0.5mV, but 3mV hum could be simulated by removing a smoothing capacitor. Apart from noise, listening tests with normal loads revealed no discernible difference between the two power amplifiers.

When a pair of distortion reducers was coupled to the power amplifiers noise was equalized at −70dB, giving "centre of the head" hiss in the stereo headphones, and the 3mV hum level was reduced to less than 0.5mV. With single loudspeaker and cross-over network loads there was virtually no overshoot or ringing on a 10kHz square wave.

Distortion curves, with and without reducers, are shown in Fig. 6 and Fig. 7. A single spot check of intermodulation distortion indicated a similar reduction factor. In the frequency response curve of Fig. 8, there is a general loss of 1dB gain attributed to circuit tolerances, and slightly disconcerting, though small, kinks at 20–30Hz and 80–100kHz.

As might be expected from Fig. 6 and Fig. 7, the subjective improvement in power amplifier sound was most noticeable at low and high frequencies, and at maximum output. Over an extended period of use no

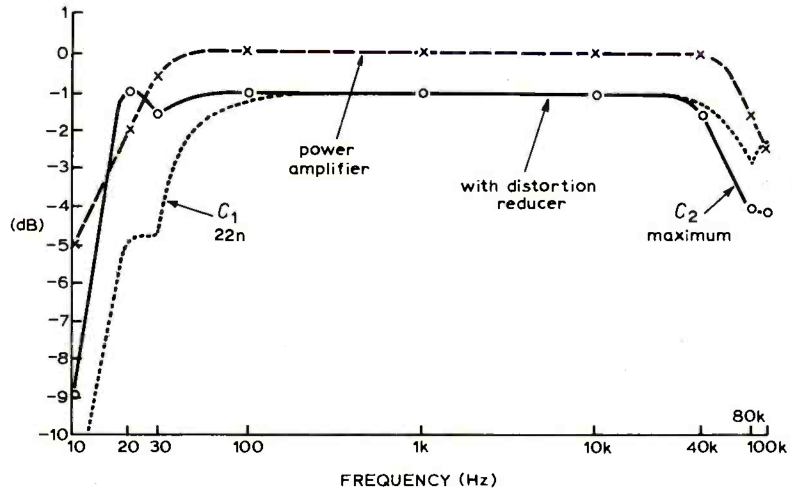


Fig. 8. Frequency response of test amplifier.

vices appeared, and the distortion reducer circuits remained in alignment.

Construction and alignment

Component layout is not particularly critical. A distortion reducer in breadboard form, coupled to a power amplifier by six feet of microphone cable, operated well at up to six times distortion reduction, but with slightly enhanced wideband noise and hum. A compact and screened layout, with the reducer situated close to the power amplifier will ensure optimum results, and a stereo pair of reducers can be assembled on a circuit board which is small enough to fit inside a 2oz tobacco tin.

The simple voltage regulator of Fig. 9 will serve to power a couple of reducers from a positive power amplifier supply rail of 30–60V. Alternatively, the reducer circuit of Fig. 4 or Fig. 5 could be modified for negative supply rail operation by substituting, say, BC159 p-n-p transistors for the n-p-n BC109, and an OC29 for the 2N3053 of Fig. 9, with the zener polarity reversed.

An oscilloscope of 10–30mV/cm sensitivity and an audio signal generator are needed to align the reducer circuit.

Remove the power amplifier load, set R_2 and R_3 to mid resistance, and C_2 to approximately half capacitance, connect the 'scope to the distortion product output terminal and switch on. Inject a 1kHz signal of sufficient amplitude to give a clear trace without overloading the power amplifier and adjust R_3 for a null. If there is any evidence of high frequency instability its source should be traced before connecting a load to the power amplifier.

Next, with the usual loudspeaker load connected, trim R_2 and R_3 for minimum trace amplitude on the 'scope until high frequency blurring of the trace occurs just past the null position of R_3, then screw down C_2. There is some interdependence between the settings of R_2 and R_3. Also, a change of load impedance, say from 8 to 16 ohms, may require a re-trim of R_3.

Finally, connect the 'scope to the power amplifier output and check the frequency response. If there is excessive peaking at 20Hz, reduce the value of C_1.

It should perhaps be stressed that the distortion reducer's alignment will be upset if there is a subsequent change of power amplifier gain, and for this reason all gain and tone controls should be situated in front of the reducer, including stereo balance. If the reducer gives excessive noise with sensitive power amplifiers a pre-set pot of 5–25kΩ can be wired to the power amplifier input, and this should be adjusted for the required sensitivity prior to reducer alignment.

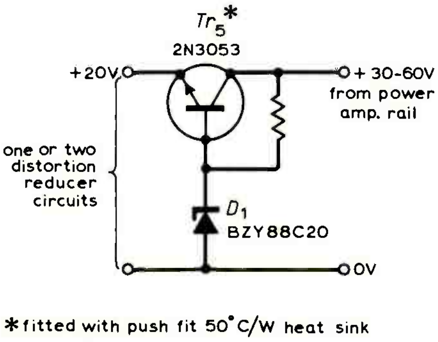


Fig. 9. Simple regulator for power supply for distortion reducer.

Components

Resistors (all 5% hi-stab or oxide, unless shown otherwise)
1—330k
2—100k min. horizontal pre-set
3—100k
4—6.8k
5—100
6—470k
7—1k
8—330k
9—100k
10—100
11—6.8k
12—100
13—2k min. hor. pre-set
14—330k
15—330k
16—100k
17—470k
18—6.8k
19—100
R_x—see text

Capacitors (all 250V polyester, unless shown otherwise)
1—47n
2—40p mica compression trimmer
3—47n
4—22n
5—100n

Transistors
1,2,3,4—BC109
5—2N3053

Diode
1—BZY88C20 (400mW, 20V, 5%)

Sixty Years Ago

This letter to the editor of *The Marconigraph* for February, 1913, was written by a thunderstruck wireless operator. Wireless telephony was, obviously, in its experimental phase, using arc transmitters and rotary r.f. generators for the production of continuous waves. Modulation was a problem (no valves) and was accomplished by the use of water-cooled microphones in the aerial circuit.

A Strange Occurrence

SIR, — On December 17th, 1912, about 4 p.m., as the ss. "Keemun" was coming out of the harbour, Yokohama, I put on my receivers, and after "listening-in" for a few moments, I was very much surprised to hear, in place of the customary Morse buzz, a faint unusual sound of varying pitch, which on "tuning-in", I recognised to be a *human voice singing*! For a few minutes the tune was drowned by the sending of a neighbouring station, but between the breaks, however, the voice was faintly but distinctly audible. When this station ceased transmitting the tune and the words became easily distinguishable, and they proved to be those of the "Village Blacksmith".

Two verses were heard, and towards the end the voice became clearer — possibly due to some readjustment of the transmitter being used, and the final words *"Like chaff from a threshing floor"*, were as distinct as though from a gramophone.

Later in the evening I called up the Japanese Government station, Chosi, and asked him if he could suggest who was likely to have been experimenting in wireless telephony, and he replied probably the Department of Communications at their laboratory in Tokyo. My receiving set is of the ordinary ship type, and as detector I then had a piece of silicon in use.

Yours, etc.,
Herbert S. Peet.

Correction

The B.B.C. has pointed out an error in the article **"High-standard Low-frequency Source"** (January issue) regarding the accuracy of frequency of the Radio 2 transmitter at Droitwich. The carrier frequency is in fact maintained to an accuracy of $\pm$ 2 parts in 10^{11} and not $\pm$ 5 parts in 10^{10} as stated.

Binding of *Wireless World*

Readers may like to know that our publishers will undertake to bind their copies of *Wireless World*. The inclusive cost is £2.25 (plus VAT after April 1st). Copies should be sent to IPC Business Press Ltd, Binding Department, c/o 4 Iliffe Yard, Walworth, London S.E.17, with a note of the sender's name and address. A separate note, confirming despatch and enclosing the remittance, should be sent to IPC Business Press (Sales & Distribution), 40 Bowling Green Lane, London EC1P 1AN.

For those who wish to bind their own copies cloth binding cases are available from the latter address at an inclusive price of 50p (plus VAT after April 1st). Readers will have noticed that the index for volume 77 (1971) was included in the December issue. Copies of the index are available price 12½p.

News of the Month

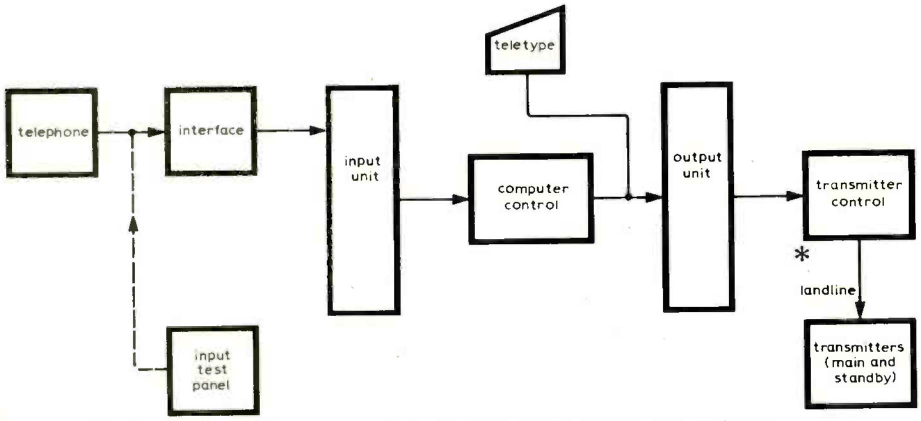
Radio-paging by telephone

The U.K's first public telephone radio-paging communication service has been introduced by the Post Office. Centred in Reading on a 500 sq. mile area of the Thames Valley, the service will provide contact with people carrying pocket radio receivers whenever they are in range, simply by dialling a telephone number. A capacity of 3,540 customers under this system can be provided with radio-paging pocket "bleepers", each being identified by its own exclusive 10-digit number. Dialling this number instructs v.h.f. transmitting equipment to send out a radio signal to activate a high-pitched 10-second "bleep-bleep" signal.

A preliminary reaction to the service is expected after the initial six months of operation and if successful, this could be the first step towards a national radio paging service operated by the Post Office with development of refinements such as a variation in the bleep to permit up to three different signals to be received, allowing users a wider choice of action. At present, communication is one-way only, so the users must prearrange the action to be taken on receipt of a radio-paging call. A call to a receiver is first accepted by the service's computer-controlled equipment and a recorded announcement informs the caller of acceptance. A radio signal is then transmitted to activate the bleeper. The receivers will work inside buildings, in cars and on trains and Post Office engineers expect to achieve better than 95% successful penetration of radio signals during the trial. A store is provided in the receiver if the person carrying it does not wish to be disturbed. Switched on later, the bleeper will emit its signal if a call has been received during the store period. Five radio transmitters are covering the area around Reading, Stokenchurch, Bagshot, Slough and Maidenhead.

The paging receivers measure 11.4 × 3.3 × 2.0cm. and weight 113g. Equipped with a 1.5V alkaline battery, each receiver will operate for 925 hours, which represents approximately three months of average use. Battery economy has been obtained by the use of c.m.o.s. circuitry and by the use of a battery saver clock, which continually switches the receiver on and off for 0.28 and 1.3 seconds respectively. The receiver is basically a double superhet constructed out of six i.c. modules. Reception is in the 150MHz band and signal pick-up is by means of a "U" shaped metal cover. The coded signal, which is an audio tone frequency modulating the carrier, contains one of 60 frequencies in the range 288.5 to 1,433.4Hz and a two-tone sequence is used. When the first tone is transmitted for 2.7 seconds, only the receivers responding to this first tone will stay on, ready to decode the second tone which is transmitted for 0.8 seconds. Once recognized, the called receiver sounds a 2kHz "bleep" note of 80dB s.p.l. at 30cm. This will persist for several seconds but may be arrested by depressing the single control switch, which has three positions, "on", "off" and "memory". An accompanying block diagram outlines the system employed for converting the identifying digits, which reach the computer-control equipment as Strowger pulses, into a binary-coded format which is suitable for handling by the control equipment. There is complete flexibility in the association of paging numbers and paging codes, the association being made by means of instructions entered into the computer from a control teleprinter. The mini-computer used in the terminal is the Digital Equipment Corporation type PDP11 with a basic storage capacity of 192,000 bits. Calls are queued and released in batches at 15-second intervals. The tone combination for each pager code is generated in turn from instructions passed to a frequency synthesizer.

Radio-paging receivers cost £5 a month to rent, with an initial payment of £5. Calls to a receiver will be free during the introductory period.



Simple block diagram of the computer and interfacing system used with the Post Office's new telephone radio-paging system (Also standby units up to).*

Licence evasion

Continuing reduction in the number of licence evaders is forecast by the Ministry of Posts and Telecommunications in a statement on the computerization of television licence records. Development of a new system has now been completed by the Post Office (acting as the Minister's agent in the collection of TV licence fees) and this will eventually hold details of over 18 million television licences on a central computer file.

Following pilot schemes at a number of London offices, national implementation of the computer system is to be provided. The larger provincial centres including Leeds, Bradford, Huddersfield, Birmingham, Liverpool, Manchester and Bristol will be first to go on the computer after London and the whole country should have been converted to the computer system by July 1976 when Lerwick in the Shetland Isles is finally included. The computer file will issue reminders and check the notifications that dealers are bound by law to supply about the disposal of television sets.

Anti-collision braking system

A set of equations describing the action of a car anti-collision automatic braking system has been worked out by a General Motors Corporation Research Laboratories engineer in the United States. The principle of the system is similar to the anti-collision device described in October 1972 News of the Month and incorporates a programmed, on-board computer that receives information from a radar mounted on the front of the car. The radar would determine vehicle speed, distance to the object ahead and the relative speed between the object and the vehicle. These parameters would be transmitted to the computer, which would then determine the proper application of brakes and signal the braking system to stop the vehicle before a collision could occur. Simply stated, the formulae compare what can be controlled (speed, distance and closing rate) with what can't be controlled (gravity and friction) and determine the conditions for keeping the vehicle on the safe side of the comparison.

Conference of the Electronics Industry 1973

The administration of the Conference of the Electronics Industry is now being carried out by the Electronic Engineering Association, under the chairmanship of Dr. B. J. O'Kane, president of the E.E.A. The Conference of the Electronics Industry is a consultative organization and provides a forum for consultation between leaders of the industry and its associations, and for reaching agreement on matters which require representation at the highest level, in particular to the government. Now that Britain has joined the E.E.C., the need for a more broadly based organization capable of speaking for the industry as a whole becomes increasingly important. The recent Devlin Report advocated a big reduction in the number of independent secondary associations and outlined various methods which could be adopted to bring this about. In view of this aim, the Conference of the Electronics Industry (C.L.I.) assumes greater importance as it broadly combines all the major associations representing the electronics industry in the U.K.

"Two-eyed" television tube

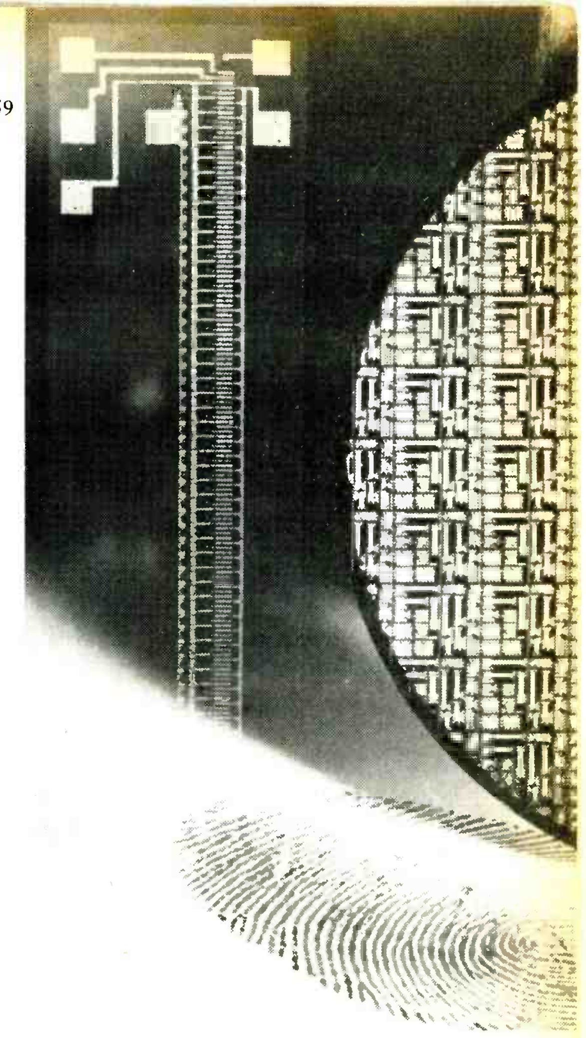
A TV camera tube with two "eyes", or targets, that is expected to enhance the performance and lower the cost of single tube colour TV cameras has been developed by RCA. Called a Bivicon tube, it was designed originally for the RCA HoloTape video recording system and is particularly well suited for generating colour pictures from two-frame holographic or photographic films in which the luminance (black and white) portion of the picture is projected onto one target and the chroma (colour) information, in suitable encoded form, onto the second target. The tube is claimed to provide excellent registration between the luminance and chroma information without additional auxiliary coils because the beams generated by its two electron guns are controlled by a single magnetic focus and deflection system. These beams "read" out the stored picture information from the two targets and provide simultaneous output signals that can be superimposed with precision.

This 38mm camera tube, designated type C23244, can also be used to replace single target vidicons in single-tube colour cameras that separate the luminance and chroma signals by optical filtering. It has an advantage over the vidicon in such an application because its second target can process the colour signals independently. In addition, the tube can be used in other TV applications in cameras designed to produce simultaneous optical images that can be played back on separate monitors or superimposed on a single monitor. The double-beam, double-target feature provides a desirable degree of redundancy for use in unattended cameras. A TV surveillance camera with two fixed lenses might be electronically switched from one "eye" to the other to provide close-up and wide angle shots of an area under surveillance.

Ion implantation of charge-coupled devices

Shift registers, for large memories, composed of l.s.i./i.cs are readily assembled from charge-coupled m.o.s. devices. A problem is posed, however, by the possible falsification of stored information when transfer losses occur between one device and the next. A novel implantation technique, developed by Siemens, reduces the disturbing influence of the potential thresholds encountered in the gaps between m.o.s. devices to such an extent that the charges can be transferred from one device to the next almost without loss.

In their simplest form, charge-coupled devices consist of a series of closely spaced m.o.s. capacitors, each composed of a metal gate electrode, an insulating film — the gate oxide — and a homogeneous semiconductor substrate. The charges representing the information are transferred by means of electric boundary fields between the electrodes of the m.o.s. devices. The efficiency depends on the potential thresholds in the gaps between the electrodes, part of the charge to be transferred being unable to pass a potential threshold in the gap. Siemens have introduced an implantation step in which boron ions are implanted in the gaps between the devices, thereby reducing the potential thresholds to a level favourable for charge transfer. Potential thresholds could hitherto only be reduced by way of the stray electric fields of the devices, which necessitated very narrow gap widths (less than 3μm). This technique allows a larger gap to be used between the metal electrodes without endangering charge transport, and since gaps of 7μm are allowed, quantity production is possible. Experiments conducted with charge-coupled devices having 150 electrodes showed that the transfer loss remains below 0.2% even with relatively large gap widths. Before the introduction of ion implantation, the information loss for a gap width of 7μm was almost 100%.



Small linear structures (the thumbprint gives an impression of the size) are l.s.i. charge-coupled devices for which Siemens have introduced an ion implantation technique, making possible the transfer of charge from one device to the next in a shift register (right in photograph), almost without loss.

Computers for fire fighting

Glasgow Corporation's Fire Department has unveiled plans to link the majority of its fleet of fire appliances directly to a central computer system in a move to fight the City's fire menace. Small facsimile printers installed in the drivers' cabs of between 30 and 40 fire engines will be used to print out detailed information on buildings and fire hazards supplied from the computer system via a radio link as soon as an alarm has been raised. Contracts for the £72,000 computer system have been signed with Honeywell Information Systems and it is due to come into operation during June and July.

The computer system, a duplex Model 316, will hold information initially on 4,500 properties, mounting up to 10,000 within two years. The information, from forms filled in by fire officers going their normal rounds, covers the plans of buildings and details of all known fire hazards. This information will be kept up to date on a daily basis. In addition, a special file will be held of 1000 different hazardous substances and how to handle them in the event of fire. This file relates directly to the fireman's "black book" of hazardous substances.

Telephone numbers of all public call boxes in Glasgow, giving their addresses, and a street number and name index covering 5,500 streets, will also be maintained on the computer as an aid to pinpointing the whereabouts of a fire.

Several developments to the computer

system are already being planned to come into operation within two years. One of these is an "unmanned watchroom" whereby the automatic fire alarms in Glasgow would be linked directly to the computer system using analogue-to-digital interface equipment. The computer system, which will also hold records of the location of fire appliances, would then automatically send the right fire appliance to the right site without anyone but the fire crew concerned knowing what has happened.

Electronic warship

Radar, weapons and communications systems, totalling more than £3M, are carried by H.M.S. Bristol, the Royal Navy's latest guided missile destroyer. Marconi Radar Systems have provided the surveillance and tracking radars in the ship, both to seek out aircraft and surface targets, and also to guide the Sea Dart missiles to their targets. Radar information on ship and aircraft movements is fed to the ship's tactical nerve centre, the Operations Room, by the type 992Q target indication radar. This provides accurate air and surface target positions for the ship's missiles and guns. The main communications on the ship are centred on a sophisticated m.f./h.f. integrated communications system ICS2 which is a Royal Navy concept, designed around a number of basic modules which can be assembled in a variety of ways to suit operational needs. Operation has been simplified by applying self-tuning techniques. Provision has been made on the ship for the satellite communication system SCOT, developed, and now in production, for the Royal Navy by Marconi Space and Defence Systems. It employs two 1m. diameter dishes mounted on either side of the superstructure. Designed to operate with both the British Ministry of Defence Skynet satellite system, and with the American Defence Satellite system, it will give the ship secure external communications on a world-wide basis.

U.K. amateur radio frequencies

The following table and footnotes provide alterations to the frequencies available to the U.K. radio amateur service, which came into force on 1st January 1973. As a result of the replanning of the 420-450MHz band, amateur use is restricted to 430-440MHz. The classes of emission and power for the band 432-440MHz remain as at present but there are limitations on the use of 430-432MHz, which is not available for use within the area bounded by 53° N02°E, 55° N02°E, 55° N03°W, 53° N03°W. Emission classes A1, A2, A3, F1, F2 and F3, only are permitted and power is limited to 10 watts effective radiated power.

The present band 21-22GHz will be withdrawn and replaced by 24-24.05GHz which may be used by both the amateur service and amateur satellite service. A new band 24.05-24.25GHz will be available for use by the amateur service (not amateur satellite service) on a secondary basis. The Ministry of Posts and Telecommunications has decided that steps must be taken to contain the health hazard which exists from radio-frequency radiation and as a result no amateur will be allowed to operate on the 24-24.25GHz band without first obtaining permission from the Ministry.

U.K. amateur service allocations (†indicates change)

Frequency[1] (MHz)	Max. d.c. input power[2,3] (W)	R.F. output power[3] (W)	Emission class[4]	Footnote reference
1.8 to 2.0	10	$26\frac{2}{3}$		5, 6
3.5 to 3.8	150	400		7
7.0 to 7.1	150	400	A1,A2	
14 to 14.35	150	400	A3,A3A	
21 to 21.45	150	400	A3H,A3J	
28 to 29.7	150	400	F1,F2	
70.025 to 70.7	50	$133\frac{1}{3}$	& F3	5, 8
144 to 145	150	400		5, 9
145 to 146	150	400		
†430 to 432	—	—	A1,A2,A3, F1,F2 & F3	5, 10
†432 to 440	150	400		5
1.215 to 1.325GHz	150	400		5
2.3 to 2.45GHz	150	400	A1,A2,A3	5
3.4 to 3.475GHz	150	400	A3A,A3H,A3J,	5
5.650 to 5.850GHz	150	400	F1,F2, & F3	5
10.000 to 10.500GHz	150	400		5
†24 to 24.05GHz	—	—		7, 11
†24.05 to 24.25GHz	—	—		5, 11
2.35 to 2.4GHz	25 mean	—	P1D,P2D,	5, 12
5.7 to 5.8GHz	2.5k pk	—	P2E,P3D	5, 12
10.05 to 10.45GHz		—	P3E	5, 12

Footnotes

1. Artificial satellites may be used in the amateur service in the bands 7 — 7.1, 14 — 14.25, 21 — 21.45, 28 — 29.7, 144 — 6, 435 — 8MHz and 24 — 24.05GHz on condition of no interference to other services.
2. D.C. input power is the total power input to the anode circuit of the valves or any other device energizing the aerial.
3. For A3A and A3J s.s.b. transmission power is determined as the peak envelope power under linear operation and limited to 2.667 times the d.c. input power appropriate to the frequency band.
4. For emission designation see symbols assigned in the Telecommunication Convention.
5. Allocated on a secondary basis on condition that interference is not caused to other services.
6. Do not use radio teletype in this band.
7. Shared by other services.
8. Available until further notice provided use ceases on demand of a Government official.
9. Avoid following spot aeronautical frequencies: 144.0, 144.09, 144.18, 144.27, 144.36, 144.45, 144.54, 144.63, 144.72, 144.81, 144.9MHz.
10. Do not use in area bounded by maximum power 10W effective radiated power. 53°N 02°E, 55°N 02°E, 55° N 03°W and 53°N 03°W.
11. Available only with prior written consent, which will indicate the power which may be used.
12. Available only with prior written consent.

Brain drain

The Register of Retired Chartered Engineers inaugurated in April 1971 is now well established as a free reference service for industry, commerce associations and institutions. The enrolled engineers are all Members of the 15 institutions which make up the Council of Engineering Institutions, each of which is prepared to offer advice and assistance based on an accumulation of knowledge and experience. Sponsored by the Engineers Guild Ltd, and supported by the United Kingdom Association of Professional Engineers, the Register is operated on an honorary basis, being dependent upon donations from satisfied users. Over 200 retired engineers registered in the first few months of operation; they are willing to make their services available in Britain and overseas. The register is located at The Engineering and Building Centre, Broad Street, Birmingham 1.

Briefly

Heraldic recognition

Pye of Cambridge Ltd, has been granted armorial bearings under letters patent presented to the company. The grant has been made by a King of Arms under the warrant of the Earl Marshal of England (the Duke of Norfolk) in recognition of the company's contribution to national life. In addition to the armorial bearings, the company has been granted the use of seven heraldic badges.

Works of art

Seven of Bang & Olufsen's audio products have been chosen by New York's Museum of Modern Art for their permanent design collection.

Defective detective

One of our readers has pointed out a cutting concerning TV detector vans from the *Portsmouth News* which reads, "Signals transmitted by the receivers are picked up by the detectors, which are so accurate that they can even determine to which station the receiver is tuned". Here's the crunch, "A receiver continues to transmit even after it has been turned off".

New technology?

"Access helps you listen in. In stereo" — a technological discovery made by the new credit card system. Let us know if you find any more electronic nuances for "Briefly".

The Realm of Microwaves

A review of the theory and application of microwaves

1: solid-state oscillators

by M. W. Hosking, M.Sc.

Since its rapid development for radar during the second world war, the science and application of microwave energy has steadily increased. Less widely publicized, perhaps, than other fields of science, microwave systems play an ever more important role in our modern world. Our holiday air flight is tracked overland by numerous radar stations, guided on its way by microwave beacons and helped on to the runway by microwave landing systems. Live television coverage of international events is beamed to us by satellite using microwaves and so also were the dramatic events of the Apollo lunar missions. Accurate descent control of the lunar module was made possible by a radar altimeter.

Both the radar and communications systems are built up from numerous sub-units, many of which are fields of science on their own. This series of articles presents a review of some of these fields, followed by a description of some complete systems.

The microwave frequency band can be arbitrarily defined as lying between 1GHz and 300GHz. It is a region where the components used are of the same order of size as the operating wavelength. This means that devices are no longer lumped-element as they are in general a.c. circuitry, nor are they "large" as in diffraction optics, and this makes for unique design problems. At the lower frequencies normal a.c. circuit theory is an approximation, albeit a very good one, and becomes invalid for microwaves, where terms like voltage and current have little practical significance and circuit problems must be solved in terms of field theory and boundary conditions.

In 1964 *Wireless World* contained a series of basic articles† on microwave techniques. Much has happened in the intervening eight years and this present series will up-date the topic of microwave power generation and describe areas not previously covered. These include aerials and radomes, miniature hybrid components, solid-state components, radar and communication systems.

The past eight years has seen immense strides made in the solid-state generation of microwaves. From virtually nothing, there is now a host of devices, including two fundamentally new types: the impatt diode and Gunn-effect device. Transistors now oscillate above 40GHz and can provide more than 100W peak at 1GHz and 5W c.w. at 4GHz. With some of the other devices, frequencies above 300GHz can be generated and kilowatts of pulse power achieved. The oscillators discussed are: the impatt diode, the Gunn-effect device operating in different modes, the different types of varactor diode and the tunnel diode.

† *"An introduction to microwave techniques" by K. E. Hancock was published in five parts over the period August to December 1964.*

The impatt diode

First demonstrated in 1965, the impatt diode has progressed extremely rapidly and the device is presently the most powerful c.w. solid-state source of high-frequency microwave power. Over 1W c.w. at 50GHz has been achieved, with nearly 50W pulse power at 10GHz. Highest frequency generated to date has been about 300GHz. The word impatt is an acronym based on the mechanisms of operation and derives from: Impact Avalanche and Transit Time.

Any oscillator can be considered to have a negative resistance, which can be produced by causing the output current to be 180° out of phase with the terminal voltage. With the invariable d.c. bias applied to oscillators, conditions are thus right for the conversion of energy from the d.c. to the a.c. field. This happens when the d.c. field causes the charge carriers to move in the opposite direction to that in which the a.c. field wants them to go. Work is thus done and the d.c. field loses energy, which is absorbed by the a.c. field. This is obviously only true for half a cycle and in a practical device the charge carriers must be prevented from giving their acquired energy back to the d.c. field on the opposite half cycle.

To explain how the diode works, it is assumed to have the impurity profile shown in Fig. 1, first proposed by W. T. Read. Many types of semiconductor material may be used, but for thermal reasons silicon is usually preferred. (The $^+$ sign denotes heavy doping.) The idea is to generate a bunch of charge by avalanche breakdown and cause it to drift uniformly across the device, thereby inducing a current in the external circuit. As the reverse bias voltage is increased, the resulting electric field is sufficient to sweep the region between n^+ and p^+ clear of carriers to form a depletion layer. Thus at the abrupt n^+-p interface a high electric field is formed. When this field reaches about 350kV/cm, avalanche breakdown occurs and electron-hole pairs are generated. Once above this field value, the rate of charge build-up is exponential and so is rapid.

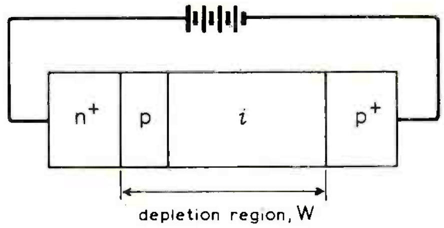


Fig. 1. Classical impatt diode Read structure. Device is reverse biased, with $^+$ indicating heavy doping.

In this particular structure, the electrons enter the n^+ region and can be neglected, while the charge of holes enters the depletion layer. The electric field in this layer is very much less than the avalanche field — several thousand volts per cm. A basic semiconductor property is that the charge carrier velocity gradually approaches a limiting value, due to scattering effects, as the electric field is increased. This occurs at about 5kV/cm and in silicon the saturated velocity is near enough 10^7cm/s. This means that the time taken for the charge carriers to cross the depletion region can be made independent of bias voltage.

We are now in a position to understand the energy-conversion process and the production of microwave oscillations. Assume that the bias voltage is increased until the electric field intensity is just below that required for avalanche breakdown. At this point there will be sufficient energy in one of the ever-present, random noise carriers to trigger off the avalanche process. For clarity, Fig. 2(a) assumes the steady-state condition where oscillations have already built up. During the first half of the a.c. cycle, the field is increased, avalanche multiplication commences and charge carriers build up at an exponential rate. When the alternating voltage falls below zero, the process decays exponentially.

The result is shown in Fig. 2(b) where,

on a linear scale, the charge density is seen to be a sharply defined spike and in particular the peak charge now lags the peak alternating voltage by 90°. Under the influence of the d.c. bias, this bunch of charge now drifts across the depletion region at constant velocity and therefore induces a constant current in some external circuit. If the diode depletion width is such that the carrier transit time corresponds to one half-cycle of the alternating voltage, then the induced current will be 180° out of phase. This is a negative resistance effect and conditions are right for the a.c. field to absorb energy from the d.c. bias.

Thus, the frequency of oscillation is approximately V_s $2w$, where V_s is the saturated carrier velocity of 10^{-7} cm/s and w is the depletion width. For a frequency of 10GHz, $w=5\times10^{-3}$ cm. Also, at this frequency, the junction area is about 5×10^{-4} cm^2 giving rise to bias current densities of around 10kA cm^{-2}. Good heat sinking is therefore essential and for this reason, among others, the semiconductor chip is usually mounted in a sealed package. A typical result is shown in Fig. 3(a), this being a standard microwave encapsulation.

Having done this, the various parasitic reactances associated with the package must be taken into account when designing the overall oscillator circuit. Although complex, the general effect of the package is to introduce a shunt capacitance across the device terminals and an inductance in series with them. The first is due to the physical separation of anode and cathode terminals and the second is due to the length of the package itself. A simplified yet practical equivalent circuit is shown in Fig. 3(b). The relative values of the main device parameters may best be demonstrated by taking a top-quality currently available commercial device as an example. Designed to operate in the vicinity of 10GHz and produce a c.w. output power of one watt, the equivalent circuit values are

diode capacitance at breakdown 1.2pF
diode negative resistance at full output power 2 Ω
package inductance 0.6nH
package capacitance 0.3pF

A simple circuit analysis is sufficient to show that the effect of the package is to alter the terminal impedance from -2–j13 ohm to $-7+$j46 ohm. The operating conditions would be

d.c. bias voltage 80V
bias current 200mA
avalanche breakdown voltage 65V
efficiency 7%

The low efficiency requires that 15 watts of bias power be dissipated from a semiconductor chip about 0.016-in diameter and 0.0002-in thick. Maximum theoretical efficiency is also relatively low, at 15% for Si and 23% for GaAs and much of the current device technology is aimed at reducing the overall thermal resistance.

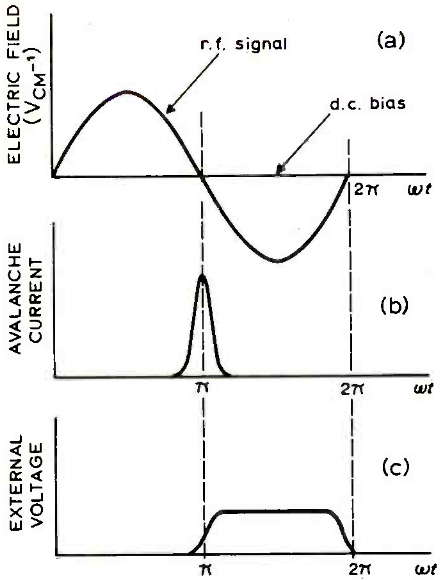


Fig. 2. Field profiles for the Read diode. Note the narrow avalanche region with peak current delayed 90° on peak voltage.

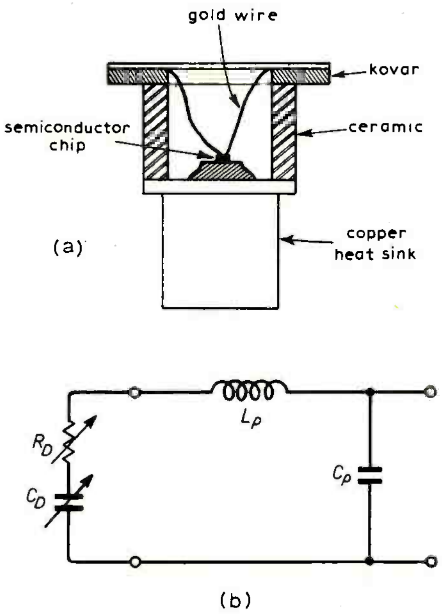


Fig. 3. (a) Typical package used up to 20GHz, 10 × full size. (b) Simplified equivalent circuit: overall effect of L_p and C_p degrades performance of the chip semiconductor

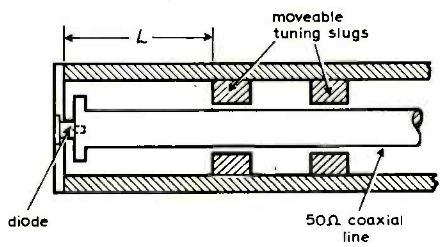


Fig. 4. Trapatt diode coaxial oscillator circuit. Tuning slugs form a variable low-pass filter which appears as a short circuit to Impatt-mode frequencies.

Trapatt diode

Another acronym, this one stands for Trapped Plasma Avalanche Triggered Transit and was first reported in 1967. The ordinary impatt diode can be made to oscillate in this mode, which is characterized by a lower fundamental frequency and much higher efficiency. Some results achieved to date are: 300W pulse power with 75% efficiency at 550MHz and 20W pulse power with 45% efficiency at 3GHz. By stacking five diodes together, a peak power output of 1.2kW with 25% efficiency has been achieved at 1100MHz.

A simple explanation of this device can be given by considering the impatt structure of Fig. 1. With the bias voltage increased to the point where avalanche breakdown occurs, then oscillations will commence as previously described. If the microwave circuit into which the diode radiates is made to present a short circuit to these oscillations, the power will be reflected back into the diode. With the proper phase relationship, the result can be a very large voltage swing in the avalanche region of the diode. This causes a massive quantity of charge to be generated by ionization and can neutralize the electric field behind the original avalanche charge build-up, causing it to drop to zero.

At the same time, the field at the front of this charge bundle is sufficiently high to produce ionization throughout the remainder of the diode. Thus, what we have is an avalanche shock-front which propagates rapidly through the material, leaving trapped behind it a dense hole-electron plasma; trapped because the carrier density is great enough to reduce the bias field almost to zero. Gradually, however, the field intensity will recover due to the steady influence of the bias voltage and a large current will flow; holes drifting to the right and electrons to the left in our model.

This recovery period is much slower than the normal impatt transit time, due to the fact that the electric field is, for most of the time, below the 5kV/cm or so required for a saturated velocity. The situation will then revert to the starting point of a locally high electric field and very little current flow. Direct-to-alternating energy conversion is basically the same as in the impatt case; here it may be considered as occurring at one of the impatt subharmonics. Note that the conditions for high efficiency are more pronounced in the trapatt mode. That is, high current at low voltage and vice versa.

A simplified circuit suitable for supporting trapatt oscillations is shown in Fig. 4. The diode itself is mounted at one end of a coaxial line and radiates into a low-pass filter. The diagram shows the form that such a filter might take in practice.

Thus, at harmonics of the trapatt fundamental, this filter looks like a short circuit, while at the trapatt frequency, it looks like an open circuit. By altering the relative position of diode and filter, it is possible to vary the frequency, as the diode oscillates with a wavelength given approximately by $2L$.

Both the impatt and trapatt diodes are the subject of much theoretical and technical study at present as their potential application is widespread and they bid fair to replace the low-power klystron and medium power travelling wave tube for many applications.

Gunn-effect device

Named after its discoverer and also called the transferred electron device, its microwave oscillations were first demonstrated in 1965. Unlike the impatt effect, which can be obtained from virtually any semiconductor with a carefully doped profile, the Gunn-effect is a bulk phenomenon, particular to only a few semiconductors having a certain energy band structure. These are known as two-valley semiconductors as in their conduction bands there are two different energy levels which can be occupied. In the lower energy band, electrons have a low effective mass and high mobility, while in the higher energy band they have high mass and low mobility. This arrangement is crucial to the Gunn-effect and is exhibited in materials such as indium phosphide, cadmium telluride, zinc selenide, indium arsenide and gallium arsenide.

At present, all commercial devices are made from n-type GaAs; not because this is necessarily the best, but because the GaAs material technology is more advanced. The energy band structure for n-type GaAs is shown in Fig. 5 (a); note the large difference in carrier mobility – hence drift velocity and resistivity – between the two states.

A Gunn-effect device consists of a chip of uniformly doped n-type GaAs with an ohmic contact at each end. With no d.c. bias, nearly all of the electrons occupy the low-mass, high-mobility energy band. If a voltage is applied across the sample and steadily increased, the electron kinetic energy also increases. At the point where about 0.36eV has been gained, the electrons jump abruptly into the higher band. Here they are much heavier and slow down very quickly. As the bias voltage is increased, the electrons slow down still further and thus exhibit a negative differential mobility i.e. a negative resistance effect. Fig. 5 (b) shows the velocity versus electric field curve caused by the above effect. The overall result of this energy transfer is to build up a travelling bunch of charge, as in the impatt diode. However, the process is completely different and can be visualized as follows.

With bias applied, then the electrons travel from the bias supply to the ohmic contact at their normal high velocity. On entering the semiconductor, they are abruptly slowed down and near the cathode, there results a sort of electron traffic jam – a local accumulation of charge. This domain, as it is called, continues to grow until it effectively neutralizes the field at the contact and causes it to fall below the critical value for energy band transfer. Thus, no further bunch of charge will accumulate and the domain propagates across the semiconductor as a sharp spike at near the saturation velocity of 10^7cm/s.

On reaching the anode the domain disappears giving rise to a pulse of current and at the same time the field at the cathode rises again and so continues the process. Thus the natural oscillating frequency is given by the domain velocity divided by the device length and results in the semiconductor being about twice as thick as for the impatt diode, i.e. 0.001cm for 10GHz oscillation.

To obtain good efficiency from the Gunn-effect device, it must be operated in a resonant circuit. The current pulses

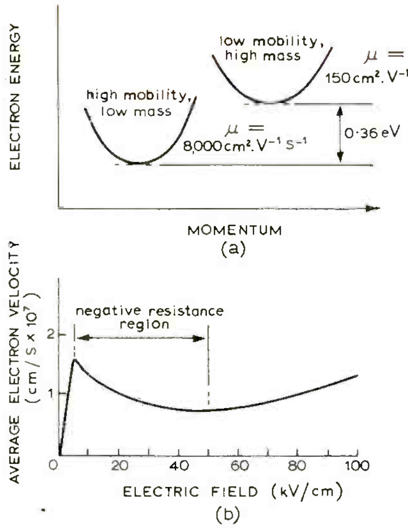


Fig. 5. (a) Energy band diagram for GaAs. The 0.36-eV level represents the quantum energy step between the two levels. (b) Velocity versus electric field for GaAs. Peak indicates the stage at which electrons jump from one level to the other and start to slow down.

described above will then shock-excite the circuit into resonance, thereby producing an alternating voltage and hence microwave output power. When mounted in this way, the resonant frequency and operating bandwidth are primarily determined by the circuit itself and the device can be made to operate in any of several energy transfer modes.

The efficiency of these devices is relatively low, the theoretical maximum being about 13% and 27% depending on the mode of operation. Power output is generally lower than for the impatt diode due to more severe thermal limitations. A typical commercially available device might have the following parameters

package reactances as in Fig. 3.	
operating frequency	10GHz
output power	200mW
bias voltage	9V
bias current	900mA
efficiency	2.5%

An advantage of the Gunn-effect device is that it operates at more usual power supply voltages which is useful in small portable or airborne radar systems.

LSA device

The external resonant circuit has a large effect in controlling the Gunn-effect. In particular, if the resonant alternating voltage is large enough, it can subtract sufficiently from the bias field to cause quenching or delayed starting of the Gunn domain. Thus, if the circuit is designed to have a resonant frequency several times that of the Gunn-effect frequency, then the domains will not have sufficient time to form before they are quenched by the voltage swing. With the right circuit conditions, the complete semiconductor length is thus biased into the negative resistance region and held there. The rapid a.c. field thus absorbs energy continuously from the d.c. field and the frequency is independent of sample length.

This is termed the "limited space-charge accumulation" (l.s.a.) mode and holds promise of very high powers at high frequency. Because the effect is not a transit time one the sample can be made much longer, improving its power handling. The main technical problem at present is obtaining pure enough GaAs, as impurities can give rise to spurious domains being formed, leading to thermal runaway. However, to give an idea of its capabilities, the following results have been obtained: 150 watt peak power at 18GHz with 6% efficiency, 200W peak at 7GHz with 5% efficiency and 6kW peak at 1750 MHz with 15% efficiency. We are still talking about devices the same order of size as a pin-head. The above represents the highest output powers ever achieved from a single semiconductor device.

Tunnel diode

Since its discovery in 1958 a lot of attention, both theoretical and practical, has been devoted to this device and many claims made for its application. In spite of this the tunnel diode has never really caught on significantly in the microwave field. This is largely due to its poor power handling capabilities, leading to very low oscillator outputs. Typical results might be: 10mW at 5GHz and 0.2mW at 50GHz with about 2% efficiency, now greatly overshadowed by the Gunn and impatt devices. The upper frequency limit of the diode is, however, very high and frequencies in excess of 100GHz have been generated. Future applications are probably limited to low-noise microwave amplifiers and high-speed logic elements.

The diode gets its name from the manner in which current flow occurs, leading to the production of a negative resistance region of operation. Consider the situation when a p-n junction is formed: charge carriers in the vicinity of the junction tend to drift across, thereby forming a potential barrier either side of a space-charge or depletion region. Thus, a state of equilibrium is reached wherein there is no net current flow and both classical physics and intuition tell us that to get an electron across this barrier to the opposite side of the junction, it must be given an additional energy equal to the barrier potential.

However, when quantum physics is applied, then the position of any electron at any instant of time is a question of probability. Further, under certain junction conditions, it turns out that an electron on one side of the barrier can have a very high probability of suddenly finding itself on the opposite side. One presumes that the early experimenters shied from the idea of the electron scaling the potential barrier and gave it the more devious attribute of tunnelling beneath it.

Although a number of semiconductor materials can be used, tunnel diodes are usually fabricated from Ge or GaAs and take the form of a very heavily doped p-n junction. A typical doping density is 10^{19}/cm³, giving very narrow depletion layer widths of around 10^{-6} cm. The tunnelling probability decreases exponentially with increasing depletion width, so very small values are required and this represents the main restriction on operating power level.

Fig. 6(a) demonstrates the *V-I* characteristic of the tunnel diode and may be understood with the aid of Fig. 6(b). As drawn, this represents the condition at zero bias, corresponding to point 1 in Fig. 6(a). The doping is sufficiently high to partially fill the conduction energy band with electrons and leave a lot of unfilled levels in the valence band. With the application of a small forward bias, conduction band electrons are given more energy and the band will be raised. So these electrons "face" corresponding empty levels in the valence band, but are separated by the potential barrier of the depletion layer. A tunnelling current flows under these conditions and is represented by the portion of the curve up to point 2; this current is proportional to the amount of overlap of the energy bands. As the bias voltage is further increased, raising the conduction band still higher, the amount of overlap will start to decrease with voltage. This leads to a corresponding decrease in tunnel current and gives the negative resistance part of the curve, down to point 3. After this stage is reached, the bias is sufficiently great to cause the normal forward diffusion current to flow.

For use as an oscillator, the diode is mounted in a resonant circuit and coupled to the load. Usually a resistance is placed in series with the diodes as a stabilizer to suppress unwanted oscillations. Two important factors affecting oscillator and amplifier stability can be deduced from the equivalent circuit of Fig.6(c). From the expression for input impedance it can be seen that there is a particular frequency for which the resistive part of the impedance becomes zero and another for which the reactive part becomes zero. These are termed the resistive and reactive cut-off frequencies, f_R and f_x.

At frequencies above f_R, the resistive part of the input impedance becomes positive and the diode is no longer an active device. Below f_x, the diode is inductive and changes, through self-resonance at f_x, to capacitive at frequencies above f_x.

Compared with Gunn and impatt devices, the tunnel diode would seem to offer little competition in output power. Unlike these devices, though, tunnelling is not a transit-time effect, so the diode can operate at very high frequencies, above 100GHz, before being limited by the various parasitic reactances. The tunnel diode also has a very low noise figure, about 5.5dB at 10GHz, and can compete in some circumstances with mixer diodes and thereby find application as an amplifier in receiver front ends. In a slightly different form, it is also a very sensitive r.f. detector, when it is usually called a backward diode.

Varactor diode

Unlike the devices so far reviewed, the variable reactance (varactor) diode is not a fundamental oscillator but instead multiplies an input frequency by generating its required harmonic. Such harmonics can be generated by an oscillating signal acting on any non-linear impedance. However, for

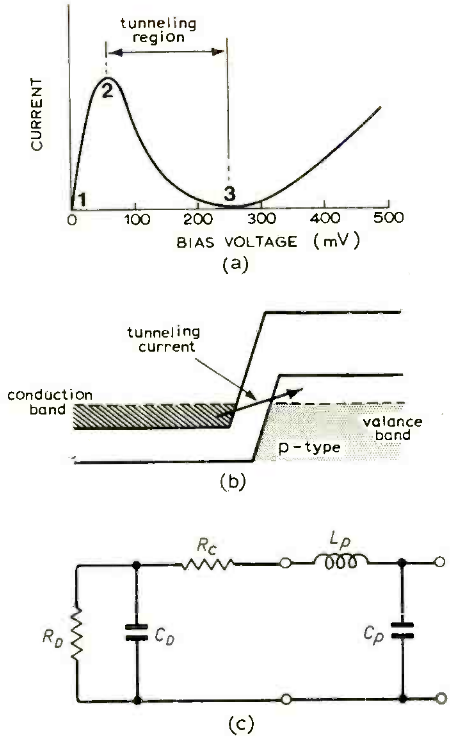


Fig. 6. (a) Typical I-V curve for the tunnel diode. (b) Valence and conduction bands for a p-n junction. Tunnelling current is a function of the amount of overlap of these bands. (c) Equivalent circuit of a packaged tunnel diode.

the case of a variable resistance diode, such as the conventional mixer, the efficiency cannot be greater than I/N^2, where N is the harmonic number. Whereas the varactor diode, which makes use of a non-linear capacitance, has a theoretical efficiency of 100% and can be up to 80% in some circuits.

Varactor diodes are generally made from silicon or GaAs and take the form of a p-n junction with the non-linear element being provided by the junction depletion layer capacitance. This capacitance can be made to have a strong dependence on the applied voltage, where values might range from many tens of pF at 0V to 1pF or less at the reverse breakdown voltage. The capacitance is $C_o/(1 + V/\phi)^m$ where C_o is the capacitance at 0V, V is the applied bias, ϕ is the barrier potential and is typically 0.5V for Si and 1.1V for GaAs, m depends on the junction doping profile, being 1/2 for an abrupt junction and 1/3 for a linearly graded one.

If an alternating waveform is impressed across the varactor, an infinite series of harmonic frequencies will be generated. By the design of suitable resonators to give impedance matching and filtering, the extraction of power at the required harmonic can be obtained. Basically the non-linear action can be considered as firstly doubling the input frequency and producing harmonics and intermediate harmonics and secondly, acting as a mixer to produce the further range of output frequencies.

These intermediate harmonics are known as idlers and, in the case of the abrupt junction varactor, currents at the idler frequencies must be allowed to flow if more than a doubling action is required. While not essential to the graded junction varactor, idlers are often introduced to increase the efficiency. Although higher harmonics can be produced, the varactor is usually designed as a doubler, tripler or quadrupler. Above this, the circuit becomes very complex and power handling is reduced. Higher frequencies and powers are produced by coupling together chains of varactor multipliers.

For the generation of high-order harmonics from a single device, there exists a variation on the varactor called the step-recovery diode (s.r.d.). By suitable doping of the p-n junction profile and choice of material (usually Si), the incident r.f. waveform can switch the s.r.d. rapidly between a high-capacitance, forward-biased state and a low-capacitance, reverse-biased state. If the diode is now made to form the *C* part of an *L-C* circuit, the inductance will store the capacitance discharge energy and produce a train of voltage impulses occurring once per input cycle across a resistive load. A Fourier analysis of this impulse would reveal it as an harmonic-rich transient. To form a multiplier, the output from this impulse generator is coupled to a resonant circuit having a loaded Q of $n\pi/2$. The resonator is shock-excited and responds by producing a damped, ringing waveform at a frequency n times the input frequency. Sidebands are present in this output, so the usual technique is to feed it through a band-pass filter to obtain the final output signal.

Harmonic generation using the s.r.d. offers the advantage of simplicity and higher efficiency over chains of varactor diodes. The s.r.d. is generally used for orders of multiplication greater than about 6 and can easily produce a $\times$ 20 output from a single device.

A third method of producing frequency multiplication is to use the varactor non-linear capacitance as a mixer to generate the sum of two input frequencies. This is generally referred to as an up-converter as the output frequency is made the sum of an input signal frequency and a pump frequency. This latter is analogous to the local oscillator of the conventional diode mixer which is a down-converter. In addition, the varactor or parametric up-converter has gain and finds application in low noise (1.5dB) receiver front ends.

Subsequent parts in this series will cover hybrid and lumped-element circuits, aerials and radomes, and radar systems.

Further reading

Impatt, trapatt, Gunn and l.s.a. devices: Hot Electron Microwave Generators by J. E. Carroll, Arnold 1970.
Tunnel diode: Principles of Tunnel Diode Circuits by Woo F. Chow, Wiley 1964. Varactor diode: Varactor Applications by P. Penfield and R. P. Rafuse, M.I.T. Press 1962.

The Semiconductor Story

2: Search for the best transistor: continuing a four part series of articles commemorating the 25th anniversary of the transistor

by K. J. Dean, M.Sc.,Ph.D., and G. White†, M.Phil.,B.Sc.*

At the start of the 1950s the transistor was a novelty. Industry needed to be convinced of its advantages over valves and electromechanical devices such as relays and magnetic amplifiers. Besides, there were a number of types being developed—which was the best? Even the textbooks of the period hedged their bets, taking as much space over point contacts as over junction transistors. But the electronics industry, at least, was just beginning to take notice. In 1952 the Post Office Research Station at Dollis Hill had demonstrated the first line amplifier to be made in the U.K. which used junction transistors, while a year later in America, Texas Instruments produced their first pocket transistor radio.

1953 was an important year for the U.K. semiconductor industry. One might almost say that was its birth, for in that year a number of companies set up manufacturing plants, among them G.E.C., Mullard, Ferranti and Pye, who were not then in the Philips group. One of the problems at that time was that the available germanium transistors did not have worthwhile gain at radio frequencies. Naturally, therefore, one of the first commercial applications that they chose to exploit was that of transistor amplifiers for hearing aids. The Post Office was the authority for National Health hearing aids and under its guidance Mullard developed the OC56 and OC57 junction transistors specifically for this market. At the same time, Pye at Cambridge had interested Acousticon Ltd, manufacturers of valve-operated hearing aids, in transistors and the first 300 were delivered at the end of 1955. Some of these early devices were packaged in glass cases which were filled with silicone grease and were then painted to prevent the photoelectric effect (amplified by the transistor) making the other current changes due to transistor action. Many an engineer carefully scratched the paint away to use them as sensitive photocells until the manufacturers foiled this dodge by using metal cans. Some of the first metal cases were sealed with solder, leading to examples of flux contamination. The Post Office was not satisfied with these types of encapsulation and insisted on hermetic sealing.

So difficult was the technology of junction devices to master that one manufacturer in those early days recorded that the yield in the first week of production was one device and another calculated that his first working transistor represented an investment of £1 million.

One seldom stops to think why the U.K. semiconductor industry developed as it did. Where did the money come from? Who made the decisions that got it all started? Many companies owed their place in transistor research to the encouragement of C.V.D. (Commercial Valve Development!) This government committee, on which the services, the Post Office and our national research establishments were represented, placed contracts for the development of transistors. It is always popular to blame government for wrong decisions or for no decisions at all, but without C.V.D. help few U.K. companies would have got started. One exception was Mullard, owned by the Dutch Philips Group, whose research was funded from the profits of selling valves. In fact their early transistors used valve nomenclature: A for diodes, B for double diodes and C for triodes. The first symbol of the type number was reserved for the heater voltage, zero for transistors of course. So the OC70 was clearly a triode with no heater.

Difficulties with germanium

The first transistors were germanium devices but for a long time the material which would eventually be best was in doubt. Supplies of germanium were limited as there were only three known ores. Two sources were in Zaire (then Belgian Congo) not a particularly stable part of the world; a third ore, germanite, came originally from South Africa, but the mines were exhausted there so that its chief source was from ores imported into Germany before World War I. In addition certain coals contain germanium and at that time the principal supplier in the U.K. was Johnson Matthey who indicated that their main source was from flue dust. Hence, the price of pure germanium was high—about £100 per lb. Meanwhile in Japan the Tokyo Gas Company was extracting germanium from waste coal-gas liquid—one of the first signs of competition from the Far East. It was estimated that one ton of germanium would make 200 million transistors and that in a few years 40 tons per annum would be needed for the world market, against the current production of three tons per annum, including the germanium needed for other purposes. Something had to be done.

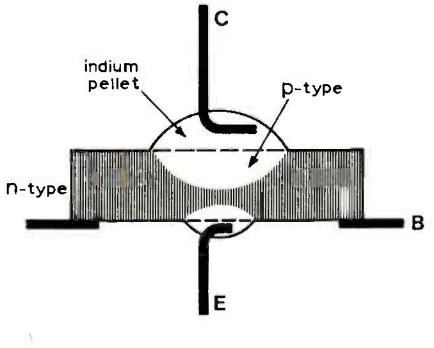


Fig. 1. Slab of n-type germanium with two indium-doped pellets alloyed to it so that it will be modified to p-type immediately below them after heating. The resulting alloy junction transistor was illustrated by a photomicrograph in Part 1 of this series.

Silicon was the obvious contender. Like germanium it is a group IV element; also, after oxygen it is the most common element in the earth's crust, but its melting point is 1420°C compared with 937°C for germanium. The purification of germanium requires a heating and cooling cycle of seven hours, one hour of which was at 1050°C in an atmosphere of pure dried hydrogen. The temperatures for silicon are correspondingly higher. Large quantities of expensive argon are used, which had to be reclaimed, and there were difficulties with phosphorus and boron impurities. Also the quartz (that is, silica) of the crucibles used tended to dissolve in the silicon. As late as 1955, S.T.C. (Standard Telephones and Cables) reported that their own attempts to purify silicon to the extremely high standard of purity required had not been successful. "No further work was done," the report adds, "due to the loss of the man doing it." Nowadays a large proportion of manufacturers are content to buy-in purified semiconductor material in slices for them to process.

Successes with silicon

Texas Instruments were first in the field with silicon transistors in 1952 and had a virtual monopoly for three years. At first the current gain was low and the frequency response was poor due to the lower mobility of charges compared with germanium.

*South East London Technical College.
†Twickenham College of Technology.

There were difficulties in controlling the technology, but leakage currents, always a difficulty with germanium, were much less. Ferranti, which had not until now been in semiconductors, decided to work solely with silicon (except for a small production of germanium tunnel diodes) on entering the field.

Difficulties with materials were by no means the only problems: there were insistent demands for higher frequency operation and higher power also. Receivers at that time were even being designed with valve "front ends" and transistor audio stages operating earphones. In 1954 S.T.C. had joined the semiconductor club, much of the work being done in germanium at the Brimar Valve Company's Engineering Division at Footscray, the basic research going on at Enfield and Ilminster. Their first junction device was the 3X/300N, later renamed TS1. It had a rating of 50mW while Philips cautiously rated their transistors at only 6mW, although after 15 months of life tests they were upgraded to 25mW. Pye moved their semiconductor plant to Newmarket primarily to develop a solid-state radio which was marketed by Pam in 1956. Meanwhile in Japan, Sony had started manufacturing transistors in 1953. A year later, they produced their first transistor radio and so started a virtual monopoly of short-wave and f.m. transistorized receivers, which was to last a decade. At this time, the best that the U.K. could offer was the V6/R2 of Newmarket Transistors and OC44 of Mullard, both of which had f_T = 6MHz.

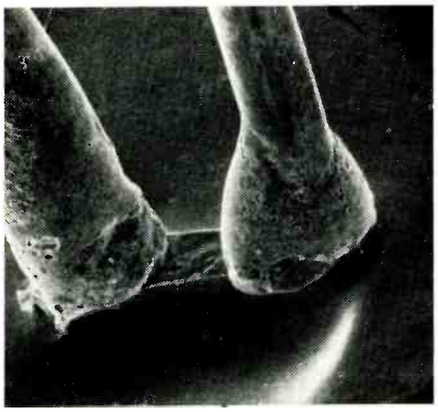
New types of transistors

The first junction transistors had grown junctions, produced by overdoping, in which the predominant impurity of the melt was interchanged at regular intervals as the crystal was drawn from it. The method was unsuitable for quantity production. The characteristics of these transistors left much to be desired—with light doping at the start and heavy doping with correspondingly lower resistivities at the end of the pull. Consequently, the alternative method of alloying which had been known since 1948 was the one which was principally developed and which resulted in most of the devices described earlier. In this process, small pellets of impurity material are fused to one side of the germanium slice and somewhat larger ones to the other side to form emitters and collectors respectively. For p-n-p transistors indium was used and lead-antimony pellets for n-p-n types. Subsequently, the slice was cut up into chips. It was an adaptation of this process which seemed to offer the best solution to higher frequency operation. This was the alloy diffused process developed simultaneously in Holland and in the U.K. (by Julian Beale) by Mullard.

The alloy for one of the pellets was a mixture of two impurities. There was a fast diffusing n-type impurity to define the base, with a slower diffusing p-type material. Hence, on heating, the first diffuser goes ahead of the alloy front. This process produced a graded base in which carriers crossed the base region more quickly than in the simple alloy types. Furthermore, the process lent itself to mass production. The OC170 was developed first in 1959 for operation at 100MHz, and later the AF114 and u.h.f. transistors like the AF186 with f_T = 600MHz, so that from 1961 to 1967, 30 million alloy diffused transistors were sold.

Germanium was also used for power transistors, the V30/10P for example, capable of 3W dissipation, produced by Newmarket in 1956 and the Mullard OC28 in 1963, the collector current of which was 15mA. The essence of the art of making power transistors was to keep the thermal resistance between the active region of the junction and the case as low as possible so that heat could be dissipated easily by a heat sink on which the transistor was bolted. However, it was clear that for most applications silicon would be the best material. It is perhaps ironic that at this time large contracts were being given to manufacturers in the States by the U.S. Government to set up substantial production facilities to support projects such as Minuteman and other defence programmes, whilst at precisely the same time the U.K. Government was abandoning the idea of a U.K. based nuclear deterrent so that similar British projects were not forthcoming and manufacturers in this country were not so actively encouraged to establish manufacturing plants. These American plants were large, because at that time the yield of good transistors from semiconductor chips was small, calling for a number of parallel production lines. As yields became greater, the manufacturing potential of the plants rose. Thus the U.S. production scene prospered whilst development at this critical time in Britain was much slower.

Of course all this resulted, in time, in a substantial cut-back in prices. The *Financial Times* of 27th March 1958 stated that a typical price for a transistor in 1956 was £3, £1.75 in 1957 and £1.4 in 1958 (expressing the figures in new currency). A letter of about the same time from Pye to the Radar Research Station, then at Tolworth Rise, Surbiton, gave the price of an audio transistor, for large quantities, as 80p. All this was but a foretaste of things to come ten years later.



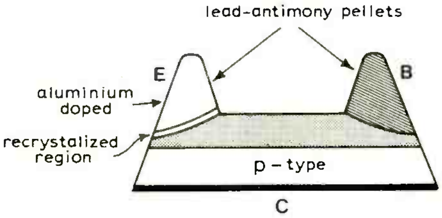
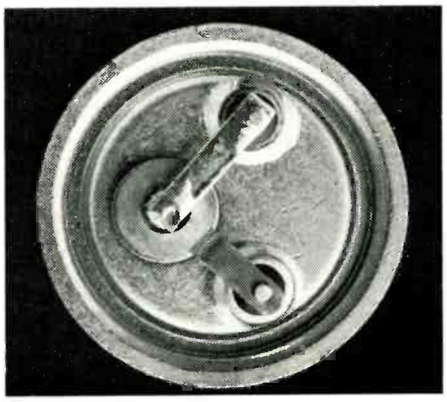


Fig. 2. Cross-section of a p-n-p alloy diffused transistor. Two 100μm wires are soldered to two lead-antimony pellets. The left-hand pellet also contains a small quantity of aluminium, applied as a paint after an initial alloying cycle. After subsequent heating to complete the alloy the left-hand pellet forms the emitter. The other lead is for the base. (Photo: Mullard Ltd)



Header of an OC28 power transistor. The semiconductor chip is towards the left of the header. The longer strap connects to the emitter. The base strap (at the bottom) carries the chip which is about 4.5mm square.

Risks of the game

The end of the 1950s left manufacturers still looking for higher frequency and power, but some of them were by now particularly conscious that the major outlet for transistors would be in data processing. Hence these companies concentrated on faster switching transistors and, incidentally, changed the whole outlook of the electronics industry from being dependent on the fortunes of the communications industry, as had been the case prior to 1939, to being dependent on the ups and downs of the computer industry as is predominantly the case today. Patents covering transistors had been filed on behalf of the Bell Telephone Labs. and any structure which looked as though it would not be an infringement of these patents was particularly attractive, since there was such a large market potential. A number of these cases have been before the courts since.

No discussion of switching transistors can omit reference to gold doping. The use of gold as a dopant had been known from experience with diodes. The presence of gold reduces the lifetime of minority carriers in the collector region and thus reduces the turn off time of the transistor. However, its presence can reduce lifetime in any region of the transistor, including the base region where it is not wanted. The process which is used for most switching transistors is one of diffusion followed by rapid quenching. The diffusion parameters are somewhat critical, hence the yield of devices tends to be reduced by gold doping.

Research being carried out by W. E. Bradley of the Philco Corporation under a U.S. Navy contract had resulted in a fundamentally new type of transistor—the surface barrier transistor. It depended on the properties of the surface of a uniform germanium crystal being different from that of the bulk material. The production method consisted of etching a germanium slice from both sides with a metal salt solution through which current was passing. Then by reversing the current flow, electrodes could be plated on to the germanium. These electrodes not only made contact with the n-type germanium but provided a suitably high density of holes for the device to operate. Bradley's original paper, in late 1953, mentions a frequency of 60MHz and, if this was not enough, it was whispered that this owed nothing to Bell Labs patents. Thus the surface barrier transistor seemed at that time to be a highly saleable commodity.

Philco was a company of some repute and the second-largest U.S. radio manufacturer pre-1939. Their interest in semiconductors had extended to taking part in the Bell Symposium in 1952 which was the first opportunity companies had to "buy-in" on the results of Bell's research. Records for 1955 show that Philco was one of the top three U.S. transistor manufacturers with 70% of

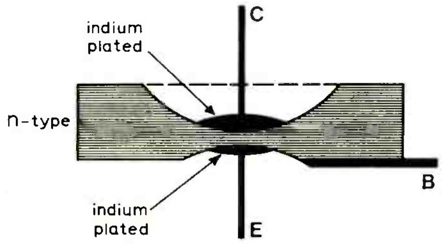


Fig. 3. Microalloy diffused transistor etched by liquid directed at both sides of the slab. By reversing the polarity of the etching current a suitable impurity could be plated, so that the transistor was produced with precise control of physical dimensions, such as the base width.

the American h.f. transistor market. But Philco were looking for a partner and the company with whom they linked was Plessey. Thus in 1959 the jointly-owned company, Semiconductors Ltd, was set up at Swindon. In addition to the new transistor, Philco brought to the partnership an automated production line and the know-how to run it—and this at a time when other companies were still talking about "green fingers". Plessey were soon disenchanted with the process and found that it was only automated when graduate-controlled—an expensive operation, However, they bought out the Philco interest and adapted the electrochemical process to plate, not just electrodes, but p-type collector and emitter regions to the etched base; the transistor was sold as the M.A.D.T.—Micro-Alloy Diffused Transistor. By 1967, Plessey's interests were growing in other processes using silicon. They decided to cease manufacture of discrete transistors, the company was closed and the whole process abandoned. Philco stayed solely in the germanium market and made no efforts to develop a silicon process. Each year sales and profits fell, until the company was taken over by Ford in 1961 as Philco-Ford. It was finally closed in 1969, much of its production and test equipment being sold to General Instrument Microelectronics. The disappearance or virtual disappearance of companies like Philco, who were leaders just after World War II, shows the heavy cost of bad management decisions or technological mistakes, often leading to an inability to attract and keep good researchers and other key staff.

Silicon takes over

If 1953 was the "Year of the Transistor" as the American magazine *Fortune* proclaimed in an article recently, 1960 was the year of silicon. The Post Office had carried out a study on the accelerated ageing of germanium transistors, and, as a result of this, it was definitely decided that future C.V.D. contracts should concentrate on the use of silicon. S.T.C., Mullard and Ferranti were making silicon transistors. Research was going on at the Services Electronic Research Laboratory at Baldock to make silicon mesa transistors.

In this process, an n-type silicon slice had a p-type layer diffused on to one face. Part of the face was then protected with a photo-resist and an n-type layer diffused into the p-type region to give an n-p-n transistor. Finally, the active region of the slice was covered with resist and the uncovered parts of the diffused layers etched away, so that when the resist was removed the transistor was raised up above the remainder of the slice. Hence the name, mesa, after the shape of the hills around Mesa in Arizona, U.S.A., which this profile somewhat resembles.

The process was attractive since it was entirely carried out on one side of a silicon slice. It was soon seen, however, that this was no more than a further step on the road to success. The final etching to make the mesa which controlled the dimensions of the transistor was eliminated leaving the device with an entirely flat surface—the planar transistor.

Ferranti were making the ZT20 in 1960, the first European-made silicon transistors, and S.T.C. following in 1961. The ZT20 was made on 1in silicon slices, later diced into 0.4mm square chips of which 0.13mm was the length of the active area. Transistors like this were made in batches of about 2000 on a slice. A process well suited to mass production was now available.

Epitaxy

The fact that the diffusion of planar transistors was entirely carried out on one face of the silicon slice was at the same time an important advantage and a drawback of the process. Whilst it made mass production a reality, it also meant that collector material of high resistivity had to be used so that there was the resistance of an appreciable mass of silicon between the collector contact and the active collector region near the base. This was a drawback for operation at high power and also resulted in a poorer high frequency performance than had been hoped. Thus even in 1962 S.T.C. could continue to sell germanium tunnel diodes and similar devices as high speed logic elements capable of 50MHz operation, despite all their inherent disadvantages. The solution to this problem was the use of epitaxy.

In the epitaxial process a layer of high resistivity silicon, perhaps 1Ω, was first of all laid down on a much lower resistivity substrate material, perhaps 0.001Ω.cm. The transistor was then diffused with selective masking by photo-resist into this epitaxial layer. Such devices are sometimes referred to as triple-diffused. Although the epitaxial layer had to be sufficiently thick to contain the successive diffusions of the transistor, clearly the bulk of the substrate material is now of much lower resistivity. Faster switching transistors of this kind first made their appearance in the U.K. in 1962.

Perhaps the impact of these advances can

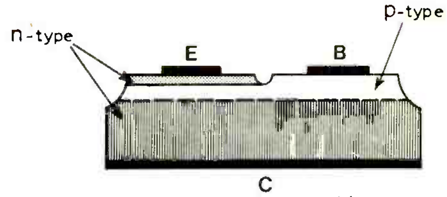
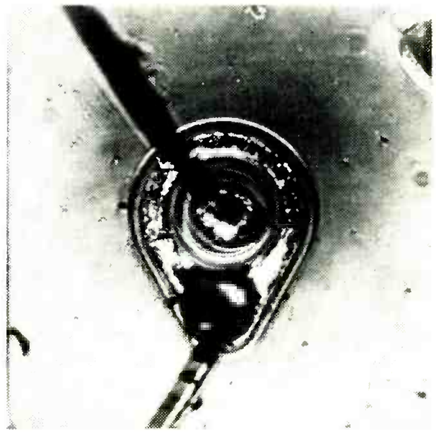


Fig. 4. Mesa transistor, produced by selective masking, diffusion and etching, carried out entirely on one side of the semiconductor slab.



Silicon mesa transistor designed for high speed switching applications, with a current rating of 200mA and a maximum dissipation of 1W. The chip is 0.4mm square.

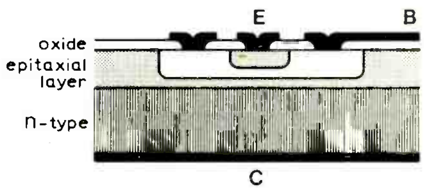


Fig. 5. Planar transistor, like the mesa, produced in one side of a slab of silicon, but with greater control of parameters. The process of epitaxy although first applied to mesa transistors was more fully developed with planar devices.

February Meetings

Tickets are required for some meetings: readers are advised therefore to communicate with the society concerned

LONDON

6th. IEE — "Stability of non-linear feedback systems" by A. Mees and Prof. Sir J. Lighthill at 17.30 at Savoy Pl., WC2.

6th. IEE/IEETE — Discussion on "Teaching techniques" at 17.30 at Savoy Pl., WC2.

7th. IERE/IEE — "A brief review of techniques in foetal, infant and child audiology" by Dr. R. J. Bench at 18.00 at 9 Bedford Sq., WC1.

7th. BKSTS — "Video and film special effects" by William Fitzwater and A. B. Palmer at 20.30 at the National Film Theatre, South Bank, Waterloo, SE1.

12th. IEE — "DICE — a digital equipment for converting between North American and European television standards" by J. L. E. Baldwin, J. A. Coffey, R. L. Greenfield, A. D. Stalley and J. H. Taylor at 17.30 at Savoy Pl., WC2.

13th. IERE/IEE — Colloquium on "The 25th anniversary of the transistor" at 10.00 at the Royal Society, 6 Carlton House Terrace, SW1.

13th. AES — "Loudspeaker evaluation using a digital Fourier analyser" by R. V. Leedham and L. R. Fincham at 19.15 at the IEE, Savoy Pl., WC2.

14th. IEE/IERE — "The invention of the transistor: an example of creative-failure methodology" by Prof. W. Shockley at 17.30 at Savoy Pl., WC2.

15th. IEE — Symposium on "Electro-magnetic interference" at 9.30 at the Royal Aeronautical Society, 4 Hamilton Pl., W1.

15th. IEE/IERE — Discussion on "What next in semiconductors?" at 10.30 at Savoy Pl., WC2.

15th. IEE — "The influence of the transistor in our society and economy" by Prof. W. E. J. Farvis at 15.30 at Savoy Pl., WC2.

15th. IEE — Faraday lecture on "Navigation: land, sea, air and space" by Dr. A. Stratton at 18.00 at Central Hall, Westminster, SW1.

15th. RTS — "Tape or film — marriage or divorce?" by G. Cook and D. Kentish at 19.00 at I.B.A., 70 Brompton Rd., SW3.

16th. IEE/IERE — Colloquia on "Computer memories: The expected impact of semiconductor memories" at 10.00 and "Future bulk storage technologies" at 14.00 at Savoy Pl., WC2.

16th. IEE Grads. — Faraday lecture on "Navigation: land, sea, air and space" by Dr. A. Stratton at 18.30 at Central Hall, Westminster, SW1.

16th. R. Institution — Discourse on "Lasers: present and future" by Prof A. L. Schawlow at 20.50 at The Royal Institution, 21 Albemarle St., W1.

19th. IEE — "Space instrumentation" by R. Young and B. R. Kendall at 17.30 at Savoy Pl., WC2.

21st. I.Phys — One-day meeting on "Semiconductor low light level detectors" at 11.00 at Imperial College, SW7.

21st. IERE — "Electromagnetic interference in ships" by T. Morgan at 18.00 at 9 Bedford Sq., WC1.

26th. IEE — Colloquium on "Interactic graphics in circuit design" at 10.30 at Savoy Pl., WC2.

28th. IEE — "Seeing in the dark" by Dr. P. Schagen and Dr. A. J. Goss, E. D. Henry and R. D. Nixon at 16.00 at Savoy Pl., WC2.

28th. IERE — "Digital phase lock loops" by K. Throwet and P. Atkinson at 18.00 at 9 Bedford Sq., WC1.

ABERDEEN

20th. IEE Grads. — "Microelectronics" by Dr. E. Price at 19.30 at Robert Gordon's Institute of Technology, Schoolhill.

BELFAST

20th. IERE — Discussion on "Reliability in electronics, fact or fiction" at 19.00 at Cregagh Technical College, Montgomery Rd.

BLANDFORD

21st. IEE — "Current needs and applications of h.f. propagation" by W. R. Piggott at 18.30 at Blandford Camp.

BIRMINGHAM

14th. RTS — "Television service fit for artists" by Dr. Boris Townsend at 19.00 at ATV, Broad St.

19th. IERE — "Modern dynamic measurement techniques" by Dr. J. D. Lamb and Dr. P. A. Payne at 18.00 at the Dept. of Engineering Production, The University.

26th. IEE — "The development and application of a computer-based colour c.r.t. display system" by A. J. H. Wilkins at 18.00 at MEB, Summer Lane.

BRIGHTON

20th. IEE — "Tomorrow's world in telecommunications" by W. J. Bray at 18.30 at The Polytechnic.

BRISTOL

12th. IEE — "Solid state devices useful for engineering" by A. A. Buck at 18.00 at Queen's Bldg., The University.

CAMBRIDGE

22nd. IEE/IERE — "5km radio telescopes" by Sir Martin Ryle at 18.30 at the University Engineering Laboratories, Trumpington Street.

CARDIFF

14th. IERE — "A short-hop radio-relay system at 20GHz" by R. R. Walker at 18.30 at UWIST.

CHELMSFORD

7th. IERE/IEE — "Feed forward: yesterdays techniques applied to tomorrow's amplifiers" by Dr. T. J. Bennett at 18.30 at the Civic Centre.

CROYDON

7th. IEE Grads. — "Viewphone and confravision" by J. R. Taylor at 18.30 at Croydon Technical College, Fairfield.

EASTBOURNE

6th. IEE — "Audio systems for the average home" by H. Mayo at 18.30 at Seeboard Offices, Willingdon Road.

EVESHAM

13th. IERE — "How high is hi-fi?" by D. Aldous at 19.30 at B.B.C. Evesham Club.

HULL

22nd. IEE/IERE — "Developments in radio telephone communications" at 18.30 at Y.E.B.

LEEDS

15th. IEE/IERE — "Induction motor speed control by use of permanent magnetic materials" by W. Shepherd at 19.00 at the University.

LIVERPOOL

7th. IERE — "Self organizing control systems" by Dr. D. W. Russell at 19.00 at the Electrical Engineering and Electronics Dept., The University.

19th. IEE — "Modems in transmission lines" by A. Galpin at 18.30 at Electrical Engineering Bldg., The University, Brownlow Hill.

LOUGHBOROUGH

13th. IERE — "25 Years with the transistor" by Dr. K. J. Dean at 18.45 at Edward Herbert Building, The University.

20th. IERE — "Modern dynamic measurement techniques" by Dr. J. D. Lamb and Dr. P. A. Payne at 19.00 at Edward Herbert Building, The University.

MANCHESTER

12th. IEE — "Some aspects of electromagnetic field theory" by Dr. J. Rawcliffe at 18.15 at Renold Bldg., UMIST.

15th. IERE — "Noise reduction techniques" by D. P. Robinson at 18.15 at Renold Building, UMIST.

NEWCASTLE-ON-TYNE

5th. IEE — "Optical communications" by F. F. Roberts at 18.30 at Room M421, The University.

14th. IERE — "Electronics and crime prevention" by A. T. Torlesse at 18.00 at Ellison Building, The Polytechnic.

NEWPORT, I.o.W.

9th. IERE — "Acoustic surface wave devices and applications" by Dr. J. Heiway at 19.00 at the Technical College.

PLYMOUTH

1st. IEE/IERE — "Marine satellite communication system" by Dr. W. P. Williams at 19.00 at The Polytechnic.

PORTSMOUTH

14th. IEE/IERE — "Design of British scientific satellite" by D. J. McLauchlin at 18.30 at the Polytechnic.

PRESTON

20th. IEE Grads. — "Colour television" by A. Gee at 19.30 at Harris College.

READING

15th. IERE — "Digital communications in the mobile environment" by B. D. Parker at 19.30 at the J. J. Thomson Laboratory, The University.

RUGBY

20th. IEE — "European communications satellite proposals" by J. L. Crauder at 18.15 at Lanchester Polytechnic.

SALFORD

21st. IERE — Modern dynamic measurement techniques" by Dr. J. D. Lamb and P. A. Payne, at 14.30 at Maxwell Buildings, The University.

SHEFFIELD

13th. IEE Grads. — "Electronics in motor vehicle testing and servicing" by B. M. Forster at 19.30 at the University.

21st. IEE — "25 years of semiconductor devices" by K. J. Dean at 18.30 at Telephone House, Charter Square.

SOUTHAMPTON

28th. IERE — "Port of Southampton Signal and Radar Station" by D. J. Doughty, J. C. Gunner and J. R. Laver at 18.30 at the Geography Lecture Room G1, The University.

STONE, Staffs.

26th. IEE — "High fidelity sound reproduction" by R. L. West at 19.00 at Post Office Technical Training College, Duncan Hall.

TAUNTON

15th. IEE Gads. "Technical aspects of TV programmes" by E. Benn at 19.45 at County Hotel.

Permanent Magnets

Fundamental properties, and the quantities used to measure them

by "Cathode Ray"

My last treatise, on magnetism*, though it went to a length that no doubt you thought was excessive enough, said no more about permanent magnetism or magnets than a half-promise to deal with the matter later. The Editor having made some encouraging noises with reference to that proposition, here we are. Some justification for giving it special attention can be found in the odd fact that although permanent magnets are nowadays encountered by readers of *Wireless World* much more than electromagnets, in such things as loudspeakers, pickups, microphones, meters and recorder tape, most of the books that explain the principles of electromagnets are much less forthcoming on permanent magnets.

All magnetic effects are due to electric currents. Electric currents are movements of electric charges. We are familiar with electric currents flowing around circuits, but every atom and molecule of every substance is made up largely of electric charges (electrons and protons) which are continually moving. In gases and liquids and the great majority of solids the molecular structure is such that these tiny currents normally cancel out. If a magnetic field is brought to bear on them, very complicated things happen†. For practical purposes the net magnetic results in most materials are negligible, and we are going to neglect them and consider only the small group of materials classed as ferro-magnetic. This word comes from *ferrum*, Latin for iron, because iron was the first and still is an important substance found to respond very strongly to a magnetic field. But many modern permanent magnets are made of alloys of such metals as aluminium and copper and contain no iron, and others (ferrites) are not even metallic.

The molecules of ferromagnetic substances form groups, known as domains, but unlike the proud kingly ones in history they are microscopically small. In each domain the molecules are so aligned that as a whole it is a tiny magnet. In the natural state of the material the domains are randomly aligned, so their magnetic effects tend to cancel out and there is little or no external magnetism. But when placed in a gradually increasing magnetic field more and more domains come into line with that field, in effect multiplying its strength. The multiplying factor is relative permeability, μ_r. (In SI units the permeability of empty space, μ_0, is not 1 but $4\pi \times 10^{-7}$. The multiplying value of ferromagnetic materials, μ_r, is therefore μ/μ_0.)

This μ_r is a very valuable property, for such things as transformers. At audio and power frequencies, at least, the strength of magnetic field needed to generate the required voltage in the secondary winding would call for an excessively large magnetizing current in the primary if a ferromagnetic core were not used. Ideally the core material would provide a large and constant value of μ_r. This would be shown as a steep linear slope of a graph of magnetic flux density (B) against magnetizing force (H), as in Fig. 1. But the domain-aligning process is far from linear. Very small values of H have a comparatively small effect, yielding only moderate μ_r. As H is increased, domains swing into line faster, and μ_r increases. When most of them have already responded, large increases of H are needed to persuade the remainder; and finally there are none left, so the curve levels off at what is called saturation value, Fig. 2. For such purposes as transformer cores the working H has to be limited to the steep (high-μ_r) part.

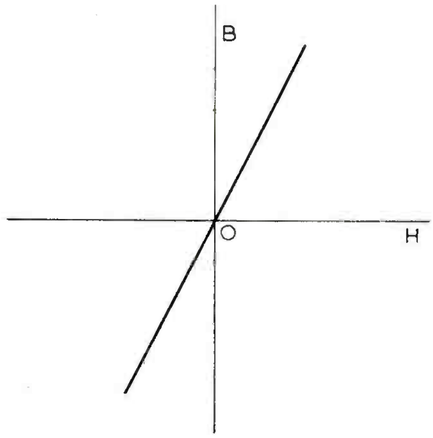


Fig. 1. Ideal magnetization curve for transformer core material, one of its advantages being complete absence of permanent magnetism.

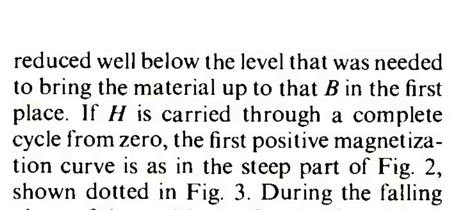


Fig. 2. Typical actual magnetization curve of ferromagnetic material, with H held at its maximum value.

You may be wondering why in Fig. 2 I have shown only the $+H+B$ quarter (or quadrant) and in particular not the $-H-B$ quadrant that is equally important in a.c. applications, where there are negative as well as positive half-cycles. The reason is that there is a second departure from the ideal. Fig. 1 implies that after the first positive half-cycle has reached its peak and is declining, the domains get jumbled up again exactly in proportion to the decline in current, so that the magnetization continues to be proportional to the current, throughout the cycle. This is shown by the graph passing through the origin O on its way to and from the negative quadrant.

No ferromagnetic material behaves in this way. Soft annealed iron, usually improved by a small proportion of silicon to increase its resistance to eddy currents, is about the best that can be found, and transformer core stampings are commonly made of some such material. But just as it is usually easier to get people into a pub than to get them out again, there is a tendency for the domains to stay put until H has been reduced well below the level that was needed to bring the material up to that B in the first place. If H is carried through a complete cycle from zero, the first positive magnetization curve is as in the steep part of Fig. 2, shown dotted in Fig. 3. During the falling phase of the positive half-cycle, the fall in B lags behind that of H, so by the time H is back to zero B still has a positive value, represented by OR. B reaches zero only when H is appreciably negative, by the amount OC. The negative half-cycle is of course similar.

For many years I have raised my feeble protest against the many unsatisfactory technical terms in our art. Here we have another example. In the old days, when electric bells, relays, etc. began to be used, it was soon found that there was a tendency for the armature to remain stuck to the pole

*January 1973 issue, p. 23.
†See *The Electron in Electronics*, M. G. Scroggie, Chapter 9.

of the electromagnet after the current had been cut off—as one would expect from consideration of Fig. 3. This effect became known as *residual magnetism*, and as far as I know it still is. At a rather more sophisticated stage, when *BH* curves came into vogue, the value of *B* represented in Fig. 3 by OR was called *residual magnetization* or *residual flux density* or *residual induction*. In some books this is alternatively called *remanence*. In other books this term is reserved for the highest possible value of residual magnetization, which is obtained after the material has been magnetized to saturation. In yet another book, *remanence* is defined for a magnetic *circuit*, whereas it is normally applied to magnetic *materials*, explicitly or (more usually) implicitly in the form of a continuous ring, with no gap or variation in cross-sectional area. In view of this ambiguity I propose that *remanence* be abolished. There is yet another word, *retentivity*. A word ending in *-ivity* signifies a property of a material under standard conditions. The value of residual magnetization in general depends on the amplitude of *H* if less than saturation, but if the material has been taken to saturation it should be the same every time. So retentivity figures enable materials to be compared. On the same principle OC is called (in general) *coercive force*, and its highest possible value, following saturation, has the special name *coercivity*.

The one-way traffic circulation system shown in Fig. 3 is an example of the well-known hysteresis curve. The fact that the up and down lines are comparatively close together shows that it refers to a fairly low-hysteresis material such as could be used for transformer cores. The reason it is important to use a material in which the area enclosed by the hysteresis loop is as small as possible is that this area represents power lost due to hysteresis. If you insist on a proof of this statement you can find it in textbooks on electrical engineering.

The usefulness of a magnet, electro or permanent, usually depends on its forming part of a magnetic circuit. It may be needed to set up a certain flux density (*B*) in an air gap, as in loudspeakers and meters, in order to make a coil therein move in accord with the current it carries. Or it may be needed to magnetize a piece of iron, to produce an attractive force governed by the principle that opposite poles attract and like poles repel. Pieces of high-μ_r material, called polepieces, are often used to serve the same sort of purpose as connecting wires in electric circuits, to connect the magnet to its "load" with the least possible reluctance.

Last time we saw (I hope) that magnetic circuits can be calculated in the same way as electric circuits with their Ohm's law. But Ohm's law is based on the discovery by Dr. Ohm that the resistance of ordinary circuit materials does not depend on the current flowing (if heating effects are disregarded). Electronics deals with circuit components that are not ordinary in this sense; their ratios of *V* to *I* are not constant, so Ohm's law cannot be applied. Instead, *I* is plotted against *V* as a characteristic curve. Suppose we have a diode, complete with characteristic curve (Fig. 4), and want to find the resistance (*R*) is series with it which will pass a certain current (I_0) through both when the voltage applied is V_T. All we have to do is mark V_T on the *V* scale of the graph, and point P on the curve, level with I_0, and join the two points by a straight line. The slope of this line is equal to I_0/V_R, which is the conductance of the resistor in series with the diode, so V_R/I_0 is its resistance. Which is what we wanted. The same thing can be done in reverse, to find I_0 or V_T, given *R*. If *R* is zero its line is vertically upwards from V_T, so I_0 is large; if *R* is infinite (open circuit) its line is horizontal, so I_0 is nil.

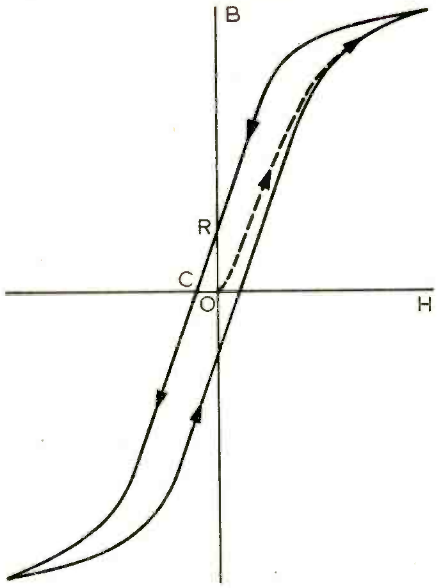


Fig. 3. For comparison with Fig. 1, a typical magnetization curve of transformer core material, taken from zero to maximum (dotted) and then over a complete cycle.

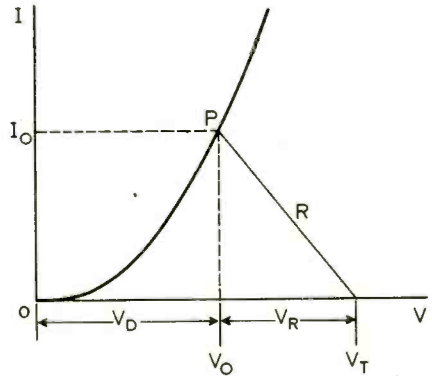


Fig. 4. Example of a load-line diagram for an electric circuit consisting of a diode in series with a linear resistor.

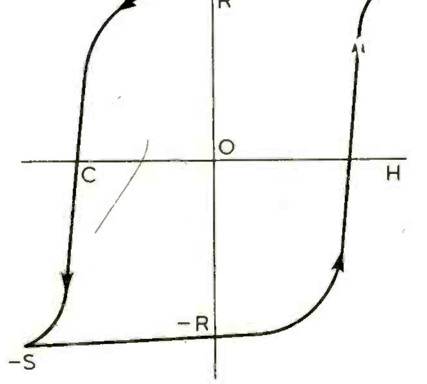


Fig. 5. For comparison with Fig. 3, a typical magnetization curve of a permanent magnet material.

Precisely the same method is used for magnetic circuits containing ferromagnetic and therefore non-linear material (call it "iron" for short). Corresponding to V_T is the total magnetomotive force (call it F_T), and corresponding to I_0 is Φ. F_D is the m.m.f. needed for the iron and F_R the m.m.f. needed for an air gap in series.

In an electromagnet circuit F_T is provided by the current in the coil, and in SI units is equal to it (every turn of the coil being counted as a separate current). It is obvious that with a diode having a curve as in Fig. 4, typical of semiconductors, if V_T were zero there would be no current, no matter what *R* was. Readers in the higher age groups and with good memories will recall that there used to be such things as thermionic diodes, whose curves began to the left of O, so current flowed through a resistance even if it was connected straight across the diode, with no V_T. We have just noted that ferromagnetic characteristic curves always extend to the left of O, as in Fig. 3, provided that the material has been magnetized. So if we use an electric current to raise *H* to a high value, and then switch the current off, we still have some *B* (and therefore Φ). (Our curves are *B* against *H*, but *B* is simply Φ per square metre and *H* if *F* per metre.) If the iron having the curve shown in Fig. 3 was a completely closed circuit, without even the smallest gap in series, then the value of *B* would be represented by *R*. There is no such thing as a perfect magnetic open circuit, but if the air gap was large its reluctance line would be nearly horizontal and the working point close to C, so almost no flux. This would obviously not be useful, neither for most purposes would the largest possible flux density (*R*) because it would all be inside the iron and so not directly available. As with the diode, practical "load" lines come somewhere between these extremes. Where?

Now that we have at last got on to permanent magnets it is time we took leave of Fig. 3, which illustrates a type of material in which permanent magnetism has been deliberately minimized, and looked at Fig. 5, typical of permanent magnet materials and obviously far more rewarding for that purpose. Having taken in the contrast between it and Fig. 3, we move rather swiftly to Fig. 6, in which the only quadrant that now matters has been repeated in the left-hand half, leaving the other half free for answering the question that has just been posed.

We shall take as a typical permanent magnet circuit the magnet itself in series with an air gap. Loudspeakers and meter magnet circuits are of this type. The magnets employed to hold papers on boards or keep the fridge door shut may appear not to be, but in one there is a paper gap and in the other probably a rubber gap, and even when there is no intentional gap there is almost bound to be an unintentional one with appreciable reluctance. Allowance has to be made for polepieces where used, but their reluctance is small compared with a gap even when its length is many times less. The biggest practical departures from theory lie in what is called leakage flux. But theory is enough to be getting on with just now. And to make things as basic and simple as possible we shall assume that a magnet l_m in length and A_m in constant cross-sectional area is "feeding" a gap l_a long and A_a in area.

Neglecting leakage flux, as we are doing, we must accept that the flux Φ is the same in both:

$$\Phi = B_m A_m = B_a A_a$$

Therefore $$A_m = A_a \frac{B_a}{B_m} \qquad (1)$$

And the magnetic "potential drop" must be the same across both, being equal and opposite as in Kirchhoff's voltage law for electric circuits:

$$H_m l_m + H_a l_a = 0$$

Therefore $$l_m = l_a \frac{H_a}{-H_m}$$

and because $H_a = B_a/\mu_r$, and μ_r for air is practically the same as for vacuum, $4\pi/10^7$, this becomes

$$l_m = \frac{B_a \times 10^7}{4\pi(-H_m)} \qquad (2)$$

Multiplying (1) and (2) together we get the volume of the magnet:

$$A_m l_m = A_a l_a \frac{B_a^2 \times 10^7}{4\pi(-H_m B_m)} \qquad (3)$$

So the volume of magnet material required is directly proportional to the volume of the gap and to the square of the flux density therein. And for given values of these it is least when $-H_m B_m$ is most. So our question is answered by finding the point on the second quadrant of the demagnetization curve that corresponds to the highest value of $-HB$. This can be found by selecting a number of points on the curve, multiplying their co-ordinates, and plotting these products to a scale of $-HB$ to the right of O, as shown dotted. The maximum value of $-HB$ is of course where the resulting curve sticks out most, and by drawing a horizontal line from here to the magnet curve we find P, the working point for the smallest magnet to do the job. The gap "load" line can be drawn to it from O.

If we are too lazy or short of time to plot the $-HB$ curve we can usually get very near it very quickly by completing the rectangle with ROC as its corners and drawing the diagonal from O to cut the curve at a point that turns out to be a good approximation to P. Even this reduced effort on our part is rendered superfluous by the magnet makers, who thoughtfully mention the optimum B

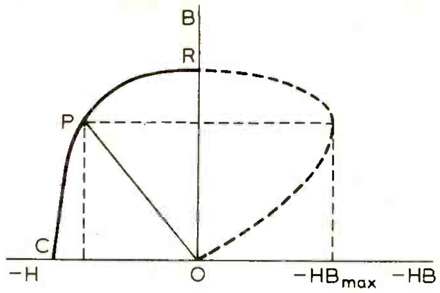


Fig. 6. The left-hand half is a "load-line" diagram for a permanent magnet material in series with an air gap, analogous to Fig. 4; the dotted lines are a construction for finding the best working point, P.

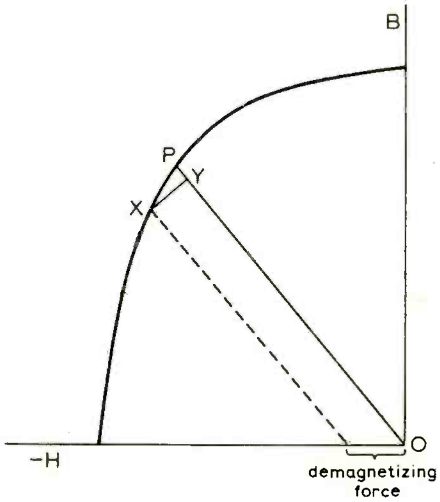


Fig. 7. What happens when a permanent magnet originally working at point P is demagnetized to point X. The recovery is to point Y.

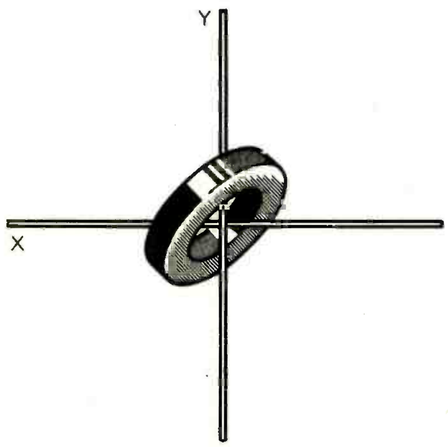


Fig. 8. One of the many ferrite ring cores in a computer magnetic store, encircling one each of the network of X and Y magnetizing wires. A third wire (not shown) is used to sense changes in the core magnetization.

and $-H$ and their product $(-HB)$ among their data. This value of $(-HB)_{max}$, however found, is the one to use in place of $(-H_m B_m)$ in (3) above.

These data figures enable fair comparisons to be made between different materials, and help one to choose the best material for a job. But I hope I've made clear that designing an actual magnetic circuit is not nearly so simple and demands a lot of experience. But again, the makers are ready to put their experience at your command, if an order is likely to be forthcoming.

There are however some points to be remembered when *using* magnets. Sometimes permanent magnet circuits are exposed to intentional or unintentional magnetic fields. These shift the working point to right or left from the original point, P in Fig. 6. If it is to the left (a demagnetizing field) the working point continues along the demagnetization curve from P to say X in Fig. 7. If now this external field is withdrawn, the working point finds itself in a one-way street (remember the arrows in Fig. 5?) and is bound by hysteresis to follow another track, to Y say. The strength of the magnet has been reduced. In a meter this would definitely be a bad thing. So such magnets are aged by submitting them in advance to fields stronger than they are likely to experience after calibration.

This also shows why it is not a good idea to take a permanent magnet circuit to pieces. Doing so generally introduces a relatively large reluctance in series, which makes the gap line move close to the horizontal, bringing the working point low down so that the value of B is much reduced. When the system is reassembled, much of the original magnetism is likely to have been lost. If possible, the magnet should first be short-circuited, but that needs care, for if the iron shorting piece is drawn against the magnet violently the resulting shake-up is likely to demagnetize it considerably.

Ceramic magnets, although short on retentivity, have exceptionally large values of coercivity. So they are relatively immune to external fields, and because of the shapes of their curves they are especially suitable for high-reluctance circuits.

An application of permanent magnetism not yet mentioned is in computer memories—the ferrite-core store. Here the permanent magnets are small (down to 0.35mm) closed rings, as in Fig. 8, and they are magnetized by current passed through straight wires threading the cores and acting thereon as one-turn coils. There are large numbers of X and Y wires forming a network or matrix, with a core around each point where they cross. Because there are no gaps in the cores, only a moderate current is needed even through the single turn to reverse the magnetization, from R to $-S$ in Fig. 5. After the current ceases the core is then at $-R$ instead of R. This large change of flux induces a pulse in a third wire (not shown in Fig. 8). If the core had been at $-R$ before the current, there would have been only a small change, from $-R$ to $-S$ and back, insufficient to induce an effective signal. The currents actually passed through the X and Y wires are made only half as much as needed to reverse the magnetization, so the only core to be reversed is the one encircling the particular X and Y wires selected, where the currents add up. So any core in the whole matrix can be selected for storing a 1 digit, corresponding to state $-R$, all in state R being 0 digits. That core can be interrogated by $+H$ currents in that particular pair of X and Y wires; if the encircling core was previously in the $-R$ state a signal is induced in the third wire; if in the R state, it is not.

Some of the newer ferrites have such enormous coercivities (such as 10 times greater than for the most effective magnet alloys) that even when powdered and embedded in rubber they are still strongly magnetic, with the added attraction of being able to surprise the uninitiated by their flexibility.

The principles we have been studying apply also to recorder tape in spite of the fact that the signals to be recorded are usually a.c. Because the tape is being drawn past the recorder head, any one line of magnetic material coating across the tape (call it L) is exposed to only one phase of one cycle of the signal; so as far as L is concerned the magnetizing force begins at zero, before L reaches the head, rises to a certain amount depending on the phase of the signal in the head coil at the moment L crosses the head gap, and then declines to zero again.

Good retentivity is needed to ensure that the coating retains enough magnetism to provide the playback head with an adequate signal. And coercivity should be enough to resist stray fields but not enough to necessitate an unreasonable erasing current. In connection with Fig. 3 I mentioned that the area inside the loop was a measure of the power loss in the core. To be more precise, it indicates the energy loss per unit volume per cycle. Now that we are thinking about materials for permanent magnets we look on this area from quite a different point of view and want it to be as large as possible. It still represents energy, but now it is the energy usefully stored in the material. Some recorder tape is described as "high-energy" tape, which one can correctly guess is tape coated with material having higher retentivity or coercivity or both compared with the usual sort which consists of ferric oxide. By treating this oxide with cobalt the retentivity and coercivity can be about doubled. This permits better signal/noise ratio (largely because of a small improvement at the high-frequency end) and signal level. Somewhat similar results are obtainable using chromium dioxide instead of ferric oxide. But unless the recording signal current and erase current are increased to the right extent, not only will benefits not appear but previous recordings will not be completely erased.

Of course the whole thing is complicated in ways we cannot go into here by h.f. "bias". Incidentally, have you ever considered that the magnetic detector used in the early days of wireless was a magnetic recorder in reverse, the incoming signals playing the part of what is now known as bias?

Letters to the Editor

The Editor does not necessarily endorse opinions expressed by his correspondents

Seeing in the dark

Though neither broadcaster nor camera manufacturer, may I be allowed to jump on the coat which Mr R. C. Whitehead trailed in your January issue?

He makes statements about the operating range of a television camera and the acuity of the human eye with which I, for one, will not quibble.

He goes on to suggest that modification should be made to camera channel characteristics when the camera is allowed to view scenes of low luminance in order, as he says, that the viewer should not be presented with information which a direct viewer of the scene would not perceive.

No doubt, as an engineer, Mr Whitehead resents the idea of unnatural reproduction but he must surely realize that the whole art of television broadcasting is the portrayal of an illusion, and I suggest that in his more relaxed moments he would find little to enjoy if he were presented with a truly accurate rendering of the scene in front of the camera.

The dark alleyway he mentions was probably anything but dark in the studio and it would have been inconvenient for it to be so. However, careful adjustment of the amount of light available to the camera tube together with adjustment of black level by the vision operator ensured that the illusion of gloom was successfully portrayed.

If a sports fan, would Mr Whitehead relish a true and accurate reproduction of the murky visibility of a football field or the low colour perception of a November handicap?

Some broadcasts from stately homes and gardens have inevitably been recorded under less than good lighting conditions. Should we not be grateful for the ability of the broadcaster to paint the lily and let us see something better than nature would have it be?

Mr Whitehead has not been fallacious but merely forgetful that there is more to broadcasting than the engineer's need to be faithful.

Gwilym Dann,
Chipstead,
Surrey.

If one is viewing under average ambient light, i.e. in the home, the "d.c." level about which the eye will operate on the 10-10 range will be different to that when the eye is subjected to low ambient conditions.

Thus when the broadcaster wishes to present to the viewer a scene shot under low luminance conditions he knows that his pictures are not going to contribute much to setting the "d.c." level about which the eye is operating at the time. The eye will probably be set at a much higher level than that coming off the screen.

Therefore some of the realism must be sacrificed for the sake of clarity, otherwise we would have to turn down the ambient lighting every time a night scene came up so that the eye could shift its "d.c." level down to that point which it would be if it were actually viewing the scene.

This brings me to the role of the programme director. It is his job to present via the TV medium a programme that the viewer can watch satisfactorily and understand. If he wishes to shoot some night scenes he must ensure that the viewer will understand the action or detail in that scene immediately because the viewer cannot get up out of his chair and inspect the scene more closely or at a different angle as one would if one were actually in the situation depicted.

This is the situation at the moment and if one were to degrade the pictures to the extent that Mr Whitehead suggests for the sake of more realism I'm sure that the viewer would find it very difficult to follow the action.

I cannot see why Mr Whitehead only picks on these points to say that the reproduction is unnatural because until we get 3D television of lifelike dimensions it will always appear unreal to the realist.

Stephen Waring,
Worcester Park,
Surrey.

Doppler effect in loudspeakers

In his letter in the January 1973 issue Mr Harwood draws attention to the large difference between my figure of 0.001% for the "just audible" Doppler distortion and the B.B.C. figure of 0.2% derived from the Stott and Axon investigations in the B.B.C. Research Dept in 1955.

He rightly points out that the two values cannot be compared because mine were obtained using pure tones, whereas the B.B.C. data was the result of group listening tests using ordinary programme material. This is an explanation with which I would entirely agree. In fact the listening conditions in my tests were even more critical than would appear from the simple statement above. In a semi-live room the distortion components produce their own standing wave system with the result that relatively large differences in the audible distortion thresholds may result from small head movements. In my tests the "just detectable" point was always determined with the head in the most sensitive position. In addition the Doppler distortion could be varied by a simple control so the minimum detectable value could be the result of several trials.

I would, however, comment on one aspect of the Stott and Axon data that appears to be outside the range of my experience. They suggest that wow and flutter values as high as 0.2% are acceptable on listening tests using programme material. My own experience using expert listening panels, first generation tapes and machines having known (measured) values of wow and flutter, suggest that criticism begins to appear at about the 0.05% level and that there is strong criticism of a machine with wow and flutter values around 0·1%. Simple single figures are being quoted as an indication of the wow but the frequency spectrum of the wow has a significant effect on the annoyance that is aroused, as Mr Harwood notes.

James Moir,
Chipperfield,
Herts.

Mr Harwood's summary of the subject of Doppler distortion, coming from such a source, is very valuable, but it immediately raised a question in my mind which may be puzzling others beside myself. So perhaps he could be persuaded to elucidate.

He himself emphasizes the enormous difference (29dB) between the levels of frequency modulation (such as Doppler effect) that are subjectively perceptible with continuous tones and with programme material. But what about programme material which for significant periods takes the form of continuous tones? It can happen for several seconds at a time in the reproduction of musical slow movements, in which (for example) a flute-stop organ note is held over a pedal note. The fact that these tones may not be quite so pure as from a good audio generator would seem inadequate to account for a difference of 29 dB.

There is another curious aspect. I understand that Stott and Axon found that the kind of programme to which the ear was most sensitive was not that which most closely resembled continuous tones (as one would expect from what Mr Harwood said) but piano music, which being percussive is one of the least similar. Is there any acceptable explanation for this remarkable finding?

Could it be that the tape flutter tests of Stott and Axon are in some way not entirely valid for Doppler effect in loudspeakers?

M. G. Scroggie,
Bexhill,
Sussex.

In praise of horn loudspeakers

Mr Kelly's November 1972 article "Loudspeaker Enclosure Survey" inevitably raises queries and, in this lay reader at least, grouses as well — all of a general nature and not directed at Mr Kelly! But I was disappointed to read so small mention of the hornloaded loudspeaker, an omission too remarkable to escape comment. As one who has laboured long, and with love not entirely unrequited, in designing and making loudspeaker mountings of every possible sort with sole purpose of gaining from records and radio best loudspeaker quality in order to extend pleasure in music, I have found that the hornloaded system makes an incomparably better approach to realism than any other. It is obvious that hornloading of an l.s. motor produces virtues of many sorts and that the end product assumes a grandeur — there is no other term possible — which no other method seems capable of emulating. Nor can the old bogey of too large bulk be legitimately levelled at possession of such superlative means to heaven. A very agreeable and exciting quality is obtainable from comparatively small installations and a sample is a cabinet 16in × 16in × 30in high, which surely cannot be objectionable to any except those who look for doublebass likeness from little bookcase boxes. Moreover, it can be shown that a well designed and made horn will yield a satisfactorily wide frequency range and prove to possess an efficiency rating substantially better than 30%.

But there is another matter of great importance to consider. Let us be reminded that there is not one musical instrument but it generates very individually beautiful sounds and that these sounds all possess extremely vibrant resounding "reedy" quality which reflects their complex nature and complexity of waveform. No proper realization of this "reedy" vibrant quality emerges from any available loudspeaker even if some make better effort than others. This subtraction is replaced with, amongst other defects, a "glitter and gloss" effect and often by a hardness. None of these ever appear in the sound of any musical instrument and the cause must surely lie, in the main, in motor slip of the speech coil within the magnet gap, aided and abetted by too much compliance of diaphragm perimeter suspension. The result is a weakened realization of the signal content applied and which signal we must accept as being much better informed about the quality of the original sound than ever we recreate from it. There is similarly an ineffective end product from electrostatic and electroquartz mechanisms and great lack of power too, in both, which makes for still further subtractions. It is significant I believe that the hornloaded loudspeaker, because of its more effective loading, "hardens" the sloppy moving coil movement and that this in turn provides no "glitter and gloss" effects.

There is another subtraction caused by use of electronic crossovers, which invariably cause loss of musicality. This is never regained and the matter can be proved by demonstration of a hornloaded system which uses none of these items, with resultant excitingly more musical likeness and incidentally a balanced frequency range second to none.

It seems a pity we can't conduct a survey of l.s. motors concerned with merits and demerits, as no loudspeaker mounting can be used without a drive unit and these have such fundamental effect upon the quality of any mounting that it would be most helpful to learn of all information available. The number of l.s. motors decreases every year and this is greatly to be deplored as many better samples have completely disappeared.

All in all and despite apparent sophistication our loudspeakers remain primitive affairs awaiting creative work by some dedicated and big-hearted human who will produce an improved moving coil action or a still better motor which will make the diaphragm very aware of how it has to behave in giving absolutely "electrical" attention to the demands of the signal. When that advanced apparatus comes about it is likely that the diaphragm will be quite small and unlikely to be made of paper and quite firmly though pliably held around its perimeter. The *only possible* loading will be a horn and the efficiency of it will be very high — maybe as much as 80% or even more. The end product will be the most amazing advance in gramophonic history. This is no idle dream or chatter. Something of the proof of it already exists.

Gilbert Telfer,
Kelso,
Roxburghshire.

Tree effects in TV reception

I have observed effects similar to those described by Mr M. G. Scroggie *(W.W.* Oct. 1972, p.478) and later correspondents, but my situation was more favourable and, unlike them, I was able to effect a cure. I am situated approximately 9½ miles from the Crystal Palace transmitter and during clear weather in winter its masts can be seen through a row of tall trees in the front garden of the house. The TV set was connected to an existing loft aerial system which was duplexed with Band 1 and Band 3 aerials. There was a variation in the colour saturation which was more marked on windy nights and in rain but, strangely, the BBC2 colour channel was not affected. The set installers said that the signal strength was off-scale on their meter and blamed the trees for the interference. However, it seemed difficult to equate this with the perfect reception of BBC2 and this suggested that there may be a pattern of standing waves set up by other objects in the loft. This view was reinforced when it was found that movement of the arms of the Band 1 aerial was the apparent reason for the improvement in one of the other TV channels at the expense of BBC2. The loft is not a congenial place to work and so the arms of the Bands 1 and 3 aerials were folded up and disconnected. The u.h.f. aerial was resited a foot or so behind the tiles and facing the transmitter and it was connected directly to the set on the ground floor through the same down-lead but without the duplexing arrangement. The aerial was also pointed slightly skywards to minimize signal fluctuation caused by traffic passing along the road in front of the house. The effect of these changes was to produce a perfect picture on all three programmes.

Simultaneous observation of the trees and the TV screen on a windy night showed that the slow changes in colour corresponded with the swaying of the tree tops. A clear explanation of the effect is not possible because too many variables were changed at one time, but it would appear to be connected with the formation of standing waves, the pattern of which would be changed by a variation of a few inches in the path-length of the reflected signal. Under multi-path conditions the subcarrier conveying the colour information would also have a pattern of standing waves which would not be the same as that of the main carrier, and the relative positions of the two would vary with the path-length. The effective path-length can also be varied by the passage of the wave in a straight line through media having a dielectric constant greater than that of air since the velocity of propagation is lower. Doppler effects should also be considered.

The observations discussed were made in February last year when the trees were not in leaf but reception was perfect throughout the summer and is still so.

B. Dudley Sully,
Ewell,
Surrey.

Nelson-Jones f.m. tuner

Constructors of the Nelson-Jones f.m. tuner may be interested in two of my experimental findings.

First, the u.h.f. instability which has plagued a few constructors seems to be associated with gate 2 of *both* of the m.o.s.f.e.ts. "Decoupling" the potential divider on gate 2 of the first device seems in fact to close a feedback loop which permits oscillation to occur. Despite the use of the recommended ferrite bead next to gate 2 of f.e.t. 2, my own tuner initially exhibited the instability at the high frequency end of the band. A resistor of 470Ω inserted between gate 2 of f.e.t. 1 and the decoupling capacitor removed all trace of instability in the tuner. Possibly removing the capacitor is the simplest answer, though I have not tried this. The unusually high drain current associated with unstable conditions and mentioned by Nelson-Jones in his recap article on the tuner seems not to be an intrinsic quiescent property of the f.e.t. but an indication of internal instability. When oscillation is suppressed, as above, the drain current resumes a value akin to the data sheet value at a relatively lower level.

I have repeated this exercise in an attempt to re-vamp a now out of date Radford F.M.T. 3 tuner front end of similar double m.o.s.f.e.t. design, with the same appearance of instability and the same cure (and, incidentally, most worthwhile results).

In both this latter case and in the construction of the Nelson-Jones tuner, I have used the Texas 3N201 m.o.s.f.e.t. which has an extended u.h.f. gain, thus presenting the most severe test of stabilization.

The ferrite bead used to suppress instability at gate 2 of the second m.o.s.f.e.t. of the Nelson-Jones tuner should be retained, as a resistor used here will alter the pulling of the oscillator and affect tuning.

It does certainly look as though some research should be done to ascertain the precise nature of the unstable feedback mechanism involved in the above cases so that the dual gate m.o.s.f.e.t. can be used to best advantage in such circuits.

My second finding is that, not unexpectedly, the oscillator coil is microphonic. If it is stuffed with foam plastic and then has some hot candle wax dropped on to it, the microphony is suppressed. The Q of the coil does not seem to be affected by this procedure.

N. J. Phillips,
University of Technology,
Loughborough,
Leics.

Mr Nelson-Jones replies:

I would disagree slightly with the comment that the instability that has plagued a few constructors is entirely due to g2 of the m.o.s.f.e.ts. It may well be that this is true with some cases, but in my experience the addition of a 22 ohm resistor in the tap feeding g1 of the r.f. amplifier (*Tr1*) is a complete cure in the vast majority of cases (Letters to the Editor July 1972 pp.318, 319), since the u.h.f. oscillation is due to long wire multiple resonance on the aerial feeder. It is probably true that the decoupling circuit of g2 is part of this oscillatory circuit and therefore decoupling changes will affect the oscillation. All one is doing in adding a resistor in the ways described is to add a loss to the circuit, hopefully in a way that does not appreciably reduce gain at the desired frequency, but which greatly reduces gain at the frequency of spurious oscillation.

I note that Mr Phillips used the Texas 2N301, a transistor which on paper is nearly identical to the 40673 or 40822 normally used in the tuner. My experience with this device is that it does have a rather higher slope, and a much higher cut-off frequency, probably above 1GHz. The device is therefore in my experience much more prone to "take-off" at u.h.f. than the other similar devices. The 2N301 is a very good device but needs greater care in use.

I am a little concerned at the thought of putting in a resistor as high as 470 ohms as suggested in that even at 100MHz this is a relatively high impedance compared to the circuit and stray capacitances and will, I feel, reduce gain at 100MHz (10pF = 1.6k at 100MHz); I would have thought a value of around 47 ohms more appropriate.

Finally I would also be unhappy about the microphony cure suggested in that I would expect it to have a very adverse effect on the temperature drift of the tuner. I have not myself experienced any problem with microphony in this way, indeed the tuner on the "*WW*" stand at the Audio Fair was fitted with an internal 3 watt amplifier and an 8 × 5in speaker within about 6in of the oscillator coil and even at the maximum output level no problem is experienced. This leaves me wondering if the oscillator coil in question has a slight construction fault, or is rather too near the body of the tuning capacitor, where it will have a rising distance versus frequency effect, due to eddy current and capacitive effects.

Power supply units

I note a letter from Mr Roy Whitehead on the subject of low cost power supply meters and the inadequacy of the one meter type units (January issue).

I would like to point out to Mr Whitehead that there are available in the United Kingdom power supply units that do more than meet his requirements, in as much that these units have two meters, one monitoring voltage, the other continuously monitoring output current. These units are available with output currents of up to 2 amps from this company.

C. A. Hill,
B. Hepworth & Co. Ltd.,
Kidderminster,
Worcs.

I was interested to read the letter on the problems encountered by users of stabilized power units.

I would suggest two alternative solutions to this problem, one of which I have adopted as standard practice. The first is the cheapest solution; always (i.e. without fail) turn the voltage control switches or potentiometer to zero before connecting or switching-on any load. The second may be considered a little extravagant. It consists of utilizing an electronic circuit to cause the meter movement to read a left-hand zero for VOLTS and a right-hand zero for AMPS. Thus the effect would be that if the meter switch is left at AMPS, the meter races to f.s.d. on switching-on, even with no load, and the operator's reaction would be to reduce the voltage control setting to zero in double quick time. The effect on the meter reading would be negligible but the voltage controls would have been adjusted in a safe direction until it was realized that the meter was reading current.

Either solution would achieve the desired result although if I were a power supply manufacturer, I know which I would suggest.

L. Write,
Portchester,
Hants.

Solid State Teleprinter Demodulator

by R. W. Addie, G8LT

The article describes a modern radio teleprinter terminal unit using the operational amplifier technique and illustrating the practical problems for which these devices provide admirable solutions. The author describes his approach to an American design, providing various options such as auto-start and anti-space circuitry which may be excluded should the constructor require a simpler project.

In the world of amateur, radio the use of machine telegraphy in addition to the more common modes of telephony and c.w. morse, has increased in popularity during the last ten years. Generally referred to as RTTY*, the technique has advanced to the point where good copy can be received in limiting conditions of signal strength and noise by the same order as c.w. but with speeds of 60 w.p.m. and higher. It represents about the most economical use of channel space of all the modes of communication. It is not surprising therefore, that many, not involved in transmitting activities, have been interesting themselves in receiving RTTY transmissions.

The unit to be described represents probably the best practice in amateur use today and no originality is claimed by the author whose object is to create interest and show a unit that can be made by anyone with an understanding of the principles involved.

Principles

RTTY is a stop-start system of machine communication where the receiving printer is kept in synchronism with the transmitting machine by means of two signals, one at the beginning of a character to start the machines scanning the elements of that character and one at the completion of it to halt both machines in readiness for the following one. In the Murray code used in RTTY, seven units are used, two for stop-start and five for transmitting the character. It follows that, when a radio link is used, only two significant signals are sent, i.e. stop and start or, as they are usually called, mark and space, respectively. These two signals are sent by shifting the carrier frequency by an exact number of hertz, moving it from the mark or resting state, to the space or starting condition. Early practice used a shift of 850Hz, but because of channel space and the prevalence of interference in the overcrowded amateur bands a 170Hz shift is rapidly becoming the norm. The latter enables better receiver selectivity to be employed but increases the stability problems. At v.h.f. it is common practice to use tone modulated a.m. transmission where the tone frequencies correspond to the amount of shift used in frequency shift keying systems.

The purpose of the demodulator is to accept two discrete audio tones representing mark and space from the output of the receiver and to process them so that the output signal from the demodulator is capable of driving the operating magnet of a teleprinter. The tones are obtained by the use of the beat frequency oscillator or envelope detector in the receiver and certain frequencies have become established as standard. For 850Hz shift, mark is 2125Hz and space is 2975Hz. For 170Hz shift, mark is 2125Hz and space is 2295Hz. Since precise frequencies are used, part of the function of the unit is to discriminate to the greatest possible degree against all frequencies other than those for mark and space. It must also cope with a wide dynamic range of signal and, because of selective fading, a large disparity at times between the two signals at its input.

A number of devices are used to achieve a clean and constant output to the printer. The design includes two bandpass filters (one for each shift), an effective limiter, sharp frequency filters for mark and space on both shifts, also an automatic threshold corrector which balances the mark and space signals to enable the slicer which follows to operate at the correct changeover point.

A number of other features have been designed-in which will appeal especially to the enthusiast. The first of these is the 'anti-space' circuit. This comes into use should an unwanted signal appear on the space channel which would normally allow the printer to run free. The second is the 'autostart' circuit by means of which the receiving station can be left on a frequency so that as soon as an RTTY signal is recognized the receiving printer starts and, after a predetermined delay, copy can be printed. When the signal disappears, the process is reversed so that all signals appearing on a given channel can be copied without the printer motor being left running. Also, misprints caused by non-RTTY signals or interference are automatically eliminated.

The design evolved from two earlier versions using valve techniques and incorporates all solid state devices including some nine of the more readily obtained op-amp i.cs.

The unit constructed by the author and illustrated in the photographs uses SN72709 op-amps and the circuit diagram shows pin numbers referring to this type. Another suitable type is the 709-C the pin numbers for which are shown in Fig. 2. Both types are readily available, relatively inexpensive and enable the whole unit to be concentrated into a very small space.

For those who want the simplest arrangement, it is possible to feed the signal directly to the limiter stage but the use of a separate bandpass input filter for each shift is well worth the extra trouble. The circuit shows the latter method and the photographs illustrate the terminal unit complete with both filters.

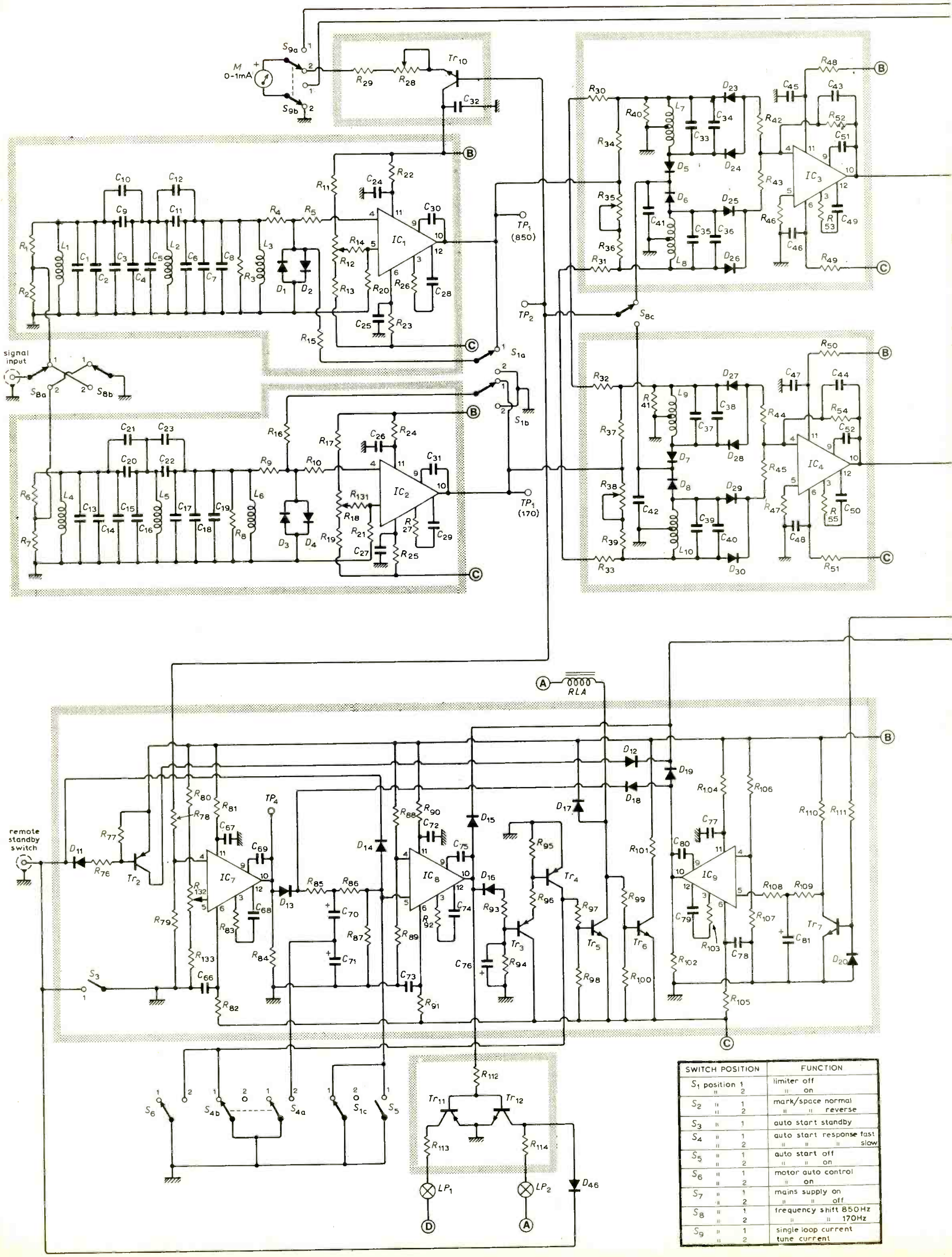
Circuit

Referring to the circuit diagram (Fig. 1), limiting is carried out in the op-amps IC_1 and IC_2 and as little as 200μV will cause limiting to occur. The signal diodes at the input are to protect the amplifier from overload. While the amplifiers operate *open-loop* to give limiting, reception without limiting is available when a 47kΩ resistor is switched-in by S_1a/b to control the amplification.

Bandpass filters are of the three-pole Butterworth type using a dual winding, 88mH toroid commonly used in telephone practice and therefore easily obtained. The wide filter (850Hz shift) has a bandwidth of about 1kHz and the narrow one (170Hz shift) is about 275Hz wide. In the first case the two halves of each toroid are connected in series to give 88mH and in the second they are in parallel, giving 22mH. By this means the terminal impedances for each filter are made about the same.

The mark and space channel filters for the different shifts are quite separate. No attempt at switching the space filter components is made. Earlier demodulators have used up to three stage passive filters for this purpose but the present design of discriminator filter uses only one active filter in each

*Radioteletype.



SWITCH POSITION	FUNCTION
S_1 position 1 " 2	limiter off " on
S_2 " 1 " 2	mark/space normal " " reverse
S_3 " 1	auto start standby
S_4 " 1 " 2	auto start response fast " " " slow
S_5 " 1 " 2	auto start off " " on
S_6 " 1 " 2	motor auto control " on
S_7 " 1 " 2	mains supply on " " off
S_8 " 1 " 2	frequency shift 850Hz " " 170Hz
S_9 " 1 " 2	single loop current tune current

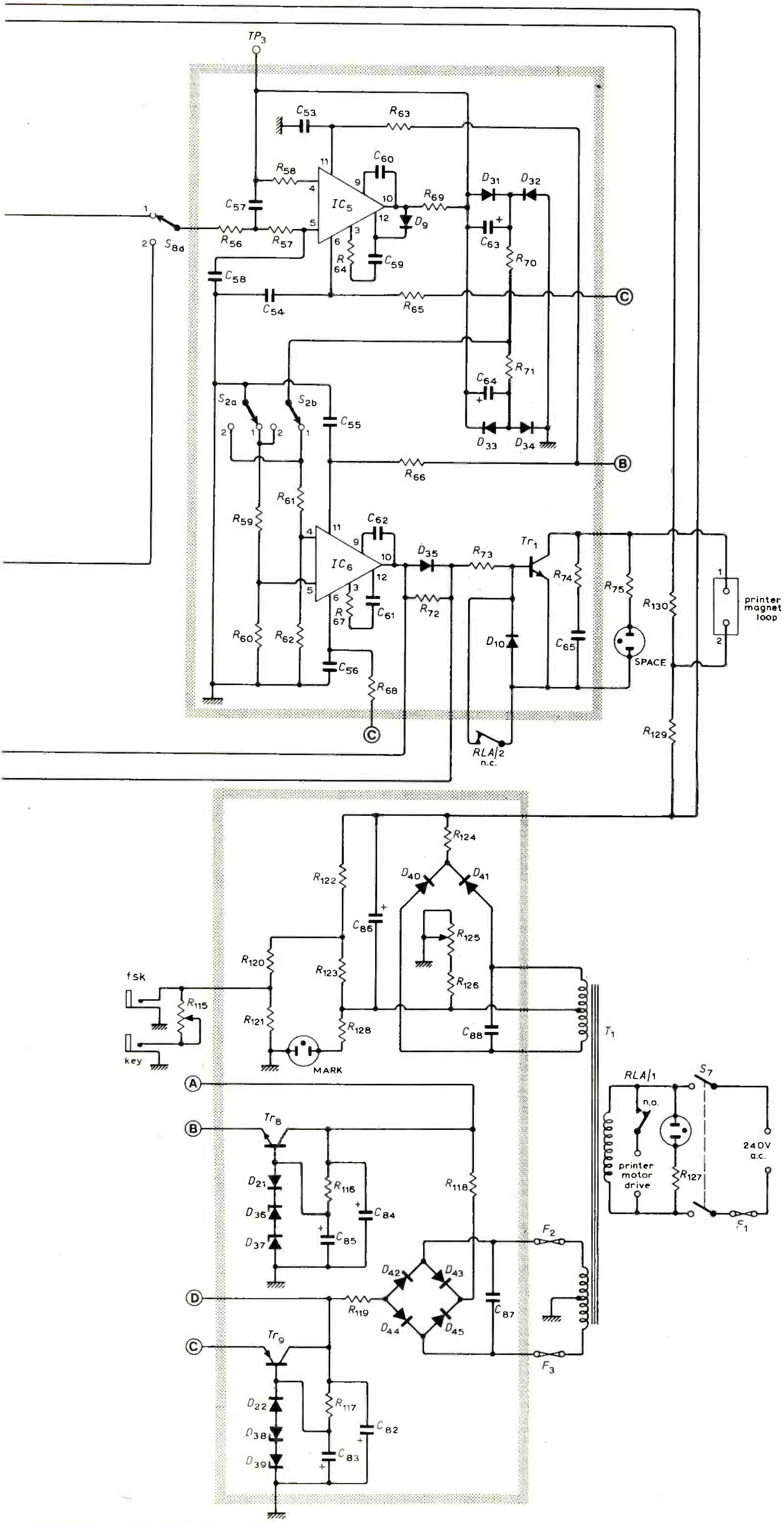


Fig. 1. Circuit diagram. (Partition lines show the limits of printed circuit boards, when used.)

channel. The adjustment of these is critical and will be described later in the article but, provided they are set up with care, results are entirely satisfactory. The two diodes D_5 and D_6 provide a control voltage on both mark and space for the operation of the autostart and tuning meter system.

Full-wave detection is used in both channels (D_{23} to D_{30}) and germanium diodes are used because of their lower forward voltage drop compared with silicon types.

The low-pass filters IC_3 and IC_4 use amplifiers with frequency selective feedback applied. Fig. 1 shows the pin connection numbers for the dual-in-line package. The alternative TO5 type package may be used in which case the pin connections shown in Fig. 2 can be directly transposed into the circuit. Mechanical pin layouts for the different packages are shown in Fig. 3.

There are conditions in which better copy is obtained when a.m. detection is used without the limiter; a method of balancing the mark/space signals from the low-pass filter is necessary. This ensures that the change-over point of the slicer IC_6 occurs at the right signal transition point. The 'automatic threshold control' IC_5 uses diodes D_{31}, D_{32}, D_{33} and D_{34}, the output signal being symmetrical about earth. Switch S_2 simply reverses the polarity of the signal feed to the slicer if the transmitted frequencies of the mark and space signals are reversed.

The slicer is operated at full gain and as steps have been taken in the design to keep the output of the low-pass filter as clean as possible, it is extremely sensitive and Irvin Hoff's original model* could be changed at the slicer from full mark to full space with the input to the limiter changing as little as 1Hz—even with the 850Hz channel filter in use. The author's version exhibits similar characteristics and has proved to be one of the most attractive features of the unit.

The output of IC_6 at pin 10, swings from about +11V on mark to −11V on space. This drives the keyer transistor Tr_1 with about 5mA forward base current, via resistor R_{73} on mark signals. For space signals D_{35} blocks negative potentials yet allows a small negative current to be applied via the reverse resistance of the diode and R_{72} to assist the transistor in switching-off. The keyer is rated such that the magnet of a single current operated machine can be driven directly from the collector which requires up to 60mA. In the author's version the unit had to run a Creed machine using double current operation for which this keyer stage was unsuitable. This was overcome by making the keyer drive a high-speed mercury-wetted, reed relay which had the added advantage of providing keying for two quite separate loops. Furthermore the keyer current could be limited to a much lower value, considerably under running the 2N5655. The changes to revert to double

*"Mainline Solid State Demodulators" by Irvin M. Hoff, W6FFC, *RTTY Journal*, Sept., Oct., Nov., 1970.

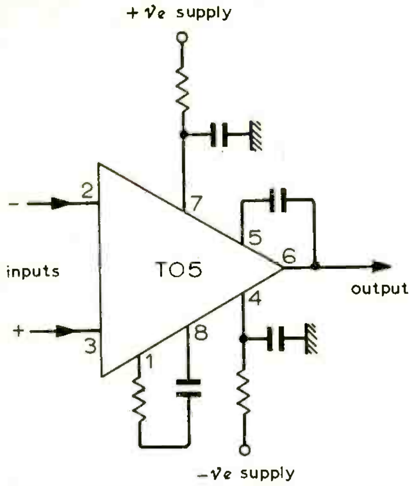


Fig. 2. Alternative circuit connections for TO5 package.

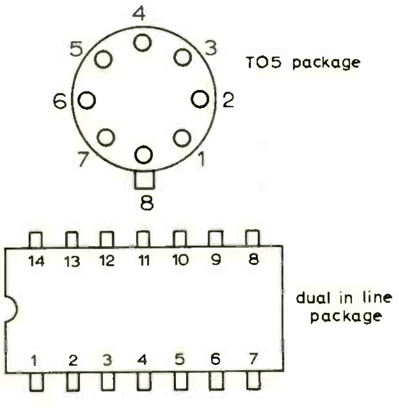


Fig. 3. Pin connections (top view).

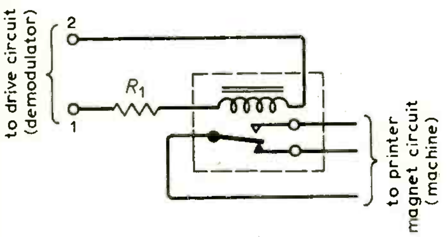


Fig. 4. Typical mechanically biased keying relay (Clare type HGSM, 2000Ω coil, or similar).

current operation are simple and do not require any changes to the printed circuit boards. Two examples of additional keying relays are shown in Figs. 4 and 5. In the former, a mechanically biased reed or similar relay is used and the coil should be energized to make the mark contact and de-energized to make the space. The relay current should be set to the recommended value by R_1. In Fig. 5, a Carpenter or similar type of polarized relay is used with the two coils connected as shown so that the current flowing through L_2/R_2 provides electrical bias towards the space contact. Resistor R_1 is selected to give twice as much current through L_1 as is flowing through L_2 when the keying transistor Tr_1 is conducting, thus allowing the mark contact to be made. The mark and space contacts on either of these relays would drive a double current printer magnet in the conventional way.

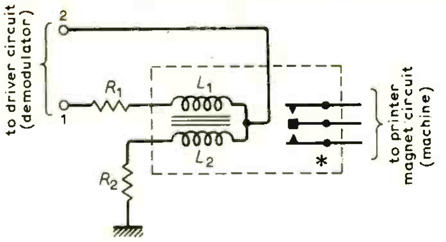


Fig. 5. Typical electrically biased keying relay (Carpenter type 3SE1, 250Ω coils or similar).

There are two separate power supplies, one being a differential supply giving +12V and −12V regulated as well as positive and negative unregulated. The second is the loop supply for driving the printer and gives 180V as well as shift voltage for transmitter keying if required. The regulated supplies use transistor stabilization in conjunction with zener diodes.

So far, only the signal circuits have been described but as mentioned earlier there are a number of other features built into the design, the first being the 'anti-space' circuit.

For a 60 w.p.m. RTTY signal, the character which contains the most space units is the one that is controlled by the *blank* key, and does not exceed 132 milliseconds. It follows that any space signal longer than this will not be an RTTY signal and may well be an unwanted one which, without steps being taken to suppress it, would put the keyer to space and let the machine run loose. The anti-space device continually monitors the space signal and when this exceeds the 132ms by a significant amount, it overrides the incoming signal and places a mark voltage on the keyer stage until the condition ceases. At the same time it places the autostart circuit to the no-signal state. The first mark signal that arrives when the printer is thus held discharges the anti-space circuit instantly and copy is resumed. All this is achieved by transistor Tr_7 tied to the output of IC_6 and followed by IC_9. The output of IC_9 runs from −10.8V on mark to +10.8V on space. The space voltage is then fed to the base of Tr_1 putting it into mark-hold after the time predetermined by the circuit constants R_{109}, R_{110} and C_{81}. This feature is very necessary when unattended operation is used as it effectively prevents the printer running wild and producing sheets of useless spoiled copy due to the presence of an unwanted signal on the space channel.

It is now appropriate to turn attention to the associated autostart circuit included in this design. Basically, its purpose is to discriminate between a genuine RTTY signal from which copy can be taken and other signals, be they morse code or voice transmissions. Advantage is taken of the fact that a morse signal probably consists of no more than 50% key-down time; voice has an even lower duty cycle whilst RTTY, in the form of a frequency shift signal, represents 100% duty cycle when both mark and space signals are considered. The autostart circuit therefore is designed so that a high duty cycle will actuate it while a lower one will not. It samples both mark and space signals simultaneously, combining them into one control voltage which, in turn, charges a capacitor and, after a predetermined time, trips a relay. This relay turns on the printer motor, at the same time removes the mark-hold bias and allows printing to take place. The delay time is largely determined by C_{70}/C_{71} and can be selected to give a turn-on delay to suit the user. Should the signal stop, a network quickly discharges this capacitor and restarts the count-down in the relay control circuit. If it does not reappear then the motor is allowed to shut-off and the system is ready for the start-up cycle again. The finite delay for turn-on is essential if transient signals are not to cause the printer to start for the wrong reasons. When operating into an autostart net, the sending operator starts his transmission with a 3–4 second mark signal or a few preliminary letters to ensure that the delay is overcome and the receiving machine readied for use. The turn-off delay is kept just long enough to prevent accidental operation in the event of a sudden fade of signal and in practice will allow two or three characters to be printed at random after the signal disappears.

The circuit uses two diodes D_5 and D_6 which sample the mark and space channels and combine output voltages; the product is applied to the input of IC_7. If the signal is properly tuned, the two voltages should be similar and the combined positive voltages exercise steady control of the amplifier. Resistors R_{78} and R_{79} reduce the control voltage for the op-amps, which will not accept more than about 5 volts. At the onset of a signal therefore the following sequence takes place to put the printer in operation. A voltage of about +7.5V appears at $TP2$ which in turn produces about +3.8V at the inverting input of IC_7. There is a fixed bias on the non-inverting input, preset by R_{81}, which determines the trigger point of the amplifier. This bias is overcome by the positive sample voltage and causes the amplifier output to go negative. Diode D_{13} will not conduct so that the positive voltage which previously existed on C_{70}/C_{71} disappears and this capacitor discharges via R_{86} and R_{87}. When it reaches about 2.2V, the fixed bias on IC_8 takes charge, causing the output to change from positive to negative. At this point the holding bias on the keyer stage via D_{15} disappears and the printer becomes active while C_{76} charges fast, via R_{93}. This puts Tr_3, Tr_4 and Tr_5 in the conduct state and this operates the motor relay, the coil of which is in the collector of Tr_5. The function of Tr_6 is really nothing to do with this sequence save that, as Tr_5 starts to conduct, Tr_6 is shut-off and as Tr_5 passes about 50mA, the load on the power supply is kept virtually constant.

A remote stand-by connection is provided which overrides the autostart feature, keeping the motor running but placing the unit in the stand-by condition so that under manual control the unit can be made to print without delay of any kind.

Two further facilities are included which, though optional, are well worth building-in as they are independent of the printed circuit boards and take little room. The first is a tuning meter which can be seen on the front panel in the photograph and which is also used as a check on the current in the printer loop. It simply indicates the combined mark and space voltage generated at TP2, using an MPS-3394 transistor to drive a 0–1mA meter movement. If the tuning is not exactly centred on the two channel filters then the mark and space voltages will be unequal and as the meter reads the sum of the two, the indication will be less than would be the case when both channels are generating full signal volts. Thus the indication for correct tuning is simply to maximize the meter reading. Switch S_9 transfers the meter to shunt a resistor in the d.c. printer loop of the keyer transistor, to measure the current in the loop. The second is the inclusion of two indicator lamps LP_1 and LP_2 which show the state of readiness of the unit. Controlled by the autostart circuit, LP_2 shows the stand-by condition in the absence of signal whilst LP_1 indicates when it is ready for receiving. Both lamps are illuminated when the unit is put into the stand-by state either by the remote stand-by or local stand-by (S_3) switches. This is a useful indication showing when the equipment is under the control of the signal as distinct from the operator. Low-consumption lamps are used as they each have to be driven by a transistor. Those which will operate with currents of about 30mA at 12–18V were chosen. They are fed from the unregulated supply. One of the newer gallium phosphide light-emitting diodes would also fit this application and would dispense with the MPS-6518 and MPS-3395 driver transistors. These diodes operate on about 2V at 10mA.

Construction and alignment

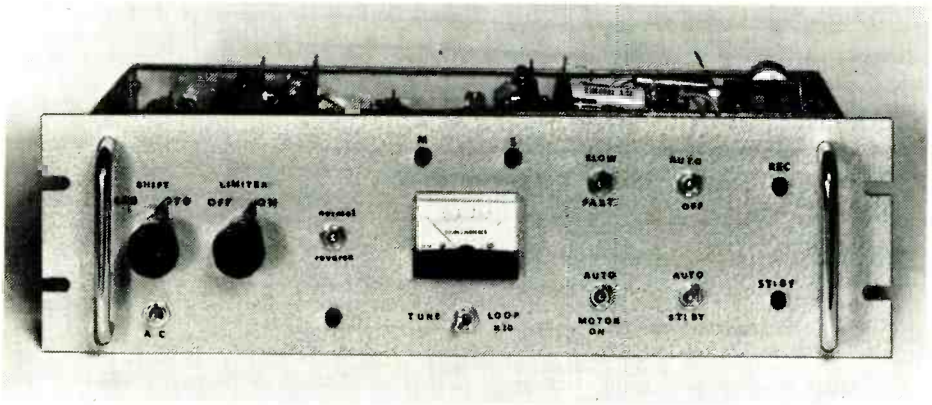
Construction of the demodulator presents no major problems provided that care is taken to position the circuit boards carefully in relation to the front panel controls.

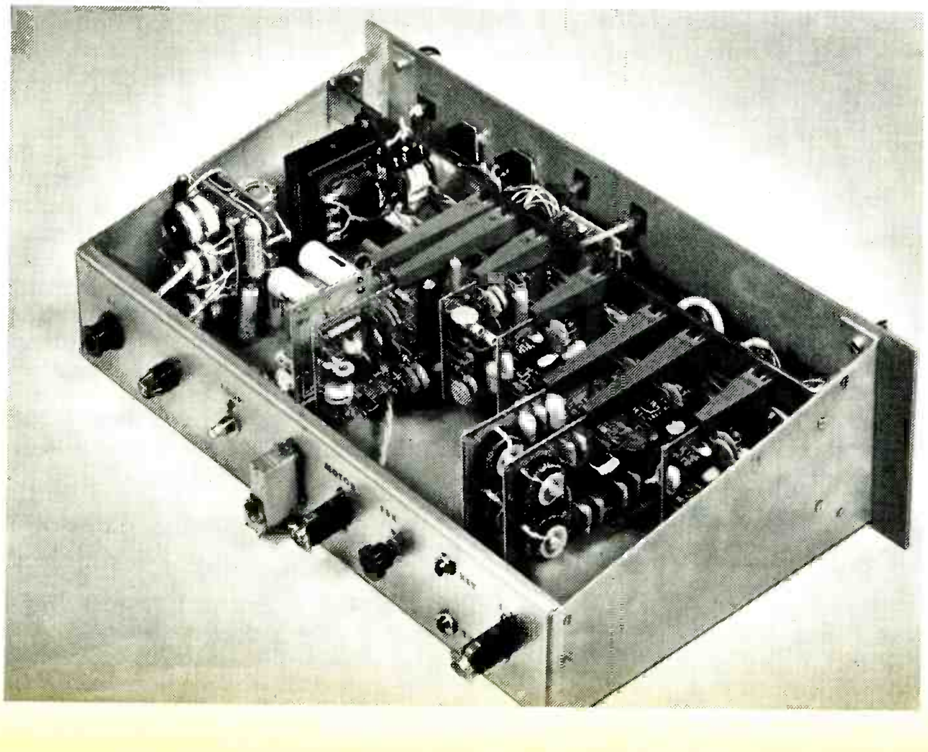
The photograph shows the front panel layout used in the author's version. The shift and limiter rotary switches S_8 and S_1 are the most critical in their placing. They should be kept as close as possible to the channel filter boards and the bandpass filters when these are used. The two low-consumption lamps already mentioned are at the right, LP_1 above LP_2, while the mark and space neons are central above the tuning meter. A word about the group of four switches to the right of the meter may be appropriate at this stage. The top left-hand one S_4, when put in the *slow* position and all other switches set to *auto*, puts the unit in readiness for unattended autostart. As described, this leaves the motor off but brings it on after a few seconds delay as soon as an RTTY signal is passed by the filters. The lower left switch, S_6, overrides the motor relay but leaves all other autostart characteristics as for unattended operation. The auto/off switch, S_5, disables the autostart circuit and also overrides the motor relay so as to keep the motor running. This applies in both slow and fast positions of S_4. Finally, the stand-by switch, S_3, at bottom right, puts the unit into the mark-hold condition while also disabling the autostart facility. The remote stand-by control parallels this switch.

The front panel measures $19 \times 5\frac{1}{4}$in although if space were at a premium both these dimensions could be reduced. The view of the rear of the instrument gives a fairly clear idea of the general arrangement of the printed boards. From right to left these are:

2/850	850Hz channel filters.
1/850	850Hz bandpass input filter.
1/170	170Hz bandpass input filter.
2/170	170Hz channel filters.
3	Low-pass filter, slicer and keyer stage.
4	Autostart and antispace circuitry.
5	Power supplies.

The reason for the above nomenclature is because no attempt is made to switch parts of an active channel filter or a bandpass filter from 170 to 850Hz. Instead, entirely separate filters are used and mounted on separate boards which are themselves switched as a completely assembly. Thus on 170Hz shift, for example, the boards in use will be 1/170, 2/170, 3, 4, and 5. Only the first two are changed for operation on the wider shift. These boards are carried on edge connectors and are slid into guides which, though optional, provide enough support to obviate the use of any other staying method. The connectors themselves are insufficient. At the left will be seen the mains transformer which is mounted across the two brass rails which also carry the edge connectors and run the length of the unit. To the right of the transformer is the motor control relay. At the extreme left and rear can be seen the assembly containing the mercury wetted keying relay used by the author and its contact suppression components which are essential if the relay life is to be prolonged.





The rear panel carries, from left to right: mains input, main supply fuse, loop series resistance R_{115} (for adjusting the loop current), multi-way outlet socket for double loop keying circuits plus connections to an external shift monitor and the remote stand-by control. Next to the right is the connection to the motor relay, the shift control (when the units shift voltage is being used to key a transmitter), two jack sockets for the transmitter f.s.k. line and one for a morse key. The latter gives the facility for identification by shifting the carrier by an amount so that the keyer stage is not driven from mark to space. The right-hand socket carries the input signal from the receiver.

If the layout illustrated is followed it should not be essential to use screened cable but the author, taking no chances, used some between the channel switch, the limiter on/off switch and the boards. If this is done, longer leads can be used which enables the whole board assembly to be swung-up clear of the chassis by the simple expedient of releasing all the rail fastening screws with the exception of the top one on each side. This is very useful when testing, as with the boards up and forward of the vertical, access is acquired to the interconnection wiring. One other small board which carries the drive transistors for the receive/stand-by lights and the tuning meter, is conveniently mounted on the rear of the meter itself.

The mechanical construction should not present any problems but it should be remembered that the op-amps used have considerable gain and attention to earthing between boards and boards to chassis will avoid a number of troubles. Apart from the points mentioned above, no additional screening is required.

Undoubtedly the most difficult part of the construction programme is the making and tuning correctly of the bandpass and channel filters and a detailed description of this may prove helpful.

All the inductances used are standard toroids commonly used in telephone practice and are wound on the core with two equal and separate windings. This gives the facility of obtaining 88mH when series connected or 22mH when in parallel. Both connections are used in this design. Care must be taken to ensure that connections are made in the correct direction of winding. The start of each winding is easily found as it has a short length of sleeving which the ending does not. For 88mH the start of one winding must be connected to the finish of the other. For 22mH both starts and finishes are paralleled. Mounting the toroids presents no difficulty. A good method is to sandwich them between two plastic cheek pieces and put a brass screw down the middle and through the board. If one of the proprietary printed boards is used, the positioning will be self evident but if not, they can be laid out much in line with the circuit diagram. A good ground rail is important as all the inductances and all but two of the capacitors are joined to it. Mylar capacitors should be used for both the bandpass and channel filters; ceramic, electrolytic and paper types should be avoided.

The input filters are the least critical and are relatively easy to tune by the following method. A good audio oscillator and a valve voltmeter or oscilloscope are needed; the latter is probably the easiest to use for the purpose. The test arrangement is shown in Fig. 6 and the isolating resistor, which may be of the order of 100kΩ, ensures that the low impedance audio source exerts little influence upon the tuned circuit under test. If the accuracy of the audio source is at all suspect then a counter should be employed because tolerances of the order of 6Hz for the 850Hz filter and 3Hz for the 170Hz filter are important.

Reference to Table 1 will show the frequencies to which each of the three sections of the input filters is to be tuned. To tune L_1 for example, the source is placed across it while L_2 and L_3 are shorted. It will probably be found that resonance occurs at a somewhat higher frequency than 2400Hz in the first place and additional capacitance (C_3) is added until this frequency is achieved. Inductor L_2 is treated in a similar manner with L_1 and L_3 shorted, tuned to 2300Hz and so on. If by chance the frequency is low, the value of the parallel capacitors can be reduced or turns may be removed from the inductors. When doing this be careful to remove turns equally from each half. A tolerance of 15/20Hz is acceptable for these filters.

Table 1

TO TUNE	SHORT-CIRCUIT	ADJUST	f_0
L_1	L_2, L_3	C_3	2,400Hz
L_2	L_1, L_3	C_{10}, C_{12}	2,300Hz
L_3	L_1, L_2	C_8	2,400Hz
L_4	L_5, L_6	C_{15}	2,195Hz
L_5	L_4, L_6	C_{21}, C_{23}	2,195Hz
L_6	L_4, L_5	C_{19}	2,195Hz

The discriminator filters however must be held to a tighter tolerance; 6Hz for the 850Hz and 3Hz for the 170Hz filter. Time taken with this operation will be well repaid by improved performance and a good deal of trial and error may be required before each filter peaks at the proper frequency. Series connection of the inductances is used in both filters. For 850Hz operation the mark frequency is 2125Hz and space 2975Hz. For 170Hz these are 2125Hz and 2295Hz respectively.

If p.c. boards are used, it is best to mount all components first and carry out a rough alignment with the board on the bench. Use the arrangement shown for the test gear and peak each filter to the frequencies given above for mark and space on each assembly. Experience shows that, when inserted in the connectors the final frequency may prove to be low and the last operation is to carry out a trimming procedure when the whole demodulator is running. As a rough guide it will be found that each turn removed from a toroid will raise the resonant frequency in these filters by about 3Hz and as the Q is high, the resonant point is very sharp and adjustments can be made to one or two hertz in practice. In this first phase, the filters may be left a few hertz on the high side since this will turn out to be lower when finally assembled.

Remember that most capacitors have a value tolerance of 10 or 20% and when substituting different values it pays to try several of the same marked value as the tolerance between one and another may be sufficient to provide the needed value.

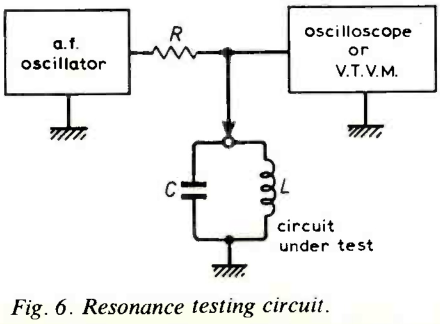


Fig. 6. Resonance testing circuit.

Once the filter tuning has been completed, there remain a few simple checks on the power supplies before the final alignment of the demodulator is carried out. Check both +12V and −12V regulated and unregulated supplies. This is best attempted by checking all the interconnections between the seven edge connectors, if used, with none of the boards plugged in. Make sure that common earth connection is a good one and is in turn well grounded to chassis since unless this is done properly, some instability in the very high gain op-amps may be experienced. Next insert No. 5 board, which has the power supplies, while leaving the rest for the time being. Apply power and make the voltage checks. If a complete kit of components including the boards is obtained from the sources listed at the end, a manual is also provided which sets out a complete table of these measurements and which is useful in ensuring that the interconnections give correct voltages on the right pins.

With the above completed satisfactorily, plug in the remaining boards and apply power, at which stage the input limiters may be aligned. A valve voltmeter is best used for this and the author employed a Heath IM-16 which is ideal for the purpose and can be used for the rest of the alignment checks as well. Short-circuit the input to the unit and, with the shift switch S_8 to 170 and the voltmeter connected to TP1, adjust the trimming potentiometer R_{18} to give zero volts. Not all 72709 amplifiers will do so and it may help to swop it with one of the others if this cannot be done. The adjustment is not exact and the zero may drift slightly but the best position should be chosen. Switch to 850 and do the same adjustment using R_{12}. The two discriminators can now be adjusted. For this the audio generator used in setting the filters is required. As described earlier the filters being active must be adjusted finally when in the circuit and it is at this point that the final trimming is done. With the generator connected to the input, feed in first mark and then space frequencies and adjust each toroid by the method described so that the tuning meter peaks at the correct point. There is really no short-cut to this method which necessitates the removal of the board for each adjustment, but when complete it is never touched again.

When this has been done, feed in mark frequency (2125Hz) and adjust the potentiometer R_{29} to give a reading in the region of 0.7mA. Then feed in the space frequency (2975Hz) and adjust the potentiometer R_{35} on the discriminator board to give the same reading. Note that these adjustments are done on the 850Hz filter board. On the 170Hz filter board, note the meter reading for mark (2125Hz) and adjust the potentiometer R_{38} on the discriminator board to give the same value on space (2295Hz). Do not alter the potentiometer on the meter board. The readings may not be as high on the 170Hz shift but the method is the same.

The final adjustment is the sensitivity of the autostart circuit. Connect the valve voltmeter to TP4 and, with the autostart switches in the *auto* position, feed 2125Hz to the input with the shift switch in the position most likely to be used. In the author's case this is unquestionably the 170 position. Detune the oscillator to give 80% of the meter reading shown at peak and adjust the trimming pot R_{81} until the voltage at TP4 flickers around zero. A degree of personal preference may be used here because adjustment close to peak frequency means that the autostart will only operate at exact shifts whereas the other direction will cause the circuit to respond to noise and other unwanted signals. Resetting after some experience is recommended.

The whole unit may now be tested. An oscilloscope connected to TP1 on the two input filter boards will show the response as the generator is tuned over the passband. Check the limiter which should show almost constant amplitude with frequency as limiting occurs at very low levels indeed.

The anti-space circuit may be checked by feeding in 2125Hz so that the mark lamp is on. If the reverse switch S_2 is operated, the space lamp should light for a second and then return to mark. This shows that the anti-space is working as otherwise the unit would remain in the space mode when the switch is moved. The motor control relay is tested by applying mark frequency which should cause the motor relay to close after about a second's delay. Next switch off the signal, the unit should place itself on mark condition and, after a time determined by the time constant in the circuit, the relay should drop out (20 to 40 seconds).

All the bench checks are now complete and it remains only to connect the printer and a suitable receiver to take printed copy.

A few hints may be helpful to the newcomer. The remote stand-by switch, if used, will cause both receive and stand-by lamps to light, which acts as a warning that the unit is at stand-by and cannot be put into operation except manually. When under auto control, the lights change from stand-by to receive under the control of the incoming signal. With the auto control off, the unit responds to all signals and the anti-space circuit is also disabled.

The best place to mount the lamp/meter board, which is quite small, is near the meter. In the case illustrated, it is fixed to the rear lugs of the meter itself. It may be found that the brightness of the two lamps LP_1/LP_2 is not quite equal but should be accepted.

It is well worth while giving each board a very careful visual check after the parts have been soldered and before testing. Some of the conductors are very closely spaced and it is easy to get spots of solder not easily seen by the naked eye but sufficient to cause short circuits. A watchmaker's glass with an old veterinary hypodermic needle are all that is needed to clear faults which can be detected if a light is shone behind the board.

In use, the demodulator has proved to be capable of printing signals that were barely readable by ear. It can cope with greatly differing signal levels and discriminate against unwanted signals to a very marked degree. The autostart facility has proved itself consistently and with the tuning meter and the rec/stand-by lamps, is well worth including if time and money allow.

Grateful acknowledgement is made to Irvin M. Hoff, W6FFC, of Los Altos Hills, California, who has been responsible for a number of the best designs of demodulator unit for RTTY and whose ST-6 formed the basis of the described work.

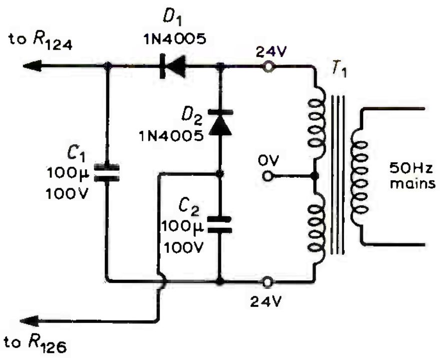


Fig. 7. Alternative high voltage supply circuit.

Kits of parts and p.c. bs: HAL Devices, P.O. Box 365, Urbana, Illinois 61801, U.S.A., or Spacemark Ltd, Thornfield House, Delamer Road, Altrincham, Cheshire, can supply kits or boards and toroids separately. The power supply transformer T_1 is not readily available in the U.K. Therefore, a modification has been made to replace T_1 with two miniature transformers both having secondary windings of 24V–0–24V. This does not affect the low-voltage supply but circuit changes for the high-voltage supply are shown in Fig. 7.

Components list

Resistors

10Ω 2W	R118,119,124,129
47Ω	R22,23,24,25,48,49,50,51,63, 65,66,81,82,90,91,104,105
100Ω	R20,21
150Ω ½W	R113,114
220Ω	R69
330Ω	R109
470Ω	R74
470Ω 1W	R116,117
500Ω 5W w.w.	R101
500Ω 5W w.w. pot.	R115
620Ω	R2,7
820Ω	R130
1kΩ	R5,10,77
1.5kΩ	R26,27,53,55,64,67,83,92,103
2.2kΩ	R8,73,89,93
2.5kΩ 2.5W w.w. pot.	R125
2.7kΩ	R86,107
3.3kΩ	R3
3.6kΩ	R85
3.9kΩ	R99
4.7kΩ	R34,97,98,100
5kΩ skeleton pot. (linear)	R12,18,35,38,132
5kΩ 5W w.w.	R126
5.1kΩ	R87
5.6kΩ	R29
6.8kΩ	R36,37,39
8.2kΩ 1W	R120
10kΩ	R11,13,17,19,76,88,95,96, 106,111,112
10kΩ linear pot.	R28
11kΩ	R80,133
12kΩ 1W	R121
15kΩ 2W	R122,123
16kΩ	R56,57
22kΩ	R70,71
27kΩ	R1
33kΩ	R40,58,72,84,102,110
47kΩ	R4,6,9,15,16
56kΩ	R108
68kΩ	R78,79
100kΩ	R41,42,43,44,45,46,47,75,128
150kΩ	R14,131
180kΩ	R52,127
220kΩ	R59,60,61,62
270kΩ	R54
1MΩ	R30,31,32,33,94

All fixed resistors are ¼W, unless stated otherwise.

Capacitors

3pF	C30,31
47pF	C28,29
220pF	C51,52,60,62,69,75,80
270pF	C32
0.0047µF	C49,50,59,61,68,74,79
0.01µF	C87
0.047µF	C41,42
0.1µF	C24,25,26,27,45,46,47,48,53, 54,55,56,65,66,67,72,73,77,78
0.22µF	C58
0.68µF	C57
10µF, 15V	C63,64,81
20µF, 15V	C76
100µF, 15V	C83,85,86
100µF, 250V	C88
150µF, 15V	C71
350µF, 9V	C70
1000µF, 25V	C82,84

All above capacitors are ±20% tolerance.

0.0047µF	C10,12
0.01µF	C9,11
0.022µF	C4,5,20,22,44
0.033µF	C1,2,6,7,35,43
0.056µF	C39
0.068µF	C33,37
0.10µF	C13,14,17,18
see text	C3,8,15,19,21,23,34,36,38,40

C16 is made up of 0.100+0.068+0.010µF
C39 is made up of 0.033+0.022µF
All above capacitors are ±10% Mylar.

Inductors

88mH toroids	L1,2,3,7,8,9,10 (Series connected windings)
22mH toroids	L4,5,6 (Parallel connected windings)

Mains transformer
T_1 = 125–0–125V secondary, 25–0–25V " } American type
or 24–0–24V secondary, 24–0–24V " } 2 × type MT100 Henry's Radio (ref: Fig. 7)

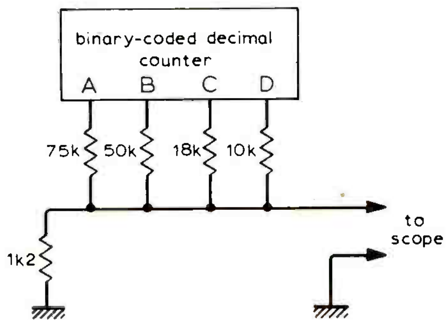
Semiconductors

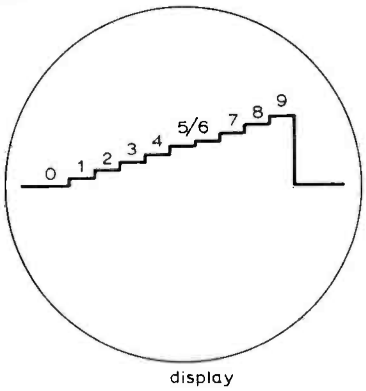
1N914/916 or similar	D1 to D22
1N270	D23 to D35
1N753	D36 to D39
1N4005 or similar (600 p.i.v.)	D40,41
1N4002 or similar (100 p.i.v.)	D42 to D45
2N5655/5656	Tr1,8
2N697	Tr5,6
MPS3703	Tr2,3,4
MPS3394	Tr7,10
MPS6518	Tr11
MPS3395	Tr12
MJE370	Tr9
SN72709	IC1 to IC9

Circuit Ideas

Digital counter display

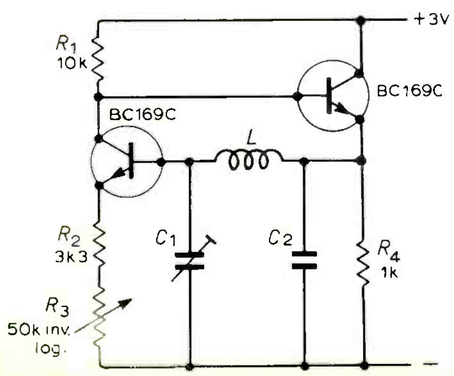
When working on circuits involving digital counter chains, lack of a multi-beam oscilloscope makes determination of counter behaviour difficult, especially with closed-loop systems. The resistor matrix shown, when connected to the b.c.d. outputs of a counter, and the 0.1V/cm input of an oscilloscope, provides an easily-read step-function of about 0.5V pk-pk. The nth step of the function then represents the counter output n. It has proved easy to read off counter outputs and as the step from 5 to 6 is set to about half the height of the other steps and easily recognized, poor sync on simple oscilloscopes can be coped with.
John A. Stephenson,
Spalding.





Good-tempered LC oscillator

Transistor oscillator circuits are prone to the vices of squegging, operating at the wrong frequency, or just failing to oscillate if used in conjunction with "unsuitable" inductors or capacitors in the tuned circuit. The arrangement illustrated was derived from the Colpitts circuit to provide a simple way of checking the inductance of a collection of iron-cored inductors, but it can be used as a general-purpose oscillator circuit up to about 10MHz. Feedback is negative at all frequencies at which the LC network does not provide phase inversion and voltage step-up, and the only time-constant is the inevitable one introduced by the tuning components and associated resistances. Capacitances C_1 and C_2 are effectively in series, and it is possible to make C_2 much greater than C_1 and so avoid curtailment of the tuning range. If waveform is unimportant R_2 and the regeneration control R_3 may be replaced by one 10kΩ fixed resistance.
G. W. Short,
South Croydon,
Surrey.



Noise-immune monostable circuit

A common-emitter monostable circuit may be falsely triggered by a transient reduction of power supply voltage. While it is possible to attenuate this transient, its elimination may prove difficult due either to capacitor and conductor inductances, transient energy content, or both. It is better to design for immunity from a given amplitude of power supply "noise" voltage. This is possible without the use of additional components but at the cost of a reduced maximum "shot" time duty cycle.

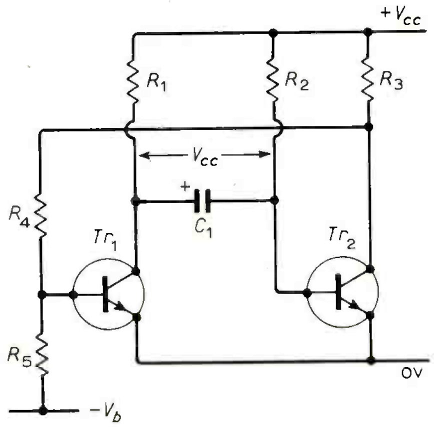
The first diagram shows a basic monostable in the quiescent state with Tr_1 off and Tr_2 on. For the initial argument it is assumed that, for Tr_2, both V_{be} and the required I_b are zero and that during a quiescent period capacitor C_1 charges to V_{cc}. The effect of power supply noise is to turn off the conducting transistor. If Tr_2 cannot be turned off, Tr_1 will not be turned on. Hence eliminating the non-participating components and transposing C_1 and R_1 the second diagram may be drawn. Resistors R_1 and R_2 form a potential divider to Tr_2 base and the emitter-base junction of Tr_2 cannot be reverse biased (and hence the ideal transistor turned off) if:

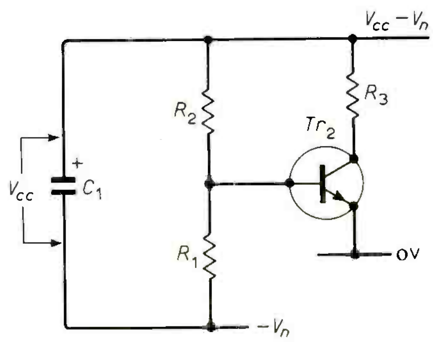
$$\frac{R_1}{R_2} \geqslant \frac{V_n}{V_{cc}-V_n} \quad \text{or} \quad \frac{R_1}{R_1+R_2} \geqslant \frac{V_n}{V_{cc}}$$

where V_n is the voltage by which V_{cc} is transiently reduced.

If immunity from a 25% reduction of V_{cc} is required, R_1 must be greater than or equal to $R_2/3$. As the shot time approximately equals $0.7C_1R_2$ and the recovery time (to 0.98 V_{cc} on C_1) is $4C_1R_1$, the maximum shot time for the chosen noise immunity may not exceed 0.34 of any period.

Although the noise immunity predicted by the above equation may be closely approached in practice particularly with a high gain Tr_2 a worst-case design should consider both the required base current and base-emitter voltage of that transistor. This





will cause a further deterioration in permitted duty cycle. If it is taken that for maximum power supply noise Tr_2 shall remain in saturation, for immunity,

$$\frac{R_1}{R_1+\dfrac{N_1}{N_1-1}\cdot R_2} \text{ must be } \geqslant \frac{V_n}{V_{cc}-V_{be}}$$

where $N_1 = (h_{FE} \min I_b)/I_c$ for Tr_2 at the trough of the noise input and V_{be} is the maximum base-emitter or base to 0-V voltage for Tr_2 in the on state.

As a further example, say V_{cc} is 5V, V_n is 1.25V (i.e. 25%), V_{be} is 0.5V and N_1 is 2. Substituting in the second equation, noise immunity is provided when R_1 is greater than or equal to $0.77R_2$. Using the equations for shot time and recovery time previously stated, the maximum shot time may not now exceed 22.5% of any period.
A. Bishop,
London NW8.

Circards — 5
Audio Circuits

Pre-amps, mixers, filters and tone controls

*by J. Carruthers, J. H. Evans, J. Kinsler and P. Williams**

Cinemascope or the Magic Lantern? The breadth of choice available to the user of equipment reproducing audio signals is just as great. We are here seeking the happy medium and sidestepping such difficulties as to whether the medium should be disc or tape — or for Menuhin fans, the message.

The starting point is the assumption that the signals though complex can be represented as a mixture of sinusoidal waves of different amplitudes with frequencies lying between certain limits, say 20Hz to 20kHz. Generally the aim of good audio equipment is to produce at the ear of the listener a pattern of sound most closely resembling that which he would have heard as a direct listener to the original sound source. The system has to take account of the characteristics of the transducers at both ends of the chain as well as any intervening media used for storing or transmitting this signal.

If the input transducer had a linear amplitude response and gave the same output voltage for a given sound intensity regardless of frequency, then the following amplifiers could themselves have a linear response. The design of such amplifiers, with the aid of modern technology in the form of operational amplifiers is by now routine. There are three distinct departures from this idealized existence.

- The output voltage for constant signal strength may be frequency dependent in some controlled manner e.g.: tape-head e.m.f. proportional to frequency for constant amplitude recorded signal.
- The signal may have been recorded and/or processed by some preceding stage with some characteristic defined according to some standard (R.I.A.A., B.S., C.C.I.R. etc).
- Imperfections in some other part of the system may have resulted in anomalies in the desired response e.g.: resonance effects in transducers.

Any one of these would call for correcting action in the amplifying chain, though in some cases as in the design of loudspeakers, resonance effects in the speaker itself can be dealt with by careful design of the enclosure. As each transducer is a very complicated mechanism involving the interaction of several electrical and mechanical properties it is common to operate them with amplifiers whose impedance characteristics are closely controlled, thus eliminating one possible source of variation in performance. This article considers only the input transducers, such as microphones, tape-heads, and assumes that any succeeding power amplifier/loudspeaker combination can have its imperfections accounted for by tone controls.

The matching problem at the input reduces the design of amplifiers whose input impedance is either equal to, much less than, or much greater than that of the source. Equal source and input impedances are used in line amplifiers where, for example, input, output and attenuator resistances might be 600Ω. This allows for easy calculation of power levels at all points in a system, and for the interconnection of multiple elements in a system. On the other hand, even within such a system the power output amplifier might be designed to have an output resistance $<<$ 600 ohms so that several such loads might be paralleled without diminishing the power fed to each.

A second important feature of the matched impedance condition is that it maximizes power transfer from a source of given e.m.f., and internal resistance. In most modern circuits using heavy negative feedback, the natural impedances tend to be either very high or very low and there is then no advantage from a power transfer standpoint of artificially modifying their terminal impedances to some arbitrary value. To do so simply throws away power in the passive network added for this purpose.

In the case of very small signals where noise is a severe problem, matching of impedances plays an important part. A moving-coil microphone having a low internal impedance (e.g. 200Ω) generates a low e.m.f. of, say, 100μV r.m.s. Fed directly to a semiconductor amplifier, the input noise voltage would be relatively large, while it would be possible to have a high input impedance using series negative feedback. A step-up transformer of large turns-ratio would greatly increase the signal e.m.f. at the amplifier input and would dominate the noise voltage. However the effective source impedance seen by the amplifier would also be raised by the transformer action and with it the contribution to noise due to the amplifier's input noise current. The optimum condition is when the contributions due to noise voltage and current generation are comparable. Other parameters such as amplitude response are also affected but the condition chosen is often close to the matched condition.

For microphones, the mechanical properties are normally designed so that they are self-equalized, i.e. that they give an output e.m.f. that depends only on the sound intensity and not on frequency. The most common microphones are magnetic in some form, variants including moving-coil, moving-iron and ribbon microphones. Reduction of the moving mass to extend response tends to reduce both sensitivity and impedance with the problems described above. Crystal microphones are used for low-cost applications such as simple cassette recorders and require a high input impedance pre-amplifier to avoid attenuation at low frequencies where the capacitive reactance of the microphone increases. The pre-amplifier design is similar to that for crystal/ceramic pickups, i.e. a flat response and generally an impedance in excess of 1MΩ, possibly up to 10MΩ or more for low capacitance units with extended low-frequency amplitude response. Alternatively, the feedback may contain a capacitance whose change in reactance compensates for that of the transducer.

These ceramic elements could in principle be designed to give a frequency-independent output when used for record reproduction, but another factor enters the argument. During recording, signals are first passed through frequency-dependent amplifiers. These have strictly controlled characteristics, usually referred to as R.I.A.A. and further defined in BS1928. If all signals were recorded with a so-called constant-velocity characteristic it would be found in practice that the amplitude at low frequencies would result in breakthrough between neighbouring sections of the groove. This is because constant velocity fixes the velocity at the zero-crossing point of the signal.

At low frequencies the longer period would allow proportionately larger excursions. Hence low-frequency signals are recorded with amplitude proportional to signal e.m.f. (whereas a velocity-proportional recording would otherwise have merits since a magnetic playback element would re-convert that velocity

How to obtain Circards

Order Circards by sending remittance (£1 per set, postage included) to "Circards", *Wireless World*, Dorset House, Stamford Street, London SE1 9LU, indicating which sets you are buying. Availability of new Circards is indicated by articles in the journal introducing the selected topic. The first four topics were

1. Basic active filters
2. Comparators, Schmitts and level-sensing circuits
3. Waveform generators
4. A.C. measurement

The Circard concept was outlined in the October 1972 issue, pp. 469/70.

*All at Paisley College of Technology

back into e.m.f. proportionately). This constant amplitude characteristic merges into a constant-velocity region at around 1kHz, but at still higher frequencies the recording again changes to constant amplitude. The reason is different. The majority of the noise in any system is concentrated in the higher octaves as in most cases noise is proportional to bandwidth. By emphasizing high frequency signals during the recording process and reversing the procedure on playback, the overall amplitude response remains linear, but any noise due to the record surface and playback pre-amplifier is diminished as it is relative to a much larger signal. Noise accompanying the original signal emerges from the system at an unchanged ratio.

This recording characteristic of BS1928 accommodates the larger low-frequency amplitudes common in music, and does not lead to distortion at high frequencies as the signal amplitudes are relatively small. The playback transfer function is

$$T_0 = k\,\frac{(1+j\,\omega\,T_2)}{(1+j\,\omega\,T_1)\,(1+j\,\omega\,T_3)}$$

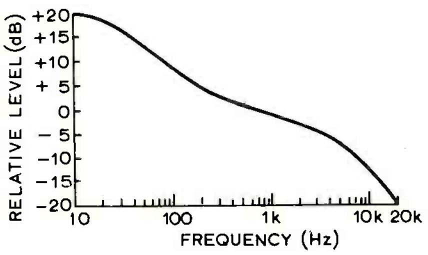
Where $T_1 = 75$, $T_2 = 318$ and $T_3 = 3180\mu s$. To achieve this with a magnetic cartridge, the preamplifier input resistance should be higher than that of the cartridge at all frequencies of interest, or should have a fixed value that can be allowed for in tailoring the cartridge response in terms of its electro-mechanical properties. A typical value is $50k\Omega$. The voltage gain must fall between 50Hz and 500Hz at 6dB/octave, passing through a point of inflection at 1kHz, and falling again at 6dB/octave beyond 2.2kHz. These three time-constants may be defined by three separate *CR* circuits; in some cases two of the time constants are achieved using a single capacitor in a suitable network of resistors.

With ceramic cartridges, equalization is not a result of circuit design but of the transducer itself. The various parameters such as compliance as well as resonances are carefully combined to provide a good approximation to the desired equalization subject to correct loading as outlined above. Where an amplifier has in-built equalization (i.e. for magnetic cartridge) then a separate network may be inserted between the ceramic cartridge and that input to remove the effect of that equalization — a cumbersome process that might be called re-de-equalization.

Tape-recorded signals followed a C.C.I.R. characteristic recently re-defined and extended in BS1568 part 1. There is a low-frequency time constant identical to that in the R.I.A.A. curves, i.e. a time constant of $3180\mu s$, with one further time-constant depending on tape speed, but giving a response that is constant above a particular frequency. These characteristics are quite independent of any imperfections in particular combinations of heads and tapes though intended to optimize their operating conditions. Feedback networks are then similar to those for magnetic cartridge pre-amps equalized as above though requiring only two *CR* time constants in the ideal case. In practice the imperfections of the system may force for example the addition of some treble boost on playback, operating in the 5 to 20kHz region. This is not covered by any standard, but may readily be incorporated by a further decrease in feedback factor in these regions.

Once these preamplifiers have converted the transducer outputs into voltages bearing a nominally linear relationship to the original sound intensity, it might be thought possible simply to amplify the signals further and apply them directly to an output transducer. Such trusting simplicity exposes one to ridicule for ignorance of that recent discovery. Finagle's axiom on reproducing circuitry and equipment — FARCE for short — viz "All signals are equalized but some are more equalized than others". Most audio systems use one or more circuits to modify the amplitude response of the signals passing through them to correct for this effect.

Where unwanted material occurs at the extremes of the spectrum then low-pass or high-pass filters are used for sharp attenuation of these unwanted signals with minimum attenuation of the desired signals. These filters when used in audio equipment are generally called scratch and rumble filters respectively but the basic principles underlying them are the same (see Circards series 1). Second- or third-order filters are used, and as the ultimate judgement of these audio systems is rightly the subjective one of a listening test, the choice of filter characteristic is often empirical.



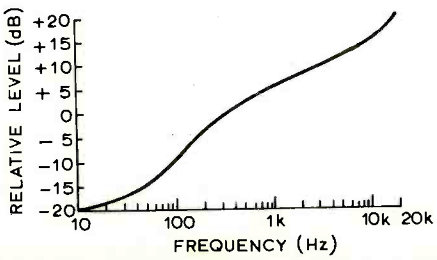


Table 1: proposed classification for loudspeakers.

Frequency range (Hz)	Title
10- 30	grunter
30-100	boomer
100-300	roarer
300- 1k	crooner
1k- 3k	howler
3k- 10k	screamer
10k- 30k	screecher

During such a listening test, the parameters of the room housing the loudspeaker plays a large part, while sound sources including commercial recordings are not above suspicion in respect of the linearity of amplitude response. Even if all such sources reached the impeccable standards which the engineers concerned strive so successfully to meet, there would remain the personal preferences of the user. It takes a brave man to refrain from just-a-touch on the tone controls when demonstrating the superiority of his latest equipment to a fellow enthusiast (competitor?). Of all the tone controls proposed, the most generally accepted is due to P. J. Baxandall, basing itself on a feedback rather than a passive network. This allows for true boost or cut to either low or high frequencies relative to an unchanging centre frequency, generally 1kHz. Two potentiometers are used, adjusting the feedback in the two frequency regions separately around a virtual earth amplifier such that the gain in these regions varies typically from 0.1 up to 10 i.e. 20dB. The higher the quality of the sources and other links in the chain the smaller the range covered by these tone controls need be.

More complex tone controls may be used to sub-divide the frequency spectrum still further; though purists will reject this approach as it smacks of gimmickry, there can be a case for it for various forms of electronic musical instruments and in sound effects. One possibility is the use of parallel channels each consisting of a low-*Q* band-pass filter using sufficient channels that the mixed signal has very little ripple in its overall amplifier response characteristic when all controls are level. It is convenient for producing relatively small amounts of boost and cut at selected regions in the spectrum and may be augmented by active filters with higher *Q* if stronger effects are needed.

The mixer circuits used in such a system, as when mixing inputs from tape, disc, radio, are now frequently based on the see-saw amplifier feeding to the virtual earth through appropriately scaled resistors. If it is desired to obtain significant voltage gain from the mixer as well as having multiple inputs, the bandwidth restrictions are more severe, being in effect determined by the total gain used, i.e. the sum of the gains with respect to various inputs. Phase shift in the operational amplifier at all frequencies above 10Hz is such as to make the virtual earth point have a largely inductive impedance, i.e. one that rises proportional to frequency.

As a final comment on the possibility of multi-band operation of audio systems it can be argued that limiting the number of loudspeaker drive units to two (a woofer and a tweeter) with the occasional addition of a mid-range squawker is too restrictive. Accordingly we suggest a new classification scheme of dividing the spectrum from 10Hz to 30kHz into seven bands each to be handled by a separate loudspeaker, see table. Combined with quadraphonic operation surely an export boom must be the result?

Versatile Triangle Wave Generator

A constructional project which forms a 'building brick' for more complex test systems

*by D. T. Smith**

This article describes a triangle wave generator whose frequency can be controlled in a variety of ways. Its frequency can be made to vary linearly with a potentiometer setting; the period can be made to vary linearly with a resistor and frequency can be varied exponentially over several decades, or swept with an input voltage. It uses cheap non-critical components, and is suitable for use from well below 1Hz to the MHz region. If required the triangle can be shaped to a sinewave, so that the oscillator can be used as a wide range or swept sinewave generator that avoids the problems associated with the direct generation of sinewaves at low frequencies. Also, a square wave output is available if required.

Principle of operation

A block diagram of the oscillator is shown in Fig. 1. The output of a constant current generator is fed through an electronic switch either directly to the capacitor C_1,

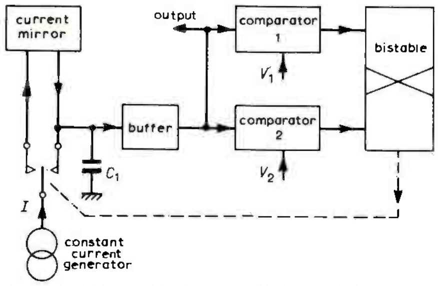


Fig. 1. A block diagram of the oscillator.

or via a "current mirror" circuit to C_1. This current mirror gives an output current equal in size but opposite in direction to its input current. Thus the capacitor voltage sweeps linearly—up or down as controlled by the switch. When the switch is feeding current to the current mirror, the capacitor voltage will sweep in the positive direction until the output exceeds the bias of the upper level comparator. Then the comparator triggers the bistable so that the switch reverses and the capacitor voltage sweeps in a negative direction. This continues until the output falls below the bias of the lower level comparator, when the bistable is triggered back to its original state and the cycle is repeated.

If the buffer has unit gain, and there is a difference, V, between the comparator bias levels, the capacitor voltage must change by 2V per cycle. Hence the frequency of oscillation is

$$f = \frac{1}{2C_1V}$$

Circuit details

Fig. 2 shows the circuit diagram of the oscillator (except for the current generator which is described later). The emitter coupled pair Tr_3, Tr_4 switch the input current, and the switch is controlled by 200mV signals from the bistable. In the current mirror Tr_1, Tr_2, the voltage drop caused by the input current flowing in R_1 and the emitter junction of Tr_1 equals the

*Clarendon Laboratory, Oxford.

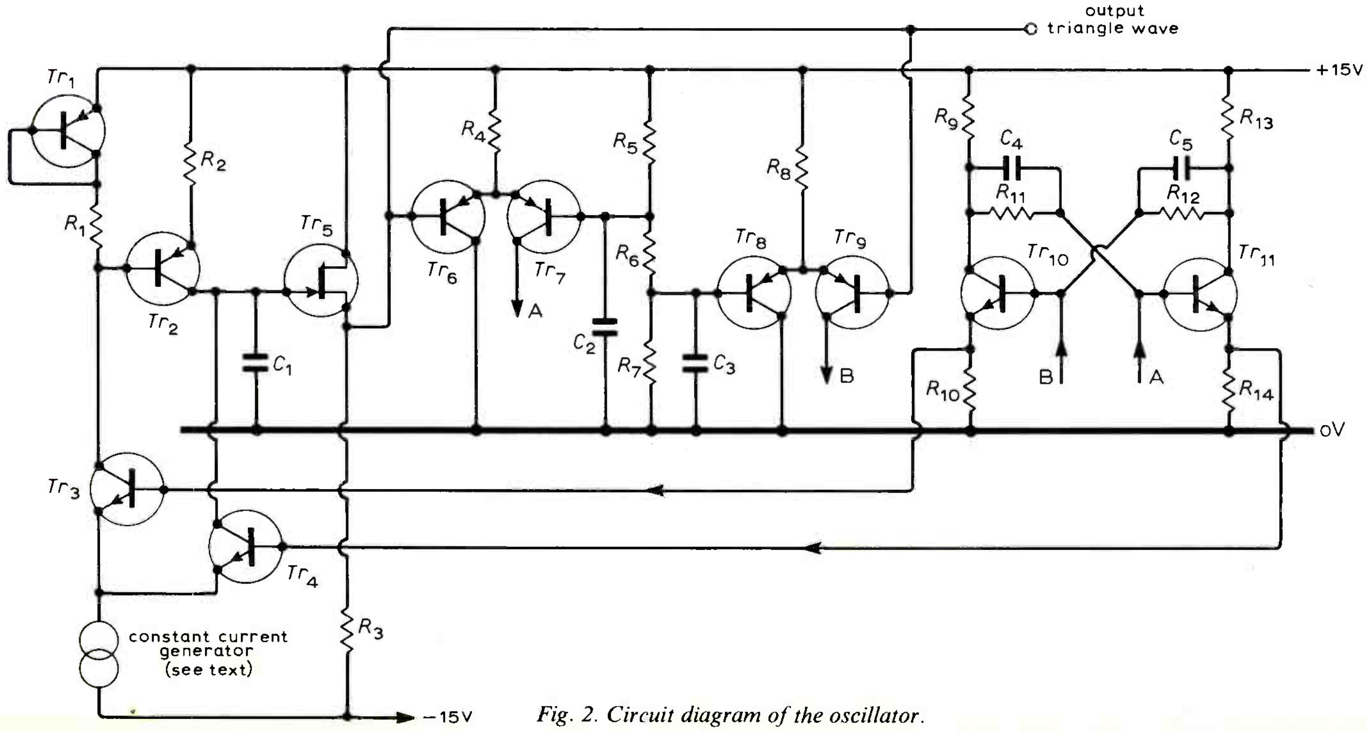


Fig. 2. Circuit diagram of the oscillator.

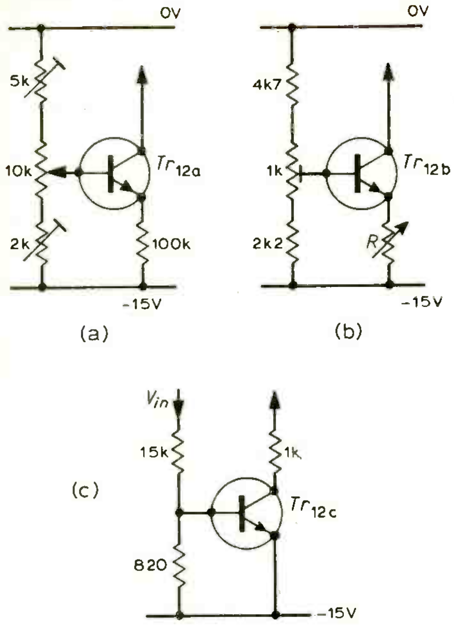
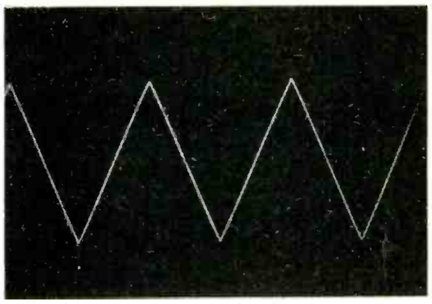


Fig. 3. (a) Current generator for the direct calibration of frequency. (b) Current generator for the direct calibration of period. (c) Current generator for a very wide frequency range.



The output waveform at 1kHz.

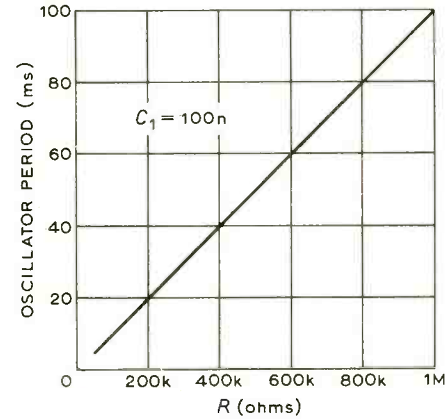


Fig. 5. Oscillator performance with current generator 4(b) demonstrating linear period calibration.

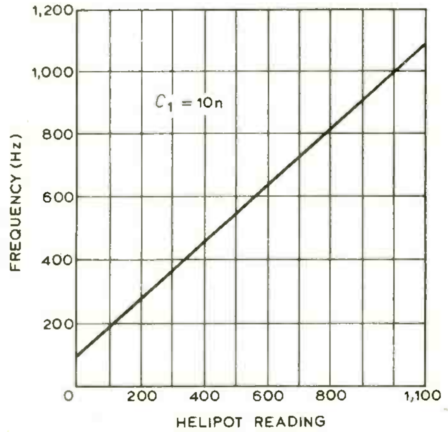


Fig. 4. The oscillator performance using the current generator shown in Fig. 4(a) demonstrating a linear frequency calibration.

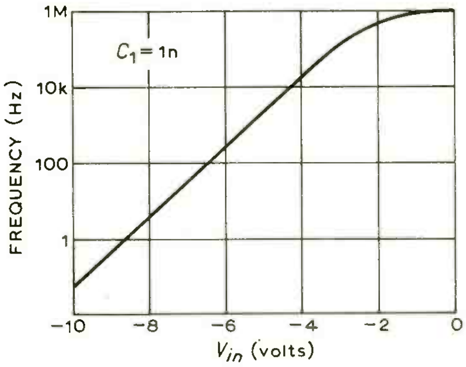


Fig. 6. Performance of the oscillator using the very wide frequency current generator.

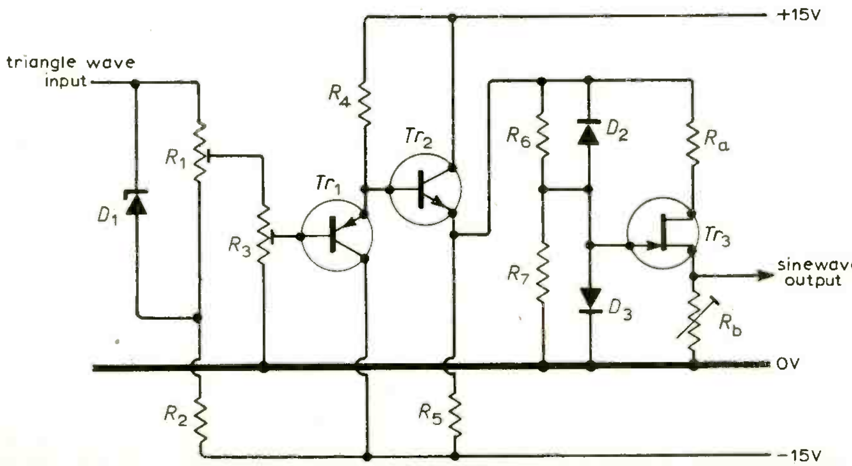


Fig. 7. A sine wave shaping circuit.

drop caused by the output current in R_2 and the emitter junction of Tr_2. Thus, if R_1 and R_2 are equal, and the transistors are similar, the output current will equal the input current, and with the values shown the circuit operates for currents ranging from below 1nA to about 500μA.

The capacitor voltage is buffered by a source follower Tr_5. The output is taken to the comparator Tr_6, Tr_7 and compared with a fixed bias of +10V. When the output exceeds +10V, Tr_7 conducts and triggers the bistable circuit Tr_{10}, Tr_{11}. The output is also fed to a second comparator Tr_8, Tr_9 and compared with a +5V bias, so that the bistable is reset when the output falls below +5V. The output is thus a triangle wave between the limits +5 and +10V. A photograph of the output waveform is shown on the left.

Constant current generator

The versatility of this oscillator stems largely from the fact that its frequency is controlled by a single current generator, and this generator can be adapted to meet a variety of needs. If only a single frequency is required, this generator can be a simple resistor to the negative line. Fig.3(a) shows a current generator suitable for use when an oscillator with a linear frequency calibration is wanted, as the frequency varies linearly with the potentiometer setting. If C_1 is 10nF and a ten turn helipot is used with the dial set to read from 1 to 11 turns, the trimmer potentiometers can be set to give maximum and minimum frequencies of 1100 and 100Hz. The oscillator frequency can then be read straight from the helipot dial, as is shown in Fig. 4. By switching the capacitor in decade steps, a useful test oscillator can be built to cover a wide range of frequencies.

If voltage control of frequency is required, a control voltage can be fed directly into the base of Tr_2 in place of the voltage from the potentiometer. When an oscillator calibrated in period is required, the current generator shown in Fig. 3(b) is suitable. This gives a period proportional to R, as shown in Fig. 5. The exponential relation between collector current and base-emitter voltage in a transistor can be used to give a very wide frequency range in one band, as was previously described for use with multivibrators[1]. Fig. 3(c) shows a suitable generator and its measured performance is shown in Fig. 6. When this circuit is used R_1 and R_2 should be changed to 470Ω to allow the current mirror to work up to 10mA.

Conversion to sine waves

A triangle wave with its reasonably low harmonic content can be used in many applications where a sinewave has been traditionally used. However, when a low harmonic content is necessary, the non-linear characteristics of a junction f.e.t. can be used to shape the triangle into a sinewave[2]. A suitable circuit is shown in Fig. 7. The d.c. output of the emitter follower is set to zero using R_1 and the amplitude set with R_2. The emitter follower is necessary to give a low impedance drive to the shaping circuit.

Some care in setting up is necessary here for good results. The V_p and I_{dss} of the f.e.t. should be measured (i.e., the gate bias where the drain current falls to zero, and the saturation current at zero gate bias), and the peak-to-peak input level set to about $2.7V_p$ with R_a and R_b set to about $\frac{V_p}{2I_{dss}}$. The input level is then adjusted for minimum 3rd harmonic and R_b set for minimum 2nd harmonic, using a wave analyser if available. A total harmonic content of less than 0.5% r.m.s. can be obtained with this circuit.

References

1. D. T. Smith, "Multivibrators with seven-decade range in period", *Wireless World*, Vol. 78, No. 1436, 1972, pp. 85–6.

2. R. D. Middlebrook and I. Richer, "Non-reactive filter converts triangular waves to sines", *Electronics*, Vol. 38, No. 5, 1965, pp. 96–101.

Components List (Figs. 2, 4)

Resistors

R_1	10k
R_2	10k
R_3	22k
R_4	4.7k
R_5	10k
R_6	10k
R_7	10k
R_8	10k
R_9	6.8k
R_{10}	100
R_{11}	10k
R_{12}	10k
R_{13}	6.8k
R_{14}	100

Capacitors

C_1	see text
C_2	0.1μF
C_3	0.1μF
C_4	4.7pF
C_5	4.7pF

Semiconductors

$Tr_1, Tr_2, Tr_6, Tr_7, Tr_8, Tr_9$	All 2N4061
$Tr_3, Tr_4, Tr_{10}, Tr_{11}, Tr_{12}$	All 2N5172
Tr_5	2N3819

Components List (Fig. 8)

Resistors

R_1	22k pot.
R_2	10k
R_3	100k pot.
R_4	100k
R_5	4.7k
R_6	1M
R_7	1M
R_a	see text
R_b	see text

Semiconductors

D_1	12V zener
D_2	1S44
D_3	1S44
Tr_1	2N4061
Tr_2	2N5172
Tr_3	2N3819

Announcements

A one-day **standards course** is to be held by the British Standards Institution at Hampden House, 61 Green Street, London W.1, on 23rd February. The course is intended primarily for firms new to standards work and deals with preparation of an individual standard to inter-relationship between British, international and European standards in the Common Market. Applications to the Secretary, Standards Associates Section, British Standards Institution, 2 Park Street, London W1A 2BS.

A three-day course, **"Minicomputers in industrial process control"**, is to be held at the Polytechnic of Central London, 115 New Cavendish Street, London W1M 8JS, from 21st to 23rd March. The course is intended for managers, engineers and scientists interested in appraising state-of-the-art minicomputer technology.

The management control of the Science Research Council's **Astrophysics Research Unit** has been transferred to the Radio and Space Research Station, Slough, Bucks. The unit will continue its activities for the present at the Culham Laboratory, Abingdon, Berks.

ESPA — the **European Selective Paging Manufacturers Association** — has been formed by AEG Telefunken, Autophon, Hasler, Multitone, N.I.R.A., Philips, Svenska Radio AB and Telekontroll AB with headquarters in Eindhoven, Holland. The main purpose is to produce a standardization of regulations and technical specifications throughout Western Europe.

Submissions for the 1973 **MacRobert Award for technological innovation** are invited by the Council of Engineering Institutions. Entries should reach the C.E.I. by the 30th April 1973. Copies of the rules and conditions can be obtained from The MacRobert Award Office, Council of Engineering Institutions, 2 Little Smith Street, London S.W.1.

Siliconix Ltd, the Swansea-based semiconductor manufacturers, have opened a sales office at Shirley Lodge, 470 London Road, Slough, Bucks.

Murphy Telecommunication Systems Ltd has opened additional premises at Brockenhurst Film Studios, Fibbards Road, Brockenhurst, Kent. The company's offices and works at Warrington and Trowbridge remain fully operative.

Welwyn Electric Ltd have announced that their Strain Measurement and Equipment Division, based at Teddington, Middlesex, has opened an office in Sweden. The address is Uppfartsvagen 13, 171 32 Solna, Sweden.

Italtel s.p.a., of Milan, Italy, export commissioner of SIT Siemens s.p.a. of the IRI-STET group, has been awarded a contract worth approximately £0.9M for the construction of three microwave radio relay links in Ethiopia and their respective multiplex equipments.

Radar video recording equipment has been ordered from EMI to assist in flight testing new radars being developed for Europe's multi-role combat aircraft (M.R.C.A.). The contract has been placed with EMI Electronics' Systems & Weapons Division, Wells, Somerset, by Panavia GmbH — the Munich firm developing the M.R.C.A. project.

Under contract to the Spanish Army, **Racal-Mobilcal Ltd**, 464 Basingstoke Road, Reading, Berks RG12 ORY, is to supply a rangs of h.f. radio communications systems worth approximately £500,000.

An agreement has been reached between **Jermyn Distribution**, Vestry Estate, Sevenoaks, Kent, and Weir Electronics Ltd, whereby Jermyn will stock printed circuit board power supplies manufactured by Weir.

Lauriestone Electronics Ltd, 1 Stepfield, Witham, Essex CM8 3TH, has signed an agreement with the Marconi Co., for the manufacture and sale under licence of the **Marconi Meniscometer** — an instrument for measurement of solder "wettability" of components or p.cs.

V.A. Howe and Co. Ltd, 88 Peterborough Road, London S.W.6, have been appointed sole U.K. agent for Denton Vacuum Inc., who manufacture equipment for **electron microscopy.**

Electrocomponents Associates Ltd, P.O. Box 19, Orchard Road, Royston, Herts. SG8 5HH, have taken over Pact International Electronics Ltd, who marketed test equipment and specialized instruments.

Data Laboratories Ltd, Wates Way, Mitcham, Surrey, has developed a range of digital peripheral interfaces for the DL905 transient recorder, to permit direct connection to a digital computer as a high-speed signal acquisition device.

Memorex Ltd, an American audio tapes company based at Freight House, Long Lane, Stanwell, Middlesex, has introduced a **cassette storage system** consisting of an aluminium library rack, six cassette album cases and a link piece for further additions.

The address of both the **Electronic Components Board** and the **Radio and Electronic Component Manufacturers' Federation** is now 6th Floor, Liberty House, 222 Regent Street, London W1R 5EE. Tel. 01-437 4127.

The Marconi International Marine Co. Ltd., Marconi House, Chelmsford, Essex, a GEC-Marconi Electronics company, has formed an Oil Industry Division which, in liaison with the specialist departments within the company, will be responsible for all sales, installation and service functions of Marconi Marine U.K. offshore oil industry activities.

Electrocomponents Associated Limited, 13/17 Epworth Street, London EC2P 2HA, the public company that includes RS Components, has taken over **The Radio Resistor Co. Ltd**, of Harrow, Middlesex.

Reslosound Ltd, Reslo Works, Spring Gardens, London Road, Romford, RM7 9LJ, a subsidiary of Derritron, have been appointed U.K. and European marketers for Broadcast NC, of Maryland, U.S.A., manufacturers of the Spotmaster range of radio station **cartridge systems.**

A.D.L. Technicare, 3C The Industrial Estate, Cores End Road, Bourne End, Bucks., an electronic **repair and calibration** company, have acquired the business of M.C.R. Avionics Ltd, of Elstree Aerodrome, Hertfordshire. The company will carry on trading under the name of Technicare Avionics and will specialize in the installation, maintenance and repair of communication and navigational equipment, primarily in the aviation field.

EMI Television Equipment, a division of EMI Sound and Vision Equipment Ltd, Hayes, Middlesex, has provided two monochrome television outside broadcast vehicles with power generators to the Nigerian Broadcasting Corporation for its Channel Ten service based in Lagos.

The Decca Navigator Company Ltd, Decca House, 9 Albert Embankment, London S.E.1., has been awarded a contract worth over £100,000 to supply Mk. 19 Decca navigator airborne receivers, Danac computers and pictorial displays to the fleet of ten Sikorsky S-61 air/sea rescue helicoptors of the Royal Danish Air Force.

B.A.C. is to install additional **navigation aids** in Jet Provosts operated by the R.A.F. Work valued at about £2M will include installation of direction and distance measuring equipment.

Royal Air Force Strike Command has taken delivery of the MATELO (Maritime Air-Radio Telegraph Organization) ground-to-air, high-frequency communication network supplied to the Ministry of Defence (Air) by Marconi Communication Systems Ltd, Marconi House, Chelmsford, CM1 1PI.

Marconi Communication Systems Ltd, Marconi House, Chelmsford, CM1 1PL, are to install a tropospheric scatter communications link between Dacca, the capital of Bagladesh, and Chittagong, the country's main port, a distance of 200km. This order has been placed at the request of the Bangladesh Ministry of Posts, Telegraph and Telephones through Global Imex, the Marconi representative in Bangladesh.

About People

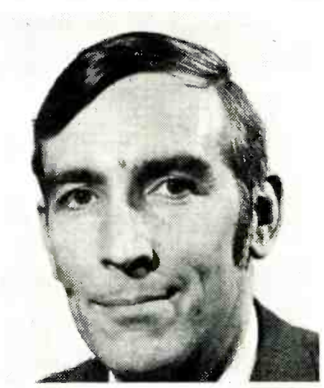
Paul Rhodes has joined the senior technical staff of Nelson Tansley to work on hospital nurse-call and ENTAL railway communications systems. He is well qualified for the position, having explored both fields of activity in his recent experience. Work on the commissioning of British Rail's trackside communications, during which he obtained a knowledge of world-wide codes of practice, was followed by eight years' service with Multitone, where he was engaged in marketing, installation and servicing of hospital communications in Europe and the Middle East.

Aubrey Buxton, M.C., took office as president of The Royal Television Society for a two-year term on January 1st 1973. Mr. Buxton, who is executive director of Anglia Television and producer of Anglia's "Survival" films, was educated at Ampleforth and Trinity College, Cambridge and served in The Royal Artillery from 1939–45. In 1968 Mr. Buxton was awarded the Royal Television Society's Silver Medal for outstanding artistic achievement.

J. Stevenson, has been appointed director of operations for one of the five divisions of E.M.I. Sound and Vision Equipment Ltd., E.M.I. Industrial Components. He will be responsible for the administration of the Treorchy, Glamorganshire, factory and for component marketing at Hayes.

Three employees of Standard Telephones & Cables and Standard Telecommunication Laboratories have been successful in the 1972 Telecommunication Engineering and Manufacturing Association T.E.M.A. Awards competition. **Kevin Kelly**, of S.T.L. Harlow, gained first prize in the Technologist Class for his essay "The Doppler Microwave Landing System" and in the same class, **Derek Glanville,** also of Harlow, was awarded second prize for an essay on "The Spectrum of Round-Off Noise in a Digital Filter". **Roger Faulks,** who is in the Transmission Division at S.T.C., Basildon, won first prize in the Technician Class for his specially commended essay "Model Automatic Location Store".

D. I. Williams, B.Sc., has been appointed a director of Electroplan Limited, the instrument distribution company of the Electrocomponents Associated Group. Mr. Williams, who is 37, has been



general manager of Electroplan since its inception in April 1972.

Farnell Electronic Components Ltd, of Leeds, announce the appointment of **Ken Gledhill** as sales and marketing director and of **Ian Johnstone** to the position of executive director.

H. C. Maguire, a director and general manager of Marconi Marine, retired on December 31st after 45 years with the company. Mr. Maguire served at sea as a radio officer from 1927 to 1936, when he joined the shore technical staff in Glasgow, work which was interrupted by a three-year wartime appointment in Montevideo. In 1948, he became contracts representative for southern Scotland, moving in 1950 to Liverpool, where he was later promoted to depot manager. Mr. Maguire was appointed manager of the export sales division at Chelmsford, becoming general manager in 1962. He also relinquishes his directorships of Norsk Marconikompani A/S, Oslo, and Coastal Radio.

Richard Slatter, B.Sc., has been appointed systems engineer by Perex, the Reading-based firm specializing in peripheral interfacing, off-line data handling and system design. Mr. Slatter received his honours degree in Electrical Engineering at Newcastle-upon-Tyne, and went to A.E.I. Scientific Apparatus to work on data-acquisition and analysis systems. He was subsequently employed by I.C.L., West Gorton, where until joining Perex, he was a design engineer on test equipment for large computers.

K. G. Smith has been appointed engineering consultant to the Electronic Components Board to assist **Sir Richard Melville,** K.C.B., the director. Mr. Smith has been one of the R.E.C.M.F. representatives on the Board since 1968, having been chairman (1958-59) and vice-president (1960-64) of the R.E.C.M.F. He was also chairman of the R.E.C.M.F. Technical Committee from 1962-1966. Before his retirement in 1971, Mr. Smith had been joint managing director of N.S.F. Limited and a director of Simms Motor and Electronic Corporation Ltd. He was leader of the representatives of the passive components makers to the "Burghard" Committee.

M. A. Gates has become deputy divisional manager (Lincoln) and manager of the Gas Tube Department of the English Electric Valve Company Limited. Coming to E.E.V. from the Sunderland c.r.t. factory of A.E.I. in 1958. Mr. Gates was head of the Chelmsford c.r.t. section until 1960, when he was appointed assistant manager of the Large Valves Section, becoming manager in 1966.

NEW YEAR HONOURS

Among recipients of honours in the New Year list were the following:

Knight Bachelor

Dr. E. Eastwood, F.R.S., director of research, General Electric Company.

C.B.

C. P. Fogg, B.A., deputy controller of electronics, Ministry of Defence.

C.B.E.

P. A. Allaway, C.Eng. chairman and managing director, E.M.I. (Electronics) Ltd.

A. Deutsch, technical director, Thorn Electronic Industries Ltd.

G. C. Gaut, M.A., B.Sc., director of the Plessey Company Ltd.

G. G. Gouriet, F.I.E.E., chief engineer, research and development, B.B.C.

Prof. N. Kurti, F.R.S., professor of physics, Clarendon Laboratory, Oxford.

O.B.E.

J. W. H. Cheesbrough, M.I.E.R.E., regional engineer, Midlands Telecommunications region, Post Office.

W. G. D. Gunn, for services to sound broadcasting and television, S.E. Asia.

J. R. Pickin, B.A. (Hons.), general manager, engineering, Ferranti Ltd.

M.B.E.

W. W. Beebee, lately radio officer/purser, Coastal Relieving Duties, Glen Line.

P. J. Darby, M.I.E.R.E. head of technical quality control, Independent Broadcasting Authority.

K. G. Eve, officer-in-charge, Radio Communications Branch, Lancashire Constabulary.

H. Hirst, chief electronics engineer, Naval guided weapons division, Hawker Siddeley Dynamics Ltd.

P. H. Rice, electronics engineer, Marconi Space and Defence Systems, Stanmore.

V. Rubenstein, head of reception department, monitoring service, External Broadcasting, B.B.C.

C. H. Snell, senior production controller, Radar and Equipment Division, E.M.I. Electronics Ltd.

Obituary

Philip R. Berkeley, M.I.E.E. head of engineering for Thames Television, died suddenly on 10th January, aged 54. Mr. Berkeley spent twenty-five years with Marconi's, working on many aspects of television, including transmitters, the Mk III camera and early outside-broadcast vehicles. He was responsible for the planning and installation of television studios in all parts of the world, including I.T.V's first studios, and was more recently concerned with the planning of Channel TV, Hong Kong Television Broadcasting, Thames studios at Teddington and television for South Africa. Mr. Berkeley was vice-president of the British Kinematograph Sound and Television Society.

W. H. George, Ph.D., F.Inst.P., well known as a physicist in the field of acoustics, died in December, aged 75. He graduated at University College Nottingham, where he received his doctorate in 1925. Amongst the appointments he held was that of Royal Society Moseley Research Student, working under Sir W. H. Bragg in the Davy Faraday Laboratory at the Royal Institution, London. Later he lectured at Leeds and Sheffield Universities and at Southampton University College, finally being appointed Head of the Physics Dept. Chelsea College of Science and Technology. Dr. George was especially interested in music, in all its aspects. He published a number of research papers, including *"A sound reversal technique applied to the study of tone quality"* and *"Science and Music"*. Dr. George become more widely known in the 50s and 60s with his series of lectures, broadcast on the Third Programme, dealing with musical instrument acoustics. He frequently lectured on these subjects at Morley College and elsewhere and read papers to the B.S.R.A. and the B.K.S.T.S.

Experiments with Operational Amplifiers

7 (concluded). Log circuits for multiplication, division and the generation of powers

by G. B. Clayton, B.Sc., F.Inst.P.*

Operational amplifier log and antilog converters may be combined in order to generate many non linear functions. The circuits are connected together in such a way that they perform the operations normally involved in logarithmic computation. Examples of such computations are described by the equations:

$$\text{antilog}\,(n\log x) = x^n$$
$$\text{antilog}\,(\log x + \log y) = xy$$
$$\text{antilog}\,(\log x - \log y) = x/y$$

Thus in order to generate an output signal proportional to the nth power of an input signal, a log converter is used to generate the log term, a resistive divider network is used to multiply the log term by a constant n and an antilog converter is then used to form the output signal. The action of such a system may be investigated using the circuit illustrated in Fig. 7.8. The circuit consists essentially of a combination of the temperature compensated log converter and temperature compensated antilog converter previously described.

Referring to Fig. 7.8 the output of amplifier A_1 is, from eq. 7.4 (Jan. issue), given by

$$e_{o1} = -\left[\frac{R_5+R_6}{R_6}\right]E_o\log_{10}\frac{I_{c1}}{I_{c2}}\frac{I_{o2}}{I_{o1}}$$

Using eq. 7.1 the collector current of transistor Tr_4 is determined by

$$V_{EB4} = -E_o\log_{10}\frac{I_{c4}}{I_{o4}}$$

where

$$V_{EB4} = V_{EB3} + e_{o1}\frac{R_8}{R_7+R_8} \qquad (7.6)$$

and

$$V_{EB3} = -E_o\log_{10}\frac{I_{c3}}{I_{o3}}$$

Substituting for V_{EB4}, V_{EB3} and e_{o1} in eq. 7.6 gives

$$E_o\log\frac{I_{c3}}{I_{o3}} + \frac{R_8}{R_7+R_8}\,\frac{R_5+R_6}{R_6}\,E_o\log\frac{I_{c1}}{I_{c2}}\frac{I_{o2}}{I_{o1}} = E_o\log\frac{I_{c4}}{I_{o4}}$$

If all transistors are at the same temperature the E_o terms cancel, and by rearrangement we obtain:

$$\log\frac{I_{c4}}{I_{c3}}\frac{I_{o3}}{I_{o4}} = n\log\frac{I_{c1}}{I_{c2}}\frac{I_{o2}}{I_{o1}}$$

where
$$n = \frac{R_8}{R_6}\cdot\frac{R_5+R_6}{R_7+R_8}$$

If we assume that the I_o terms cancel

$$\frac{I_{c4}}{I_{c3}} = \left[\frac{I_{c1}}{I_{c2}}\right]^n$$

Now $I_{c4} = \dfrac{e_o}{R_4}$, $I_{c3} = \dfrac{e_3}{R_3}$, $I_{c2} = \dfrac{e_2}{R_2}$ and $I_{c1} = \dfrac{e_1}{R_1}$

Thus

$$e_o = \frac{e_3}{R_3}R_4\left[\frac{R_2}{e_2R_1}\right]^n e_i^n \qquad (7.7)$$

In the circuit of Fig. 7.8 component values are chosen so as to make the scaling factor unity and the power $n = 3$. It is suggested that e_3 be made variable so as to allow for mismatch in the I_o terms. The setting up procedure for the circuit then consists of applying an input signal of exactly one volt and adjusting the value of e_3 so as to obtain an output signal of exactly one volt.

Experimental results obtained with the circuit are shown graphically in Fig. 7.9. The second set of results in Fig. 7.9 were obtained with resistor values R_5, R_6, R_7 and R_8 chosen so as to make $n = \frac{1}{2}$. The following values were used: $R_6 = R_8 = 1\text{k}\Omega$, $R_5 = 5.6\text{k}\Omega$, $R_7 = 12\text{k}\Omega$.

In Fig. 7.9 the lines show the calculated functions, $e_o = e_i^3$ and $e_o = e_i^{\frac{1}{2}}$ respectively and the plotted points indicate experimentally obtained data. The resistor values used to set powers were of 5% tolerance. Greater conversion accuracy would, of course, be assured by selecting resistor values to precisely fix the power n. Accuracy at low signal levels would be improved by balancing offsets of amplifiers A_1 and A_4.

*Department of Physics, Liverpool Polytechnic.

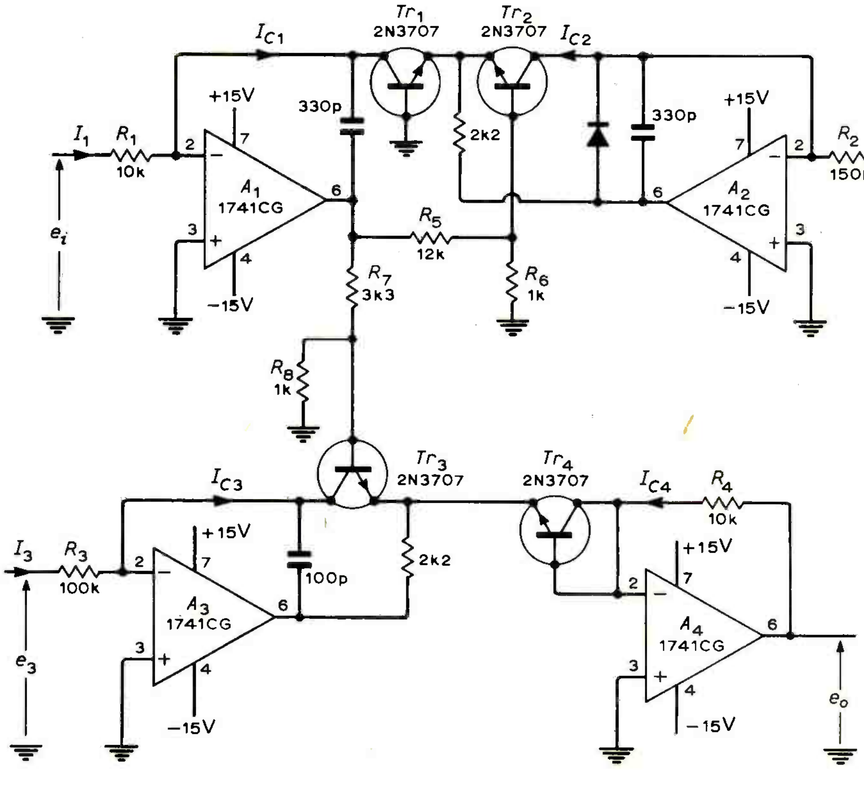


Fig. 7.8. Cube generator.

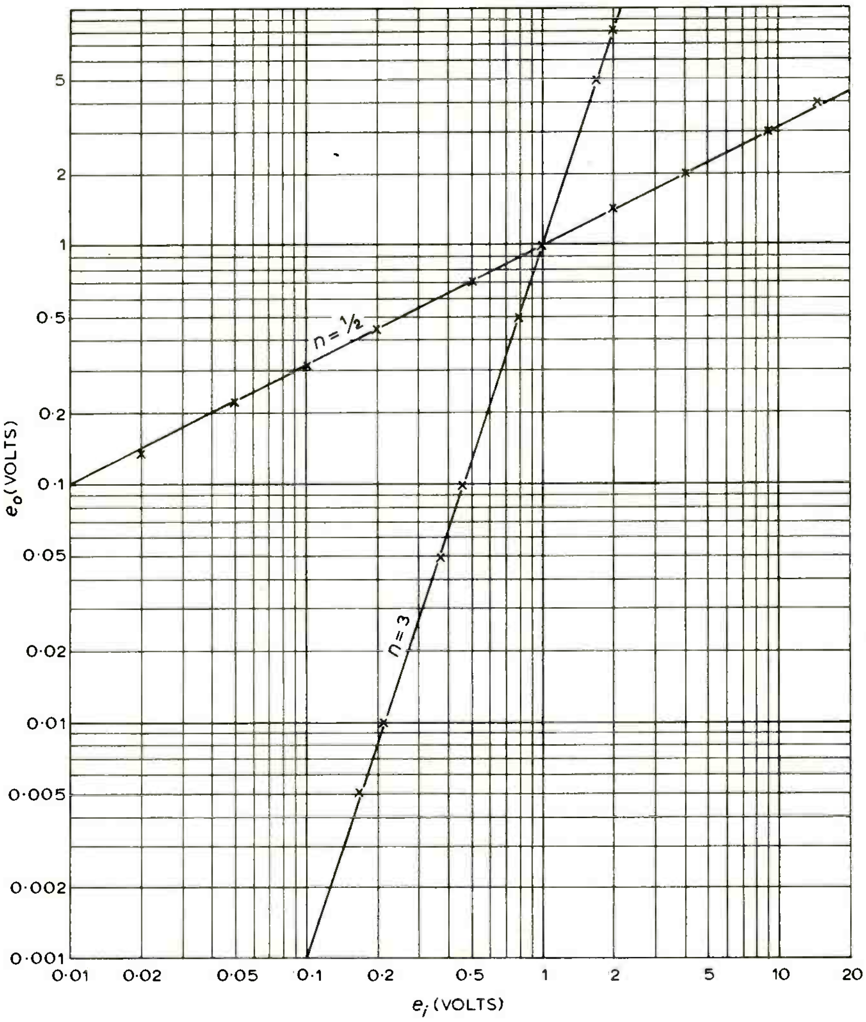


Fig. 7.9. Experimental results (marked points) obtained with power generator.

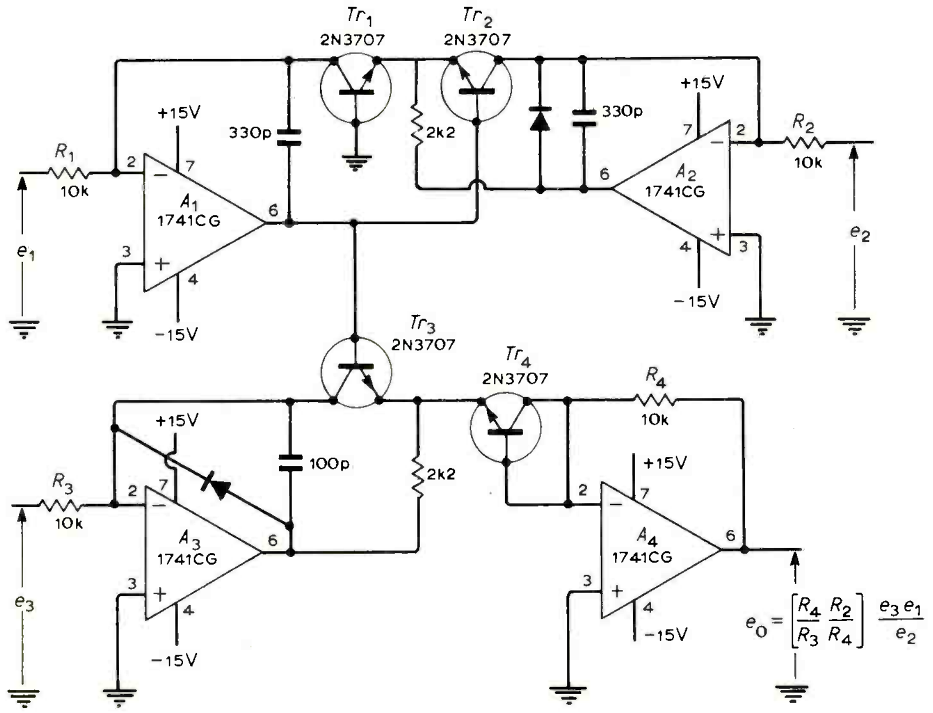


Fig. 7.10. Multiplier/divider.

Multiplier/divider

Examination of eq. 7.7 shows that if the power n is made unity the response of the circuit in Fig. 7.8 is given by the equation

$$e_o = \frac{R_4}{R_3}\frac{R_2}{R_1}\frac{e_3 e_1}{e_2} \qquad (7.8)$$

The power n may be set to unity by appropriate choice of log scaling resistors, or log scaling resistors may be simply omitted from the circuit.

In the circuit shown in Fig. 7.10 the log output at the base of transistor Tr_2 is connected directly to the antilog circuit at the base of transistor Tr_3. The circuit response is described by eq. 7.8 and the circuit may be used for either multiplication or division. The circuit allows only single quadrant operation, that is, all signals are of the same polarity (positive).

When using the circuit in Fig. 7.10 for multiplication the signals to be multiplied are applied to inputs e_1 and e_3. Scaling is determined according to eq. 7.8 by resistor values R_1, R_2, R_3 and R_4 and by the signal e_2. In practice, because of mismatch in transistor I_o terms, it is normally necessary to make one of the scaling parameters adjustable. A convenient procedure is to fix resistor values, apply measured values of e_1 and e_3 and adjust the value of e_2 to give the output product multiplied by a desired scaling factor.

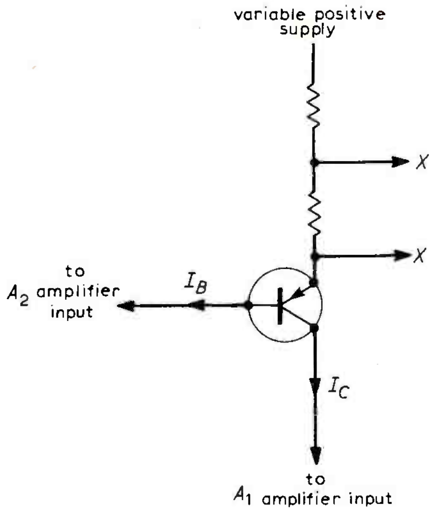
When using the circuit for division the variables are applied to e_1 and e_2, and e_3 may be adjusted for a desired scaling factor.

Practical notes

The circuits shown were all connected using "bread board" techniques. Capacitor values were chosen so as to achieve closed loop stability. The values required for this purpose are to some extent dependent upon the actual circuit layout, so that it is always advisable to check for closed loop stability by oscilloscope monitoring of amplifier outputs. Frequency compensating capacitor values may be increased if necessary in order to achieve closed loop stability. Increase in capacitor values slows down the circuit response, particularly at low signal levels, although this is no real disadvantage for experimental purposes.

Temperature differentials between logging transistors should be avoided if temperature compensation is to be effective. In the systems employing a combination of log and antilog circuits E_o terms cancel and it is not necessary to use a temperature sensitive resistor to compensate for the temperature dependence of E_o.

If the widest possible dynamic range is to be achieved with the circuits the offsets of the input operational amplifier should be balanced. Performance limits are then determined by amplifier bias current and offset voltage drift. A further increase in dynamic range will require the use of an operational amplifier type with smaller values of bias current and input offset voltage. If log converters are to perform accurately at very low signal levels considerable care must be taken to avoid leakage currents. Possible leakage through



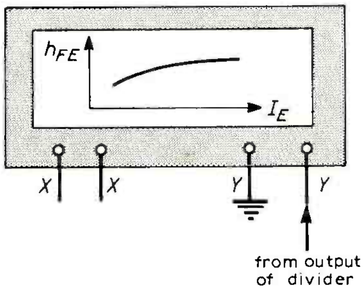


Fig. 7.11. Measurement of transistor h_{FE} variations using divider circuit.

circuit boards or capacitors requires consideration, and amplifier input circuitry may require guarding.

Application of log circuits

Log circuits may be applied in performing functional operations. They are also very useful in obtaining a wide dynamic range in signal processing systems. In linear systems there is a marked loss of accuracy when the input signal is small compared with full scale. In the case of log amplifiers the accuracy is a percentage of signal rather than a percentage of full scale over most of the dynamic range.

A comparatively simple application of log multiplier/divider circuits is for the measurement of the current gain of a transistor over a range of operating currents. A practical arrangement for this purpose is illustrated in Fig. 7.11.

The multiplier/divider circuit of Fig. 7.10 is used to measure the current gain of a p-n-p transistor. The collector current of the transistor provides the input current to amplifier A_1, the base current provides the input current to amplifier A_2. Resistors R_1 and R_2 are not required in the circuit and are omitted.

The output of the divider circuit is proportional to I_C/I_B. Scaling may be set by adjustment of e_3. The operating current of the transistor is determined by a resistor connecting its emitter to a positive supply.

Books Received

1-2-3-4 Servicing Stereo Amplifiers by Forest H. Belt follows the philosophy that it is easier to service electronic equipment if it can be visualized as being made up of divisions that the author calls sections, stages, circuits and parts. In servicing a defective piece of equipment, using this method, trouble is localized first to the offending section, then to the stage, then to the circuit and finally to the defective part. The advantages of this methodical procedure are outlined in the first chapter. Following chapters acquaint the reader with types of stereo systems, specifications and measurements, transistor circuit operation and various stages in transistor amplifiers. Remaining chapters show how to apply the servicing method to stereo amplifiers. Pp.240. Price £2.50. W. Foulsham & Co. Ltd., Yeovil Road, Slough SL1 4JH.

50 Photoelectric Circuits & Systems by P.S. Smith contains design details of circuits incorporating over one hundred basic applications. Since requirements vary widely for different applications, many of the circuits are intended as a starting point for further experiment, although all circuits are complete and operable as described. Details are given of all components so that alternatives can be selected if necessary. Applications of photoelectric cells include simple light measuring instruments, switching circuits for operating lights and control equipment, counting units capable of distinguishing between containers of various colours and smoke-detecting elements for use with fire alarms. Pp.83. Price £2.30 (hardback), £1.30 (limp edition). Butterworth & Co. Ltd., 88 Kingsway, London WC2B 6AB.

110 Thyristor Projects using SCRs and TRIACS by R.M. Marston describes projects making use of thyristor devices capable of handling mains voltages that can control currents of tens or hundreds of amperes. Triacs and s.c.rs can be used in applications such as control of electric lamps, motors, heaters and alarm systems and can be used to replace mechanical switches and relays in many a.c. and d.c. control systems. The projects described, which range from simple electronic alarms to sophisticated self-regulating electric heater power controllers, should be of equal interest to the electronics amateur, student and engineer. Pp.138. Price £2.40. Butterworth & Co. Ltd., 88 Kingsway, London WC2B 6AB.

Modern Data Communication, concepts, language and media, by William P. Davenport, provides a fundamental knowledge of how business and technical information is transmitted and received through electrical and electronic systems. The basic requirements of a telecommunications network, with an outline of the way in which these requirements are met, is a major aspect of the book. Review questions on the topics covered are found at the end of each chapter, and technical terms are defined in an extensive glossary. Space is provided for the reader to write in data of particular interest.

The contents include an introduction to data transmission and the language of data, coding for communications, characteristics of transmission media, efficiency and error control, modulation and multiplexing commercial communications channels and services, switching and network concepts and data-set uses and characteristics. Pitman Publishing, 39 Parker Street, London WC2B 5PB. Pp.198. Price £2.75 (hardback).

Pulse Code Modulation by P. T. Wakling describes the basic features of p.c.m. systems, the principles of which have been known for over thirty years, but whose technique has only come into widespread use during the last ten years, following the development of transistor circuits. The subjects of terminals, sampling, quantizing, companding, coding and sychronization are simply described, together with timing extraction, jitter and transmission codes. The advantages and disadvantages, applications and future developments of p.c.m. systems are also discussed. Price £1.50. Pp.72. Mills & Boon Ltd, 17019 Foley Street, London W1A 1DR.

Ham Radio — A Beginner's Guide, by R. H. Warring, introduces in simple terms the technicalities of the subject and the "language" of amateur radio communication. Pp.152. Price £1.60. Lutterworth Press, Luke House, Farnham Road, Guildford, Surrey.

Collins Radio Diaries 1973 contain much valuable information for radio engineers and amateurs. Price 63p (69p with pencil). Collins Stationery/Diary Division, P.O. Box 30, 144 Cathedral Street, Glasgow C.4.

Hi-Fi Stereo Hints and Tips, by John Borwick, deals with the initial setting up of equipment, routine care and maintenance. Pp.48. Price 32p. Bib Sales, P.O. Box 78, Hemel Hempstead, Herts.

Conferences and Exhibitions

Further details are obtainable from the addresses in parentheses

LONDON
Feb. 26-Mar. 2 — Bloomsbury Centre
Seminex
(Evan Steadman and Partners, 4 Lyewood Common, Withyham, Hartfield, Sussex)

TEDDINGTON
Feb.20 & 21 — National Physical Lab.
Precision and Accuracy in Pressure and Force Measurement
(Inst. Physics, 47 Belgrave Sq, London SW1X 8QX)

OVERSEAS
Feb.14-16 — Philadelphia
International Solid-State Circuits
(I.E.E.E., 345 East 47th St, New York, N.Y. 10017)
Feb. 19-25 — Paris
International Sound Festival
(Société pour la Diffusion des Sciences et des Arts, 14 rue de Presles, Paris 15.)
Feb. 20-22 — Rotterdam
A.E.S. Convention
(Herman A. O. Wilms, Zevenbunderslaan 109, B-1190 Vorst-Brussels)

Literature Received

For further information on any item include the WW number on the reader reply card

ACTIVE DEVICES

A quick-reference, colour wall chart providing pin numbers, common parameters and logic diagrams for each of 47 current devices in the Motorola family of m.o.s. integrated circuits available from Motorola Semiconductors Ltd., York House, Empire Way, Wembley, Middlesex. WW401

The MI 14007 series of impatt diode, microwave power amplifiers covering the band 6-8.5GHz with nominal power outputs of up to 3.0W is the subject of bulletin L/0014 received from Microwave Associates Ltd., Dunstable, Beds LU5 4SX. .WW402

A 40-page brochure containing the latest prices for integrated circuits, discrete semiconductors and opto-electronic devices now totalling nearly 1600, received from Ferranti Ltd, Electronic Components Division, Gem Mill, Chadderton, Oldham OL9 8NP WW403

Thyristor product matrix TPM-510 providing reference information about more than 300 triacs and s.c.rs in terms of electrical ratings and package data. RCA/Solid State Ltd., Sunbury-on-Thames, Middlesex TW16 7HW. WW404

A leaflet describing the CE1000 range of low cost single decade counters for totals counting or select counting application, with or without count display or store facility, and operating speeds of up to 10MHz, can be obtained from Chesford Enterprises, 11 Atherton Heights, Bridgwater Road, Wembley, Middlesex. WW405

A range of encapsulated, high-stability modules covering analogue multipliers and dividers, D-A and A-D converters, sample and hold units and miniature power supplies, is described in a catalogue from Guest International, Nicholas House, Brigstock Road, Thornton Heath, Surrey CR4 7JA WW406

A folder containing complete product specification and application data ranging from high speed s.c.rs for military application to a broad range of C-line s.c.rs intended for industrial use, is available from Unitrode Corporation, 580 Pleasant Street, Watertown, Massachusetts, U.S.A. WW407

A copy of the latest leaflet describing vidicon monochrome and colour TV camera tubes for both magnetic and electrostatic focusing and providing graphical information about photosurface and resolution characteristics with an equivalents index, is available from English Electric Valve Co. Ltd., Chelmsford, Essex CM1 2QU. ....,......WW408

A data sheet describing an extensive range of plug-in solid state chopper units for applications such as d.c. amplifiers, voltage to current converters and self-balance recorders. They all make use of f.e.t. switches and are designed to be direct replacements for vibrating reed types. Measurement Technology Ltd., 26-30 John Street, Luton, Beds. LU1 2JE. WW409

PASSIVE DEVICES

Right-angle card connector blocks moulded to mate with 0.100 or 0.150 inch grids in single or double rows of 0.025 inch, square wire-wrapping pins are described in bulletin 112 from Berg Electronics NV, Helftheuvelweg 1, P.O. Box 2060, 's-Hertogenbosch, Holland. ....,..............WW410

An information brochure about the Norm series N-35 electronic timing units having timing periods from 40ms to 600s in various ranges and including modes of operation such as delay on energization, delay on de-energization, dwell, recycling, pulsing and blinking. Thricis Electronics Ltd., 46 The Ridgeway, Watford, WD1 3TN WW411

Push-button, bell-push, pendant, torpedo, chord and chain, toggle, slide and rocker are all types of electric switch described in a brochure available from Castelco (GB) Ltd., Castle Works, High Street, Old Woking, Surrey. WW412

A six-page brochure describing the design capability in precision potentiometer manufacture covering special packaging and applications, custom design, special dials, trimmers and miniature switches, available from Spectrol Reliance Ltd., Drakes Way, Swindon, Wilts. WW413

A 30-page booklet illustrating the large range of spring loaded test probes used for making electrical connections to p.c. boards and electronic equipment by means of mechanical pressure. The range covers single element and coaxial probes as well as test fixtures and fittings. Ultra Electronics (Components) Ltd., Fassetts Road, Loudwater, Bucks. WW414

Data sheet SD410-30 issue 872, giving details of type CX62, d.c. operated, a.c. contactor intended for motor switching functions in industrial and lift control equipment, received from Dewhurst and Partners Ltd., Melbourne Works, Inverness Road, Hounslow, Middlesex. WW415

Catalogue M-111 describes high-power microwave ferrite circulators and isolators covering the frequency range 0.45 to 12.0GHz designed in both coaxial and waveguide configurations. Merrimac Industries Inc., 41 Fairfield Place, West Caldwell, New Jersey 07006, U.S.A. WW416

A leaflet gives the specification of series T7000 panel mounted, integrated circuit electronic tachometers, the meter output of which is linearly proportional to an input signal rate generated at a magnetic pick-up shaft encoder. Meter f.s.ds are selectable in nine standard ranges from 50Hz to 20kHz with custom specified scale legends. Dynalco Corporation, 4107 N.E. 6th Avenue, Ft. Lauderdale, Florida 33308, U.S.A. WW417

EQUIPMENT

A technical paper discussing the conflicting requirements of bandwidth, tuning range, sensitivity and linearity in radio receiver design. Dealing with such criteria as gain distribution, filtering, local oscillator rejection and equipment shielding, the paper is illustrated by charts, diagrams and examples and is available from C.T. (London) Electronics Ltd., Sutherland House, Sutherland Road, Walthamstow, London E17 6BU WW418

A leaflet describing the "Naked Mini 8", an 8-bit minicomputer having a basic 4k core memory, which is expansible up to 32k and a 115 basic instruction capability leading to a claimed increased memory efficiency over other comparable computers. Computer Automation Inc. Ltd., 95A High Street, Rickmansworth, Herts. WD3 1RB. WW419

Technical bulletin K107, an eight-page illustrated booklet providing technical and applications detail of "Series Seven" alarm annunciator system for use in industrial plant and process control environments, is available from Rotraco Systems Ltd., Gordon Street, Darlington, Durham. WW420

A short-form catalogue describing low-frequency (10Hz-5MHz) and high frequency (10kHz-100MHz) solid-state noise source modules, solid-state noise generator plug-in cards (10Hz-5MHz) and a range of general purpose bench-type noise generators throughout the range d.c. to 100MHz, received from Lyons Instruments Ltd, Hoddesdon, Herts. ..WW421

A brochure describing the RTS2 tape recorder audio test unit which has many measurement features such as frequency response, signal/noise ratio, distortion, crosstalk, wow and flutter, drift, erasure, sensitivity, gain and power output, is available from the Ferrograph Co. Ltd., Auriema House, 442 Bath Road, Cippenham, Slough, Bucks, SL1 6BB. WW422

Model 471, dynamic strain gauge amplifier offering a 1V f.s.d. output for six input ranges covering 10 microstrain to 30 millistrain with single-ended gauge excitation from a precision current source (normally a bridge technique), is the subject of a leaflet from Techmation Ltd., 58 Edgware Way, Edgware, Middlesex HA8 8JP. WW423

APPLICATION NOTES

Two RCA application notes dealing with linear and digital integrated circuits are:

AN6026, describing a series of hybrid circuit d.c. voltage regulators supplying 5V, 12V or 15V at up to 4A WW424

ICAN6080, illustrating the use of the CD4007A, c.o.s./m.o.s. dual complementary pair and inverter, as the digital-to-analogue switch and output stage in a digital-to-analogue converter. WW425

RCA/Solid State Europe, Sunbury-on-Thames, Middlesex.

GENERAL INFORMATION

More than 4800 components and prices covering a product range of semiconductors, passive components, electromechanical products and production aids are listed in the "Electronic components stock catalogue" from Celdis Ltd., 37/39 Loverock Road, Reading, Berks. RG3 1ED. WW426

Three data catalogues dealing with products used over the ultraviolet, visible and infrared regions are:

"The Infrared Handbook" discusses and illustrates the range of infrared filters which span the spectrum of wavelengths 0.8 to 15.0 microns WW427

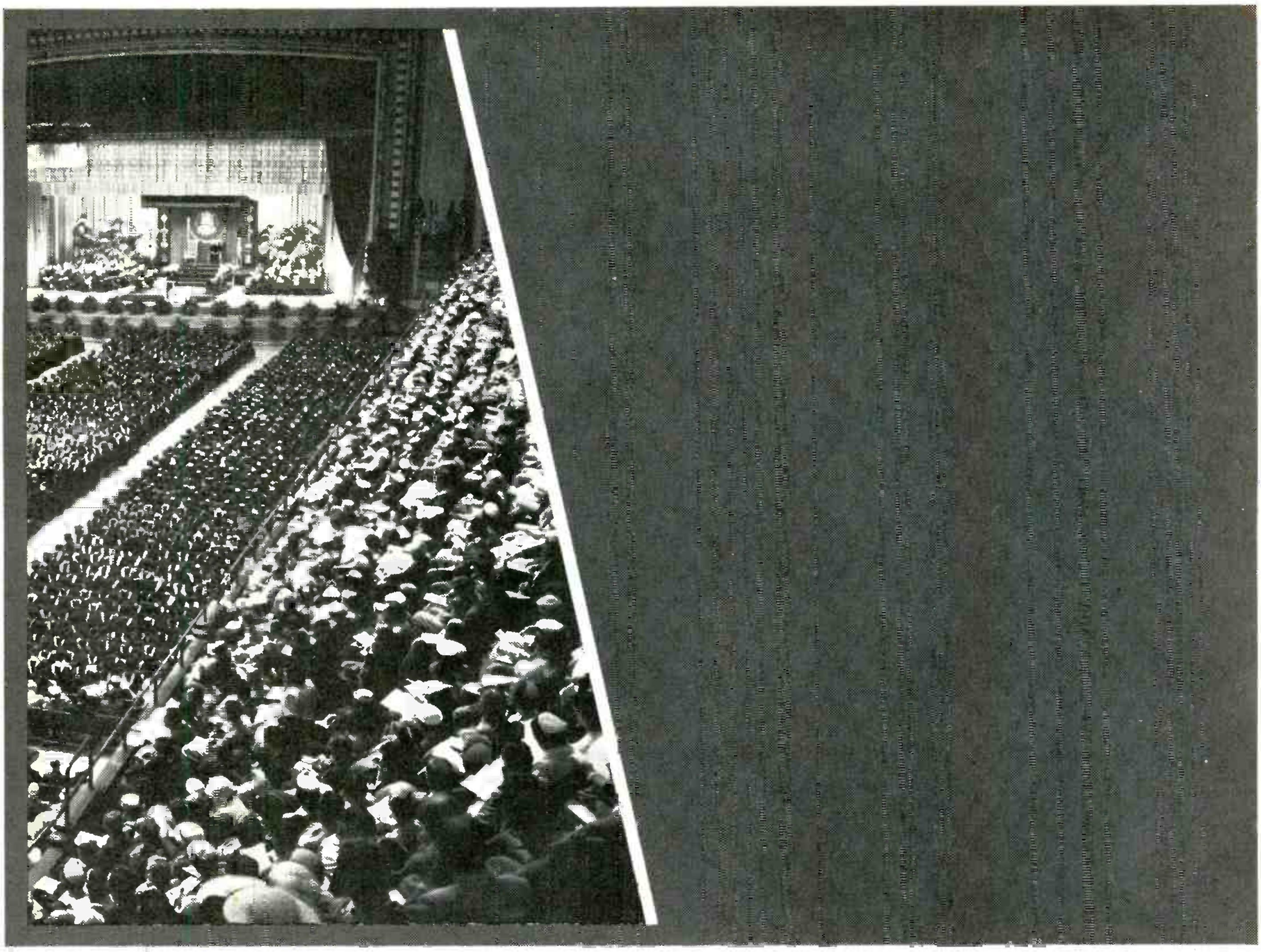
"Multilayer Antireflection Coatings" characterizes a number of substrate coatings which produce low reflection over the ultraviolet and visible wavelength of between 0.3-0.8 microns as well as specialized wideband materials extending out to 15 microns WW428

Brochure 0970 covers the general range of products available and includes elements such as solar cell covers, mirrors and reflectors, beam splitters, lenses, prisms, instrument glasses and laser optics. WW429

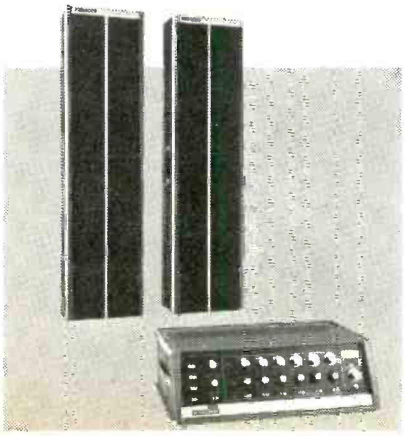
Ocli Optical Coatings Ltd, Hillend Industrial Estate, Dunfermline, Fife.

"Method of measurement of speed fluctuation in sound recording and reproducing equipment" is the title of Standard BS4847 detailing a method of measurement using the weighted peak technique and is applicable to all types of sound recording and reproducing equipment. B.S.I. Sales Branch, 101 Pentonville Road, London N1 9ND. Price £1.05

A catalogue of "Circuitape draughting aids" which are matt acetate self-adhesive labels, precision printed to an accuracy of plus or minus two thousandths of an inch is available from Circuitape Ltd., 33 New Street, Aylesbury, Bucks. WW430



Vocal Master of Ceremonies



There are precious few ceremonies, functions, meetings or entertainment events that *Shure Vocal Master Sound Systems* can't cover — regardless of room size or apparent acoustic difficulties. The Vocal Master is designed to project the voice with intelligibility and authority to the rear of large areas without overwhelming the listeners up front. It's versatile, easy to operate, and totally reliable. It's the system that earned its reputation for superb sound amplification by meeting the standards of professional entertainers — and is now used in hotels, churches, schools, executive meeting rooms and entertainment facilities from Land's End to John O'Groats in preference to built-in "custom" systems costing *many* times more.

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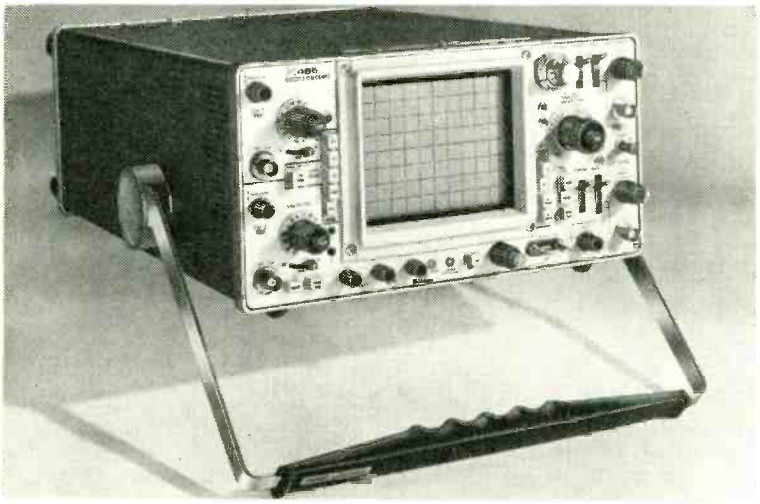
SHURE

WW—066 FOR FURTHER DETAILS

a new family of portable oscilloscopes

High standards of performance, versatility, laboratory grade accuracy and Tektronix quality make these instruments not only the finest field oscilloscopes available, but also an excellent choice for the less mobile design and development engineer.

The new dual-trace Tektronix 475 and 465 oscilloscopes
supersede the world's most travelled and widely used general purpose oscilloscopes . . . . the Tektronix 453A and 454A. They have significantly more bandwidth, twice the sweep speed, a bright 25% larger (full 8 × 10cm) display and additional user conveniences, and all of this in a shorter, thinner, lighter and much lower-priced package.



The 200 MHz Tektronix 475 Oscilloscope at 2mV/div and 1ns/div sweep speed contains the highest gain bandwidth and sweep speed now available in a general-purpose portable oscilloscope and for only £1,173. Add to this many user conveniences including push-button trigger view, knob skirt sensitivity readout, ground reference button on the probe tip, simple to interpret vertical and horizontal mode push buttons and many more . . . .
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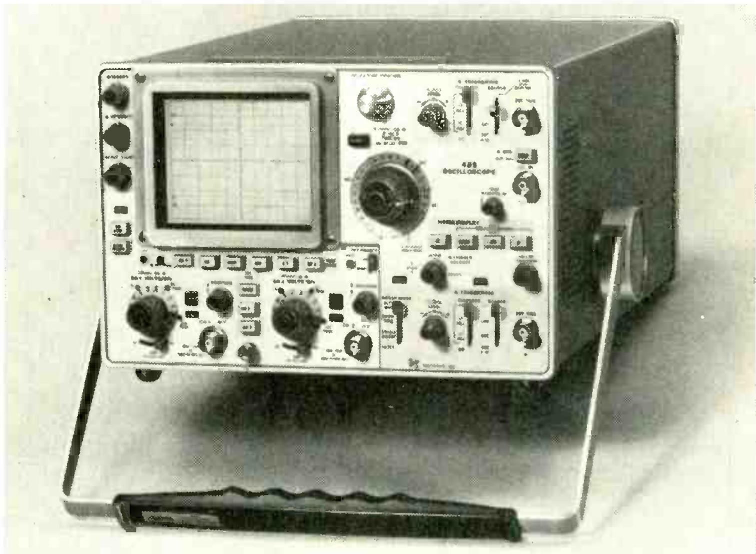
The dual-trace, 350 MHz Tektronix 485 oscilloscope
is the performance leader in the Tektronix portable oscilloscope family. Many features of earlier Tektronix portables are retained, many others are expanded and many new ones added. The result is a new product which significantly extends the performance spectrum of portable scopes. Following are some of the features of the 485, an oscilloscope which measures with laboratory precision and carries with small-package ease . . . 350 MHz bandwidth at 5mV/div; more dual-trace high frequency measurement capability at 5mV/div than any other laboratory-quality scope, portable or cabinet; 1MΩ and 50Ω selectable inputs, scope circuitry automatically disconnects the 50Ω inputs when signals exceed 5V RMS or 0·5 watts to protect your equipment; time resolution to 1ns/div, more time resolution than any other portable, and it's direct reading. A—External Trigger; just press this button to display the external trigger signal and quickly verify your trigger source or check timing reference. Alternate sweep switching, to view intensified waveforms and delayed waveforms at the same time. When you move the intensified zone you always know precisely where you are, and still see the delayed waveform. It saves time and adds operation convenience. The price of the 485 is £2,051.



Learn more about this family of portables, contact Tektronix for detailed information or to arrange a demonstration of these new instruments.

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WW—067 FOR FURTHER DETAILS

Portable Oscilloscopes

A review of the performance and facilities offered by currently available instruments on the U.K. market

If you asked a man fifteen years out of touch with electronics to use the three basic instruments (signal generator, various types of electronic meter and oscilloscope) you would probably find that, after a few minutes to collect his wits together, he would be able to drive the first two with every appearance of competence. In the case of the average, modern oscilloscope, however, a quick glance at the front panel would probably have him reaching for his hat and coat.

He would, for instance, find no timebase frequency control. There is the delaying and delayed timebase, sometimes mixed, and an assortment of dual-trace switching modes. Sampling and storage controls would have little relevance to his experience and he might well be a little shaken by the astronomic frequency-handling capabilities and sensitivity of quite ordinary instruments. In fact, he would rapidly come to the conclusion that the oscilloscope of today is a different animal altogether from the instruments in use fifteen years ago.

The rapidly expanding use of high-speed digital circuitry forced the development of oscilloscopes in both x and y directions; dual-trace operation, with a comprehensive selection of timebase modes, was required at higher and higher sweep speeds, and the phenomenal transition times of integrated digital circuits meant that y amplifier bandwidth must now be measured in terms of at least tens of megahertz if the true picture of events is to be observed.

On the other hand, there is still the need for simpler instruments, to be used for the servicing of less-sophisticated equipment, but even here the performance is often equal to that of a highly expensive oscilloscope of a few years ago.

In a sense, oscilloscopes have always been portable. Even the early Cossors and the big Tektronix valve instruments could be carried, but whether one was then well enough to do any work with the 'scope was another matter. Happily, the introduction of semiconductors on printed-circuit boards (a slower process than in some fields) has meant that truly portable instruments are now common, with all-up weights of 12kg or less and conceding little, if anything, in performance to the more monumental variety.

To obtain the full benefit of portability, instruments should ideally be independent of mains supplies, at least for limited periods. Many oscilloscopes are equipped with internal batteries and chargers, or are designed to work on low-voltage d.c. supplies; such instruments are truly portable and can be used literally "in the field". On the other hand, many other instruments are termed "portable" because they are small and light, and these too are included in the survey, subject to a weight limit of about 12.5kg.

It is not possible, in a review of this nature, to provide a critical appraisal of the performance of available instruments. To do so would require access to each instrument and to a great deal of test equipment. The aim, therefore, is to provide a picture of the type of equipment that is currently on the market and to give as much information on each as is practicable.

It seems likely that professional readers will already be in possession of much of the information which will be set out, and that readers of this review will include many who are not completely up-to-date with current practice. For their benefit, it seems a good idea to describe at the outset some of the features to be found in a modern oscilloscope.

The "y" axis

This is the signal-handling part of the oscilloscope and is the section that decides which class of oscilloscope one is discussing. Relevant features are the bandwidth and rise-time of the y amplifier, and its sensitivity.

Bandwidth and rise-time are related parameters in an amplifier whose frequency-response is not specially shaped, and are connected by the expression $t_r f = 350$, where t_r is the rise-time of the amplifier in nanoseconds and f is the bandwidth at -3dB in megahertz. An amplifier with a -3dB bandwidth of 10MHz and a gaussian roll-off would therefore exhibit a rise-time of 35 nanoseconds. To decide on the bandwidth required for a particular application, the expression $t_{rd}^2 = t_{ra}^2 + t_{rs}^2$ must be called into play, where t_{rd} is the displayed, apparent rise-time, t_{ra} is the amplifier rise-time and t_{rs} is the actual rise-time of the transition under examination. Assume, for example, that a pulse whose rise-time is 100ns is to be examined, but that the apparent rise-time displayed must not be artificially lengthened by more than 5%,

then $t_{ra} = \sqrt{105^2 - 100^2}$

$\approx$ 32 nanoseconds.

From this it is seen that to perform the task, an amplifier with a rise-time of 32ns or less, or bandwidth of 11MHz or over is needed. Its sensitivity must also be adequate, and a common figure for maximum sensitivity is between 1 and 5mV/cm spot deflection. It is sometimes found that an extra position of the sensitivity switch, or a separate switch, is provided to give a 5 or 10 times increase in gain, possibly at a reduced bandwidth.

Input impedance is virtually standard at 1MΩ and 30-50pF in parallel. This is a very high impedance for bipolar transistors and the input stage of the y amplifier was the last position to use semiconductors. Nowadays, this position is usually filled by a field-effect transistor, but valves are still seen in some instruments by virtue of their more easily controlled drift performance; a degree of microphony is sometimes "traded" for stability. Higher input impedances are obtained by the use of resistive, frequency-compensated probes, which consist simply of a 9MΩ resistor in series, so that for a ten times increase in impedance, the signal is reduced ten times.

In the specification tables, it will be seen that the y amplifier bandwidth is something like 0(3Hz) – 10MHz. This simply means that in the second case, the signal is coupled to the amplifier by way of a large capacitor, so that the d.c. component of the signal is eliminated. It is a method of overcoming the impossibility of displaying for example, 5mV of ripple on a 250V power rail without the use of an external backing-off voltage. Normally, the signal is directly coupled, so that waveforms can be studied at their correct potentials relative to each other.

Displays which provide two traces are known by different names, depending on the technique employed. The simplest method is to use two completely separate electron guns, giving true double-beam operation as in the Philips PM3231. This is an expensive, but effective technique, although precise gun alignment must be ensured if the time axis is not to be in error. It has the advantage that each beam can be controlled in brightness independently of the other.

Single-gun methods are of two kinds, the split-beam being the least complicated. The beam emerges from the gun and is divided in two by a splitter plate in the beam. Of recent years, this method has been improved considerably, and its former drawback of low brightness has been overcome. Only one brightness control is possible with both the single-gun methods, differing spot speeds giving uncontrollably different brightnesses.

The third, most commonly used, method is to use electronic switching, sharing the single beam between two y amplifiers. It is common practice to switch the amplifiers in several different ways, the sequence employed depending on the timebase speed and the nature of the signal, and is selected by a front-panel switch.

The beam can be switched at high speed, around 100kHz, so that the traces consist of short segments of the relevant signal, continuity being afforded by the lack of phase relationship between the chopping frequency and most signals, by the high chopping frequency and by persistence of vision. As the timebase speed is increased, the display becomes inconvenient and each amplifier is switched in on alternate sweeps. Additionally, it is usually made possible to allow each channel to operate separately or algebraically added.

When the timebase is triggered by the y signal, a finite time must elapse before the sweep gets under way and unblanking is applied, and the initial part of the trace would, without precautions, be lost. This state of affairs is avoided by delaying the y signal applied to the later stages of the y amplifier (after the output to the trigger amplifier) in a delay-line in the form of a delay cable of 100-200ns. In this way the signal does not arrive at the deflection plates until the sweep is away.

The "x" axis

Except in special cases — x-y displays, frequency-response indicators and spectrum analysers — the x axis is concerned with time and, together with the y axis, forms a voltage-time graph.

It is taken for granted now that any commercial oscilloscope possesses a liniar timebase, and that its calibrated speed is correct to within 5% or so.

The modern instrument is not simply a way of illustrating wave shape, but is essentially a tool for the *measurement* of waveforms in both axes. With digital circuits changing state at the rates we are now accustomed to, the timebase generator in a modern oscilloscope has no mean task to perform.

The function of the timebase is, of course, to draw out the y signal in graphical form. Signals being of an extremely diverse nature, a range of sweep speeds is needed and the fact that the same circuit is sometimes capable, with a few switchable components, of sweeping at either 0.01μs/cm or 1s/cm — a range of 10^8 — is really quite remarkable.

When assessing the speed range of a timebase, it should be considered in relation to the rise-time of the y amplifier. It would be very little use having an amplifier able to swing from maximum positive to maximum negative in 20ns if the transient were compressed into 1mm of timebase. It is essential that the y rise-time should be displayed over a respectable length of trace — preferably three or four millimetres or more. Whether this maximum speed is achieved by the generation of a fast sweep or by amplification of a slower sweep to give an apparent speed increase is not of great importance, so long as the amplified (or "magnified") sweep is still calibrated. In the specifications, the amount of timebase covered in the rise-time of the y amplifier is referred to as "y extension".

The use of two timebase generators is now common in even low-cost instruments. A mode of operation called the delayed-sweep mode is thereby obtained wherein one sweep triggers the other or, in some instruments, enables the y-derived trigger to the second. In this mode, small phenomena at any part of a long, uneventful, cycle can easily be observed at full sweep speed. The setting-up of this display is in two stages. Initially, the delaying sweep is displayed with a section of it, corresponding to the second, delayed, sweep brightened. The brightened portion is centred, by front-panel controls, on the section of the delaying sweep of interest whereupon the delayed sweep is switched in, filling the screen with the part of the original sweep that was brightened. Two exceptions to this procedure are exemplified by the Tektronix 485 and the Dynamco 7200. In the first, both delayed and delaying sweeps are effectively simultaneous, being switched on alternate sweeps and, in the Dynamco, they are displayed, mixed, on the same sweep.

Triggering is of considerable importance in a modern oscilloscope. The old type of free-running timebase, calibrated in frequency, passed from favour many years ago, to be supplanted by timebases which sweep at a number of fixed, calibrated speeds. In normal operation, the sweep does not run in the absence of a triggering signal, although a position marked "AUTO" is usually provided, whereby the sweep does free-run at constant speed to give a base line in the absence of a signal, and automatically locks to signals over a given level and below a certain frequency.

Triggering is applied through either a.c. or d.c. coupling to the trigger amplifier and sweep generator from a variety of sources, which can include the y signal, a built-in television sync separator or external signals applied to a front-panel socket. Positive or negative-going parts of the triggering signal can be selected as trigger points by a "SLOPE" control and the exact point on the signal at which the sweep fires is selected by the "LEVEL" adjustment.

A fairly recent development, which is similar in some respects to a delayed timebase, is trigger hold-off. It is often the case that the waveform to be examined contains several points at which triggering could take place before the correct point is reached. To eliminate spurious triggering at these points, the triggering signals are inhibited or "held-off" for an adjustable period, being enabled just before the desired point is reached.

As has been mentioned, the timebase is used to measure and is therefore calibrated. Over the years, many methods of doing this have been tried, from time-marker pips to slide-back techniques using calibrated potentiometers in the x amplifier, but it is now almost universally conceded that accurate, preset timebase speeds used in conjunction with a graticule on the tube face offer the most convenient and reliable form of calibration, accurate to around 3%.

Two further facilities sometimes offered are the provision of the sweep waveform at an output socket, for use with swept oscillators, and the switched selection of one y amplifier in place of the timebase generator to give an x-y display with little phase shift between x and y axes.

The display

The end result of timebase generation and signal amplification must eventually be a display and, although reports have emerged from time to time of revolutionary new methods of display, the cathode-ray tube is still the only viable display device. In essence, it is virtually unchanged, but recent developments in post-deflection acceleration spirals and mesh lenses have produced brighter, bigger displays with greater deflection sensitivity, running often at lower p.d.a. potentials. In general, the higher the figure for p.d.a., the brighter the trace is likely to be.

The calibration grid or graticule, which is often illuminated, is gradually becoming a part of the tube itself, in order to avoid the effects of parallax. In these cases, it is inscribed on the inside of the screen, where it is completely co-planar with the image, and parallax vanishes.

The specifications

The review consists of an abridged specification and short description of all the instruments we have found and been able to obtain information upon. A short description is included to bring out salient points not in the specification, but it must be emphasized that the review is basic and that only the manufacturers can provide full information. Lack of space prohibits the inclusion of much interesting information on circuitry and on some of the more exotic facilities afforded by the highly sophisticated (and expensive!) end of the range.

ADVANCE

OS250 (dual-trace): **bandwidth** 10MHz, **sensitivity** 5cmV/cm, **modes** single, chopped, alt., **timebase** 1.25s/cm to 1μs/cm, **magnification** × 10, **y ext.** 3.5mm., **trigger** source, coupling, slope, level, auto, t.v., **e.h.t.** 3.6kV, **display** 10 × 8cm, **power** a.c., **dimensions** 17.8cm.W, 28.6cmH, 49.4cm.D, **weight** 6.8kg, **price** £135.

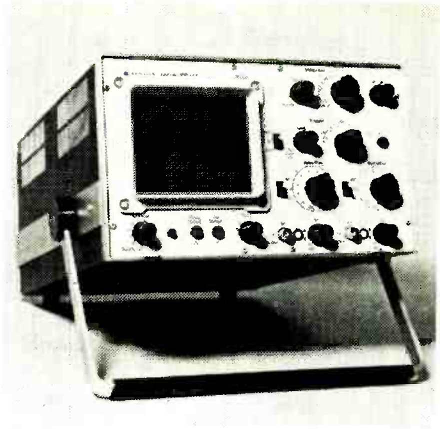
A general-purpose, dual-trace oscilloscope, intended for both laboratory and servicing work. A calibrating square wave of 1V at supply frequency is provided and there is a timebase ramp output. The dual-trace switching mode, chopped or alternate, is automatically selected by the sweep-speed switch, which also has a position for *x-y* operation.

OS1000A (dual-trace): **bandwidth** 20MHz, **sens.** 5mV/cm, **signal delay** 50ns, **timebase** 2.5s/cm to 0.5 s/cm, **mag.** ×10, **y ext.** 5mm, **trigger** source, coupling, slope level, auto, t.v., **e.h.t.** 4kV, **display** 10 × 8cm, **power** a.c., **dimensions** 29.2cm.W, 18.1cm.H, 42.3cm.D, **weight** 9.1kg, **price** £205.

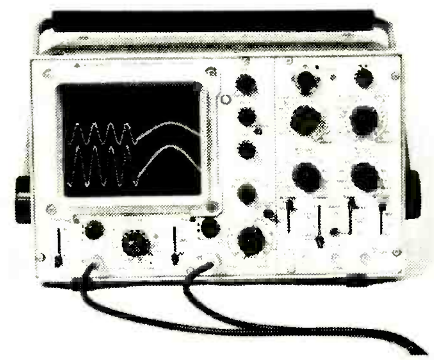
A simple dual-trace instrument for slightly more complicated servicing and development work. A signal delay is incorporated in the *y* amplifiers, which may be cascaded to give a single-channel sensitivity of 1mV/cm at a bandwidth of 5Hz-5MHz. *Y* extension is ample, and a cal. waveform and ramp output are available. The automatic *y* mode selection is again provided as is *x-y* operation.

OS3000 (dual-trace): **bandwidth** 40MHz, **sens.** 5mV/, **mag.** ×5 (0-10MHz), **modes** single, chopped, alt., summed, **sig. delay** 20ns, **delaying sweep** 5s-200ns/cm, **mag.** ×10, **delayed sweep** 2.5s/cm-200ns/cm, **mag.** ×10, **y ext.** 4.5mm, **trigger** source, coupling. level, slope, auto, t.v., **e.h.t.** 10kV, **display** 10×8cm, **power** a.c., **dimensions** 18cm.W, 29cm.H, 42cm.D, **weight** 12kg, **price** £360.

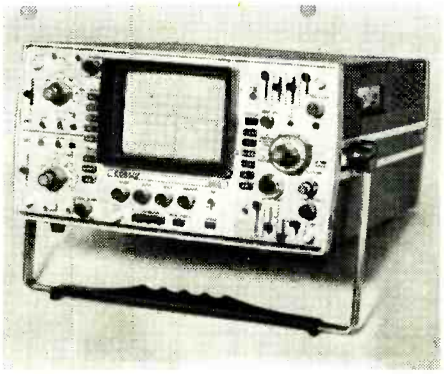
The highest-performance Advance portable instrument, which is sufficiently advanced for work on computing equipment as well as more routine servicing and development



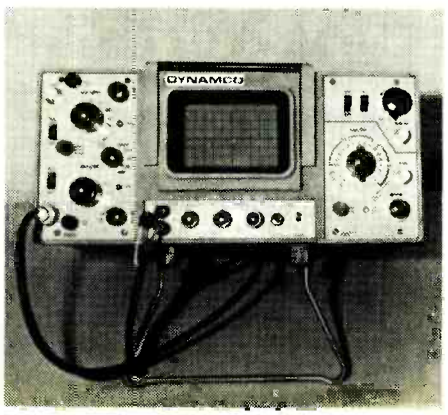
Advance OS250



Advance OS3000



Cossor 4100



Dynamco 7200

work. The twin timebase allows the examination of any part of a waveform, and the mixing of delaying and delayed sweeps in one scan is a considerable aid to location. Each timebase is independently triggered as a means of eliminating jitter in the delayed sweep. *X-y* operation is made possible by the provision of a *y* output socket. The front panel is exceptionally well laid out, with clear separation between the tube controls and *x* and *y* functions. The 3001 is a single-timebase version.

COSSOR

4100 (dual-trace): **bandwidth** 75MHz (20MHz at 1mV/cm), **sensitivity** 5mV/cm, **mag.** ×5, **modes** single, chopped, alt., summed, **timebase** (delaying) 0.5s/cm to 5ns/cm, **trigger** source, level, auto, single-sweep, variable hold-off, **timebase** (delayed) 0.25s/cm to 5ns/cm, **trigger** source, level, **modes** B after A, B triggered after A. A intensified by B., mixed, **y ext.** 1 cm, **e.h.t.** 20kV, **display** 10 × 8cm, **power** a.c., **dimensions** 35.8cm.W, 17.8cm.H, 46.3cm.D, **weight** 12.7kg. **price** £750.

An advanced instrument, with all facilities required for work on fast digital circuitry, such as mixed delayed and delaying sweeps, trigger hold-off and a very fast sweep, sufficient to display the 5ns amplifier rise-time over 1cm of screen. Push-buttons are used for amplifier switching and sweep mode selection, with slide switches for trigger control, giving a neat, uncluttered appearance.

DYNAMCO

7200 (dual-trace): **7212** y plug-in **bandwidth** 15MHz, **sensitivity** 10mV/div. (each div. 0.7mm), **mag.** channel 1 has ×10 provision, **modes** single, chopped, alt. or summed, **sig. delay** 180ns; **7201 timebase plug-in** 0.5s/div to 0.5μs/div, **mag.** ×10, **y ext.** 3.3mm, **trigger** source, slope, level, auto; **7202 timebase A sweep** 0.5s/div. to 0.5μs/div to 0.5μs/div, **mag.** ×10, **y ext.** 3.3mm, **trigger** source, slope, level, auto, **B sweep (delayed)** 2.5ms/div to 0.5μs/div, **mag.** ×10, **trigger** source, slope, level, **modes** A, B intensifies A, B after A or triggered after A, mixed, **e.h.t.** 6kV, **display** 10 × 6 divs. (0.7cm), **power** a.c., d.c (22-30V) clip-on battery pack, **dimensions** 29cm.W, 13.2cm.H, 36.2cm.D, **weight** 8.1kg, **price** (with 7201) £435 (with 7202) £485.

Adopted by the Post Office as their Type 14A, the 7200 is intended for the servicing of digital equipment. It offers the mixed-sweep type of delayed timebase, with separate triggering for the delayed sweep. The battery pack renders the instrument truly portable, while tube brightness does not suffer from the low supply power used, the tube being a high beam current, mesh p.d.a. type, working at 6kV. Its graticule is internal.

GRUNDIG

G10/13Z (dual-trace): **bandwidth** 10MHz, **sens.** 2mV/cm, **modes** single, chopped, summed (A + B, A − B) alt. with trig. from chan. A or separate, **timebase** 0.5s/cm to 0.1 μs/cm, **y ext.** 3.5mm, **trigger** source, slope, level, auto, **e.h.t.** 2kV, **display** 10 × 8cm, **power** a.c. or d.c. (21.5V to 32V at 1.5A), **dimensions** 30cm.W, 27cm.H, 41cm.D, **weight** 9.8kg, **price** £262.96.

A general-purpose instrument, rather more comprehensive than its single-trace companion, the G10/13. It has a full range of dual-trace switching modes, and is claimed to be suitable for "data-processing, colour television and stereo engineering". Front-panel layout is clear and logical — in particular the push-button trigger controls.

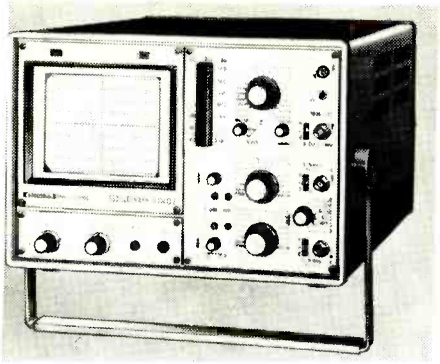
HEWLETT-PACKARD

1200 series (1200, 1205, 1206, 1217) (dual-trace) **(1202)** (single trace): **bandwidth** 500kHz (1217-7MHz), **sens.** 0.1mV/cm or 5mV/cm, **dual-trace modes** single, chop, alt. A + B versus *x* input, A + B as *xy*, **timebase** 12.5s/cm to 1μs/cm, **mag.** ×10, **y ext.** (1217) 5mm, **trigger** source, coupling, level, slope, auto, **e.h.t.** 3kV, **display** 10 × 8cm, **power** a.c., **dimensions** 21cm.W, 30cm.H, 47.5cm.D, **weight** 9.5kg to 11.4kg, **prices** £335-£1009.

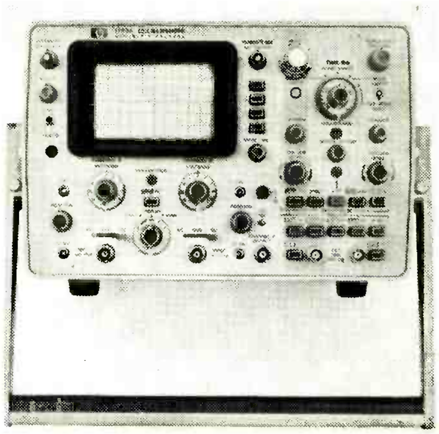
Very sensitive, low-frequency instruments, with a common-mode rejection of up to 100dB. Optional automatic triggering (free-running-locked to a signal) makes for simple operation, as does the beam finder button. The controls are well separated into functional groups and to avoid parallax, the screen graticule is internal.

1700 series (dual-trace): **bandwidth** 35MHz or 75MHz, **sensitivity** 10mV/cm, **modes** single, chopped, alt. or summed, **sig. delay** included but not specified, **timebase** (delayed) 0.5s/cm to 0.1μs/cm, **mag.** ×10, **y ext.** 1cm or 4.7mm, **timebase** (delaying) 5s/cm to 0.1μs/cm, **mag.** ×10, **trigger** (both) source, coupling, level, slope, auto, **e.h.t.** 8.3kV or 22kV, **display** 6 × 10cm, **power** a.c. or d.c. (11.5-36V at around 25W) or int. battery pack (6 hours), **dimensions** 19.8cm.H, 32.5cm.W, 39.7cm.D, **weight** 10.8kg, **prices** £746-£758.

A very advanced range of instruments, which are expressly designed for field servicing of electronic data-processing and fast digital equipment of all kinds, where it can be expected that fast, low p.r.f. pulses will be encountered. Unusual in a battery-powered instrument, the c.r.t. accelerating voltage is 22kV, with a mesh electrode. Most of the facilities required in servicing complex equipment are present in one or other of the range, including



Grundig G10/13Z



Hewlett-Packard 1703A

Philips PM3200

variable-persistence and storage. The 1710A incorporates a 50Ω or 1M switchable input impedance. The delayed timebase, which is extremely fast, can be triggered via a hold-off circuit.

PHILIPS

PM3110 (dual-trace): **bandwidth** 10MHz, **sensitivity** 50mV/cm, **mag.** ×10, **modes** single, chopped, alternate, **timebase** 50ms/cm to 0.5μs/cm, **mag.** ×5, **y ext.** 3.5mm, **trigger** source, coupling, slope, **e.h.t.** 2kV, **display** 10 × 8cm, **power** a.c., **dimensions** 30.5cm.W, 19.5cm.H, 55.5cm.D, **weight** 8.5kg, **price** £125.

This instrument is designed to be simpler than usual to operate, particularly in triggering. The level control is absent, and the timebase free-runs when no signal is present. Dual-trace switching mode is linked to the sweep-speed selector, and selection of line or frame sync. pulses is automatic when triggering from a television signal. Feedback in the *y* amplifiers avoids the necessity for d.c. balance and gain controls. This approach has produced a remarkably uncluttered front panel.

PM3200 (single trace): **bandwidth** 10MHz, **sensitivity** 2mV/div, **timebase** 0.5s/div to 0.1μs/div, **y ext.** 2.6mm, **trigger** automatic, with selection of source, slope, peak or mean level, **e.h.t.** 1.5kV, **display** 10 × 8 divs (each 7.5mm), **power** a.c. or d.c. (22-30V, 0.6A) or detachable battery pack (4.5 hours), **dimensions** 21cm.W, 17.5cm.H, 33cm.D, **weight** 5.3kg. **price** £135.

A mains-battery powered teaching or service-technician's instrument, with the automatic triggering facility for normal and television signals. Philips have not used *x* magnification in this case, preferring to provide a faster sweep. The avoidance of magnification is said to give a brighter trace (e.h.t. is 1.5kV), but does result in a small *y* extension. This must be one of the simplest instruments to operate now in production.

PM3230/31 (dual-beam) (3231 spec. in brackets): **bandwidth** 10MHz (15MHz), **sensitivity** 20mV/div. (10mV/div.), **mag.** ×10 at 2MHz (5MHz), **signal delay** (200ns), **timebase** 0.5s/div to 0.5μs/div. (0.2μs/div), **mag.** ×5, **y ext.** 2.8mm (4.7mm), **trigger** source, coupling, level, slope, auto, t.v., **e.h.t.** 4kV, **display** 10 × 8 divs (each 0.8mm), **power** a.c., **dimensions** 21cm.W, 30cm.H, 45cm.D, **weight** 11kg, **price** £198 (£180).

Two general-purpose units, using double-gun tubes to give complete control over each beam with no switching. The guns are side by side, giving full vertical coverage of the tube. The 3231 offers an improvement in drift control over the earlier 3230. A 1V calibration waveform is provided.

PM3232/3 (split beam) (3233 spec. in brackets): **bandwidth** 10MHz, **sensitivity** 2mV/cm, **sig. delay** (150ns), **timebase** 0.5s/cm to 0.2μs/cm, **mag.** ×5, **y ext.** 8.75mm, **trigger** source, slope, level, coupling, auto. t.v., **e.h.t.** 10kV, **display** 10 × 8cm, **power** a.c. or d.c. (22-30V, 0.85A), **dimensions** 32.6cm.W, 18.5cm.H, 50.3cm.D, **weight** 9.5kg, **price** £170 (£185).

One of the newest instruments, intended for general use, but sufficiently advanced for development work on complex equipment. Triggering is comprehensive, and signal delay is incorporated. A form of split-beam tube is used, using one gun, which is claimed to avoid the problems of spurious, out-of-phase triggering that can occasionally occur with beam-switching. A mesh-type, 10kV p.d.a. tube is used, giving a high light output. The bandwidth of the y amplifiers could be higher to take advantage of the fast timebase.

PM3210 (dual-trace): **bandwidth** 25MHz, **sensitivity** 1mV/cm, **modes** A, chopped, alt. summed A + B, A − B, B − A, −A −B, **sig. delay** 170ns, **timebase** 0.5s/cm to 0.1μs/cm, **mag.** ×5, **y ext.** 7mm, **trigger** source, slope, coupling, auto, **e.h.t.** 10kV, **display** 10 × 8cm, **power** a.c, **dimensions** 30cm.W, 20cm.H, 43cm.D, **weight** 12.5kg, **price** £395.

Unusually, the 3210 possesses identical delay lines in both y channels before the beam switch, to facilitate the use of one y channel as the x co-ordinate with identical characteristics. The phase error between x and y is thereby kept to less than 2°. High sensitivity and ample bandwidth are well matched by a very fast sweep.

RACAL/BWD

BWD 509B (in brackets): **BWD 539A bandwidth** 10MHz (7MHz), **sensitivity** 10mV/cm, **modes** (539) B, chopped or alt, **timebase** 2.5s/cm to 1μs/cm, **mag.** ×5, **y ext.** 1.75mm (2.5mm), **trigger** source, slope, level, auto, t.v, **e.h.t.** 3kV (1.6V), **display** 10 × 8cm, **power** a.c, **dimensions** 19cm.W, 24cm.H, 42cm.D, **weight** 7kg, **price** £199 (£125).

Two very small, lightweight, instruments of Australian origin for general use, one of them dual-trace. Panel layouts are clear and uncluttered, and the solid-state circuitry is drift-free, no front-panel balance or gain pre-sets being required. The timebase speed is a little low in comparison to the y bandwidth.

S.E. LABORATORIES

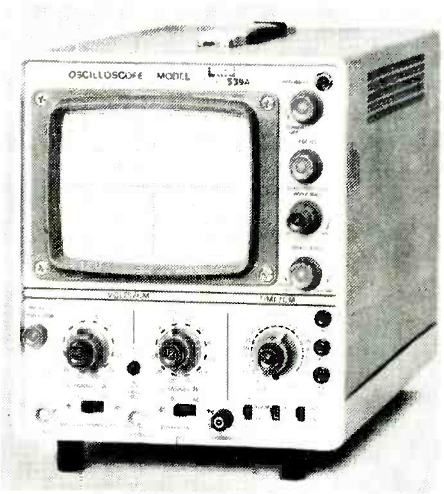
EM102D (dual-beam mainframe and y plug-ins): **EM102D (mainframe): timebase** (delayed) 0.5s/cm to 0.1μs/cm, **mag.** ×5, **timebase** (delaying) 10ms/cm to 1μs/cm, **y ext.** (delayed sweep, **EM530)** 5.9mm, **trigger** (applied to either timebase) source, coupling, level, slope, auto, t.v, **e.h.t.** 10kV, **display** 10 × 6cm, **power** a.c. or d.c. (11-16V, 25-35W) or internal batteries and charger, **dimensions** 35.6cm.W, 18.1cm.H, 47cm.D, **weight** 12.7kg, **price** £290.

EM515 (2 channel y plug-in): bandwidth 15MHz, **sensitivity** 10mV, **mag.** ×10, **modes** normal or A − B differential, **y ext.** 11.5mm, **price** £70.

EM505 (2 channel y plug-in): One channel same as EM515, other differential. Spec. refers to diff. channel. **bandwidth** 500kHz, 50kHz, 5kHz, 500Hz or 50Hz, **sensitivity** 50μV/cm, **drift** 100μV/h, 50μV/°C, **noise** 30μV, **CMRR** 100dB at 1kHz, **price** £120.

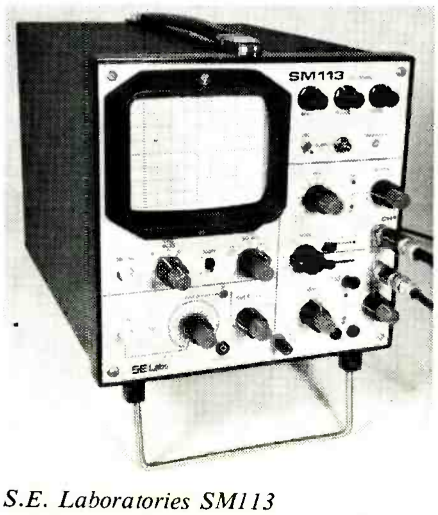
EM530 (2-channel y plug in): bandwidth 30MHz (15MHz at 1mV, single-channel), **sensitivity** 10mV/cm, **modes** normal or A − B differential, **price** £95.

The EM102 system is an extremely comprehensive collection of units, particularly as the instrument is, or can be, battery-powered. The instrument is a little heavier than usual at 12.7kg, but is of the flat, portable shape. Maximum p.r.f. is obtainable from the delaying sweep by virtue of the fact that it terminates directly after the delayed sweep, without staying to run its allotted course. True double-beam operation is provided by a split-beam tube, with full beam overlap.



Racal/BWD BWD539A

S.E. Laboratories EM102D with EM530 plug-in



S.E. Laboratories SM113

SM113 (dual trace): **bandwidth** 35MHz (8MHz at 2mV/cm), **sensitivity** 20mV/cm, **sig. delay** 170ns, **modes** single, chopped, alt. or summed, **timebase** 2.5s/cm to 0.2μs/cm, **mag.** ×10, **y ext.** 5mm, **trigger** source, coupling, slope, level, auto, **e.h.t.** 10kV, **display** 10 × 8cm, **power** a.c. or d.c. (24V at 1.3A), **dimensions** 25.4cm.W, 25.4cm.H, 35.5cm.D, **weight** 11kg, **price** £295 (SM111 £270).

This is a developed version of the SM111, which is a Ministry-approved test instrument at around the same cost. It is described as a "general work-horse", and can be supplied with line and frame television sync. triggering facilities. A battery pack is available to provide 4 hours of operation. A high-impedance input to the x amplifier is provided, and the calibration waveform is accurate over the Ministry working temperature range of −10°C to +55°C. The graticule is internal. Marconi Instruments Ltd. market the SM111 under the name TF2204.

HAMEG HM312 (single-trace): **bandwidth** 10MHz, **sensitivity** 50mV/cm, **mag.** ×10, **timebase** 0.3s/cm to 0.3μs/cm, **mag.** ×3, **y ext** 3.5mm, **trigger** source, coupling, slope, auto, **e.h.t.** 1kV, **display** 10 × 8cm, **power** a.c., **dimensions** 21.6cm.W, 28.9cm.H, 36.5cm.D, **weight** 10kg, **price** £138.

The HM312 and its 8MHz, 50mV/cm companion, the HM207, are low-cost, simple instruments for servicing and production-line testing. No unnecessary features are incorporated.

HZ36 A single-to-dual channel adapter, converting any single-trace oscilloscope to dual-trace. It is battery-powered, and simple to operate. **Bandwidth** 2Hz-30MHz, **input** 50mV to 30V, **mode** chopped, at 80Hz, 800Hz or 80kHz, **price** £45.

TEKTRONIX

211 (single-trace): **bandwidth** 500kHz (100kHz at 1mV/div), **sensitivity** 1mV/div, **timebase** 0.2s/div to 5μs/div, **mag.** ×5, **y ext.** 3.6mm, **trigger** source, slope, level, auto, **e.h.t.** 1kV, **display** 6 × 10 divs. (each 5mm), **power** a.c. or int. batteries (5 hours), **dimensions** 13.3cm.W, 7.6cm.H, 22.6cm.D, **weight** 1.4kg, **price** £266 + £26.80.

This must surely be the smallest and lightest oscilloscope currently available. Intended for audio and low-frequency industrial work, it features an extremely rapid turn-on from cold — one second for a useful display. The tube graticule is internal. All controls are on the side of the instrument, giving a total frontal area which is less than that of the average tube face and surround.

324 (single-trace): **bandwidth** 10MHz. (8MHz at 2mV/div.), **sensitivity** 10mV/div, **mag.** ×5, **timebase** 0.5s/div to 1μs/div,

mag. $\times 5$, **y ext.** 1.1mm, **trigger** source, coupling, slope, level, auto, **display** 10×6 divs (each 6.3mm), **power** a.c. or d.c. (6.5V to 16V at 8.5W), or internal batteries with charger, **dimensions** 21.6cm.W, 10.8cm.H, 27cm.D, **weight** 3.6kg, **price** £567 + £57.10.

The flat, easily portable shape has been adopted for this and the **323** 4MHz instrument. Front-panel space is conserved by the placing of input and output sockets at the side. The low-power c.r.t. cathode is again used, giving a two-second turn-on. The maximum sweep speed is a little slow.

326 (dual-trace): **bandwidth** 10MHz(5MHz at 1mV/div.), **sensitivity** 10mV/div., **mag.** $\times 10$, **modes** single, chopped, alt. summed, **sig. delay** included but unspecified, **timebase** 2.5s/div to 1μs/div, **mag.** $\times 10$, **y ext.** 2.2mm, **trigger** source, coupling, slope, level, **display** 10×8 div (each 6.3mm), **power** a.c., d.c. (7.2 − 32V at 12W) or int. batteries with charger, **dimensions** 22cm.W, 10.1cm.H, 31cm.D, **weight** 4.5kg, **price** £763 + £77.

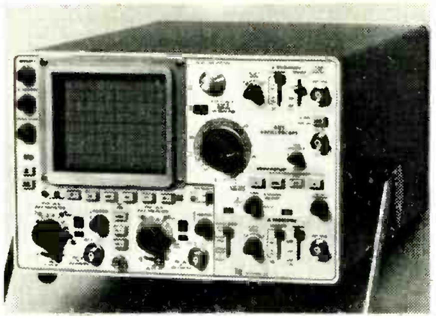
One of the smallest, lightest, dual-trace instruments extant, with a full-scale performance, and many of the facilities associated with much bulkier oscilloscopes. It is suitable for field work on most equipment not needing a delayed-sweep facility.

422 (dual-trace): **bandwidth** 15MHz (5MHz at 1mV/div.), **sensitivity** 10mV/div, **mag.** $\times 10$, **modes** single, chopped, alt., summed, **sig. delay** included, but unspecified, **timebase** 1.25s/div to 0.5 μs/div, **mag.** $\times 10$, **y ext.** 3.7mm, **trigger** source, coupling, slope, level, auto, **e.h.t.** 6kV, **display** 10×8 div (each 8mm), **power** a.c. or d.c. (11.5 − 33V at 23W), or battery pack (5 hours), **dimensions** 48.3cm.W, 17.8cm.H, 31.8cm.D, **weight** 10.6kg, **price** £781 + £78.80.

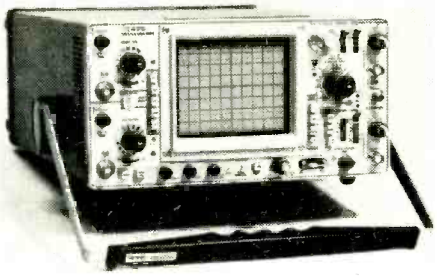
Two models are available, one as above and a mains-powered version. A rack-mounting model of the a.c.-only instrument is also offered—the **R422**. The illuminated, internal graticule gives parallax-free measurement.

432/434 (dual-trace) (**434** storage type): **bandwidth** 25MHz (15MHz at 1mV/cm), **sensitivity** 1mV/cm, **modes** single, chopped, alt, summed, **sig.delay** included but unspecified, **timebase** 12.5s/cm to 0.2μs/cm, **mag.** fastest sweep 20ns/cm, **y ext.** 7mm, **trigger** source, coupling, slope, level, auto, **e.h.t.** 4kV, **display** 10×8cm, **power** a.c. or d.c. (105-250V d.c.), **dimensions** 33cm.W, 14.5cm.H, 47.5cm.D, **Weight** 9.4kg, **price £774** + £78 (432) £995 (434).

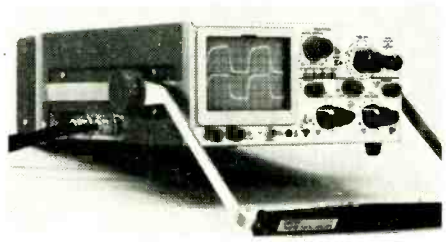
Two instruments with identical specifications, except that the **434** possesses a storage c.r.t., giving a stored display of transient events for as long as four hours. The tube operates with either full-screen storage, or in a split-screen mode, with one half storing, the other being used normally. Either half can perform either function.



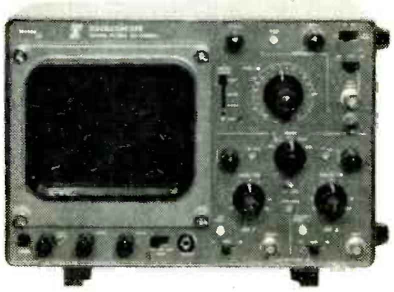
Tektronix 485



Tektronix 475



Tektronix 326



Telonic 9526A

465/475 (dual-trace) (spec. refers to 475): **bandwidth** 200MHz, **sensitivity** 2mV/cm. (400 V/cm at 50MHz cascaded), **modes** single, chopped, alt, summed, *x-y*, **sig. delay** included, unspecified, **timebases** A + B 1.25s/cm to 10ns/cm, **mag.** $\times 10$, **y ext.** 1.75cm, **modes** A, A intensified by B, B delayed, mixed, **trigger** source, level, slope, delayed trig. for B., single sweep, **e.h.t.** 18kV, **display** 10×8cm, **power** a.c. or d.c., **dimensions** 32.8cm.W, 15.7cm.H, 46cm.D, **weight** 10.3kg, **price** £795 (465) £1173 (475).

An extremely fast, sensitive pair of instruments. The **465** is reduced in bandwidth and sensitivity to 100MHz at 5mV/cm (50MHz at 1mV/cm cascaded). A large number of features are presented, including single-point-trigger selection, mixed-sweep, beam finder, trigger hold-off, and the provision for viewing the triggering signal in use by an overriding push-button. The mental calculation of sensitivity with $\times 1$ or $\times 10$ probes is eliminated by an automatic indicator on the front panel. The 18kV p.d.a. provides a readily viewable signal at the speeds possible with this oscilloscope.

485 (dual-trace): **bandwidth** 300MHz, **sensitivity** 5mV/div, **modes** single, chopped, alt, summed, *x-y*, **timebase A and B** 1.25s/div to 1ns/div, **y ext.** 9.3mm, **modes** all usual delaying modes plus trig. hold-off and "**B** ends A", **trigger** all facilities, **e.h.t.** 21kV, **display** 10×8 div (each 0.8cm), **power** a.c., **dimensions** 32cm.W, 16.7cm.H, 47cm.D, **weight** 10.5kg, **price** £2051 + £206.80.

Without question the most advanced portable oscilloscope on the market, in both performance and flexibility. The features included are too numerous to mention, but include all that the other Tektronix instruments possess and more. To compress an instrument of this nature into a case that will fit into a desk drawer is a remarkable feat.

TELONIC

9526A (dual-trace): **bandwidth** 10MHz, **sensitivity** 20mV/cm, **mag.** $\times 10$, **modes** single, chopped, alt., summed, **timebase** 1.25s/cm to 0.5μs/cm, **mag.** $\times 5$, **y ext.** 3.5mm, **trigger** source, coupling, slope, level, **e.h.t.** 2.2kV, **display** 10×8cm, **power** a.c., **dimensions** 28.5cm.W, 20cm.H, 41cm.D, **weight** 7.5kg, **price** £240.

A small, lightweight instrument, using a high beam-current tube to improve brightness, while retaining a small spot size. "Auto-fix" triggering retains the trigger point at a given proportion of the *y* signal, ensuring that stable triggering is obtained when the input varies. The unit can be used for 2mV/cm dual-trace *x-y* operation, with *x-y* phase errors of less than 3°.

Manufacturers

Advance Electronics Ltd., Raynham Road, Bishop's Stortford, Herts.
Cossor Electronics Ltd., The Pinnacles, Harlow, Essex.
Dynamco Division of D.C.A., East Mains Industrial Estate, Broxburn, West Lothian, Scotland.
Grundig (Great Britain) Ltd., Newlands Park, London S.E.26.
Hewlett-Packard Ltd., 224 Bath Road, Slough, SL1 4DS, Bucks.
Philips. Pye Unicam Ltd., York Street, Cambridge, CB1 2PX.
Racal Instruments Ltd., Duke Street, Windsor, Berks.
S.E. Laboratories (Engineering) Ltd., North Feltham Trading Estate, Feltham, Middx.
Tektronix U.K. Ltd., Beaverton House, 36-38 Coldharbour Lane, (P.O. Box 69), Harpenden, Herts.
Telonic Industries U.K., The Summit, 2 Castle Hill Terrace, Maidenhead, Berks. SL6 4JR.

New Products

Audio frequency millivoltmeter

A Rogers a.f. millivoltmeter designed for voltage measurements in the audio and low r.f. range is now exclusively available from Pact International Electronics. The AM324 is particularly suitable for measuring low level signals in high impedance circuits. An additional application is as a pre-amplifier in conjunction with the Rogers distortion factor meter DM344A for the measurement of distortion of millivolt signals.

The high input impedance of 10MΩ, together with the low input capacitance, ensures that the instrument does not load the circuit in which the measurement is being made. Measurements can be made from 300μV to 300V and this, coupled with the wide bandwidth, 10Hz to 500kHz, means that measurements can be made on tape recorder bias oscillators, and low r.f. equipment. Long term calibration accuracy has been achieved by designing the amplifiers with considerable feedback so that the gain accuracy of the amplifiers and calibration accuracy of the instrument is dependent only on the stability of high quality metal film feedback resistors, and not on the stability of the semiconductors and other components.

A high grade taut-band meter movement is incorporated to obtain good resolution. As the common negative rail has a low capacitance to case, the instrument may be used as a floating meter when the earth link is removed. Under these conditions the amplifier output will also be floating. The use of batteries as a power source greatly reduces the problems of "hum" and earth loop currents which may invalidate readings when very small voltages are being measured. A battery check facility is incorporated. For routine laboratory/bench use a regulated mains power unit is available as an optional extra.

Three designs of bench housing cases are available, H2B, H4B and H6B accommodation units, having respective modular widths of 2, 4 and 6.

Basic technical specifications include:

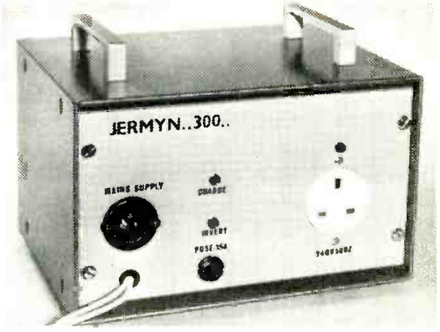
Voltage range:	1mV to 300V f.s.d. in twelve ranges: −70dB to +40dB referred to 1V.
Frequency response:	10Hz to 500kHz ±3% of f.s.d.
Input impedance:	10MΩ and 20pF for all ranges.
Oscilloscope output:	Nominal 1V, output impedance 5kΩ, derived from pre-amplifier, giving linear response.
Residual noise:	Less than 10μV.
Overload:	300V d.c. plus peak a.c. any range.
Dimensions:	Front panel 8.5 × 5.6in (standard module × 2) Chassis depth (behind panel) 6¼in Bench case (including feet) 6½in × 9¾ × 9½in.

Pact International Electronics Ltd., Pact House, Church Lane, Wallington, Surrey.
WW336 for further details

150W and 300W inverters

Jermyn Distribution have introduced an inverter unit for providing a 250V supply at 50Hz from a car battery. Available in two models, for 150W and 300W operation, the former version operates from a 12V battery, while the higher-power unit requires a 24V power source.

A feature of the inverters is that they have been specially designed to charge the 12/24V batteries (up to 10A) when plugged into any household power socket. Should the mains supply fail for any

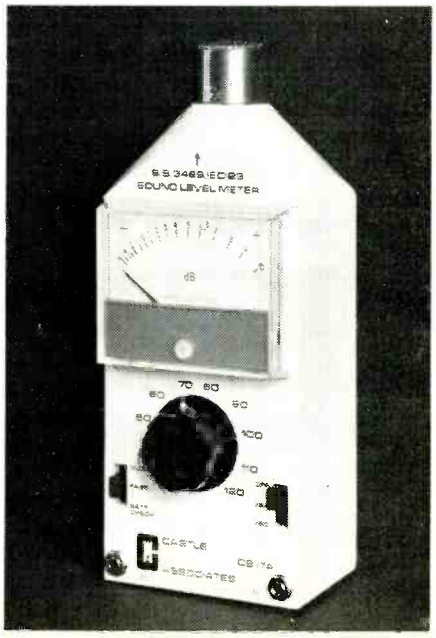


reason, then the unit automatically goes into its invert mode, thus providing a 240V emergency supply immediately. It is an interesting thought that if the main household power switch remains operated, the inverter would try to supply the neighbourhood and so it is just as well that in the event that the inverter is accidentally overloaded, the unit's drive is adjusted so that the output voltage falls to zero, thus protecting the unit. Additional circuitry ensures that the unit's 15A fuse will blow if the battery leads are connected incorrectly, thus giving added protection to the inverter. Indicator lights are illuminated if the unit is charging the battery or if it is providing a 240V 50Hz output.

Both versions of the inverter are available from Jermyn Distribution as a kit of parts or built up units. Prices are as follows: 150W kit—£25.00, 150W built up unit—£29.00, 300W—£34.00, 300W built up unit—£39.00. Jermyn Distribution, Vestry Estate, Sevenoaks, Kent.
WW303 for further details

Sound level meter

Castle Associates have introduced a new sound level meter, the CS17A. This unit, while being in the price range usually reserved for general level indicators, is a general purpose sound level meter which fully complies with the appropriate British Standard, BS 3489. The CA17A has both "A" and "C" weighting with provision for



the connection of recorders and oscilloscopes or even a noise dosemeter. The meter can make measurements from 24dB to 140dB s.p.l. using the same microphone type as is fitted to most British units and thus microphone accessories are interchangeable. The CS17A is priced at £68 complete. Custom Electronic Associates Ltd, Castle Associates Division, Redbourne House, North Street, Scarborough, Yorks. YO11 1DE.
WW334 for further details

Low cost digital multimeter

A digital, battery operated, multimeter is the first instrument designed for the professional electronics market from Sinclair Radionics Ltd. Measuring 190 × 130 × 50mm and 0.62kg (1.5lb) in weight, the instrument is powered from a single 9V dry cell with a typical current drain of 12mA inclusive of the 3½ digit, Nixie tube display driven by what is claimed to be a "unique measuring technique".

Containing over 300 discrete devices, the circuit is operated with a switched scaler unit bringing all inputs to within a 0-1V range which is then converted into a pulse train, the length of which is proportional to the input voltage. An analogue technique using "cup and bucket" circuitry is then employed to decode this pulse train directly into decimal notation suitable for driving the Nixie tube display.

The available ranges cover f.s.ds from 1.0V-1000V d.c. and a.c. (resolution 1mV), 1.0μA-1.0A d.c. (resolution 1nA), 1.0mA-1.0A a.c. (resolution 1μA) and 1.0kΩ-1MΩ resistance (resolution 1Ω). The input resistance is up to 1000MΩ on the higher ranges and unlike analogue instruments, the resolution is superior to the overall accuracy, the latter being typically between ±0.4 and 0.5% on the d.c. ranges and ±1.0% on the a.c. ranges.

The instrument is contained in a light polypropylene case with integral test leads. Sinclair Radionics Ltd., London Road, St. Ives, Huntingdonshire PE17 4HJ.
WW311 for further details

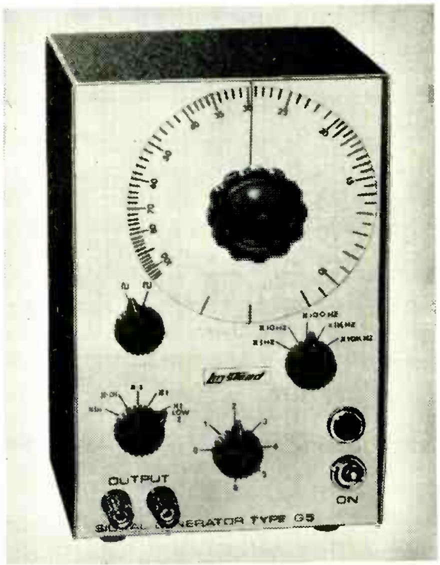
Circuit breakers

For resettable overload protection a new range of panel mounting thermal bi-metallic circuit breakers is available from R. S. Components. These are mounted in grey moulded flame retardant plastic case with a reset button and single-hole panel fixing for easy mounting. Breakdown voltage is 900V. The contacts are rated at 259V a.c./d.c.

Available in the following current ratings: 0.5A, 2A, 2.5A, 3A, 4A. Price 65p from R.S. Components Ltd., P.O. Box 427, 13-17 Epworth Street, London EC2P 2HA.
WW 332 for further details

Wide range signal generator

The G5 is a stable solid state signal generator covering a wide frequency range with high accuracy, manufactured by Linstead Electronics. The output may be attenuated at 600Ω or driven into low impedance loads giving substantial power.



The frequency range is 10Hz to 1MHz ±2% ±1Hz and to achieve accuracy this is covered in five decades controlled by switched close tolerance resistors and a variable capacitor. The dial is 10.5cm diameter and geared for 330° rotation giving a total scale length of 130cm. The calibration is approximately logarithmic giving an open scale and equal divisions of frequency with rotation. The sine wave output is available at two source impedances: (a) 0 to 6V r.m.s. continously variable at low impedance, which will drive loads of 30Ω over the whole frequency range. From 10Hz to 100kHz output power is sufficient to give 2W into 5Ω with low distortion and up to 3W with 10% distortion. This output will drive loudspeakers or a vibration generator such as the Linstead VI for examination of mechanical vibrations; (b) 0 to 6V r.m.s. via 600 Ω continuously variable and through a step attenuator of ×1, ×.1, ×0.01, ×0.001. A square wave output is also provided with signals of 0 to 9V peak

Continued on page 103

Decade inductance

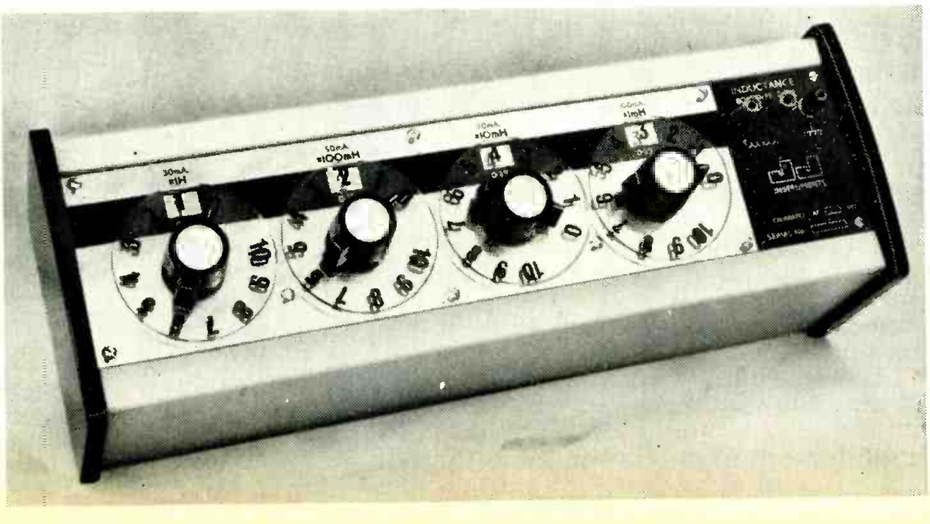
J. J. Lloyd Instruments announce further additions to their range of aids to precision measurement.

The "100" series precision decade inductances are adjustable, working standards featuring a precision of 0.3%.

Design is based on inductors wound on ferrite cores incorporating incremental trimmers to allow compensation of any slight long-term deviations due to ageing effects. Particular care has been taken with winding, layout and switch systems to keep stray capacitance to a minimum and maintain a high Q factor.

Decade setting concentrates on operator convenience. Easy-to-turn positive-action controls have large scales with sensible size numbers giving clear indication, even from a distance, of individual decade settings and consequent total inductance at the terminals.

The decades are presented in plastic-coated steel cases combining mechanical strength and electrical shielding. Two models are currently available: L300 features three decades with a range of 0–1H; L400 features four decades with a range of 0-10H. Both models are rated at 0.3% accuracy. J. J. Lloyd Instruments Ltd., Brook Avenue, Warsash, Southampton S03 6HP.
WW 330 for further details



This new digital multimeter from Sinclair costs only £49

Wide range
The new 3½ digit Sinclair DM1 Multimeter provides a total of 23 ranges to give you a really versatile instrument. An added bonus is the convenience of push-button range selection.
On all but the 1000V range, automatic overranging to 1900 is provided.

Lightweight and compact
With a weight of only 0.6kg and dimensions of 190x130x58mm the Sinclair DM1 brings true portability to the world of digital multimeters.

Good accuracy
Typical accuracies of the Sinclair DM1 are ±0.5% of reading (±2 digits) on the DC and resistance ranges, and ±1.0% of reading (±2 digits) on the AC ranges (measured at 50Hz).
Better accuracies than this are are not available at anywhere near £49.

High Input resistance
1000MΩ is a very conservative specification for the input resistance of the Sinclair DM1 on its most sensitive range, thanks to the clever design of the input circuits, which draw only 50pA.
The loading problems which beset measurements with normal analog instruments are now a thing of the past.

Robust construction
The high strength polypropylene casing has been designed to take the knocks that will inevitably occur during use. The flush fitting push-button range selection switches are moulded integrally with the case to provide an even greater degree of robustness.
This push-button design, with a lifetime in excess of 1 million operations, is yet another first for the Sinclair DM1.

Complete freedom from the mains
A total current drain of between 10mA and 12mA provides over 80 hours of useful life from the throwaway dry battery, giving total freedom of movement over weeks of use. Only Sinclair expertise can give you this. Accuracy is maintained at all battery voltages during discharging.
The Nixie tube display automatically extinguishes before accuracies deteriorate.

	Range of full scale	Maximum resolution
AC & DC Voltage	1V to 1000V	1mV
DC Current	1μA to 1A	1nA
AC Current	1mA to 1A	1μA
Resistance	1kΩ to 1MΩ	1Ω

Fill in the coupon below to order your new Sinclair DM1 multimeter.
Your money will be refunded in full if you are not satisfied with the instrument's performance, and return it in its original packing

Send the coupon to Multimeter Sales, Sinclair Radionics Ltd., London Road, St Ives, Hunts. Tel (0480) 64311.

Tick whichever is applicable. WW1

☐ I enclose a cheque for £49 for a Sinclair DM1 digital multimeter. I understand that unless I am completely satisfied with the performance of this instrument if I return it in its original packing within 14 days of receipt, I shall receive a full refund.

☐ Please send me a descriptive leaflet on the Sinclair DM1

Name

Position

Company

Address

Tel no

sinclair

WW—105 FOR FURTHER DETAILS


Are you
a resistor
man?

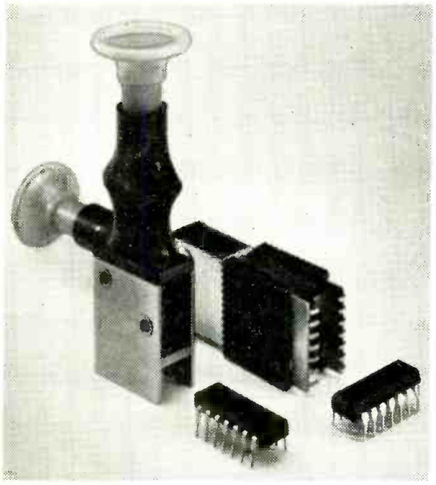
to peak up to 100kHz. Rise time at high frequencies less than 0.5μs, and the circuit is d.c. coupled to avoid droop at low frequencies. The output is via 600 Ω continuously variable and through a step attenuator of ×1, ×0.1, ×0.01, ×0.001.

Supply 220-240V. 40-60Hz. 20 V.A.
Dimensions 13 × 13 × 21cm high
Weight 2.7kg
Price £32.00.

Linstead Electronics, Roslyn Works, Roslyn Road, London N15 5JB.
WW309 for further details

D.I.L. insertion and extraction tools

Two accessories for use with d.i.l. circuits have been introduced by Guest International. The "Dip-a-Dip" insertion tool is claimed to make easy work of assembling 14/16-pin i.cs into printed circuit boards. The i.c. is gripped by the jaws of the tool and the pins are held in position while a plunger mechanism inserts the i.c. into its correct position.

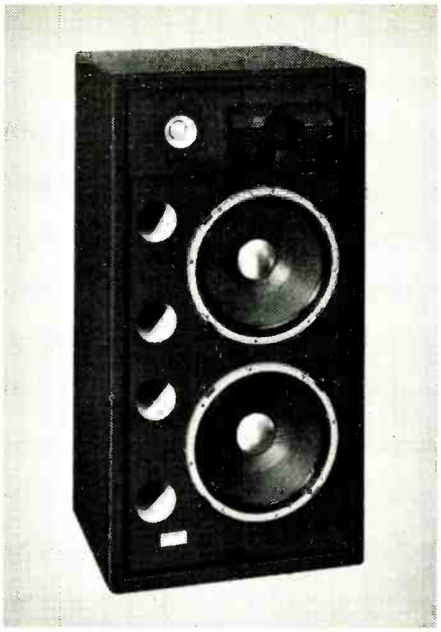


The "Clip-a-Dip" extraction tool has jaws which clamp under the pins of an i.c. and ensure a positive grip on the device during de-soldering operations. Both "Dip-a-Dip" and "Clip-a-Dip" are also available for d.i.l. i.cs with up to forty pins. Industrial Electronic Components Division, Guest International Ltd., Nicholas House, Brigstock Road, Thornton Heath, Surrey, CR4 7JA.
WW 329 for further details

Professional loudspeakers

A new series of loudspeakers for professional use has been developed by Feldon Audio Ltd, distributors for James B. Lansing Sound Inc. These units are available in a variety of configurations and use JBL components throughout. The design is based upon the 4326 Studio Monitor, also developed by Feldon and in association with EMI Research.

The new units have two bass drivers of 15in diameter with 4in voice coils which are edge wound. The power rating of each of these is 180W. Midrange frequencies from 800Hz to 7000Hz are handled by a phenolic diaphragm com-



pression driver loaded by an exponential horn with an acoustic lens to give a dispersion pattern 40° by 110°. All frequencies above the 7000Hz point are fed to a horn loaded ring radiator with a −5dB point at 21kHz. Crossover is effected by a 12dB/octave constant impedance passive circuit. The enclosures themselves are a 9 cubic ft distributed port reflex which, it is claimed, gives an improved linearity at low frequencies.

Specifications for the basic system are as follows: power requirements, 60-400W r.m.s. (8 Ω); efficiency, 1W gives 89dB at 15ft referred to 2×10^{-5}N/m² max. useful output, in excess of 115dB referred as above; frequency range, 30-20,000Hz (−10dB at 26Hz), variable crossovers, which can be active amplifier types if required; size, 48 × 26 × 20in. Feldon Audio Ltd., 126 Gt. Portland St., London W1N 5PH.
WW 301 for further details

Cordless soldering iron

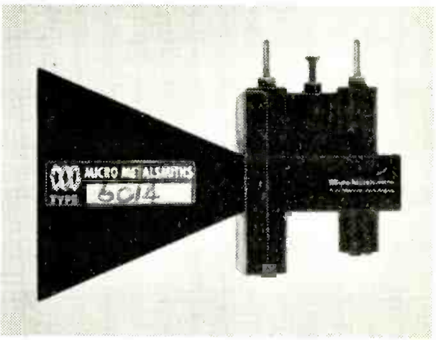
Electroplan Ltd have been exclusively appointed to handle U.K. distribution of a new cordless soldering iron. Known as the Iso-Tip, the iron is light, weighing only 6oz, easy to handle, and requires no mains power source during operation. The Iso-Tip operates from long-life nickel cadmium rechargeable cells and can perform more than 60 average soldering joints before recharging is necessary. Heating the tip is achieved by operating a

push button. Soldering temperature is reached in 3-5 seconds. A light is incorporated near the tip which is useful when soldering in dark and awkward corners.

The iron comes complete with a fine tip for printed circuit and other light work, or a heavier tip is available as an optional extra. A recharging stand is included which will charge the Iso-Tip from dead to full charge overnight. Price £9.25 (complete kit with fine tip and recharging stand). Ordering code 15-38. This unique advance in soldering is available from Electroplan Ltd., P.O. Box 19, Orchard Road, Royston, Herts.
WW307 for further details

Radar Doppler units

A new range of r.f. X-band Doppler radar units combining Gunn oscillator and mixer detector diodes in one cavity is announced by Micro Metalsmiths. The models cover U.K. and Continental frequency bandwidths. The single cavity design allows for a similarity of radiated and received signal patterns. The unit is small and light for use in miniature



equipment and can be supplied with or without horns depending on the range and sensitivity requirements of the customer. In any event the bodies and horns, where appropriate, are one piece light alloy castings.

The Doppler radar units are suitable for burglar detection systems and for speed measurement and are supplied complete with diodes electrically tested by Micro Metalsmiths Ltd, Kirkbymoorside, York.
WW328 for further details

Three-pole mains connector

The new 3-pole mains input connector by Belling-Lee is designed to meet the requirements of C.E.E. Publication 22 and I.E.C. 320. Coded L1949, the free socket is moulded on to 2 metres of 3 core black p.v.c., sheathed, 6A mains cable to BS 6500. The L1950 fixed receptacle, with pin contacts, is fully shrouded to BS 415, and is polarized. Current rating is 6A, contact resistance is less than 5M Ω and the temperature range is −55°C to + 70°C. A non-polarized 2-pole version is also available. Belling and Lee Ltd., Great Cambridge Road, Enfield, Middx. EN1 3RY.
WW 308 for further details

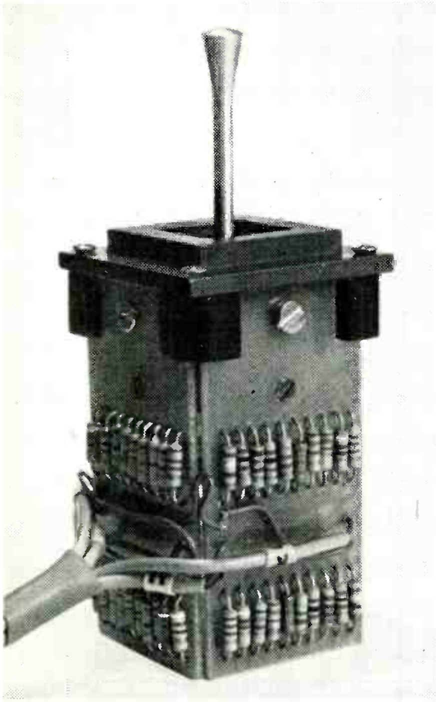
Variable cermet resistors

A new range of variable cermet trimmer resistors is now available from Neltronic UK. The resistance range is from 100Ω to 500kΩ. The resistance tolerance is ±30% (standard), ±20% (special). The resistance varies linearly, with a 100 maximum end resistance. The power rating is 0.5W at 70°C, operating temperature range −20°C to +85°C, maximum working voltage 250V d.c., mechanical adjustment 220° ±10°, rotation torque 50 to 350g cm, contact resistance 6% maximum, noise during adjustment 3% maximum and temperature coefficient ±250 p.p.m. Weight is approximately 1g. Neltronic UK Ltd., 442 Bath Road, Slough SL1 6BB.

WW 310 for further details

Four channel panpot

The panpot illustrated is made by Audiotek and is basically a six element device, the contacts of which are of the stud type (specially designed for minimum noise) the law being determined by fixed resistors. The number of contacts provided enable any one of one hundred and twenty-one positions to be selected or continuously panned. Three basic law configurations are available which provide either a 3dB, 4dB or 6dB insertion loss in each pan direction with the joystick centrally positioned. Alternatively, resistors can be fitted to



customer specification to meet a particular requirement. Specifications for standard versions are as follows: Z_i = output impedance of preceding stages is not to exceed 100Ω. Z_o = load impedance of following stages is not to be less than 15,000Ω. Insertion loss with joystick in centre (input to any output) = 2 × element value. Audiotek, Farringdon House, St. Albans Road East, Hatfield, Herts.

WW 304 for further details

Solid State Devices

The new silicon photodiodes BPX 90, BPX 91 and BPX 92 from Siemens are planar structures, making it possible to use these modules both as photocells and as photodiodes. The photosensitivity is as high as 50nA/lx. The photodiodes with their two wire leads can be combined to form complex sensing systems for card readers, angular encoders and other complex reading devices. The silicon photodiode BPX 79 has been improved by increasing its sensitivity in the short-wavelength part of the spectrum. The photosensitive surface has an area of 20mm² and the device has a sensitivity of up to 135nA/lx.

As a supplement to the phototransistor arrays BPX 80 to BPX 89, there is now a series of i.r. emission GaAs l.e.ds designated LD 260 to LD 269, with identical layout permitting up to ten systems per linear array. GaAs light emitters in combination with phototransistors have become known as optoelectronic coupling elements. They permit the transmission of electrical signals with absolute galvanic separation and high electrical breakdown strength. Siemens now offer their first optoelectronic couplers in two versions. Type CNY 17 has a six-legged plastic case and permits an insulation voltage of 2.5kV between the transmitter and the receiver. The transmission efficiency is subdivided into four groups, from 40 to 320%. Type CNY 18 is a coupler in a metal case for a maximum permissible insulation voltage of 500V and its coupling efficiency ranges from 10 to 80%. Seimens (UK) Ltd., Gt. West Rd., Brentford, Middlesex.

Photodiodes WW 324
I.R. emission l.e.d. WW 325
Opto-couplers WW 326

Suitable for use in l.s.i. computer circuits are samples of a new c.o.s./m.o.s. device, type CD4057A made available by RCA Ltd. This is a low power arithmetic array giving up to 4^n combinations of wired connections in a 28 lead d.i.l. package. A second digital device introduced is the c.o.s./m.o.s. 8 stage static bidirectional shift register designated type CD4058A.

Designed for class C v.h.f./u.h.f. use, two high gain transistors types 40964 and 40965 are now available. These are high gain devices suitable for tripling up to 470MHz and are packaged in TO-39 metal cans. A high current (300A) array of six 50A high power transistors is announced by RCA, available in a metal and plastic package with the collectors connected in common to the metal flange. Two additional external leads connected to either side of the unit provide common connections to all six bases and emitters respectively. External connecting bars can be broken to rearrange the package circuitry to give either completely separate operation or other multi-parallel combinations. Finally, a dual Darlington driver for inductive loads, type TA8590 is introduced. This device contains two amplifiers each capable of delivering 5A at a current gain of 500 or 3A at a current gain of 600. RCA Ltd., Sunbury on Thames, Middlesex.

Arithmetic array WW 319
Static register WW 320
Class C transistors WW321
300A transistor array WW 322
Darlington driver WW 323

Hewlett Packard Ltd have introduced a number of devices including a series of microwave mixer Schottky diodes, two for the 1 to 4GHz range designated 5082-2213 and 5082-2215, and two for the 4 to 12GHz range, types 5082-2217 and 5082-2219. A n-p-n stripline transistor has also been added to the range of microwave small signal devices operating in the 2 to 4GHz region and is assigned the type number 35876E. An optically coupled isolator type 5082-4360 with t.t.l.-d.t.l. compatibility completes the product range from this company. Hewlett Packard Ltd., 224 Bath Rd., Slough, Bucks SL1 4DS.

Schottky diodes WW 316
Microwave transistor WW 317
Coupled isolator WW 318

From G. E. Electronics (London) Ltd, five products are announced. This company distributes, among others, products of Unitrode, who have introduced a PIC500 series of dual Darlingtons in 8 pin TO-3 packages. Also from Unitrode is a hybrid package designed to switch high power loads for precisely tuned intervals. Called the Power Pulser, it will operate with pulse widths from 0.5ms to 50ms.

Crystalonics have produced an n-channel power f.e.t. type CP643 giving a dynamic range of 135dB which they claim is a considerable improvement over previous types available. Specified for operation from 0.5 to 100MHz, it is also usable to 450MHz. Photo-sensitive f.e.ts are also included in the products from Crystalonics, these being a range with operating voltages from 15 to 30V and called Fotofets.

A dual 4-input NAND gate made by Inselek is also released. This is constructed with s.o.s./m.o.s. n-channel and p-channel enhancement mode devices giving low power dissipation with high operating speed. Eardley House, 182/4 Campden Hill Rd., London W8 7AS.

Unitrode dual Darlington WW 331
Power Pulser WW 312
Power f.e.t. WW 313
Fotofets WW 314
NAND gate WW 315

World of Amateur Radio

Amateurs lose frequencies

As forecast in this section in the November 1972 issue, the Ministry of Posts & Telecommunications introduced its new schedule of amateur frequencies on January 1. The main changes are a drastic reduction of the 432-450MHz band and the replacement of a 1000MHz wide allocation between 21 and 22GHz with 250MHz between 24000 and 24250MHz. The revised 432MHz band is now 432 to 440MHz. In addition, 430 to 432MHz is available to British amateurs operating outside the area bounded by 53°N 02°E, 55°N 02°W, 55°N 03°W and 53°N 03°W (representing roughly most of Yorkshire and parts of Lincolnshire, Derbyshire and Nottinghamshire) with a maximum e.r.p. of only 10 watts. Any operation on the new 24GHz band requires prior written consent of M.P.T. who can stipulate the power which may be used. Pulse operation on a number of other microwave bands continues to require similar written consent. All amateur allocations above 30MHz, except 24000 to 24050MHz (which is a "shared" band) are available to amateurs only on a secondary, non-interference basis.

Amidst the general gloom at this latest loss of frequencies, the only bright spot appears to be the relaxation on the use of artificial satellites, now extended to the 7, 14, 21 and 28MHz h.f. bands, 435 to 438MHz, and 24000 to 24050MHz.

Slow-scan television and facsimile

As a result of a request from Richard Thurlow, G3WW, the M.P.T. has now amended the official British specification for amateur slow-scan television (s.s.t.v.) operation so that it now includes both 120-line and 128-line operation. The 128-line system is used in the Robot s.s.t.v. equipment which also differs from the earlier specification in its vertical sync pulses. M.P.T. has granted G3WW a two-year s.s.t.v. permit covering the 7, 14, 21, 28 and 144MHz bands. Since receiving permission to use the new specification he has had many two-way s.s.t.v. contacts with the United States, Puerto Rico, Israel, Australia, South Africa, Portugal, Germany and France, and has had one 7MHz contact with a British station.

The Ministry's s.s.t.v. specification is now: number of lines per picture 128 ± 8 lines; aspect ratio 1:1; horizontal frequency (frame) 16$\frac{2}{3}$ ± 1Hz; vertical period 7.68s (limits 6.79 to 8.68s); horizontal sync pulse 5ms; vertical sync pulse 30ms (nominally); f.m. sub-carrier sync 1200Hz, black 1500Hz, white 2300Hz.

In the United States enthusiasm is apparently running high not only for s.s.t.v. but also for facsimile operation (FAX or F4). We have yet to learn of any British amateur being granted permission to use F4 in h.f. bands.

Slow-scan pictures have been successfully sent through Oscar 6 by American amateurs.

Oscar 6

The amateur satellite Oscar 6 is continuing to function and several British amateurs have already contacted about 20 different countries (including the United States and Canada) through the 910-mile high, 145.95MHz to 29.5MHz repeater. However, there appears to have been some falling off in activity due to the problem of knowing in advance when the repeater is likely to be working and when switched off to restore batteries. AMSAT (Radio Amateur Satellite Corporation) appears to be endeavouring to keep the repeater active on Fridays, Saturdays and Sundays. It remains essential that excessive power should not be used by the 144MHz stations working through the satellite. AMSAT (PO Box 27, Washington DC, 20044, U.S.A.) is anxious to have reports of any contacts made through the satellite over terrestrial distances exceeding 4900 statute miles.

Notes and news

The 1973 Diamond Jubilee president of the R.S.G.B. — Dr J. A. Saxton — was formally installed in office on January 5 in the presence of Sir John Eden, Minister of Posts & Telecommunications; it is believed this is the first time the Minister has attended an R.S.G.B. presidential installation. During the evening the Society's "Calcutta Trophy" was presented to Lt.-Col. Per Anders Kinnman, SM5ZD, former chairman of the I.A.R.U. Region 1 executive committee.

Amateur Radio continues to figure quite frequently in events in the public eye — the most recent example being the use of amateur stations to give first news of the bad earthquake in Nicaragua.

Shortly before the loss of the 21GHz band in the U.K., a new "world record" for the band was established by British amateurs L. W. G. Sharrock, G3BNL, and A. Wakeman, G3EEZ, working between Cleeve Common, near Cheltenham, and Clee Hill, in Shropshire — a distance of 45 miles (72km). Both transmitters had an output of about 10mW using n.b.f.m. and 10inch dish aerials. These two enthusiasts have spent many months developing advanced solid-state microwave transceivers capable of working on no less than five amateur bands (13, 9, 6 and 3cm and 15mm).

A recent United States ruling on third party traffic (prohibited in the U.K.) forbids "third party traffic involving material compensations, either tangible or intangible, direct or indirect, to a third party, a station licensee, a control operator or any other person". Another new U.S. ruling prohibits "radio communication in connection with any activity which is contrary to Federal, State or local laws".

After 18 months of building, testing and modification Dick Norman, VK2BDN, operating portable in the Lower Blue Mountains of New South Wales made a new Australian microwave record by contacting Bill Cox, VK2ZAC, over a distance of 28.5 miles on 2304MHz. Power output of the portable transmitter was 0.75W.

In brief

Each edition of the "World Radio Club" 15-minute programme now goes out on the B.B.C. World Service four, instead of three, times weekly: 13.30 G.M.T. Wednesdays, 20.30 Thursdays, 23.45 Fridays (including 1088kHz), and 08.15 Sundays. . . . The Derby and District Amateur Radio Society now has a licensed membership of 186; the Society has recently started meetings for members interested in radio-controlled models. . . . *Short Wave Magazine* complains that timebase interference from colour TV sets makes weak-signal reception on 1.8MHz impossible in urban areas, adding "nothing is being done about this either by M.P.T. or set manufacturers" — its effect is often to modulate any signal with a characteristic low-frequency buzz and the magazine believes this accounts for a recent falling off of activity on 1.8 MHz. . . . New regulations affect non-citizens of the United States wishing to operate in the U.S.A. as permanent resident aliens. . . . A reunion of the Radio Amateurs Old Timers Association is being held on Friday May 18 at The Bonnington Hotel, Southampton Row, London WC1. R.A.O.T.A. is open to amateurs who have held a U.K. licence for not less than 25 years (details Miss May Gadsden, 79 New River Crescent, London N13 5RQ). . . . The U.K. FM Group (London) is holding a convention on February 24 at Brooklands Technical College, Weybridge, Surrey.

Pat Hawker, G3VA

Real and Imaginary

by "Vector"

The Post-horn Syndrome

As I write this, Christmas cards are still plopping apologetically through the letter-box; one such took fourteen days to travel half a mile: The non-arrival of the piano-top decor stirred the British public to fury. Aided and abetted by the newspapers they elected the Post Office's Bill Ryland as sacrificial lamb, and (to mix the metaphor) took him to the cleaners. And, if that wasn't enough to fill his cup to overflowing (to mix it up even more), Her Majesty's Government, with that superb sense of timing for which it is renowned, created him a knight bachelor right at the peak of the argy-bargy.

When two disasters befall, says tradition, shut your eyes tight and await the third. True to form it came when *The Sunday Times*, ostensibly to celebrate our entry into the Common Market, put in trial calls to the eight other E.E.C. capitals. Oh yes — they got their eight calls all right; after 128 tries, that is. On their ninth attempt to contact Luxembourg, they reported, they found themselves speaking to the startled proprietor of a fish shop in Sheffield.

It's all too easy to mock the afflicted and the comics have had a field day. And as far as that hoary old institution the Post Office is concerned, fair enough, but I honestly don't think that Sir Bill Ryland deserved all the vituperation he got, although others may argue that in his kind of job the chopper is an occupational hazard.

The fact is that most of his problems were inherited and, although the Christmas fiasco will be old hat by the time you read this, the problem won't be. And they will continue to multiply just so long as the Post Office retains its Rowland Hill mentality.

When the postal service was introduced, the amount of mail carried was of easily manageable proportions and the system was straightforward to operate; the labour force took what money was offered, touched its forelock and was duly grateful. In Rowland Hill's day the service was a compact entity and as such, was vastly different from today's with its amoeba growth and diversifications, and its mammoth distribution and labour problems. Yet, within sight of the twenty-first century, the sound of the post-horn is still clearly heard within the Post Office structure.

One major reason for this is that it has always discouraged revolutionaries. Its promotion system has always opted for sound, capable, solid Establishment chaps. Vertical thinkers all, with none of this lateral nonsense. And in particular, never in its entire history has it put a revolutionary into high engineering office. Never has it had anyone who seriously questioned whether it was a sensible proposition to manhandle countless tons of paper around the country every day; whole mountains of paper, most of which would be thrown away the day after.

Even by 1945, the task had become a colossal problem. Then out of the evil of war, came good; a chance to take stock and to rebuild. That, above all, was the time when the Post Office missed the boat. If only some visionary had come to authority then; one who saw clearly that grand-dad's methods were no longer valid and who had the courage to charge his engineers to find something far better.

Facsimile, possibly. Even this could scarcely be termed a new-fangled device, for it was invented about 1847 and by the 1870s a facsimile system was operating commercially in France. By the 1940s it had been enormously improved. If only whole-hearted experimental mail-transmitting facsimile had been introduced then, the archaic paper-carrying system we endure today could have been reduced to minimal size, being used only for the transport of original documents in the rare cases where only this would suffice.

The system, backed by teleprinters and of course supplemented by the telephone service, could have been introduced gradually; first between two main cities perhaps, and then, in the light of experience, extended. The costs would have been spread over the years and significantly off-set by the commensurate run-down of the paper-carrying industry. Above all, advantage would have been taken of the huge re-housing schemes and planning of new towns to ensure that coaxial cable was piped in as a matter of course with the other services; not necessarily for immediate use, but against the day.

Snags? Of course there would have been snags. Lots of them. But none that made the project technically unfeasible, given the will.

Today, even given the necessary presiding genius, the job would be immensely — indescribably — more difficult and the cost fantastic. Unless. of course, it was done on a piecemeal scale over a great number of years. In that event, the main question is this; can the present system continue to creak along for another quarter or half a century?

The replacement of the present domestic and office telephone by a combined telephone/facsimile unit doesn't present any insurmountable technical difficulties. But even if a kind fairy waved a magic wand and completed such installations overnight, nothing but chaos would result, because the lines couldn't cope. The bandwidth limitations of the ordinary telephone line slows the facsimile speed to an impracticable point; for example, it would take about 4-6 minutes to transmit one page of *W.W.* and although further technical advances will probably reduce this to about $1\frac{1}{2}$ minutes, it's still too long.

What is needed is at least 50kHz lines, such as are in long-distance operation in the U.S.A., in order to make the process much nearer to the instantaneous. And that demands all-coaxial linkage between subscriber and subscriber; unfortunately such lines between the exchange and the home or office just don't exist, while the present trunk coaxial lines have insufficient total capacity anyway. Neither could the present exchanges cope.

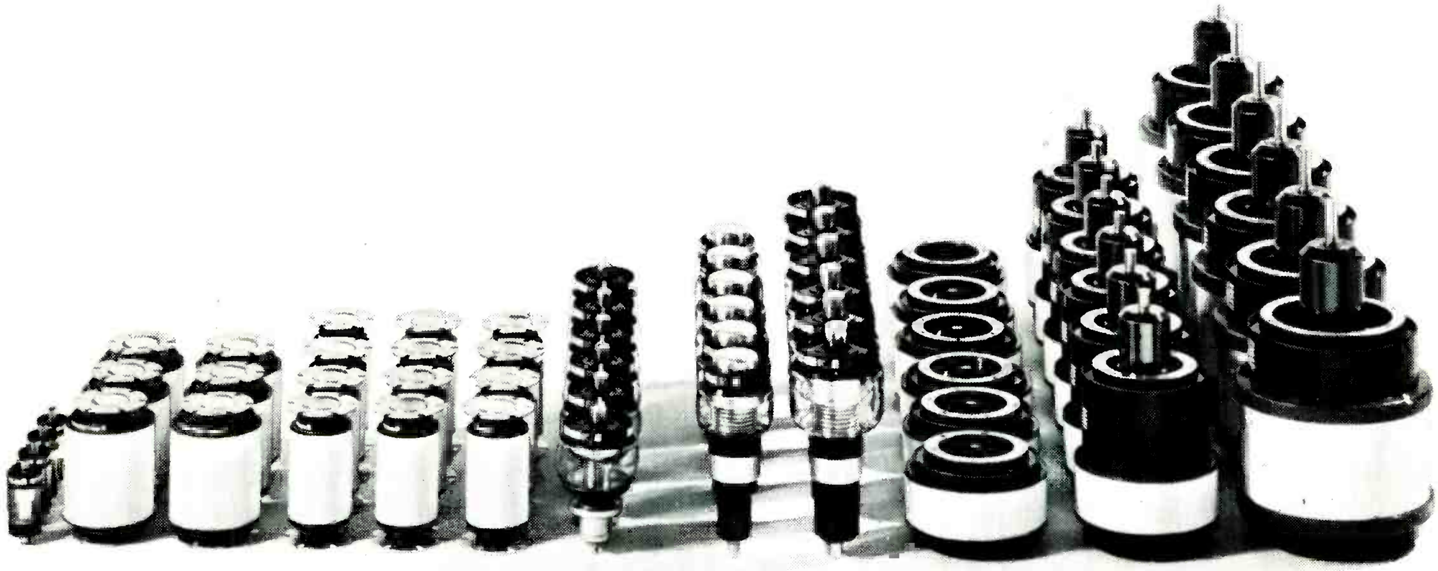
"Bury your head in the sand and the enemy isn't there any more" is the mythical ostrich policy. For half a century the Post Office has done just that and every year of procrastination has seen a worsening of the postal service and a monumental increase in the price which ultimately will have to be paid.

So is there a genius in the house?

(Vector's mention of "lateral" thinking refers to a process advocated by Edward de Bono for problem solving. The idea is that sometimes it may be advantageous to "move sideways" mentally to some new, arbitrary starting point, so that the problem is seen and tackled from a different direction. — Ed.)

EEV VACUUM CAPACITORS

The largest range in Europe: your spec could make it even larger.



The EEV range of vacuum capacitors is wider than ever. EEV manufactures more than 100 types at competitive prices. And if we haven't got the one you want, send us your specification. We can probably make it for you.

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Current ratings from 70 to 200 amps

Fixed Capacitors
Glass Types
Capacitances from 6.25 to 900pF
Voltage ratings from 3 to 20kV
Current ratings from 7 to 50 amps
Ceramic Types
Capacitances from 6.5 to 3000pF
Voltage ratings from 7 to 30kV
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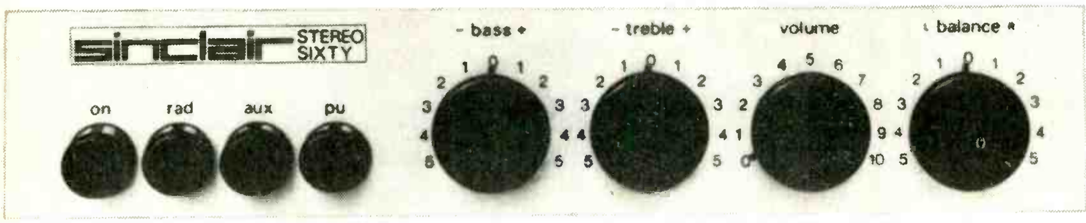
LAP 43

Sinclair Project 60

Stereo 60



Built and tested post free
£9.98

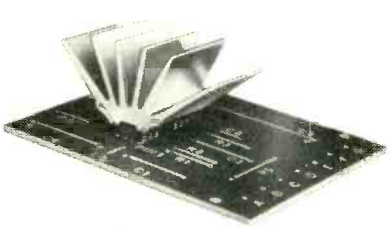
pre-amplifier/control unit

The versatility of Project 60 high-fidelity modules is well demonstrated in this excellent unit. It provides the facilities essential to good stereo and will enhance the quality of any system it is used with, whether Project 60 or any any other top line power amplifiers. Compact, yet robustly constructed, the unit is easily panel mounted and will operate satisfactorily from 18 to 35 volts supply. Silicon epitaxial transistors are used throughout to achieve a very high signal to noise ratio with excellent separation between channels. Distortion at maximum output is barely 0·02% with magnetic p.u. input. Accurate equalisation is provided for all inputs, which are selected by push buttons. For maximum effectiveness, the Sinclair A.F.U. is recommended for use with the Stereo 60 pre-amp/control unit. A comprehensive manual supplied with Project 60 modules makes installing and connecting easy and ensures best possible results from your system.

SPECIFICATIONS

Input sensitivities: Radio – up to 3mV. Mag. p.u. 3mV correct to R.I.A.A. curve ±1dB, 20 to 25,000 Hz. Ceramic p.u. – up to 3mV: Aux – up to 3mV. **Output:** 250mV.
Signal to noise ratio: better than 70dB.
Channel matching: within 1dB.
Tone controls: TREBLE ±12 to —12dB at 10KHz; BASS +12 to —12dB at 100Hz.
Front panel: brushed aluminium with black knobs and controls.
Size: 66×40×207mm.

Super IC.12 Integrated circuit high fidelity amplifier



Having introduced Integrated Circuits to hi-fi constructors with the IC.10, the first time an IC had ever been made available for such purposes, we have followed it with an even more efficient version, the Super IC.12, a most exciting advance over our original unit. This needs very few external resistors and capacitors to make an astonishingly good high fidelity amplifier for use with pick-up, F.M. radio or small P.A. set up, etc. The free 40 page manual supplied, details many other applications which this remarkable IC. make possible. It is the equivalent of a 22 transistor circuit contained within a 16 lead DIL package, and the finned heat sink is sufficient for all requirements. The Super IC.12 is compatible with Project 60 modules which would be used with the Z.50 and Z.30 amplifiers. Complete with free manual and printed circuit board.

SPECIFICATIONS

Output power: 6 watts RMS continuous (12 watts peak). 6–8Ω. **Frequency Response:** 5Hz to 100KHz±1dB. **Total Harmonic Distortion:** Less than 1%. (Typical 0·1%) at all output powers and frequencies in the audio band (28V). **Load Impedance:** 3 to 15 ohms. **Input Impedance:** 250 Kohms nominal. **Power Gain:** 90dB (1,000,000,000 times) after feedback. **Supply Voltage:** 6 to 28V. **Quiescent current:** 8mA at 28V. **Size:** 22×45×28mm including pins and heat sink..

Manual available separately 15p post free.

With FREE printed circuit board and 40 page manual.
£2.98 Post free

Project 605

The easy way to buy and build Project 60

Project 605 is one pack containing: one PZ5, two Z30's, one Stereo 60 and one Masterlink. This new module contains all the input sockets and output components needed together with all necessary leads cut to length and fitted with neat little clips to plug straight on to the modules. Thus all soldering and hunting for the odd part is eliminated. You will be able to add further Project 60 modules as they become available adapted to the Project 605 method of connecting.

Complete Project 605 pack with comprehensive manual, post free £29.95

Everything you need to assemble a superb 30 watt high fidelity stereo amplifier without having to solder.

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Sinclair Radionics Ltd, London Road, St. Ives, Huntingdonshire PE17 4HJ. Tel: St. Ives 64311

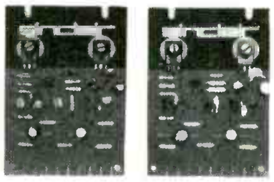
WW—071 FOR FURTHER DETAILS

the world's most advanced high fidelity modules

Z.30 & Z.50 power amplifiers

Built, tested and guaranteed with circuits and instructions manual. **Z.30 £4.48 Z.50 £5.48**

The Z.30 and Z.50 are of advanced design using silicon epitaxial planar transistors to provide unsurpassed standards of performance. Total harmonic distortion is an incredibly low 0.02% at 15w (8Ω) and all lower outputs. Whether you use Z.30 or Z.50 amplifiers in your Project 60 system will depend on personal preference, but they are the same size and are intended for use principally with other units in the Project 60 range. Their performance and design are such, however, that Z.50s and Z.30 may be used in a far wider range of applications.



SPECIFICATIONS ***(Z.50 units are interchangeable with Z.30s in all applications).*** **— Power Outputs: Z.30** 15 watts R.M.S. into 8 ohms using 35 volts : 20 watts R.M.S. into 3 ohms using 30 volts. **Z.50** 40 watts R.M.S. into 3 ohms using 40 volts : 30 watts R.M.S. into 8 ohms using 50 volts. **Frequency response:** 30 to 300.000Hz±1dB. **Distortion:** 0.02% into 8 ohms. **Signal to noise ratio:** better than 70dB unweighted. **Input sensitivity:** 250mV into 100 Kohms (for 15w into 8Ω). For speakers from 3 to 15 ohms impedance. **Size:** 14 x 80 x 57mm.

Project 60 Stereo F.M. Tuner

Built and tested. Post free. **£25**

The phase lock loop principle was used for receiving signals from space craft because of its vastly improved signal to noise ratio. Now, Sinclair have applied the principle to an F.M. tuner with fantastically good results. Other advanced features include varicap diode tuning, printed circuit coils, an I.C. in the specially designed stero decoder and switchable squelch circuit for silent tuning between stations. In terms of high fidelity this tuner has a lower level of distortion than any other tuner we know. Stereo broadcasts are received automatically, a panel indicator lighting up as the stereo signal is tuned in. This tuner can also be used to advantage with most other high fidelity systems.

SPECIFICATIONS—Number of transistors: 16 plus 20 in I.C. **Tuning range:** 87.5 to 108MHz. **Sensitivity:** 7μV for lock-in over full deviation. **Squelch level:** Typically 20μV. **Signal to noise ratio:** >65dB. **Audio frequency response:** 10Hz – 15KHz (±1dB). **Total harmonic distortion:** 0.15% for 30% modulation. **Stereo decoder operating level:** 2μV. **Cross talk:** 40dB. **Output voltage:** 2 x 150mV R.M.S. maximum **Operating voltage:** 25–30VDC. **Indicators:** Stereo on ; tuning. **Size:** 93 x 40 x 207mm.

A.F.U. High & Low Pass Filter Unit

Built, tested and guaranteed. **£5.98**

For use between Stereo 60 unit and two Z.30s or Z.50s. The unit is very easily mounted and is unique in that the cut-off frequencies are continuously variable. As attenuation in the rejected band is rapid (12dB/octave), there is less loss of the wanted signal than has previously been possible. Amplitude and phase distortion are negligible. The A.F.U. is suitable for use with any other amplifier system. There are two filter sections – rumble (high pass) and scratch (low pass). H.F. cut-off (—3dB) variable from 28KHz to 5KHz. L.F. cut-off (—3dB) variable from 25Hz to 100Hz. Distortion at 1KHz (35V. supply) 0.02% at rated output. Operating voltage from 15 to 35V. Current 3mA. **Size:** 66 x 40 x 90mm.

Power Supply Units

Designed specifically for use with the Project 60 system of your choice. Use PZ.5 for normal Z.30 assemblies and PZ.6 or PZ.8 where a stabilised supply is essential.

PZ.5 *30 volts unstabilised* **£4.98**
PZ.6 *35 volts stabilised* **£7.98**
PZ.8 *45 volts stabilised (less mains transformer)* **£7.98**
PZ.8 *mains transformer* **£5.98**

Typical Project 60 applications

System	The Units to use	together with	Units cost
Simple battery record player	**Z.30**	Crystal P.U., 12V battery volume control, etc.	**£4.48**
Mains powered record player	**Z.30, PZ.5**	Crystal or ceramic P.U. volume control, etc.	**£9.45**
12W. RMS continuous sine wave stereo amp. for average needs	**2 x Z.30s, Stereo 60; PZ.5**	Crystal, ceramic or mag. P.U., F.M. Tuner, etc.	**£23.90**
25W. RMS continuous sine wave stereo amp. using low efficiency (high performance) speakers	**2 x Z.30s, Stereo 60; PZ.6**	High quality ceramic or magnetic P.U., F.M. Tuner, Tape Deck, etc.	**£26.90**
80W. (3 ohms) RMS continuous sine wave de luxe stereo amplifier. (60W. RMS into 8 ohms)	**2 x Z.50s, Stereo 60; PZ.8, mains transformer**	As above	**£34.88**
Indoor P.A.	**Z.50, PZ.8, mains transformer**	Mic., guitar, speakers, etc., controls	**£19.43**

F.M. Stereo Tuner **(£25)** & A.F.U. **(£5.98)** may be added as required.

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Guarantee

If, within 3 months of purchasing any product direct from Sinclair Radionics Ltd., you are dissatisfied with it, your money will be refunded at once. Many Sinclair appointed Stockists also offer this same guarantee in co-operation with Sinclair Radionics Ltd.

Each Project 60 module is tested before leaving our factory and is guaranteed to work perfectly. Should any defect arise in normal use, we will service it at once and without any charge to you, if it is returned within two years from the date of purchase. Outside this period of guarantee a small charge (typically £1.00) will be made. No charge is made for postage by surface mail. Air Mail is charged at cost.

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Please send

I enclose cash/cheque/money order.

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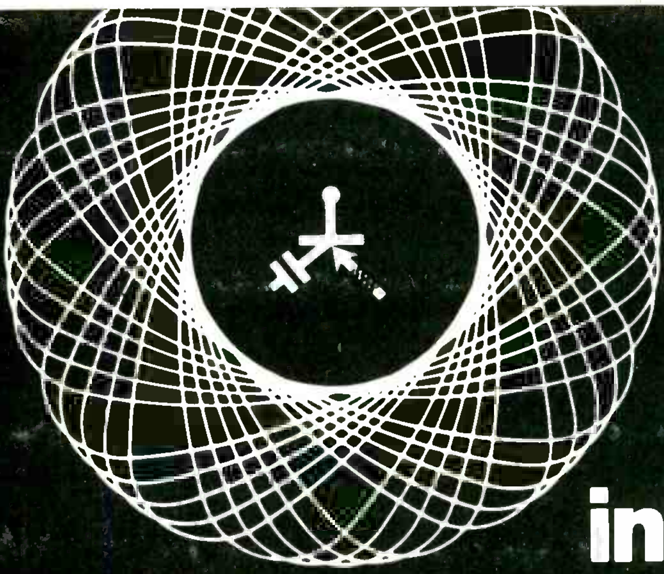
WW273



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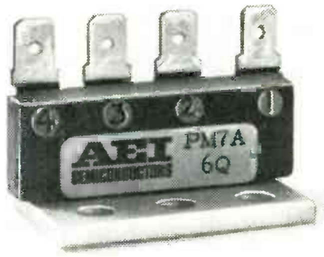
LOW COST BRIDGE RECTIFIERS



DC output		Type Nos.
Amps	Volts	
10 when mounted	60	PM7A1
	125	PM7A2
	250	PM7A4
	375	PM7A6
15 when mounted	60	PM7A1Q
	125	PM7A2Q
	250	PM7A4Q
	375	PM7A6Q

AMP tags electrically isolated from mounting bracket. Mount them on a chassis, the equipment box, transformer housing etc.

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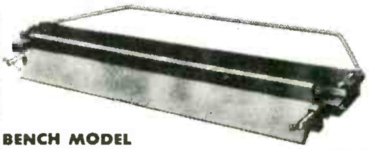

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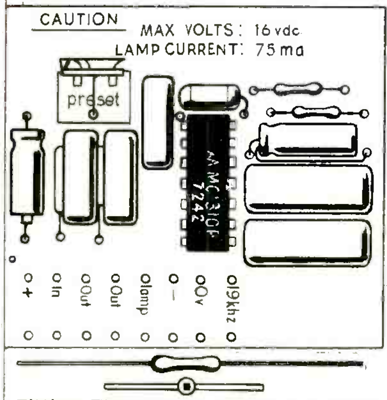
WW—077 FOR FURTHER DETAILS

Stereo radio from your existing tuner.



A complete set of parts from Jermyn to build a stereo decoder module that will convert your existing mono tuner for stereo reception whilst maintaining a high standard of reproduction.

The distortion is very low (typically 0.3% at 560 mV RMS composite input signal) with 40dB channel separation.

The stereo switching is automatic and there is a light emitting diode which acts as a stereo beacon.

The kit requires no coil and there are no alignment problems.

Fitting. The module requires a 10-16 volt power supply which can normally be tapped off the existing tuner. The signal input is taken off before the de-emphasis circuit which in practice means disconnecting one, or at the most, two capacitors. Any radio engineer will be able to spot these capacitors, but if you're really stuck send the circuit with a SAE to us and one of our engineers will indicate the output point. (This is the full extent of our involvement, no hardware please).

Of course, if you have a modern mono tuner with a multiplex output our module simply plugs in.

The outputs go via a screened twin cable to the tuner inputs of your stereo amplifier.

And the cost? £4.90 for the Kit with 100% tested integrated circuit. Also available assembled and aligned, checked and ready for use at £6.90 (includes 12 month guarantee). Beat that!

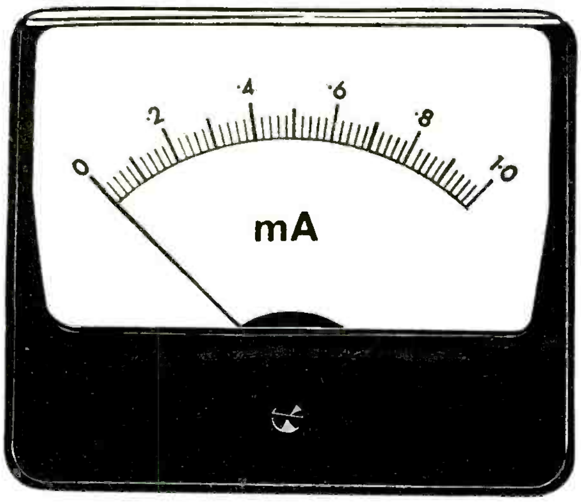
To Jermyn Industries
28 Vestry Estate
Sevenoaks
Kent

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

Block Capitals Please

WW—078 FOR FURTHER DETAILS

METER PROBLEMS?



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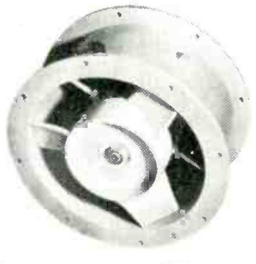

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Approved parts for this outstanding design (W.W. April 1971/2). Featuring 0·75 μV sensitivity. Mosfet front end. Ceramic I.F. strip. Triple gang tuning, ½V r.m.s. output level, suitable for phase locked decoder, as below. Designer's own P.C.B.

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(W.W. April '72). Tuning is indicated by the balance of two light emitting diodes. The kit includes, LED's, high gain transistors, P.C.B., resistors, mounting kit and instruction booklet. Order T041. Price £1·72 plus P. & P. 10p. with two LED's (or £1·98 with extra LED for "stereo" lamp-see decoder).

DIAL CHASSIS KIT

Now available—includes all dial drive components, dial plate, decoder mounting bracket, tuning scales, decoder-tuner tagstrips, etc., 4-way 2/3 pole rotary switch and instruction booklet. Price £2·15 plus P. & P. 17p (Note: may be purchased without dial drive components.)

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Now with free LED "stereo on" light—complementing this superb decoder (W.W. Sept. '70). Suitable for wide variety of tuners including the NELSON-JONES TUNER.

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NEW IC Stabilised PSU. S/C, overload protected, low ripple. £3·55. P. & P. 19p.

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Improved efficiency type, mech. identical to HP LED, panel or PCB mounting with *free* mounting clip—clear or black—please state. Order LED1A. Please add postage.

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A good aerial is essential for optimum Stereo Radio reception.

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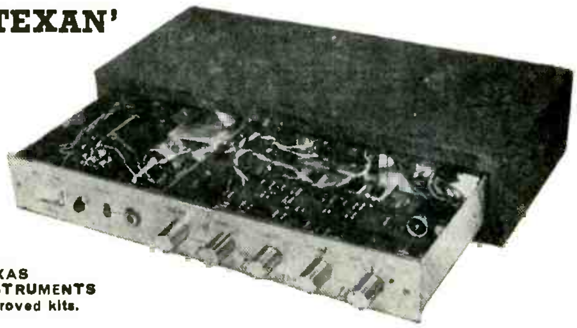

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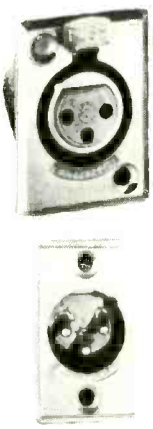

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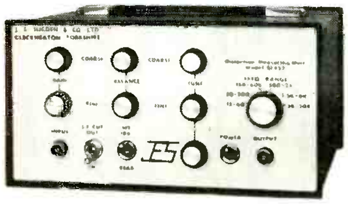
J E S AUDIO INSTRUMENTATION



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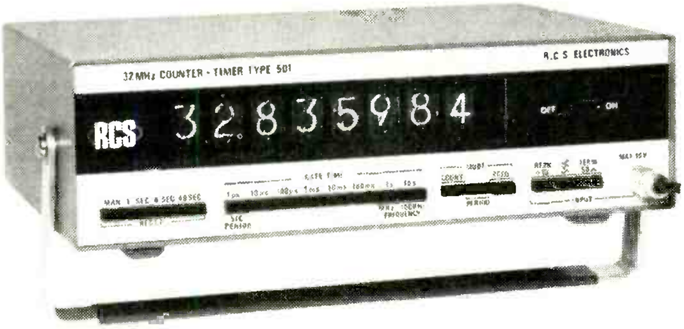

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WW—085 FOR FURTHER DETAILS

Contil Mod 3 cases come in six sizes and offer the manufacturer of small instruments an attractive low cost case available ex stock. Made in blue PVC coated steel, these cases offer strength and rigidity and come complete with front and rear panels. PCB and PSU mounting systems are also available.

Mod- 3 (including chassis)	1 off	5 off	10 off	25 off	50 off	100 off	P & P
Mod-301	2.65	2.60	2.55	2.50	2.45	2.40	30p
Mod-302	2.80	2.75	2.70	2.65	2.60	2.55	30p
Mod-303	3.20	3.15	3.10	3.05	3.00	2.95	30p
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Mod-305	3.85	3.75	3.65	3.55	3.45	3.35	30p
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Telephone: Northwood 24941/26732 Telex: 923231 Code: West Hyde Nthwd.

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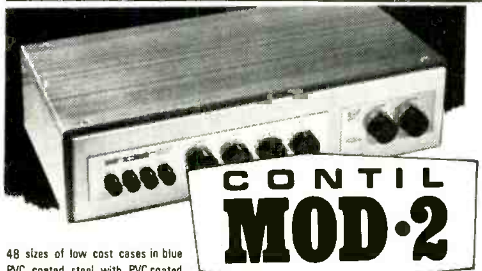
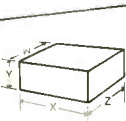


48 sizes of low cost cases in blue PVC coated steel with PVC coated aluminium front and rear panels.
The design of these cases permits the instrument to be built up or serviced without the external. Price includes all stainless steel assembly screws, rubber feet and one or two chassis according to size.
Delivery ex stock: wood grain finish: types D, G, E, H
Special punching to take Sinclair Hi-Fi modules available.



	X	Y	Z	1-4	P&P
A	4.5	3	6.5	2.35	26p
B	4.5	7	6.5	2.85	30p
C	4.5	10	6.5	3.25	30p
D	9	3	6.5	3.25	30p
E	9	7	6.5	3.60	35p
F	9	10	6.5	4.20	35p
G	13	3	6.5	3.60	35p
H	13	7	6.5	4.20	35p
I	13	10	6.5	4.65	35p
J	18	3	6.5	4.20	35p
K	18	7	6.5	5.65	45p
L	18	10	6.5	6.90	50p
M	4.5	3	13	2.65	30p
N	4.5	7	13	3.60	35p
O	4.5	10	13	4.65	35p
P	9	3	13	3.60	35p
Q	9	7	13	4.65	35p
R	9	10	13	5.65	45p
S	13	3	13	4.65	35p
T	13	7	13	5.65	45p
U	13	10	13	6.90	50p
V	18	3	13	5.65	45p
W	18	7	13	6.90	50p
X	18	10	13	8.30	55p

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WW—087 FOR FURTHER DETAILS

HART ELECTRONICS

In keeping with our policy of offering kits of parts for advanced audio projects to a standard which will please the constructor who is professionally engagedin the electronic industry and who is therefore used to the advanced standards of quality and designs used therein, we have pleasure in giving brief details of our latest projects.

The Bailey Pre-Amp., was published in 1966 and we have been supplying kits of parts for it since then. We have therefore an unparalleled length of experience on which to draw when adapting this unit to take advantage of new components which have become available to make our kit the best that has ever been offered. The new kit is easier to assemble, as there is little wiring, the controls, switches and input sockets are all mounted on the clearly marked fibreglass P.C.B.'s. The new kit is more versatile because it is split into two stereo units. The tone control unit with volume, Bass, Treble, Balance and Filter can be used on its own for 250mV flat inputs and will give an output up to 2V to drive most power amps. The front end unit has the input switch selecting Mag; PU, Cer; PU, Mic, Radio and Tape head inputs. Output 250mV.

The new kit performs better because the Tone control incorporates the Quilter Bootstrap circuit to give lower distortion at all control settings. The front end has the Burrows mod, for ceramic pickups and higher rumble cut-off with facilities to adjust the Tone balance and level to suit different makes of transducer. Switches have click suppression circuitry for ultimate refinement of operation.

Full details are in our lists.

Our kits for the Stuart tape recorder have been built by Mr. Stuart and received his enthusiastic approval. This unit is an easy way to convert that ageing recorder with a good deck up to modern top flight standards. We stock heads for 2 or 4 track stereo and also for cassettes.

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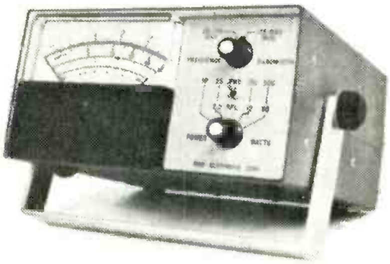
spans 25-500 MHz, measures .02-500 watts

in eight ranges. All variable RF measurement parameters – frequency range, forward/reflected power and full scale values – are switched right on the front panel. Since it requires neither AC nor battery power, the model 4370 is equally at home in the lab or atop an antenna tower, at a remote base station or in a car, boat or plane.



Model 4370

SPECIFICATIONS:
Forward Power Ranges: 10, 25, 100, 500W; ±5% OFS
Reflected Power Ranges: 1, 2.5, 10, 50W; ±5% OFS
Insertion VSWR: below 1.1 with N Conn. (50 ohms)
Frequency Range: 25 – 500 MHz
Quick-Change Connectors: N, BNC, TNC, UHF, C, SC, HN, GR Type 874 or ⅞" EIA
Finish: Rich olive leather grain
Price incl. Line Section with N Conn: **£260**

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1S5	0·20
1U4	0·29
1U5	0·48
2D21	0·35
2GK5	0·50
3A4	0·25
3B7	0·25
3D6	0·19
3Q4	0·38
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6/30L2	0·53
6A8G	0·33
6AC7	0·15
6AG5	0·25
6AH6	0·50
6AJ5	0·75
6AJ8	0·25
6AK5	0·25
6AK6	0·30
6AK8	0·29
6AL5	0·10
6AM8A	0·50
6AN8	0·49
6AQ5	0·21
6AQ8	0·32
6AR5	0·30
6AR6	1·00
6AT6	0·18
6AU6	0·19
6AV6	0·28
6AW8A	0·54
6AX4	0·39
6B8G	0·13
6BA6	0·19
6BC8	0·50
6BE6	0·20

6BG6G	1·05
6BH6	0·43
6BJ6	0·39
6BK7A	0·50
6BQ5	0·21
6BQ7A	0·38
6BR7	0·79
6BR8	0·63
6BS7	1·25
6BW6	0·72
6BW7	0·50
6BX6	0·21
6BY7	0·25
6BZ6	0·31
6C4	0·28
6C6	0·19
6C9	0·73
6CB6A	0·26
6C12	0·25
6C17	0·63
6CD6G	1·06
6CG8A	0·50
6CH6	0·38
6CL6	0·43
6CL8A	0·50
6CM7	0·50
6CU5	0·30
6CW4	0·63
6D3	0·38
6D6	0·15
6DE7	0·50
6DT6	0·50
6EW6	0·55
6E5	0·55
6F1	0·59
6F6	0·63
6F6G	0·25
6F12	0·17
6F13	0·33
6F14	0·40
6F15	0·65
6F18	0·45
6F23	0·65
6F24	0·68
6F25	0·51
6F26	0·25
6F28	0·60
6F32	0·15
6G6G	0·25
6GH8A	0·50
6GK5	0·50
6GU7	0·50
6H6GT	0·15
6J5G	0·19
6J5GT	0·29
6J6	0·18
6J7G	0·24
6J7(M)	0·38
6JU8A	0·50
6K7G	0·10
6K8G	0·16

6L1	0·98
6L6GT	0·39
6L7(M)	0·38
6L12	0·32
6L18	0·44
6L19	1·38
6LD12	0·29
6LD20	0·48
6N7GT	0·40
6P1	1·50
6P15	0·21
6P28	0·59
6Q7GT	0·43
6Q7(M)	0·43
6R7G	0·35
6R7(M)	0·55
6SA7M	0·35
6SC7GT	·33
6SG7(M)	·33
6SH7	0·53
6SJ7GT	·35
6SK7GT	·23
6SQ7GT	·38
6U4GT	0·60
6U7G	0·53
6V4	0·19
6V6G	0·17
6V6GT	0·27
6X4	0·20
6X5GT	0·25
6Y6G	0·55
6Y7G	0·63
7A7	0·88
7B6	0·58
7B7	0·32
7F8	0·88
7H7	0·28
7R7	0·65
7V7	0·25
7Y4	0·60
7Z4	0·50
9BW6	0·50
9D7	0·78
10C2	0·49
10C14	0·29
10D1	0·50
10DE7	0·50
10F1	0·75
10F9	0·45
10F18	0·35
10LD11	0·53
10LD12	·30
10P12	0·30
10P13	0·54
10P14	1·08
10P18	0·28
12A6	0·63
12AC6	0·40
12AD6	0·40
12AE6	0·48
12AT6	0·23

12AT7	0·16
12AU6	0·21
12AU7	0·19
12AV6	0·28
12AX7	0·21
12AY7	0·68
12BA6	0·30
12BE6	0·30
12BH7	0·27
12J5GT	0·30
12J7GT	0·33
12K5	0·50
12K7GT	·34
12Q7GT	0·28
12SA7GT	0·40
12SC7	0·35
12SG7	0·23
12SH7	0·15
12SJ7	0·23
12SK7	0·24
12SQ7GT	0·50
14H7	0·48
14S7	0·75
18	0·63
19AQ5	0·24
19BG6G	·80
19G6	0·50
19H1	2·00
20D1	0·49
20D4	1·05
20F2	0·65
20L1	0·98
20P1	0·50
20P3	0·76
20P4	0·89
20P5	1·00
25A6G	0·29
25L6G	0·20
25Y5	0·38
25Y5G	0·43
25Z4G	0·28
25Z5	0·40
25Z6G	0·43
30A5	0·44
30C1	0·26
30C15	0·55
30C17	0·74
30C18	0·58
30F5	0·61
30FL1	0·58
30FL2	0·58
30FL12	0·67
30FL13	0·47
30FL14	0·66
30L1	0·27
30L15	0·55
30L17	0·65
30P4MR	0·95
30P12	0·69

30P16	0·28
30P19/30P4	0·55
30PL1	0·57
30PL12	0·29
30PL13	0·75
30PL14	0·62
30PL15	·87
35A3	0·48
35A5	0·75
35D5	0·70
35L6GT	·42
35W4	0·23
35Z3	0·50
35Z4GT	·24
35Z5GT	·30
50B5	0·35
50C5	0·32
50CD6G	2·17
50EH5	0·55
50L6GT	·45
72	0·33
77	0·53
85A2	0·43
85A3	0·40
90AG	3·38
90AV	3·38
90CG	1·70
90CV	1·68
90C1	0·59
150B2	0·58
150C2	0·30
301	1·00
302	0·83
303	0·75
305	0·83
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AZ1	0·40
AZ31	0·46
AZ41	0·53
B319	0·27
CL33	0·90
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CY1C	0·53
CY31	0·29
D63	0·20
DAF96	0·33
DC90	0·60
DD4	0·53
DF91	0·14
DF96	0·34
DH76	0·28
DH77	0·18
DH81	0·58
DK32	0·32
DK40	0·55
DK92	0·35
DK96	0·35
DL92	0·23
DL96	0·35
DM70	0·30
DM71	0·38
DW4/350	0·38
DY87/6	0·22
DY802	0·29
E80CC	1·65
E80F	1·20
E83F	1·20
E88CC	0·60
E92CC	0·40
E180F	0·90
E182CC	1·00
E1148	0·53
EA50	0·27
EA76	0·88
EABC80	0·29
EAC91	0·38
EAF42	0·48
EAF801	·50
EB34	0·20
EB91	0·10
EBC41	0·48
EBC81	0·29
EBC90	0·18
EBC91	0·28
EBF80	0·30
EBF83	0·38
EBF89	0·26
EBL21	0·60
EC53	0·49
EC54	0·50
EC86	0·59
EC88	0·59

EC92	0·34
ECC32	1·50
ECC33	1·50
ECC35	0·95
ECC40	0·60
ECC81	0·16
ECC82	0·19
ECC83	0·21
ECC84	0·28
ECC85	0·32
ECC86	0·40
ECC88	0·35
ECC189	·48
ECC804	0·53
ECC807	1·70
ECF80	0·27
ECF82	0·25
ECF86	0·64
ECF804	2·10
ECH21	0·63
ECH35	0·50
ECH42	0·57
ECH81	0·25
ECH83	0·38
ECH84	0·34
ECL80	0·28
ECL82	0·28
ECL83	0·52
ECL84	0·54
ECL85	0·54
ECL86	0·33
EF22	0·63
EF40	0·49
EF41	0·58
EF42	0·33
EF73	0·75
EF80	0·21
EF83	0·54
EF85	0·25
EF86	0·27
EF89	0·23
EF91	0·17
EF92	0·28
EF97	0·55
EF98	0·65
EF183	0·25
EF184	0·27
EFP60	0·50
EH90	0·34
EK90	0·20
EL32	0·18
EL34	0·44
EL35	1·00
EL37	0·74
EL41	0·53
EL81	0·50
EL83	0·38
EL84	0·21
EL85	0·40
EL86	0·38

EL91	0·23
EL95	0·32
EL360	0·49
ELL80	0·75
EM80	0·37
EM81	0·37
EM83	0·75
EM84	0·31
EM85	1·00
EM87	0·34
EY51	0·29
EY81	0·35
EY83	0·54
EY84	0·50
EY87/6	0·27
EY88	0·40
EY91	0·53
EZ35	0·25
EZ40	0·40
EZ41	0·42
EZ80	0·19
EZ81	0·20
EZ90	0·20
FW4/500	0·75
FW4/800	0·75
GY501	0·75
GZ30	0·33
GZ32	0·39
GZ33	0·70
GZ34	0·47
GZ37	0·67
HABC80	0·44
HL13C	0·20
HL23DD	0·40
HL41DD	0·98
HL42DD	0·50
HN309	1·40
HVR2	0·53
HVR2A	0·53
IW3	0·38
KT2	0·25
KT8	1·75
KT41	0·98
KT44	1·00
KT63	0·25
KT66	0·80
KT74	0·63
KT76	0·63
KT81	2·00
KTW61	·63
KTW62	·63
KTW63	·50
LN119	0·30
LZ319	0·26
LZ329	0·26
LZ339	0·55
M8162	0·63
MHL4	0·75
MHLD6	·75
MKT4	0·98
MU12/14	0·38
N308	0·95
N339	0·44
N379	0·28

N709	0·21
P61	0·44
PABC80	0·32
PC86	0·44
PC88	0·44
PC95	0·53
PC97	0·36
PC900	0·29
PCC84	0·27
PCC85	0·24
PCC88	0·39
PCC89	0·42
PCC189	0·46
PCF80	0·26
PCF82	0·30
PCF84	0·40
PCF86	0·44
PCF87	0·74
PCF200	0·67
PCF800	0·55
PCF801	0·28
PCF802	0·37
PCF805	0·58
PCF806	0·55
PCF808	0·66
PCH200	·62
PCL82	0·29
PCL83	0·54
PCL84	0·32
PCL86	0·36
PCL88	0·62
PCL800	·75
PCL801	0·57
PCL805/PCL85	0·37
PD500	1·44
PEN4DD	1·38
PEN45	0·40
PEN45DD	0·75
PEN46	0·20
PEN453DD	0·98
PENA4	0·98
PENDD /4020	0·88
PFL200	0·50
PL33	0·38
PL36	0·46
PL81	0·42
PL81A	0·48
PL82	0·28
PL83	0·30
PL84	0·28
PL302	0·55
PL504/PL500	0·60
PL505	1·30
PL508	0·90
PL509	1·30
PL801	0·69
PL802	0·75

PM84	0·31
PY33/2	·50
PY80	0·33
PY81	0·24
PY82	0·23
PY83	0·26
PY88	0·31
PY301	0·56
PY500	0·95
PY800	0·31
PY801	0·31
PZ30	0·48
QP21	0·50
QQV03/10	1·20
QS75/20	0·63
QS95/10	·49
QS150/15	0·63
QV04/7	0·63
R11	0·98
R16	1·75
R17	0·88
R18	0·50
R19	0·28
R20	0·53
R52	0·33
RK34	0·38
SP13C	0·63
SP41	0·75
SP61	0·75
TH4B	0·50
TH233	0·98
TP2620	·98
UABC80	·30
UAF42	0·49
UBC41	0·45
UBC81	0·40
UBF80	0·28
UBF89	0·28
UBL21	0·55
UC92	0·35
UCC84	0·33
UCC85	0·33
UCF80	0·31
UCH21	0·60
UCH42	0·57
UCH81	0·29
UCL82	0·30
UCL83	0·48
UF41	0·50
UF42	0·60
UF80	0·35
UF85	0·34
UF86	0·63
UF89	0·27
UL41	0·54
UL84	0·28
UM80	0·33
UR1C	0·53
UU5	0·38
UU9	0·40
UU12	0·20

UY41	0·38
UY85	0·23
U10	0·45
U12/14	·38
U16	0·75
U17	0·35
U18/20	0·75
U19	1·73
U22	0·39
U25	0·62
U26	0·53
U31	0·30
U33	1·50
U35	0·83
U37	1·75
U45	0·78
U47	0·62
U49	0·53
U50	0·25
U76	0·24
U78	0·20
U153	0·24
U191	0·56
U192	0·23
U193	0·31
U251	0·62
U281	0·40
U282	0·40
U291	0·50
U301	0·40
U329	0·62
U381	0·23
U403	0·33
U404	0·38
U801	0·76
U4020	0·38
VP2	0·53
VP13C	0·35
VP23	0·40
VP41	0·38
VT61A	0·35
VT501	0·15
VU111	0·44
VU120	0·60
VU120A	·60
VU133	0·35
W76	0·34
W81M	0·68
W107	0·50
W729	0·60
XE3	5·00
XFY12	0·48
XH1-5	0·48
X41	0·50
X65	0·50
X66	0·50
Z329	0·61
Z729	0·27
Z749	0·65
Transistors and Diodes	
1N1124A	·53
1N4952	·50
2N404	0·18

2N966	0·53
2N1756	·50
2N2147	·85
2N2297	·23
2N2369A	0·22
2N2613	·39
2N3053	·33
2N3121	2·50
2N3703	·19
2N3709	·20
2N3866	1·00
2N3988	·50
2S323	0·50
AA119	0·15
AA120	0·15
AA129	0·15
AAZ13	0·18
AC107	0·15
AC113	0·25
AC114	0·40
AC126	0·13
AC127	0·17
AC128	0·20
AC132	0·20
AC154	0·25
AC156	0·20
AC157	0·25
AC165	0·25
AC166	0·25
AC167	0·60
AC168	0·38
AC169	0·33
AC176	0·55
AC177	0·28
ACY17	0·25
ACY18	0·20
ACY19	0·19
ACY20	0·18
ACY21	0·19
ACY22	0·15
ACY28	0·18
AD140	0·36
AD149	0·50
AD161	0·45
AD162	0·45
ADT140	·63
AF102	0·90
AF106	0·50
AF114	0·25
AF115	0·15
AF117	0·19
AF121	0·30
AF124	0·25
AF125	0·17
AF126	0·18

AF139	0·65
AF178	0·68
AF180	0·48
AF186	0·55
AF239	0·38
ASY27	0·43
ASY28	0·33
ASY29	0·50
BA102	0·45
BA115	0·14
BA116	0·25
BA129	0·13
BA130	0·10
BA153	0·15
BCY10	0·45
BCY12	0·50
BCY33	0·20
BCY34	0·23
BCY38	0·23
BCY39	0·25
BC107	0·13
BC108	0·13
BC113	0·25
BC115	0·15
BC116	0·25
BC118	0·23
BCZ11	0·38
BF154	0·25
BF158	0·29
BF159	0·25
BF163	0·20
BF173	0·38
BF180	0·30
BF181	0·40
BF185	0·40
BF194	0·15
BFY50	0·23
BFY51	0·19
BFY52	0·20
BTX34/400	2·00
BY100	0·18
BY101	0·15
BY105	0·18
BY114	0·18
BY126	0·15
BY127	0·18
BYY23	1·00
BYZ10	0·25
BYZ11	0·25
BYZ12	0·25
BYZ13	0·25
BYZ15	1·75
CG12E	0·20
CG64H	0·20
FSY11A	·23

FSY41A	·23
GD4	0·33
GD5	0·28
GD6	0·28
GD8	0·20
GD9	0·20
GD11	0·20
GD12	0·20
GD14	0·50
GD15	0·40
GD16	0·20
GET113	·20
GET116	·40
GET118	·20
GET119	·20
GET573	·38
GET587	·43
GET872	·95
GET873	·15
GET882	·50
GET887	·23
GET889	·23
GET890	·23
GET896	·23
GET897	·23
GET898	·23
GEX13	0·18
GEX35	0·23
GEX36	0·50
GEX45	0·33
GEX55	0·75
GT3	0·25
M1	0·15
MAT100	·39
MAT101	·43
MAT120	·39
OA5	0·28
OA9	0·13
OA10	0·43
OA47	0·10
OA70	0·15
OA73	0·15
OA79	0·09
OA81	0·09
OA85	0·08
OA86	0·20
OA90	0·13
OA91	0·09
OA95	0·09
OA200	0·09
OA202	0·10
OA210	0·48
OA211	0·68
OC19	1·25
OC22	0·38

OC23	0·38
OC24	0·38
OC25	0·38
OC28	0·60
OC29	0·63
OC35	0·32
OC36	0·43
OC38	0·43
OC41	0·50
OC42	0·63
OC43	1·18
OC44	0·10
OC45	0·11
OC46	0·15
OC65	1·13
OC70	0·13
OC71	0·11
OC72	0·11
OC74	0·23
OC75	0·11
OC76	0·15
OC77	0·27
OC78	0·15
OC78D	0·15
OC79	0·40
OC81	0·11
OC81D	0·11
OC82	0·11
OC82D	0·11
OC83	0·20
OC84	0·24
OC123	0·23
OC139	0·23
OC140	0·95
OC169	0·23
OC172	0·35
OC200	0·22
OC201	0·38
OC202	0·43
OC203	0·30
OC204	0·30
OC205	0·43
OC206	0·50
OC812	0·40
OCP71	0·42
ORP12	0·53
S6M1	0·25
SM1036	·50
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U14706	·25
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Y728	0·18
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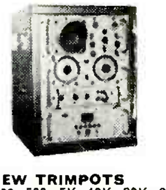

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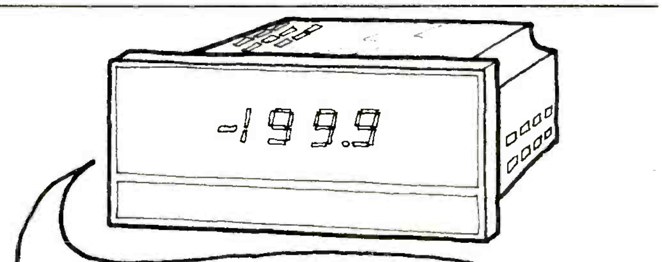

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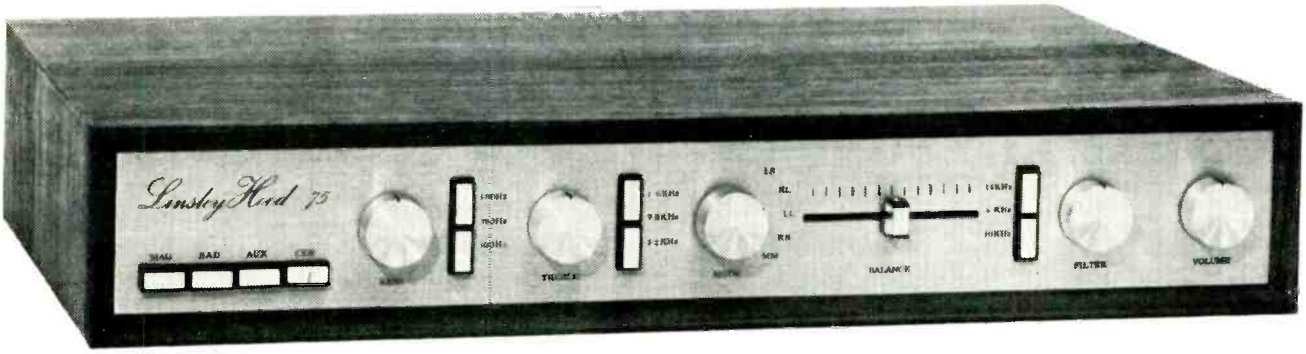

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2N3055	0·45	BF259	0·47
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2N3702	0.11	BFR79	0.25
2N3703	0.10	BFY50	0·20
2N3704	0.10	BFY51	0.20
2N3705	0.10	BFY52	0.20
2N3706	0.09	MJ481	1·20
2N3707	0.10	MJ491	1·30
2N3708	0.07	MJE521	0·60
2N3709	0.09	MPSA05	0·30
2N3710	0.09	MPSA12	0·55
2N3711	0.09	MPSA14	0·35
2N3819	0·23	MPSA55	0·35
2N3904	0·17	MPSA65	0·35
2N3906	0·20	MPSA66	0·40
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2N5830	0·30	TIP30A	0·60
40361	0·40	TIP31A	0·60
40362	0·45	TIP32A	0·70
BC107	0·08	TIP33A	1·00
BC108	0·08	TIP34A	1·50
BC109	0·08	TIP41A	0·74
BC125	0·15	TIP42A	0·90
BC126	0·15	TIP3055	0·60
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BC212K	0·12	1B40K20	1·40
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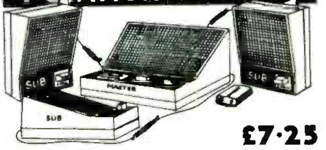

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SN7409	0·18	0·17	0·16
SN7410	0·15	0·14	0·12
SN7411	0·25	0·24	0·23
SN7412	0·35	0·31	0·28
SN7413	0·29	0·28	0·24
SN7416	0·43	0·40	0·38
SN7417	0·43	0·40	0·38
SN7420	0·15	0·14	0·12
SN7422	0·50	0·48	0·45
SN7423	0·50	0·48	0·45
SN7425	0·50	0·48	0·45
SN7427	0·45	0·42	0·40
SN7428	0·70	0·65	0·60
SN7430	0·15	0·14	0·12
SN7432	0·45	0·42	0·40
SN7433	0·80	0·75	0·70
SN7437	0·64	0·62	0·60
SN7438	0·64	0·62	0·60
SN7440	0·15	0·14	0·12
SN7441	0·67	0·64	0·58
SN7442	0·67	0·64	0·58
SN7443	£1·30	£1·25	£1·20
SN7444	£1·30	£1·25	£1·20
SN7445	£1·80	£1·77	£1·75
SN7446	0·97	0·94	0·88
SN7447	£1·00	0·97	0·95
SN7448	£1·00	0·97	0·95

	1	25	100+
SN7450	0·15	0·14	0·12
SN7451	0·15	0·14	0·12
SN7453	0·15	0·14	0·12
SN7454	0·15	0·14	0·12
SN7460	0·15	0·14	0·12
SN7470	0·29	0·26	0·24
SN7472	0·29	0·26	0·24
SN7473	0·37	0·35	0·32
SN7474	0·37	0·35	0·32
SN7475	0·45	0·43	0·42
SN7476	0·40	0·39	0·38
SN7480	0·67	0·64	0·58
SN7481	£1·20	£1·15	£1·10
SN7482	0·87	0·86	0·85
SN7483	£1·10	£1·05	0·95
SN7484	£1·00	0·95	0·90
SN7485	£3·60	£3·50	£3·40
SN7486	0·32	0·31	0·30
SN7489	£5·50	£5·25	£5·00
SN7490	0·67	0·64	0·58
SN7491	£1·00	0·95	0·90
SN7492	0·67	0·64	0·58
SN7493	0·67	0·64	0·58
SN7494	0·77	0·74	0·68
SN7495	0·77	0·74	0·68
SN7496	0·87	0·84	0·78
SN74100	£1·65	£1·60	£1·55
SN74104	0·97	0·94	0·88
SN74105	0·97	0·94	0·88
SN74107	0·40	0·38	0·36
SN74110	0·55	0·53	0·50
SN74111	£1·25	£1·15	£1·10
SN74118	£1·00	0·95	0·90
SN74119	£1·35	£1·25	£1·10
SN74121	0·40	0·37	0·34
SN74122	£1·40	£1·30	£1·10

	1	25	100+
SN74123	£2·80	£2·70	£2·60
SN74141	0·67	0·64	0·58
SN74145	£1·50	£1·40	£1·30
SN74150	£3·00	£2·70	£2·50
SN74151	£1·00	0·95	0·90
SN74153	£1·20	£1·10	0·95
SN74154	£1·80	£1·70	£1·60
SN74155	£1·40	£1·30	£1·20
SN74156	£1·40	£1·30	£1·20
SN74157	£1·90	£1·80	£1·70
SN74160	£1·80	£1·70	£1·40
SN74161	£1·80	£1·70	£1·60
SN74162	£4·00	£3·75	£3·50
SN74163	£4·00	£3·75	£3·50
SN74164	£2·20	£2·15	£2·10
SN74165	£2·25	£2·20	£2·15
SN74166	£3·50	£3·25	£3·00
SN74174	£2·30	£2·20	£2·10
SN74175	£1·60	£1·50	£1·40
SN74176	£2·50	£2·40	£2·30
SN74177	£2·50	£2·40	£2·30
SN74180	£2·00	£1·60	£1·40
SN74181	£5·50	£5·00	£4·75
SN74182	£2·00	£1·80	£1·60
SN74184	£3·50	£3·25	£3·00
SN74190	£1·95	£1·90	£1·85
SN74191	£1·90	£1·85	£1·80
SN74192	£1·95	£1·90	£1·85
SN74193	£2·00	£1·80	£1·75
SN74194	£2·70	£2·60	£2·50
SN74195	£2·00	£1·90	£1·80
SN74196	£1·80	£1·70	£1·60
SN74197	£1·80	£1·70	£1·60
SN74198	£5·50	£5·00	£4·50
SN74199	£5·50	£5·00	£4·50

The AL50 HI-FI AUDIO AMPL 50W pk 25w (RMS)

0·1% DISTORTION! HI-FI AUDIO AMPLIFIER

- Frequency Response 15Hz to 100,000—1dB.
- Load—3, 4, 8 or 16 ohms. ● Supply voltage 10·35 Volts.
- Distortion—better than 0·1% at 1kHz.
- Signal to noise ratio 80dB.
- Overall size 63 mm × 105 mm × 13 mm.

Tailor made to the most stringent specifications using top quality components and incorporating the latest solid state circuitry conceived to fill the need for all your A.F. amplification needs.
FULLY BUILT—TESTED—GUARANTEED.

BRITISH MADE. only £3·25 each

STABILISED POWER MODULE SPM80 £2·95

AP80 is especially designed to power 2 of the AL50 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 MT80, 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.

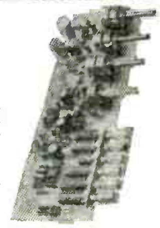
TRANSFORMER BMT80 £1·95 p. & p. 25p

NUMERICAL INDICATOR TUBES

MODEL	CD66	GR116	3015F Minitron
Anode voltage (Vdc)	170min	175min	5
Cathode Current (mA)	2·3	14	8
Numerical Height (mm)	16	13	9
Tube Height (mm)	47	32	22
Tube Diameter (mm)	19	13	12 wide
I.C. Driver Rec.	BP41/14 141	BP41 or 141	BP47
PRICE EACH	£1·70	£1·55	£1·90

All indicators 0-9 + Decimal point. All side viewing. Full data for all types available on request.

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 AL50 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	Bass control	±15dB at 20Hz
Harmonic distortion	better than 0·1%	Treble control	±15dB at 20kHz
Inputs: 1. Tape head	1·25mV into 50KΩ	Filters: Rumble (high pass)	100 Hz
2. Radio, Tuner	35mV into 50KΩ	Scratch (low pass)	8kHz
3. Magnetic P.U.	1·5mV into 50KΩ	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 £11·95

SPECIAL COMPLETE KIT COMPRISING 2 AL50's, 1 SPM80, 1 BMT80 & 1 PA100 ONLY £23.00 FREE p.&p

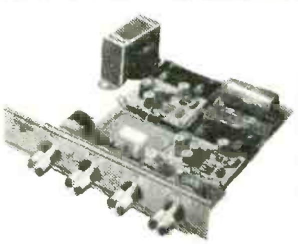
INTEGRATED CIRCUIT PAKS

Manufacturers "Fall Outs" which include Functional and Part-Functional Units. These are classed as 'out-of-spec' from the maker's very rigid specifications, but are ideal for learning about I.C's and experimental work.

Pak No. Contents	Price	Pak No. Contents	Price	Pak No. Contents	Price
UIC00 = 12±7400	0·50	UIC46 = 5 × 7446	0·50	UIC86 = 5 × 7486	0·50
UIC01 = 12 × 7401	0·50	UIC47 = 5 × 7447	0·50	UIC90 = 5 × 7490	0·50
UIC02 = 12 × 7402	0·50	UIC48 = 5 × 7448	0·50	UIC91 = 5 × 7491	0·50
UIC03 = 12 × 7403	0·50	UIC50 = 12 × 7450	0·50	UIC92 = 5 × 7492	0·50
UIC04 = 12 × 7404	0·50	UI351 = 12 × 7451	0·50	UIC93 = 5 × 7493	0·50
UIC05 = 12 × 7405	0·50	UIC53 = 12 × 7453	0·50	UIC94 = 5 × 7494	0·50
UIC06 = 8 × 7406	0·50	UIC54 = 12 × 7454	0·50	UIC95 = 5 × 7495	0·50
UIC07 = 8 × 7407	0·50	UIC60 = 12 × 7460	0·50	UIC96 = 5 × 7496	0·50
UIC10 = 12 × 7410	0·50	UIC70 = 8 × 7470	0·50	UIC100 = 5 × 74100	0·50
UIC13 = 8 × 7413	0·50	UIC72 = 8 × 7472	0·50	UIC121 = 5 × 74121	0·50
UIC20 = 12 × 7420	0·50	UIC73 = 8 × 7473	0·50	UIC141 = 5 × 74141	0·50
UIC30 = 12 × 7430	0·50	UIC74 = 8 × 7474	0·50	UIC151 = 5 × 74151	0·50
UIC40 = 12 × 7440	0·50	UIC75 = 8 × 7475	0·50	UIC154 = 5 × 74154	0·50
UIC41 = 5 × 7441	0·50	UIC76 = 8 × 7476	0·50	UIC193 = 5 × 74193	0·50
UIC42 = 5 × 7442	0·50	UIC80 = 5 × 7480	0·50	UIC199 = 5 × 74199	0·50
UIC43 = 5 × 7443	0·50	UIC81 = 5 × 7481	0·50		
UIC44 = 5 × 7444	0·50	UIC82 = 5 × 7482	0·50	UICXI = 25 Assorted 74's	1·50
UIC45 = 5 × 7445	0·50	UIC83 = 5 × 7483	0·50		

Packs cannot be split, but 25 assorted pieces (our mix) is available as PAK UIC X1.

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. 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	typically 0·25% at 1 watt	Bass control	±12dB at 60Hz
		Treble con.	±14dB at 14kHz

£12·25 free p. & p.

NEW COMPONENT PAK BARGAINS

Pack No.	Qty.	Description	Price
C 1	250	Resistors mixed values approx. count by weight	0·50
C 2	200	Capacitors mixed values approx. count by weight	0·50
C 3	50	Precision Resistors 1%, mixed values	0·50
C 4	75	⅛th W Resistors mixed preferred values	0·50
C 5	5	Pieces assorted Ferrite Rods	0·50
C 6	2	Tuning Gangs, MW/LW/VHF	0·50
C 7	1	Pack Wire 50 metres assorted colours	0·50
C 8	10	Reed Switches	0·50
C 9	3	Micro Switches	0·50
C10	15	Assorted Pots & Pre-Sets	0·50
C11	5	Jack Sockets 3 × 3·5mm 2 × Standard Switch Types	0·50
C12	40	Paper Condensers preferred types mixed values	0·50
C13	20	Electrolytics Trans. types	0·50
C14	1	Pack assorted Hardware—Nuts/Bolts, Grommets etc.	0·50
C15	4	Mains Toggle Switches, 2 Amp D/P	0·50
C16	20	Assorted Tag Strips & Panels	0·50
C17	10	Assorted Control Knobs	0·50
C18	4	Rotary Wave Change Switches	0·50
C19	3	Relays 6—24V Operating	0·50
C20	4	Sheets Copper Laminate approx. 10" × 7"	0·50

Please add 10p post and packing on all component packs, plus a further 10p on pack Nos. C1, C2, C19, C20.

RTL MICROLOGIC CIRCUITS

	Price each 1–24	25–99	100 up
Epoxy TO-5 case uL900 Buffer	35p	33p	27p
uL914 Dual 2i/p gate	35p	33p	27p
uL923 J-K flip-flop	50p	47p	45p

Data and Circuits Booklet for IC's Price 7p.

DUAL-IN-LINE IC's. TWO Ranges PROFESSIONAL & NEW LOW COST.

PROF. TYPE No.	1–24	25–99	100 up.
TSO 14 pin type	30p	27p	25p
TSO 16 ,, ,,	35p	32p	30p
LOW COST No.			
BPS 14	15p	13p	11p
BPS 16	16p	14p	12p

LINEAR I.C.'s—FULL SPEC.

Type No.	Price 1–24	25–99	100 up
BP 201C—SL201C	63p	53p	45p
BP 701C—SL701C	63p	50p	45p
BP 702C—SL702C	63p	50p	45p
BP 702—72702	53p	45p	40p
BP 709—72709	36p	34p	30p
BP 709P—µA709C	36p	34p	30p
BP 710—72710	44p	42p	40p
BP 711—µA711	45p	43p	40p
BP 741—72741	75p	60p	50p
µA703C—µA703C	28p	26p	24p
TAA 263—	70p	60p	55p
TAA 293—	90p	75p	70p
TAA 350	170p	158p	150p

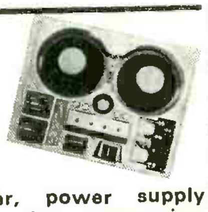
S.G.S. EA1000 £2·63

ROCK BOTTOM PRICES LOGIC DTL 930 Series I.C's

Type No.	Price 1–24	25–99	100 up
BP930	12p	11p	10p
BP932	13p	12p	11p
BP933	13p	12p	11p
BP935	13p	12p	11p
BP936	13p	12p	11p
BP944	13p	12p	11p
BP945	25p	24p	22p
BP946	12p	11p	10p
BP948	25p	24p	22p
BP951	65p	60p	55p
BP962	12p	11p	10p
BP9093	40p	38p	35p
BP9094	40p	38p	35p
BP9097	40p	38p	35p
BP9099	40p	38p	35p

Devices may be mixed to qualify for quantity price. Larger quantity prices on application. (DTL 930 Series only).

SYSTEM 12 STEREO



Each Kit contains two Amplifier Modules, 3 watts RMS, two loudspeakers, 15 ohms, the pre-amplifier, transformer, power supply module, front panel and other accessories, as well as an illustrated stage-by-stage instruction booklet designed for the beginner. Further details available on request.

ONLY £16·95 FREE p. & p.

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Postage and packing add 10p. Overseas add extra for airmail. Minimum order 50p. Cash with order please.

Guaranteed Satisfaction or Money Back

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SUNDERLAND STOCKPORT COVENTRY (Opening Jan.)

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BRADFORD 10 North Parade (Closed Wed).
COVENTRY 17 Shelton Sq. Opens Jan.
DARLINGTON 19 Northgate (Closed Wed.)
DERBY 26 Osmaston Rd. (Closed Wed.)
EDINBURGH 101 Lothian Road (Closed Wed.)
GLASGOW 326 Argyle St. (Closed Tues.)
HULL 7 Whitefriargate (Closed Thurs.)
LEEDS 5-7 County (Mecca) Acade, Briggate (Closed Wed.) Tel. 28252
LEICESTER 32 High St. (Closed Thurs.)
LIVERPOOL 73 Dale St. (Closed Wed.)
LONDON 238 Edgware Rd., W2 (Closed Thurs.) Tel. 723 1629
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R.S.C. G66 MkII 6+6 WATT STEREO AMPLIFIER

High Quality Output. Rating I.H.F.M. Ind. Ganged Controls Bass, Treble, Vol. and Balance. Solid state constr. employing 10 Trans. plus diodes. Range 20-20,000Hz. Bass control ± 12 dB Treble ± 13 dB. Selector switch P.U. or Tape/Radio. Output for 3-15 ohm speakers. Standard 200-250v. 50 Hz mains operation. Attractive Black/Silver metal face plate and matching knobs.

COMPLETE KIT OF PARTS INC. FULLY WIRED PRINTED CIRCUIT £11·50 **OR FACTORY BUILT IN TEAK VENEERED CABINET £14·99**

R.S.C. SUPER 30 MkIII HIGH FIDELITY STEREO AMPLIFIER

BUILD AN AMPLIFIER WORTH APPROXIMATELY DOUBLE THE KIT PRICE INCLUDING CABINET
Only high grade components by leading manufacturers

- Push Button Selector Switching
- Jack Socket for Headphones
- Neon Indicator
- Satin Silver Finish Metal Fascia
- Solid State Circuitry
- Twenty Silicon Transistors
- Four Diodes, Four Rectifiers

Send S.A.E. for full descriptive leaflet

For Magnetic or Ceramic Pick-Ups regardless of Price
Output (per channel) 15 watts RMS into 8 Ω
Frequency Response 7 Hz to 70 KHz ± 1½ dB

COMPLETE KIT (less cabinet). Carr. 65p Cabinet if req. £5 extra **£25**

FACTORY BUILT UNIT INC. CABINET with 12 months' guarantee. Or Dep. £7 and 9 monthly payments £3·99 (Total £42·91) **£38·75**

R.S.C. STEREO FM TUNER NOW AVAILABLE. Visually matches Super 30 Mk. III at **£44·95**

FANE ULTRA HIGH POWER LOUDSPEAKERS

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12" 'POP' 50 50 Watts — 15 Ω 13,000 Gauss **£10·90**
Or Dep. £2 and 9 monthly payments £1·20 (Total £12·80)
Pair suitable for all purposes.

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Including 2 ind. controlled inputs

Separate Bass and Treble Controls. Valves EF86, EF86, ECC83, GZ34, EL34, EL34. Sensitivity 36mV. For High Imp. mic. or pick-ups. Designed to high fidelity standards for CLUBS, SCHOOLS, THEATRES, DANCE HALLS, DISCOTHEQUES, etc. For use with Electronic Organ, Bass or Lead Guitar. For Gram, Radio or Tape. For 3 or 15 ohm speakers.
Twin-handled metal cover £1·90
FACTORY BUILT with 12 months' guarantee. Or Dep. £4 and 9 monthly payments £2·10 (Total £22·90) S.A.E. for leaflet **£19·75**

FANE SPEAKERS 'POP' 25/2

12" 25 WATT — Dual Cone. 15 ohms NOT for Bass Guitar.
£6·75 Or Dep. £1·25 and 9 monthly payments 75p (Total £8·00)

HI-FI SPEAKER ENCLOSURES

Teak veneer finish. Pleasing design. Acoustically lined. All sizes approx.
JE8 16 × 11 × 9 in. Pressurised. Gives excellent results with 8 in. Hi-Fi Speaker. **£5·35**
SE8 for optimum results with any 8 in. Hi-Fi Speaker. 22 × 15 × 9 in. **£6·47**
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300-0-300v. 130mA, 6.3v. 4a., c.t., 6.3v 1a. For Mullard 510 Amplifier	£2·65
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250-0-250v. 100mA, 6.3v. 4a., 0-5-6.3v. 3a.	£2·20
300-0-300v. 100mA, 6.3v. 4a., 0-5-6.3v. 3a.	£2·20
300-0-300v. 130mA, 6.3v. 4a. c.t. 6·3v. 1a. Suitable for Mullard 510 Amplifier	£2·60
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AUTO (Step UP/Step DOWN) Transformers 0-110/120v., 200-230-250v. 50-80 watts **110p**; 150w., **190p**; 250w., **275p**; 500w., **575p**.

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Push-Pull EL84 to 3 or 15 Ω 10-12 watts	£1·35
Push-Pull Ultra Linear for Mullard 510, etc.	£2·20
Push-Pull 15-18 watts, sectionally wound 6L6 KT66, etc., for 3 or 15 Ω	£1·99
Push-Pull 20 watt high quality sectionally wound EL34, 6L6, KT66, etc. to 3 or 15 Ω	£3·30

BATTERY/MAINS CONVERSION UNITS

R.S.C. BM1 battery eliminator completely replaces 1·5v. and 90v. Radio batteries where normal 200-250v. AC mains is available.
Complete Kit with diagram **£3·25** Ready for use **£3·75**

FANE 807T HIGH FIDELITY SPEAKER 8" 10 WATT

A full range unit to provide excellent sound quality in suitable enclosure. Roll P.V.C. cone surround and long throw voice coil to achieve very low fundamental resonance of 30 Hz. Tweeter cone extends high note response. Frequency range 25-15,000 Hz. Imp. 3 or 8/15 Ω. (state requirement.) **£3·85**
Cast Chassis **REMARKABLE VALUE**
MODEL 803T 8" 15w. with parasytic Tweeter. Response 25 Hz to 15 KHz. Gauss 13,000 Imp 3 or 8-15 ohms. ONLY **£4·95**

FANE MODE ONE SPEAKER KIT

Inc. 903 8" unit. 303 Pressure Tweeter, Printed circuit, inductive capacitive cross-over, acoustic filling, panels, screws, etc.
Response 30-24,000 Hz **£9·95**

HIGH FIDELITY SPEAKERS

AUDIOTRINE RANGE

Heavy construction. Highly efficient ceramic magnets. Plastiflex cone surrounds. "D" indicates Tweeter cone providing frequency range up to 15 KHz. Exceptional performance at low cost.

HF 808T	8"	10W	£2·88
HF 102D	10"	10W	£3·40
HF 120	12"	15W	£4·50
HF 120D	12"	15W	£4·99
HF 126	12"	15W	£5·75
HF 126D	12"	15W	£6·25

Please state impedance required. 3 or 8-15 ohm.

HI-FI SPEAKER SYSTEMS

Audiotrine 121K. 12 in. 15 watt. 11,000 Gauss bass unit. Cross-over unit and Tweeter. Smooth response and wide frequency range ensure realistic sound reproduction. Carr. 30p **£5·95**
Audiotrine 125K with extra sensitive 15,000 Gauss 12 in. speaker. **£6·95**

TRANSFORMERS

MAINS ISOLATING SERIES

Primary 200-250 Volts Secondary 240 Volts Centre Tapped (120V) and Earth Shielded
ALSO AVAILABLE WITH 115/120V SECONDARY WINDING

Ref. No.	VA (Watts)	Weight lb	oz	Size cm.	£	P & P p
07	20	1	11	7·0 × 6·0 × 6·5	1·61	30
100	60	3	8	8·9 × 8·0 × 7·7	2·39	36
61	100	5	12	10·2 × 8·9 × 8·3	2·62	52
30	200	9	8	12·0 × 10·3 × 10·0	4·39	52
62	250	12	4	9·5 × 12·7 × 11·4	5·80	67
55	350	15	0	14·0 × 10·8 × 12·4	7·77	82
63	500	27	0	17·1 × 11·4 × 15·9	11·20	*
92	1000	40	0	17·8 × 17·1 × 21·6	20·63	*
128	2000	63	0	24·1 × 21·6 × 15·2	34·10	*
129	3000	84	0	21·6 × 21·6 × 20·3	53·34	*
190	6000	178	0	31·1 × 35·6 × 17·1	87·52	*

440V 300VA ISOLATOR, Primary 440V Secondary 240V, Centre Tapped Screened and Shrouded, £9·43. P & P 67p.

AUTO SERIES (NOT ISOLATED)

Ref. No.	VA (Watts)	Weight lb	oz	Size cm.	Auto Taps	£	P & P p
113	20		11	7·3 × 4·3 × 4·4	0-115-210-240	0·85	22
64	75	1	14	7·0 × 6·4 × 6·0	0-115-210-240	1·66	30
4	150	3	0	8·9 × 6·4 × 7·6	0-115-200-220-240	2·00	36
66	300	6	0	10·2 × 10·2 × 9·5	,, ,,	3·89	52
67	500	12	8	14·0 × 10·2 × 11·4	,, ,,	5·78	67
84	1000	16	0	11·4 × 14·0 × 14·0	,, ,,	10·49	82
93	1500	28	9	13·5 × 14·9 × 16·5	,, ,,	15·20	*
95	2000	40	0	17·8 × 16·5 × 21·6	,, ,,	19·84	*
73	3000	45	8	17·4 × 18·1 × 21·3	,, ,,	26·99	*

TOTALLY ENCLOSED 115V AUTO TRANSFORMERS

115V 500 Watt totally enclosed auto transformer, complete with mains lead and two 115V outlet sockets, £7·85. P & P 67p
Also available a 20 Watt version. £1·67. P & P 22p.

LOW VOLTAGE SERIES (ISOLATED)
PRIMARY 200-250 VOLTS 12 AND/OR 24 VOLT RANGE

Ref. No.	Amps. 12V	Amps. 24V	Weight lb	oz	Size cm.	Secondary Windings	£	P & P p
111	0·5	0·25		12	7·6 × 5·7 × 4·4	0-12V at 0·25A × 2	0·85	22
213	1·0	0·5	1	0	8·3 × 5·1 × 5·1	0-12V at 0·5A × 2	1·01	22
71	2	1	1	0	7·0 × 6·4 × 5·7	0-12V at 1A × 2	1·33	22
18	4	2	2	4	8·3 × 7·0 × 7·0	0-12V at 2A × 2	1·86	36
70	6	3	3	12	10·2 × 7·6 × 8·6	0-12V at 3A × 2	2·24	42
108	8	4	5	4	10·0 × 8·3 × 8·2	0-12V at 4A × 2	2·48	52
72	10	5	6	3	7·9 × 10·8 × 10·2	0-12V at 5A × 2	2·94	52
17	16	8	7	8	12·1 × 9·5 × 10·2	0-12V at 8A × 2	4·54	52
115	20	10	11	13	12·1 × 11·4 × 10·2	0-12V at 10A × 2	5·78	67
187	30	15	16	12	13·3 × 12·1 × 12·1	0-12V at 15A × 2	10·67	82
226	60	30	34	0	17·0 × 14·5 × 12·5	0-12V at 30A × 2	19·61	*

30 VOLT RANGE

Ref. No.	Amps.	Weight lb	oz.	Size cm.	Secondary Taps	£	P & P p
112	0·5	1	4	8·3 × 3·7 × 4·9	0-12-15-20-24-30V	1·01	22
79	1·0	2	0	7·0 × 6·4 × 6·0	,, ,,	1·35	36
3	2·0	3	2	8·9 × 7·0 × 7·6	,, ,,	2·01	36
20	3·0	4	6	10·2 × 8·9 × 8·6	,, ,,	2·48	42
21	4·0	6	0	10·2 × 10·0 × 8·6	,, ,,	2·94	52
51	5·0	6	8	12·1 × 10·0 × 8·6	,, ,,	3·66	52
117	6·0	7	8	12·1 × 10·0 × 10·2	,, ,,	4·36	52
88	8·0	10	0	14·0 × 11·7 × 10·0	,, ,,	5·64	67
89	10·0	12	2	14·0 × 10·2 × 11·4	,, ,,	7·14	67

50 VOLT RANGE

Ref. No.	Amps.	Weight lb	oz	Size cm.	Secondary Taps	£	P & P p
102	0·5	1	11	7·0 × 7·0 × 5·7	0-19-25-33-40-50V	1·33	30
103	1·0	2	10	8·3 × 7·3 × 7·0	,, ,,	1·94	36
104	2·0	5	0	10·2 × 8·9 × 8·6	,, ,,	2·69	42
105	3·0	6	0	10·2 × 10·2 × 8·3	,, ,,	3·65	52
106	4·0	9	4	12·1 × 11·4 × 10·2	,, ,,	4·83	52
107	6·0	12	4	12·1 × 11·1 × 13·3	,, ,,	7·14	67
118	8·0	18	9	13·3 × 13·3 × 12·1	,, ,,	9·32	97
119	10·0	19	12	16·5 × 11·4 × 15·9	,, ,,	11·68	97

60 VOLT RANGE

Ref. No.	Amps.	Weight lb	oz	Size cm.	Secondary Taps	£	P & P p
124	0·5	2	4	8·3 × 9·5 × 6·7	0-24-30-40-48-60V	1·35	36
126	1·0	3	0	8·9 × 7·6 × 7·6	,, ,,	1·88	36
127	2·0	5	6	10·2 × 8·9 × 8·6	,, ,,	2·94	42
125	3·0	8	8	11·9 × 9·5 × 10·0	,, ,,	4·48	52
123	4·0	10	6	11·4 × 9·5 × 11·4	,, ,,	5·78	67
120	6·0	16	12	13·3 × 12·1 × 12·1	,, ,,	8·37	82
122	10·0	23	2	16·5 × 12·7 × 16·5	,, ,,	13·85	*

LEAD ACID BATTERY CHARGER TYPES
PRIMARY 200-250 VOLT FOR CHARGING 6 OR 12 VOLT BATTERIES

Ref. No.	Amps.	Weight lb	oz	Size cm.		£	P & P p
45	1·5	1	9	7·0 × 6·0 × 6·0	Please note, these units do not include rectifier.	1·34	30
5	4·0	3	11	10·2 × 7·0 × 8·3		2·03	42
86	6·0	5	12	10·2 × 8·9 × 8·3		3·07	52
146	8·0	6	4	8·9 × 10·2 × 10·2		3·49	52
50	12·5	11	14	13·3 × 10·8 × 12·1		5·20	67

All ratings are continuous. Standard construction: open with solder tags and wax impregnation. Enclosed styles to order.

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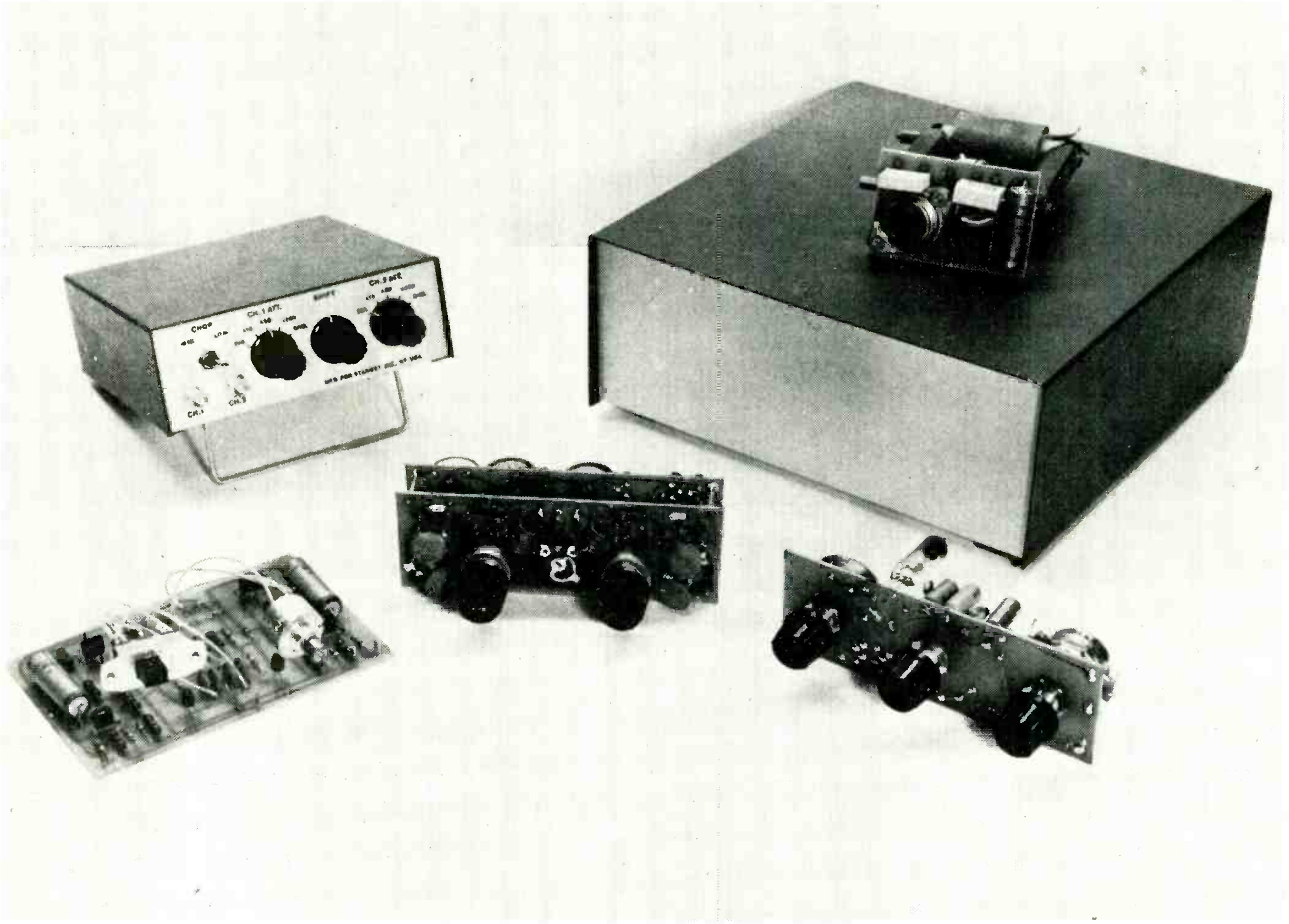

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20 HZ to 200KHZ SINE WAVE GENERATOR

In four ranges. Wien bridge oscillator, thermistor stabilised, amplitude control. 3 V peak to peak. Completely assembled P.C. board, ready to use. 9 to 15 V supply required. £4.85 each P & P 25p. SINE *AND* SQUARE WAVE version of above £6.85 each. P & P 25p.

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12V to 1.5 KV 2 MA AC. Size $1\frac{1}{2}$" x $2\frac{1}{2}$" x 4". £2.95 each P & P 25p.

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For displaying response of 10.7 MHZ (FM receiver I.F.'s) and 30-40 MHZ (TV I.F. alignment). Requires 6.3V AC and any general purpose oscilloscope. Instructions supplied. Completely assembled P.C. Board. £9.00 each P & P 25p

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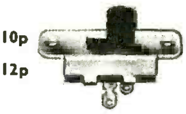

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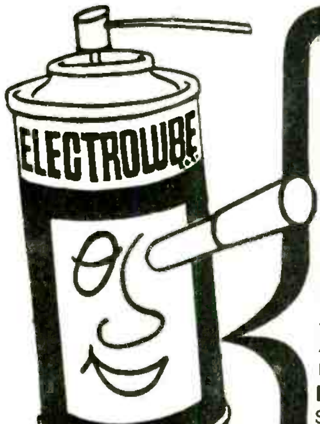

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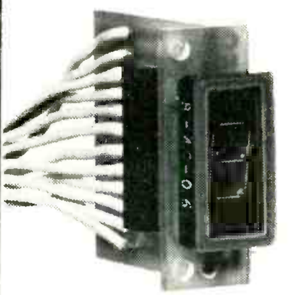
NEW RANGE



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Laskys

LASKYS — NEW DOLBY SYSTEM NOISE REDUCTION UNIT

The new Lasky's NOISE REDUCTION UNIT uses the famous DOLBY 'B' system to provide users of semi professional and cassette recorders with a way to increase performance at low tape speeds by reducing tape hiss by 3dB at 600Hz rising to 6dB at 1200Hz and 10dB for all frequencies above 3000Hz. The unit is ideal for replay of pre-recorded tapes and cassettes now being issued in the DOLBY 'B' format. Controls are provided for input levels and noise reduction on record and replay. 2 meters are fitted for instant checking of DOLBY level. Off tape monitoring is provided by the replay input button when used with 3 head machines. Brief specification. Frequency response: 20Hz to 15KHz ± 1dB 19KHz 35dB. Channel separation: 50dB at 1KHz. Signal to noise: better than 70dB (ref 580mV). Power requirements: 200/250V. AC 40/60Hz. Size 15¾x9x3¼in.

LASKYS PRICE **£32.50** POST FREE IN U.K.

Audiotronic 6 Pole Quadraphonic Decoder

This new Audiotronic Decoder is a fully transistorised system to reproduce 4-channel sound from SQ records and 4-channel discrete sources. It performs the CBS SQ matrix decoding function on SQ encoded programme material (adopted by the majority of the world's manufacturers), from disc, tape or FM radio. The four signals, when reproduced through four amplifiers and four speakers, will be presented as left, right and front, left and right back information. Switching is provided for: SQ recording and FM Broadcasts, "Ambient" for enhanced 2-channel sound by synthesizing four channels: normal stereo: 2- and 4-channel record and playback. The master volume control allows overall level to be set plus a rear control for front to back balancing. BRIEF SPEC. Input Imp 40K ohms. Output Imp. 300 ohms. Freq. Resp. 4Hz — 100KHz. Freq. Sep. 60dB. Rear Sep. 20dB. Power Req. AC 240V 50/60Hz. Size: 180 (W) x 55 (H) x 220 (D) mm.

LASKYS PRICE £22.50 C. & P. 35p

FERGUSON 3414 COMPACT SYSTEM

The 3414 is a compact FM stereo receiver fitted with a B.S.R. Auto/Manual turntable and Goldring G800H cart. Inputs for Tape play and Auxiliary and outputs for tape and headphones. Controls for volume, bass, treble and balance. The FM Tuner section has 5 pre-settable push buttons. Stereo broadcast indicator beacon. SPEC. Power Output 15 watts per channel into 4 ohms. Freq. Resp. 30-25KHz. Harmonic Dist. Less than 0.5% @ 1KHz. Power Req. AC 120-240V 50/60Hz. Size 56.5 (L) x 38 (W) x 18.5 (H) cm. Walnut veneer finish.

The Philips RH.402 Speakers include one 7" woofer and one 1" tweeter. Power 20W r.m.s.

Complete with pair of Philips RH.402 speakers. **£79.00**

Philips RH.402 Speakers available separately at **£21.50 pair.**

PACKAGE
Ferguson 3414 Compact with a pair of Lasky's Criterion Mk. X speakers. **Laskys Price £85**

LEAK TRUSPEED Mk III

Made to sell for £69.50

A low speed (250 r.p.m.) synchronous 12-pole hysteresis motor (100-130V, or 200-250V), gives constant turntable speed independent of mains voltage fluctuations. Speeds: 33⅓ r.p.m. and 45 r.p.m. Wow: less than 0.15%. Flutter: less than 0.02%. Isolated pick-up arm and balanced turntable mounting greatly reduced acoustic feedback. Cast aluminium turntable. The antistatic turntable mat holds all diameters of record correctly and drives them from the rim thus eliminating slipping caused by bowed or warped records. Size: 12⅞in x 15⅜in x 7⅛in. inc. cover. COMPLETE WITH ARM, TEAK PLINTH, AND TINTED PERSPEX COVER AND SHURE M75/6 CARTRIDGE.

LASKYS PRICE C. & P. **£47.50**

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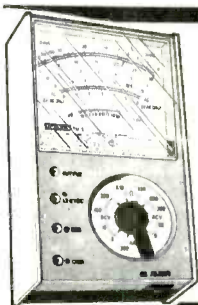

EXCLUSIVE TM-5

5K/ohms/V MULTIMETER

Another pocket multimeter from Laskys providing top quality and value. The Slimline impact resistant case size 4¾x2¾x1¾in fitted with extra large 2¾in square meter. Readability is superior on all ranges, making this an excellent instrument for servicing transistorised equipment. Recessed click stop selection switch. Zero ohms adjustment. Buff finish with crystal clear meter cover.

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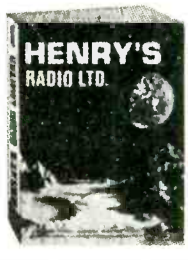

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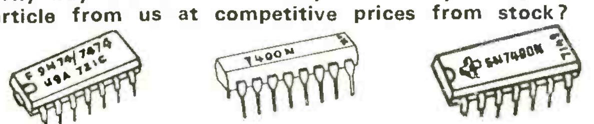

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SN7405	20p	18p	16p	SN7472	30p	27p	25p	SN74156	£1·55	£1·47	£1·35
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SN7407	30p	27p	25p	SN7474	40p	37p	35p	SN74160	£2·60	£2·40	£2·25
SN7408	20p	19p	18p	SN7475	55p	52p	50p	SN74161	£2·60	£2·40	£2·25
SN7409	45p	42p	35p	SN7476	45p	42p	39p	SN74162	£3·40	£3·25	£2·70
SN7410	20p	18p	16p	SN7480	80p	75p	67p	SN74163	£3·40	£3·25	£2·70
SN7411	23p	22p	20p	SN7481	£1·25	£1·15	£1·10	SN74164	£2·75	£2·30	£2·10
SN7412	42p	40p	35p	SN7482	87p	80p	70p	SN74165	£4·00	£3·50	£3·00
SN7413	30p	27p	25p	SN7483	£1·00	90p	85p	SN74166	£4·00	£3·50	£3·00
SN7416	30p	27p	25p	SN7484	90p	85p	80p	SN74167	£6·25	£5·60	£5·10
SN7417	30p	27p	25p	SN7486	45p	41p	38p	SN74170	£4·10	£3·55	£3·05
SN7420	20p	18p	16p	SN7490	75p	70p	65p	SN74174	£2·00	£1·75	£1·30
SN7422	48p	44p	40p	SN7491AN	£1·00	95p	90p	SN74175	£1·35	£1·27	£1·15
SN7423	48p	44p	40p	SN7492	75p	70p	65p	SN74176	£1·60	£1·35	£1·20
SN7425	48p	40p	35p	SN7493	75p	70p	65p	SN74177	£1·60	£1·35	£1·20
SN7427	42p	39p	35p	SN7494	80p	75p	70p	SN74180	£1·55	£1·30	£1·20
SN7428	50p	45p	42p	SN7495	80p	75p	70p	SN74181	£7·00	£6·00	£5·50
SN7430	20p	18p	16p	SN7496	£1·00	97p	95p	SN74182	£2·00	£1·80	£1·60
SN7432	42p	38p	35p	SN7497	£6·25	£5·50	£5·00	SN74184	£2·40	£2·00	£1·80
SN7433	70p	61p	44p	SN74100	£2·50	£2·30	£2·00	SN74185A	£2·40	£2·00	£1·80
SN7437	65p	60p	50p	SN74104	£1·45	£1·35	£1·20	SN74190	£1·95	£1·85	£1·75
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SN7445	£2·00	£1·75	£1·60	SN74121	60p	55p	50p	SN74196	£1·50	£1·40	£1·30
SN7446	£2·00	£1·75	£1·60	SN74122	£1·35	£1·25	£1·10	SN74197	£1·50	£1·40	£1·30
SN7447	£1·75	£1·60	£1·45	SN74123	£2·70	£2·55	£2·47	SN74198	£4·60	£3·70	£3·35
SN7448	£1·75	£1·60	£1·45	SN74141	£1·00	95p	90p	SN74199	£4·60	£3·70	£3·35
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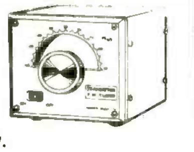
TEXAS HANDBOOK No. 2I.C. 700 PAGES DATA 60p. POST 20p.

IC SOCKETS
16 lead 17p
14 lead 15p
8 lead 15p

BUILD THIS VHF FM TUNER



5 TRANSISTORS 300 kc/s BANDWIDTH. PRINTED CIRCUIT. HIGH FIDELITY REPRODUCTION. MONO AND STEREO

A popular VHF FM Tuner for quality and reception of mono and stereo. There is no doubt about it—VHF FM gives the REAL sound. All parts sold separately. Free Leaflet No. 3 & 7.

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Mains unit (optional) Model PS900 £2·47. Post 20p.
Mains unit for Tuner and Decoder PS6/12 £3·25. Post 20p.

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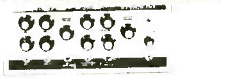

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UK's Largest Range—Write phone or call in. Details and demonstrations on request.

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IC12 £1·80; Q16's £15 pr.
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5 transistor. 300mW o/p. Fitted volume and sensitivity control, 9 volt operated. £1·75 each. P/P 15p.

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All voltages
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Any one type.

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All voltages
6.8-100 Volts
20p each
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Any one type.

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Wire Ends 5%
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Mounting 5%
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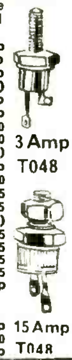
6.8-100 Volts.
40p each.

TRIACS

STUD WITH ACCESSORIES

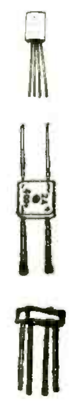


Type	Volts P.I.V.	Price 1-11
3 AMP RANGE		
SC35A	100	75p
SC35B	200	79p
SC35D	400	85p
6 AMP RANGE (TO48)		
SC40A	100	85p
SC40B	200	90p
SC40D	400	£1·00
SC40E	500	£1·20
10 AMP RANGE (TO48)		
SC45A	100	95p
SC45B	200	£1·00
SC45D	400	£1·25
SC45E	500	£1·45
15 AMP RANGE (TO48)		
SC50A	100	£1·25
SC50B	200	£1·35
SC50D	400	£1·65
SC50E	500	£1·85
DIAC D32		25p
TRIACS— Additional Types		
40430	(TO66)	85p
40669	(Plastic)	£1·00
40486	(TO5)	80p

3 Amp T048
15 Amp T048

NEW BRIDGE RECTIFIERS

SMALL SIZE AND LOW COST



Type	Volts P.I.V.	Price 1-11
HALF AMP		
BO5/05	50	20p
BO5/10	100	25p
ONE AMP $\frac{1}{4}\times\frac{3}{8}$H TUBULAR		
B1/05	50	25p
B1/10	100	25p
B1/20	200	30p
B1/60	600	35p
ONE AMP (G.I.) TUBULAR		
W005	50	30p
W01	100	35p
W02	200	40p
W06	600	45p
TWO AMPS $\frac{1}{4}$H×$\frac{1}{2}$L×$\frac{3}{16}$		
B2/05	50	35p
B2/100	100	40p
B2/200	200	45p
B2/600	600	50p
B2/1000	1000	60p
FOUR AMPS $\frac{1}{4}$H×$\frac{1}{2}$L×$\frac{3}{16}$		
B4100	100	60p
B4/200	200	65p
B4/400	400	70p
B4/600	600	75p
B4/800	800	£1·00
SIX AMPS $\frac{1}{4}$H×$\frac{1}{2}$L×$\frac{3}{16}$		
B6/100	100	70p
B6/200	200	75p
B6/400	400	90p
B6/600	600	£1·00

SILICON CONTROLLED RECTIFIERS

Type	Volts P.I.V.	Price 1-11
ONE AMP		
CRS 1/05	50	25p
CRS 1/10	100	30p
CRS 1/20	200	30p
CRS 1/40	400	35p
CRS 1/60	600	45p
THREE AMP (TO48)		
CRS 3/05	50	30p
CRS 3/10	100	30p
CRS 3/20	200	35p
CRS 3/40	400	45p
CRS 3/60	600	55p
FIVE AMP (TO66)		
CRS 5/400	400	60p
SEVEN AMP (TO48)		
CRS 7/100	100	60p
CRS 7/200	200	65p
CRS 7/400	400	70p
CRS 7/600	600	95p
SIXTEEN AMP		
SCR 16/100	100	65p
SCR 16/200	200	70p
SCR 16/400	400	80p
SCR 16/600	600	£1·00

1 Amp T05
3 Amp T048

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Just a Selection

SE250B	Pocket Pencil Signal Injector £1·90
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200H	20 K/V Multimeter £4·20. With case £9·50
AF105	50 K/V Multimeter £8·50. With case £9·50
U4341	AC/DC Multimeter with transistor tester. Steel case £10·50
TE20D	RF Generator 120KHz-500MHz £15·95 Carr. 35p
TE22D	Audio Generator 20Hz-200KHz £17·50 Carr. 35p
C1-5	3" Pulse Scope 10Hz-10mHz £39·00 Carr. 50p
TE65	Valve Voltmeter 28 ranges £17·50 Carr. 40p

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To build MW/LW Superhet Radio using Mullard RF/IF Module, 600mW o/p. Fibre glass cabinet. **All parts £7·98.** P. & P. 32p. (Battery 22p extra.)

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ML3 — Superhet MW/LW radio Tuner to build S/M Tuning, Mullard Module etc.
ALL PARTS £4·85. P. & P. 15p.

ALL PARTS SOLD SEPARATELY

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(Post 15p per 1 to 6)
XN3, XN13, GN6 0-9 side view with data. **85p.**
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12 and 24 hour clock circuits. Ref. No. 31 **15p.**

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Operate at 40kc/s up to 100 yds. Ideal remote switching and signalling. Complete with data and circuits.
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QUALITY SLIDER CONTROLS

60mm stroke singles and ganged. Complete with knobs. 5kΩ, 10kΩ, 25kΩ, 100kΩ 250kΩ, 500kΩ. 1 meg. Log and Lin. **40p** each, 10kΩ, 25kΩ 50kΩ, 100kΩ, 250kΩ, Log and Lin ganged. **60p each.**

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4 TRACK MONO or 2 TRACK STEREO

"17" High impedance	£2·00
"18" Med. Impedance	£2·00
"36" Med.-Low Imp.	£3·50
Erase Heads for above	75p
"63" 2 track mono—High Impedance	£1·75
"43" Erase Head for above	75p.

SILICON RECTIFIERS

WIRE ENDED PLASTIC

Type	P.I.V.	1-11
1 amp miniature		
IN4001	50	6p
IN4002	100	7p
IN4003	200	8p
IN4004	400	8p
IN4005	600	10p
IN4006	800	12p
IN4007	1000	15p
1.5 amp miniature		
PL4001	50	8p
PL4002	100	9p
PL4003	200	10p
PL4004	400	10p
PL4005	600	12p
PL4006	800	15p
PL4007	1000	16p

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702C TO5	75p
709C TO99	35p
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723C D.I.L.	95p
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741C TO99	55p
741C D.I.L.	55p
747C TO99	£1·10
747C D.I.L.	£1·10
72741P D.I.L.	60p
72748P D.I.L.	60p

SL4030D PLESSEY

3 WATT R.M.S. I.C.

Complete with 8 page Data Booklet and Circuits £1·50. (P.C. Board Stereo **60p**; Heat Sink **14p**).

Also Sinclair IC12 **£1·80.**

TH9013P—20 watt Power Amp Module £4·57.

TH9014P-IC Preamp **£1·50.**

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071 15332	16	3300	2·4 amps	1oz	**15p**
071 15472	16	4700	3·9 amps	1oz	**17p**
071 15682	16	6800	5·8 amps	1½oz	**22p**
071 15103	16	10000	7·9 amps	2½oz	**27p**
072 15752	16	7500 + 7500	10·5 amps	3oz	**37p**
072 15113	16	11000 + 11000	13·8 amps	4½oz	**49p**
071 16222	25	2200	2·2 amps	1oz	**15p**
071 16472	25	4700	5·4 amps	1½oz	**22p**
072 16502	25	5000 + 5000	9·6 amps	3½oz	**37p**
072 16752	25	7500 + 7500	12·6 amps	4½oz	**49p**

Type No.	Working Voltage Vdc.	Capacitance uF	Max. Ripple Current at 50°c	Weight	Price
072 17342	40	34003 + 400	9·1 amps	3½oz	**37p**
072 17502	40	5000 + 5000	12·0 amps	4½oz	**49p**
071 18681	63	680	2·1 amps	1oz	**15p**
072 18172	63	1650 + 1650	7·8 amps	3oz	**37p**

106 and 107 Series

Type No.	Working Voltage Vdc.	Capacitance uF	Max. Ripple Current at 50°c	Weight	Price
106 15103	16	10000	7 amps	2½oz	**65p**
106 16223	25	22000	17 amps	10oz	**£1·12**
106 17103	40	10000	12 amps	7½oz	**94p**
106 18153	63	15000	28 amps	18oz	**£1·79**
107 10222	100	2200	10 amps	5½oz	**74p**

A further 10% discount on lots of 100 of any one type. Please calculate the weight of your order and include appropriate postage.

RECTIFIERS 1N4007 1200 peak volts, 30 amps peak current, 1 amp mean current. 100 for £7·50, 1,000 £50.

ELECTROLYTIC CAPACITORS

2,000µf 25 volt Rev.	**25p**
1,000µf 70 volt	**35p**
10,000µf 35 volt	**50p**
10,000µf 25 volt	**35p**
60µf +200µf 300 volt	**30p**
10µf 6 volt	**2p**
10µf 25 volt	**4p**
16µf 250 volt	**8p**
32µf 275 volt	**8p**

Miniature type. Both wires same end.

5µf 10 volt	3p each
30µf 10 volt	3p each
50µf 10 volt	3p each
220µf 25 volt	3p each

AXIAL LEADS

250µf 25 volt	**10p**
500µf 25 volt	**13p**
1,000µf 25 volt	**16p**
2,000µf 25 volt	**25p**
2,500µf 50 volt	**30p**
400µf 40 volt	**20p**
125µf 4 volt	3p each
400µf 6·4 volt	3p each
320µf 10 volt	3p each
16µf 16 volt	3p each
320µf 2·5 volt	3p each
125µf 4 volt	3p each

TANTALUM CAPACITORS

Special offer to clear!—5p each; 50p dozen; £3·50 per 100.

0·047µf 20 volt	0·15µf 35 volt	2·7µf 15 volt	5·6µf 50 volt	27µf 20 volt
0·056µf 50 volt	0·22µf 50 volt	2·7µf 35 volt	6·8µf 20 volt	27µf 35 volt
0·033µf 20 volt	0·33µf 50 volt	2·7µf 50 volt	6·8µf 50 volt	47µf 50 volt
0·056µf 50 volt	0·39µf 35 volt	3·0µf 12 volt	6·8µf 75 volt	56µf 15 volt
0·068µf 35 volt	0·47µf 50 volt	3·3µf 15 volt	12µf 50 volt	56µf 20 volt
0·068µf 50 volt	0·68µf 35 volt	4·7µf 35 volt	22µf 15 volt	82µf 20 volt
0·07µf 20 volt	0·68µf 50 volt	5·6µf 6 volt	22µf 75 volt	150µf 6 volt
0·12µf 35 volt	1·5µf 20 volt	5·6µf 35 volt	18µf 35 volt	270µf 6 volt

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

NEWER THAN NEW!!!

Fibre Glass Board pre-treated with light-sensitive lacquer enabling you to produce prototype printed circuits within five minutes.

75mm × 100mm	**33p**
150mm × 100mm	**66p**
150mm × 200mm	**£1·32**

Epoxy-Resin

75mm × 100mm	**22p**
100mm × 150mm	**44p**
150mm × 200mm	**88p**

Plain Fibre Glass Board, copper-clad one side

290mm × 175mm	**45p**

Bakelite Laminate Board, 1·57mm thick

1 sq. foot	**50p**

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3p each; **24p** dozen; **£1·75** per 100

15pf	330pf	2,700pf	19,000pf
22pf	470pf	3,300pf	22,000pf
33pf	560pf	4,700pf	33,000pf
39pf	620pf	6,800pf	47,000pf
47pf	680pf	8,200pf	68,000pf
68pf	1,000pf	8,500pf	
100pf	1,500pf	10,000pf	
220pf	2,200pf	15,000pf	

MULLARD POLYESTER CAPACITORS

500,000 IN STOCK!!!

·001µf	·0018µf	·0056µf	·015µf
·0012µf	·0022µf	·01µf	·033µf
·0015µf	·0027µf	·012µf	·082µf

20p dozen; **75p**-100; **£5**-1,000; **£40**-10,000.

·15µf	·22µf	·39µf	·82µf
·18µf		·68µf	

20p dozen; **£1**-100; **£6·50**-1,000; **£50**-10,000

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2½in × 1in × 0·15in **6p**	5in × 3¾in × 0·15in **28p**	3¾in × 3¾in × 0·1in **24p**
3¾in × 2½in × 0·15in **16p**	17in × 2½in × 0·15in **55p**	5in × 2½in × 0·1in **23p**
3¾in × 3¾in × 0·15in **20p**	17in × 3¾in × 0·15in **74p**	5in × 3¾in × 0·1in **28p**
5in × 2½in × 0·15in **20p**	3¾in × 2½in × 0·1in **21p**	

Spot Face Cutter **38p**. Pin Insert Tool **48p**. Terminal Pins (0·1 or 0·15) 36 for **18p**. Special Offer Pack consisting of 5 2½in × 1in boards and a Spot Face Cutter—**50p**. "ODDS & ENDS"—IP sq. in.

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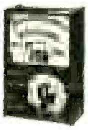

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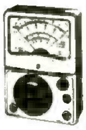

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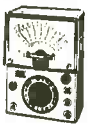
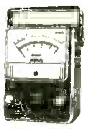


HIOKI MODEL 750X 50,000 o.p.v. 43 ranges 0-0.3 to 1,200v. D.C. 0-3 to 1,200 v. A.C. 0-30μA/300mA. 0-3K/30 meg. ohms. —10 to +17 db. **£18·97**. Post 20p.



HT100B4 MULTIMETER Features A.C. current ranges. 100,000 o.p.v. Mirror Scale. Overload protection. 0/·5/2·5/10/50/250/500/1000 V DC. 0/2·5/10/50/250/1000 V AC. 0/10/250MμA/2·5/25/250 MA/10 Amp DC. 10 Amp AC. 0/20K/200K/2MEG/20MEG. — 20 + 62 db. **£12·50**. Post 25p.

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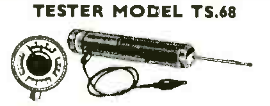
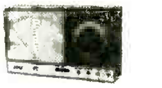
Our Price **£5·97**. Post 25p.

ROUND SCALE TYPE PENCIL TESTER MODEL TS.68



Completely portable, simple to use pocket sized tester. Ranges: 0/3/30/300v A.C. and D.C. at 2,000 o.p.v. Resistance 0-20K ohms. Only **£1·97**. Post 13p.



LT801 MULTIMETER New style 20,000 o.p.v. pocket multimeter. 5 / 25 / 50 / 250 / 2500V. D.C. 10/50/100/500/1000V. A.C. 50μA/250mA. 6K/6 meg ohms. —20 to +22db. **£3·75**. Post 20p.

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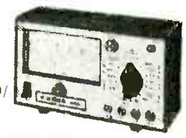
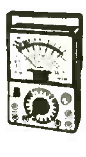
MODEL PL436. 20kΩ/Volt D.C. 8kΩ/Volt A.C Mirror scale. ·6/3/12/30/120/600V D.C. 3/30/120/600V A.C. 60/600μA/60/600 mA. 10/100K/1 Meg/10 meg Ω. —20 to +46db. **£6·97**. Post 12p.

TMK MODEL TW-50K 46 ranges, mirror scale, 50K/Vol. D.C. 5K /Volt A.C. D.C.: Volts ·125, ·25, 1·25, 2·5, 5, 10, 25, 50, 125, 250, 500, 1,000V. A.C. Volts: 1·5, 3, 5, 10, 25, 50, 125, 250, 500, 1,000V. D.C. Current: 25, 50μA, 2·5, 5, 25, 50, 250, 500mA, 5, 10 amp. Resistance: 10K, 100K, 1 MEG, 10 MEGΩ. Decibels: —20 to +81·5 db. **£8·50**. Post 17p.



MODEL K228A Taut band suspension. Overload protection. Polarity reversing switch. 30,000 o.p.v. 50/0/·5/2·5/15/250/500/1000/2500V D.C. 0/15/50/150/500/1000V. A.C. 0/50μA/5/50/150/500mA/5A D.C. 0/3K/300K/3 meg. **£8·95**. Post 20p.

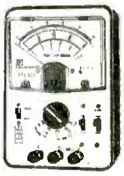


HIOKI MODEL 700X 100,000 O.P.V. Overload protection. Mirror scale, ·3/·6/1·2/1·5/3/6/12/30/60/120/300/600/1200 VDC. 1·5/3/6/12/30/60/150/300/600/1200 VAC. 15/30vA/3/6/30/60/150/300 mA. 6/12 AMP DC. 2K/200 K/2 Meg/20 megohm. —20 to +63db. **£13·50**. Post 20p.

MODEL C-7080 EN Giant 6in. mirror scale. 20,000 o.p.v. 0/·25/1/2·5/10/50/250/1000/5000V. D.C. 0/2·5/10/50/250/1000/5000V. A.C. 0/50μA/1/10/100/500mA/10 amp. D.C. 0/2K/200K/20 meg. —20 to +50 db. **£13·95**. Post 35p.

U4312 MULTIMETER Extremely sturdy instrument for general electrical use. 667 o.p.v. 0/·3/1·5/7·5/30/60/150/300/600/900 VDC and 75mV. 0/·3/1·5/7·5/30/60/150/300/600/900 VAC. 0/300μA/1·5/6/15/60/150 600MA/1·5/6 AMP. D.C. 0/1·5/6/15/60/150/600MA/1·5/6 AMP. A.C.0/200 Ω/3K/30K Ω. Accuracy DC 1%. AC 1·5%. Knife edge pointer, mirror scale. Complete with sturdy metal carrying case, leads and instructions. **£9·50**. Post 25p.

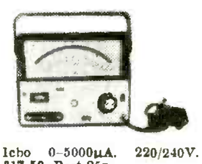
Selected TEST EQUIPMENT



FTC-401 TRANSISTOR TESTER

Full capabilities for measuring A, B and ICO. NPN or PNP. Equally adaptable for checking diodes. Supplied complete with instructions, battery and leads. **£7·50**. Post 20p.

Model S-100TR MULTI-METER/TRANSISTOR TESTER 100,000 o.p.v. MIRROR SCALE/OVER-LOAD PROTECTION 0/·12—·6/3/12/30/120/600 V DC. 0/6/30/120/600 V. AC. 0/12/600uA/12/300MA/12 Amp. DC. 0/10K/1 MEG/100 MEG. — 20 to + 50 db. 0·01 —·2 mfd. Transistor tester measures Alpha, beta and Ico. Complete with batteries, instructions and leads. **£13·50**. Post 25p.

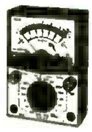


MODEL 449A IN CIRCUIT TRANSISTOR TESTER Checks true A.C. beta in/out. Checks Icbo. Checks diodes in/out. Checks SCR etc. Beta Hi 10–500. LO2–50. Icbo 0–5000μA. 220/240V. A.C. operation. **£17·50**. Post 25p.

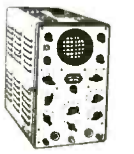
RF-300 AF/RF SIGNAL GENERATOR

All transistorised, compact, fully portable. AF sine wave 18Hz. to 220KHz. AF square wave 18Hz. to 100KHz. Output sine/square 10v. P-P. RF 100KHz. to 200 MHz. Output 1v. maximum. Operation 220/240v. A.C. Complete with instructions and leads. **£29·95**. Post 50p.

TE-20 D RF SIGNAL GENERATOR Accurate wide range signal generator covering 120 Kc/s-500 Mc/s on 6 bands. Directly calibrated Variable R.F. attenuator, audio output. Xtal socket for calibration. 220/240V. A.C. Brand new with instructions. **£15**. Carr. 37p. Size 140 × 215 × 170 mm.



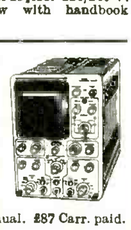
MODEL L-55 FET V.O.M. Input impedance 10 meg. ohms. 0/·3/1·2/6/30/120/600V. D.C. 0/3/12/60/120/600V. A.C. 0/120μA/120mA. D.C. 0/1K/100K/10 meg/100 meg ohms. **£15·97**. Post 25p.



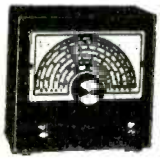
CI-5 PULSE OSCILLOSCOPE For display of pulsed and periodic waveforms in electronic circuits. VERT. AMP. Bandwidth 10MHz. Sensitivity at 100KHz VRMS/mm. .1–25; HOR. AMP. Bandwidth 500KHz. Sensitivity at 100KHz, V RMS/mm. .3–25; Preset triggered sweep 1–3,000μsec.; free running 20–200,000Hz in nine ranges. Calibrator pips. 220 × 360 × 430mm. 115-230V. A.C. operation. £39·00. Carr. paid.

TO-3 PORTABLE OSCILLOSCOPE. 3" TUBE

Y amp. Sensitivity. .1v p-p/CM. Bandwidth 1.5 cps —1.5 MHZ. Input imp. 2 meg Ω. 25 PF. X amp sensitivity. ·9v p-p/CM. bandwidth 1.5 cps—800 KHZ. Input imp. 2 meg Ω 20 PF. Time base. 5 ranges 10 cps—300 KHZ. Synchronization. Internal/external. Illuminated scale. 140 × 215 × 330 mm. Weight 15½lbs. 220/240 V. A.C. Supplied brand new with handbook **£40·00**. Carr. 50p.

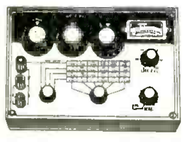


RUSSIAN CI-16 DOUBLE BEAM OSCILLOSCOPE 5 mc/s Pass Band. Separate Y1 and Y2 amplifiers. Rectangular 5in. × 4in. C.R.T. Calibrated triggered sweep from ·2 μ/sec. to 100 milli-sec. per cm. Free running time base 50 c/s–1 mc/s. Built-in time base calibrator and amplitude calibrator. Supplied complete with all accessories and instruction manual. £87 Carr. paid.

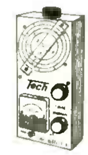


TE-16A Transistorised Signal Generator. 5 ranges 400kHz—30mHz. An inexpensive instrument for the handyman. Operates on 9v battery. Wide easy to read scale. 800kHz modulation. 5½ × 5½ × 3½in. Complete with instructions and leads. **£7·97**. Post 25p.

TRANSISTORISED L.C.R. A.C MEASURING BRIDGE.



A new portable bridge offering excellent range and accuracy at low cost. Ranges: R. 1Ω—11.1 MEG Ω 6 Ranges ± 1%. L. 1μH—111 HENRIES. 6 Ranges — 2%. C. 10PF± 1110MFD. 6 Ranges ± 2%. TURNS RATIO 1:1/1000—1:11100. 6 Ranges ± 1%. Bridge voltage at 1,000 CPS. Operated from 9 volts. 100μA. Meter indication. Attractive 2 tone metal case. Size 7¾" × 5" × 2". **£20**. Post 25p.



MODEL TE.15 GRID DIP METER Transistorised. Operates as Grid Dip, Oscillator, Absorption Wave Meter and Oscillating Detector Frequency range 440Kc/s–280Mc/s in 6 coils. 500μA Meter. 9V. battery operation. Size 180 × 80 × 40mm. **£12·50**. Post 20p.

BELCO AF-5A SOLID STATE SINE SQUARE WAVE C.R. OSCILLATOR

Sine 18-200,000 Hz; Square 18-50,000 Hz Output max. + 10 dB (10 K ohms). Operation internal batteries. Attractive 2-tone case 7½in. × 5in. × 2in. Price **£17.50** Carr. 17p.

MODEL MG-100 SINE SQUARE WAVE AUDIO GENERATOR Range: 19-220,000 Hz Sine Wave 19-100,000 Hz Square Wave. Output Sine or Square wave 10v. P. to P. Size 180 × 90 × 90mm. Operation 220/240v A. C. **£17·50**. Post 37p.

MODEL AT201 DECADE ATTENUATOR Frequency range: 0–200KHz. Attenuator: 0-111db., 0·1db. step. Impedance 600 ohms. Max. input power 30dbm. Size 180 × 90 × 55mm. **£12·50**. Post 37p.

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High quality instrument with 28 ranges. D.C. volts 1.5-1,500 v. A.C. volts 1.5-1,500 v. Resistance up to 1,000 megohms. 220/240v. A.C. operation Complete with probe and instructions. **£17·50**. Post 30p. Additional Probes available: R.F. **£2·12** H.V. **£2·50**.

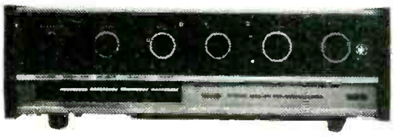
MODEL U4311 SUB-STANDARD MULTI-RANGE VOLT AMMETER Sensitivity 330 ohms/Volt A.C. and D.C. Accuracy ·5% D.C. 1% A.C. Scale length 165mm. 0/300/750μA/1·5/3/7·5/15/30/75/150/300/750mA/1·5/3/7·5 AMP. D.C. 0/3/7·5/15/30/75/150/300/750mA/1·5/3/7·5 AMP. A.C. 0/75/150/300/750mV/1·5/3/7·5/15/30/75/150/300/750V. D.C. 0/750mV/1·5/3/7·5/15/30/75/150/300/650V. A.C. Automatic cut out. Supplied complete with test leads, manual and test certificates. £49. Post 50p.

G. W. SMITH & Co. (Radio) Ltd.

Also see opposite page and next two pages

FANTASTIC OFFER!

NIKKO TRM 50 STEREO AMPLIFIER



17 + 17 watts rms stereo amplifier with inputs for Magnetic and Crystal phono, Tuner, Tape, Aux. and Tape Monitor. Outputs for two pairs of stereo speakers and Tape. Stereo headphone socket. Full range of controls including loudness control, scratch filter etc. Size 13in. × 9½in. × 3¾in Unrepeatable offer—limited stocks!

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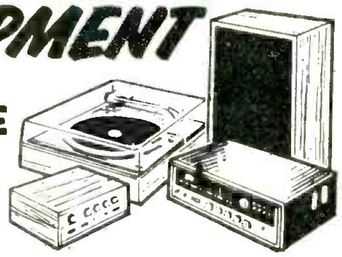
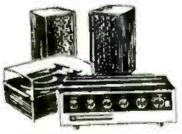


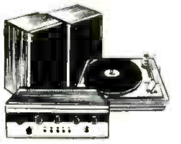
NIKKO TRM 50 SYSTEM



Nikko TRM50 17+17 watt stereo amplifier, BSR MP60, plinth and cover, Goldring G800 cartridge, pair of Linton 2 speakers and all leads.

OUR PRICE **£104·90** Carr. & Ins. £1·50

LEAK DELTA 30 SYSTEM



Leak Delta 30 stereo amplifier, Goldring GL75, plinth, cover and G800 cartridge. Pair of Leak 150 speakers and all leads.

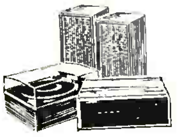
OUR PRICE **£123·50** Carr. & Ins. £1·50

AMSTRAD 8000 II SYSTEM

Amstrad 8000 II 7 + 7 watt amplifier. BSR MP60, plinth and cover, Goldring G800 cartridge, pair of Apollo speakers and all leads.
Amplifier only, £14·50. Carr. 50p.

OUR PRICE **£48·25** Carr. £1·00

AUDIOTRONIC LA.1700 SYSTEM



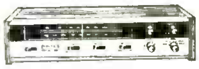
17 + 17 watt stereo amplifier. Garrard AP76 with Goldring G800 cartridge, teak veneered plinth with cover and a pair of Wharfedale Linton 2 speakers in matching teak.

OUR PRICE **£92·95** Carr. & Ins. £1·50

Matching LT1700 AM/FM Stereo Tuner £39·00 if purchased with above system.

SUPER MONEY SAVING OFFER!

TELETON R.4300L



3 waveband stereo tuner amp. 2 × 5W Medium/Long/Stereo FM. Full range of controls. Input for tape or ceramic cartridge.

List over £50·00 OUR PRICE **£27·50** Post 50p

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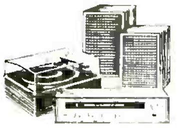
WHARFEDALE LINTON SYSTEM

Wharfedale Linton Amplifier. Linton Turntable, pair of Linton 2 speakers and all leads.

OUR PRICE **£104·00** Carr. & Ins. £1·25

LINTON RECEIVER SYSTEM £155·00. Carr. & Ins. £1.50

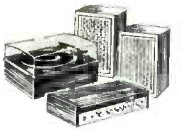
MONOTONE 6750 SYSTEM



Monotone AM/FM 4 + 4 watt stereo tuner amplifier, Garrard 2025 T/C, plinth and cover, stereo cartridge, pair of matching speakers and all leads.

OUR PRICE **£35·50** Carr. £1·00

TELETON SAQ206B SYSTEM

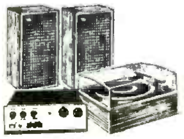


Teleton SAQ206B 8 + 8 watt amplifier, BSR MP60, plinth and cover, Goldring G800 cartridge, pair of Apollo speakers and all leads.

OUR PRICE **£55·95** Carr. £1·50

Amplifier only, £22·95. Post 50p.

TRIO KA 2000A SYSTEM



Trio KA 2000A 16 + 16 watt amplifier. BSR MP60, plinth and cover, Goldring G800 cartridge, pair of Denton 2 speakers and all leads.

OUR PRICE **£79·95** Carr. £1·25

Matching Trio KT 1000A AM/FM stereo tuner, £50·95 extra if required.

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FERGUSON 3414 STEREO TUNER AMPLIFIER TURNTABLE UNIT

10+10 watts rms. Five push buttons with separate scales for pre-tuning to desired FM station. Housed in a handsome walnut finished cabinet with BSR P128/MP60 record deck with Goldring G800H stereo magnetic cartridge. Offered complete with cover and a pair of matching Medway speakers, size 18" × 11" × 8".

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GA308 less cartridge (List £36·55) OUR PRICE £24·50. Post 50p.
LIMITED NUMBER ONLY!

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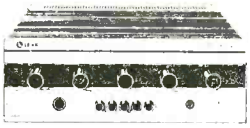

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Leak 250, pair	£47·95
Leak 600, each	£33·95

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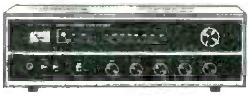

RA210 Amp.	£22·50
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RA610 Amp.	£48·25
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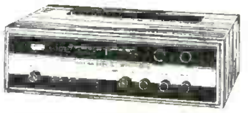
Improves the performance of cassette and semi-professional recorders. Reduces tape hiss by 3dB at 600 Hz, 6 dB at 1200 Hz and 10 dB for all frequencies above 300 Hz. Controls for input levels and noise reduction on record and replay. 2 meters for Dolby level. Off tape monitoring. Frequency response: 20 Hz to 15kHz ± 1 dB 19 kHz — 35 dB. Size 15⅞" × 9" × 3¼". A.C. 200/250 V.

OUR PRICE **£32·50** Carr. 50p.

AKAI BARGAINS!



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20+20 watts rms. Inputs for magnetic and ceramic cartridge and tape. Frequency response 20-40,000Hz. Bass, treble, volume and loudness controls. Frequency range FM 88-108MHz. AM 535-1605kHz. Headphone socket. Output for two pairs of speakers. 17¼" × 5¾" × 13¼". List Price £123·85.

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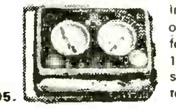

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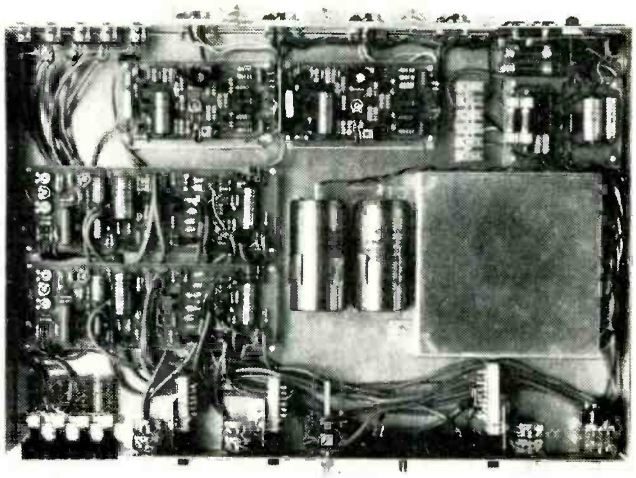

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C	Ohmmeter	£10	317/8
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MW.14/10	Waveguide to Co-axial line Transformer (Tuneable)	£60	67
MW.40/S	S-Band Oscillator	£80	252
	D.M.A.C.		
ADE2243	X-Y. Plotter	£150	—
	EDISWAN		
R.666	L.F. Oscillator	£30	125/126
	E.E.V.		
U1000/3/40A	Variable Vacuum Capacitor	£72	—
	EDDYSTONE		
770U	Communication receiver	£240	200
	E.I.L.		
22B	Micovac Electronic Testmeter	£35	59
33B	Vibron Electrometer	£45	94
44	Multimeter	£20	77/78
	ELLIOTT		
P.P.	Voltmeter (Dynamometer) 0-300V, 600V	£25	210
	FOSTER		
VRECV	Constant Voltage Transformer 1000VA. 0.25%	£43	358
	HEWLETT-PACKARD		
684B	Sweep Generator 4–8 Ghz	P.o.A.	379
540B	Transfer Oscillator	P.o.A.	176
612A	UHF Signal Generator	P.o.A.	177
1780A	Auxiliary Plug-in All brand		295
1782A	Display Scanner Plug-in new and		296
1783A	Time-Mark generator unused	P.o.A.	297
H05-1751A	Vertical Amp. and Scanner. Plug-in unit	£55	182
	MARCONI		
TF338/A/B	Variable Attenuator	£10	402/11
TF340	Output Power Meter	£25	412
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TF887A	Valve Voltohmmeter	£30	414
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TF1152/A	RF. Power Meter 25W. 500Mhz.	£35	424/5
TF1245	Circuit Magnification Meter	£65	426
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TF1291	V.S.W.R. Indicator	£50	428
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TF.886	H.F. Circuit Magnification 'Q' Meter	£65	274
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TF899	Valve Millivoltmeter	£12	349
TF.934	F.M. Deviation Meter	P.o.A.	285
TF.937	AM/FM Signal Generator 35kHz-18·3MHz	P.o.A.	286
TF.975	Wavemeter 90kHz-100MHz	£35	287
TF.1020	R.F. Power Meter. 100w. 75Ω	£35	225
TF.1026/4	Wavemeter 2000-4000MHz	P.o.A.	289
TF.1041	Vacuum Tube Voltmeter	£35	14
TF.1100	Sensitive Valve Voltmeter	£35	16
TF.1165	Electronic Counter. 7 Digit	£130	108
TF.1145	UHF Signal Generator 450-1900MHz	P.o.A.	293
TF.1165	Electronic Timer 1MHz	Complete system £350	290
TF.1220	Timing Unit (extends scope of TF.1165)		291
TF.1221	Heterodyne Unit 2kHz-100MHz, when used with TF.1165 and TF.1220 gives accuracy of ±·1 count and crystal stability of 2 parts in 10^6 per week.		292
TF.1272	Transistor Test Set	£45	122
TF.1300	Vacuum Tube Voltmeter	£35	17
TF.1330	Oscilloscope DC—15MHz	£60	142/3
TF.2002A	Timing Unit	£15	53
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TF.2600	Valve Voltmeter	£72	306
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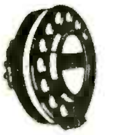

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Hex. Inverter	BMC937	12p	11p	10p
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Div. by 18 Counter	BMC939	25p	23p	21p
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Hex. Inverter	BMC941	12p	11p	10p
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4/2 Input	BMC946	11p	10p	9p
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NAND Gate	BMC949	12p	11p	10p
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Monostable Multivib.	BMC951	25p	23p	21p
Dual J/K Flip Flop	BMC953	20p	18p	16p
Dual J/K Flip Flop	BMC955	20p	18p	16p
Dual J/K Flip Flop	BMC956	20p	18p	16p
Quad. 2-Input Power	BMC958	12p	11p	10p
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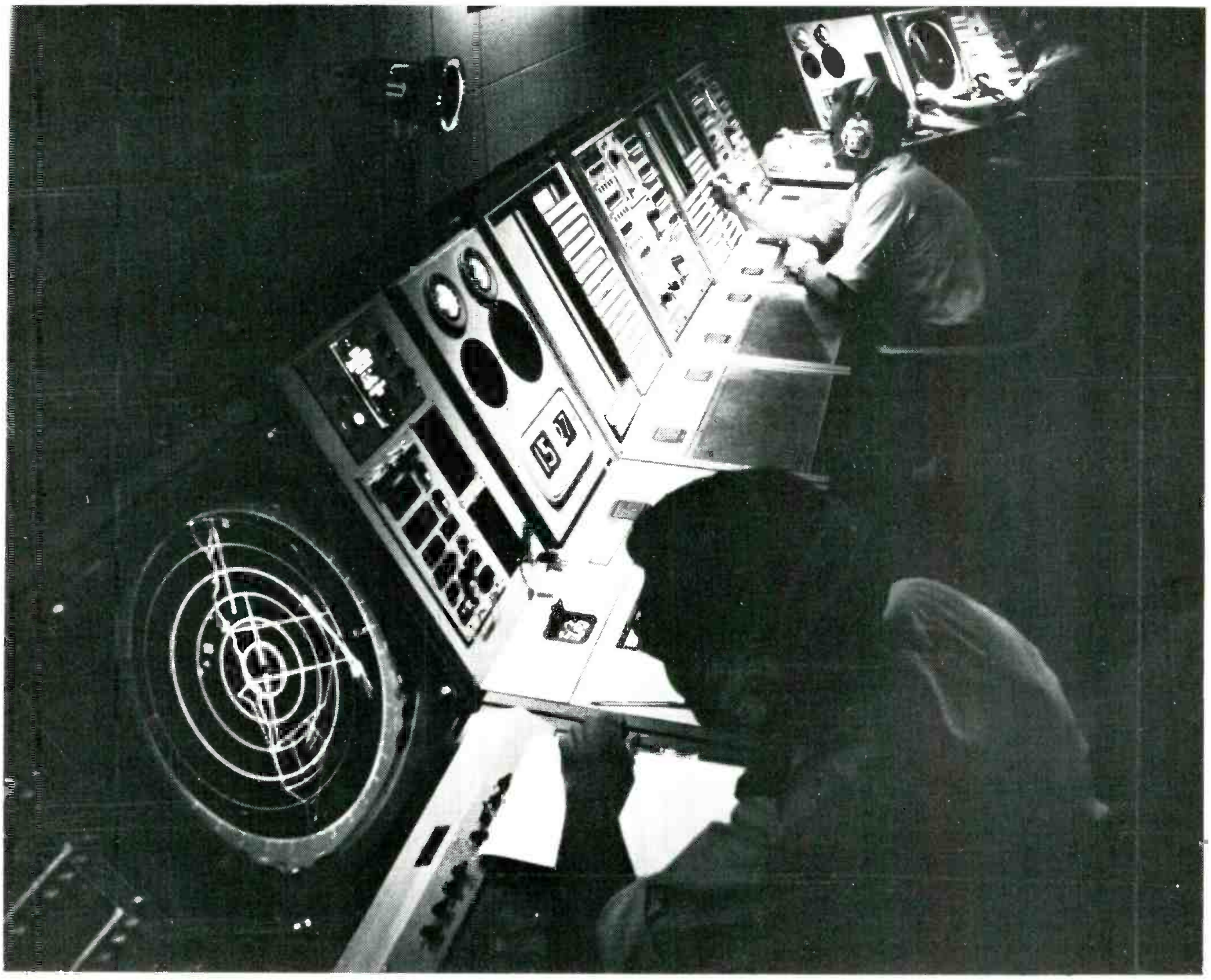


Manufacturing CRTs for radar displays is an everyday operation for M-OV. We've a whole armoury of tubes, all precision engineered to meet the highest, most stringent environmental and performance specs (including BS 9000, CV and MIL). And all quality built for the whole range of land, sea and airborne applications.

Screen sizes begin at 14 cm and run right up to 41 cm. Advanced design features include a unique-to-M-OV transistor protection device which helps safeguard vital equipment by limiting energy dissipation in the event of a voltage flashover. And you can specify a colour tube, too, which allows different information to be displayed simultaneously in at least three distinctive colours.

There's an army of other advanced, technical features to our CRTs. They are all in our comprehensive catalogue. It contains details of tubes for instrumentation, data display and TV studio applications. Please write, phone or telex for a copy.

A BRIEF SELECTION FROM THE RADAR CRT RANGE

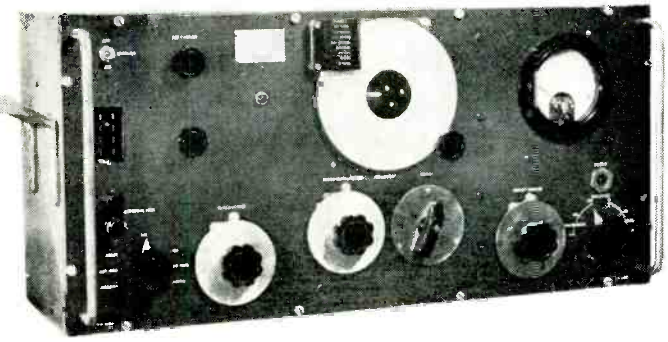
TYPE	SCREEN SIZE cm	FINAL ANODE VOLTAGE kV	FOCUS	DEFLECTION ANGLE degrees	LENGTH mm
1400E	14 rectangular	15	Electrostatic	50	268
1500B	15	9	Electrostatic	53	238
F16-10	16	14	Electrostatic	37	370
7ABP	18	7	Electrostatic	50	342·5
F21-10	21	14	Electrostatic	41	460
2200P	22	12	Electrostatic	58	408
3000R	31	16	Electrostatic	40	572
3000Q	31	12	Electrostatic	50	485
4100A	41	12	Electrostatic	50	610
MF41-10	41	12	Magnetic	70	518

Round screens unless otherwise stated

G.E.C. The M-O Valve Co.Ltd Hammersmith, London W6 7PE., Tel: 01-603 3431. Telex: 23435. Cables: Thermionic London

A member of The GEC Electronic Tube Co. Ltd., a management company which unites the activities of The M-O Valve Co. Ltd., and English Electric Valve Co. Ltd.

WW—099 FOR FURTHER DETAILS



MARCONI SIGNAL GENERATOR TYPE TF-144G: Freq. 85 Kc/s-25 Mc/s in 8 ranges. Incremental: ±1% at 1 Mc/s. Output: continuously variable 1 microvolt to 1 volt. Output Impedance: 1 microvolt to 100 millivolts, 10 ohms 100mV - 1 volt - 52·5 ohms. Internal Modulation: 400 c/s sinewave 75% depth. External Modulation: Direct or via internal amplifier. A.C. mains 200/250V, 40-100 c/s. Consumption approx. 40 watts. Measurements 29 × 12½ × 10 in. Secondhand condition. **£27·50** each, Carr. £1·50.

SIGNAL GENERATOR TYPE 902: (P.R.D.). A portable, general-purpose, broadband, microwave signal generator designed for testing and maintenance of aircraft radio and radar receivers in the SHF band. The RF output level is regulated by a variable attenuator calibrated in dbm. The frequency dial is calibrated in Mc/s. Provision is made for external modulation. Power Supply—115V, ±10% A.C., 50 c/s. Freq.—3650-7300 Mc/s. Internal Transmission—CW, Pulse, FM. External Transmission—Square Wave, Pulse. Power O/put—0.2 milliwatts. O/put Attenuator: −7 to −127 dbm. Load—50Ω. Price: **£135** each + £2 carr.

TEST SET TS-147C: Combined signal generator, frequency meter and power meter for 8500-9600 Mc/s. CW or FM signals of known freq. and power or measurement of same. *Signal Generator:* O/put −7 to −85 dbm. Transmission—FM, PM, CW. Sweep Rate—0-6 Mc/s per microsec. Deviation—0-40 Mc/s per sec. Phase Range—3-50 microsec. Pulse Repetition Rate—to 4000 pulses per sec. RF Trigger for Sawtooth Sweep—5-500 watts peak. 0.2-6 microsec. duration, 0.5 microsec pulse rise time. Video Trigger for Sawtooth Sweep—Positive polarity, 10-50V peak. 0.5-20 microsec duration at 10% max. amplitude, less than 0.5 microsec rise time between 90% and 10% max. amplitude points. *Frequency Meter:* Freq. 8470-9360 Mc/s. Accuracy—+2.5 Mc/s per sec. absolute, +1.0 Mc/s per sec. for freq. increments of less than 60 Mc/s relative, ±1.0 Mc/s per sec. a 9310 Mc/s per sec. calibration point. Accuracy measured at 25° C and 60 humidity. *Power Meter:* Input: +7 to +30 dbm. Output −7 to −85 dbm. Price: **£75** each + £1 carr.

SIGNAL GENERATOR TS-403B/U) or URM-61A): (Hewlett Packard). A portable, self-contained, general-purpose test equipment designed for use with radio and radar receivers and for other applications requiring small amounts of RF power such as measuring standing-wave ratios, antenna and transmission line characteristics, conversion gain, etc. Both the output freq. and power are indicated on direct-reading dials. 115V, AC, 50 c/s. Freq.—1800-4000 Mc/s. CW, FM, Modulated Pulse—40-4000 pulses per sec. Pulse Width—0.5-10 microsecs. Timing —Undelayed or delayed from 3-300 microsecs from external or internal pulse. O/put—1 milliwatt max., 0 to −127 db variable. O/put Impedance—50Ω. Price **£120** used, excellent condition. Unused as new condition **£150** + carr. £2.

TS-382/U AUDIO OSCILLATOR: 20 to 200,000 c/s. in four ranges. Freq. meter check 60 c/s. and 400 c/s. Emission CW. O/put voltage: 1 uv to 10V ±3% in seven ranges. Power req. 115V AC single phase. Price **£20** each, used good condition. Unused condition **£30** + carr. £1.50.

CT150 Portable valve-tester suitable for testing a wide range of valves. Manufactured by Avo. **£55** each + £2 carr.

FREQUENCY METER BC-221: 125-20,000 Kc/s, complete with original calibration charts. Checked out, working order. **£18·50** + £1 carr.; OR BC-221 (as received from Ministry), good condition, less charts, **£8·50** + £1 carr.

CANADIAN HEADSET ASSEMBLY: Moving coil headphones 100Ω with chamois leather earmuffs. Small hand microphone complete with switch and moving coil insert. New condition, **£2** each + 25p post.

HEADSET ASSEMBLY TYPE NO. 10: Moving coil headphones and microphone. (Similar to above) new cond. **£1·75** + 25p post; or secondhand cond. **£1·25** + 25p post.

HEADSET ASSEMBLY: with lightweight boom microphone. Good secondhand cond. **£3** a pair, 25p post.

DLR HEADPHONES: 2 × balanced armature earpieces. Low resistance. **£1·50** a pair + 25p post.

MOVING COIL INSERT: Ideal for small speakers or microphones. Box of 3 **£1** + 23p post.

HAND MICROPHONE: (recent design) with protective rubber mouthpiece. **£2** + 25p post.

NO. 16 HAND MICROPHONE: With carbon insert, lead and plug. **£1** + 25p post.

CT.52 MINIATURE OSCILLOSCOPE: Portable. Operates from 115V or 250V 50-60c/s; or 180V 500c/s. A small compact tropicalised instrument designed to meet requirements of radar and communication engineers and general electronic service. Measures 9 in. × 8 in. × 6½in. Time base 10c/s-40Kc/s. Y plate sensitivity 40V per cm. Tube 2¾in. Frequency compensated amplifier up to 38dB gain. Bandwidth up to 1 Mc/s. Single sweep facilities. Complete with test leads, metal transit case. As new **£27·50** each. Carr. £1.

TRANSFORMER HV: 228V input 19,500–0–19,500 4.5KVA, Wt. 220 lbs. **£30** each. Carr. £4.

MODULATOR UNIT: complete with transformer and 2×807 valves mounted in 19 in. chassis × 8 in. high × 8 in. deep. **£4·50** secondhand cond., or **£6·50** new cond. Carriage £1.

RF UNIT: suitable for use with the above unit. Complete with 2×3E29 valves. Ideal for conversion to 4 metres. **£5** secondhand cond., or **£7·50** new cond. Carriage £1.

POWER SUPPLY UNIT PN-12A: 230V a.c. input 50-60 c/s. 513V and 1025V @ 420 mA output. 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 @ 3 Amps each, and 5V @ 6 Amp and 4V @ 0.25 Amp. Mounted on steel base 19"Wx11"Hx14"D. (All connections at the rear.) Excellent condition **£6·50** each, carr. £1.

AUTO TRANSFORMER: 230-115V, 50-60c/s, 1000 watts, mounted in a strong steel case 5" × 6½" × 7". Bitumen impregnated. **£7** each, Carr. 75p. 230-115V, 50-60c/s, 500 watts. 7" × 5" × 5". Mounted in steel ventilated case. **£4·00** each, Carr. 75p.

MODULATOR UNIT: 50 watt, part of BC-640, complete with 2 × 811 valves, microphone and modulator transformers etc. **£7·50** each, 75p carr.

CATHODE RAY TUBE UNIT: With 3in. tube, Type 3EG1 (CV1526) colour green, medium persistence complete with nu-metal screen, **£3·50** each, post 50p.

TS 622/URM 44 SIGNAL GENERATOR: Freq. range 7 to 11 GHz. O/put −10 to −127 dbm; CW, FM, Pulse. Direct reading. 115V, 50 c/s. **£185·00** each plus £2·00 carriage.

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.

DECADE RESISTOR SWITCH: 0.1 ohm per step. 10 positions. 3 Gang, each, 0·9 ohms. Tolerance ± 1% **£3** each, 25p post. 90 ohms per step. 10 positions, total value 900 ohms. 3 Gang. Tolerance ± 1% **£3·50** each, post 30p.

CRYSTAL TEST SET TYPE 193: Used for checking crystals in freq. range 3000-10,000Kc/s. Mains 230V, 50c/s. Measures crystal current under oscillatory conditions and the equivalent parallel resistance. Crystal freq. can be tested in conjunction with a freq. meter. **£12·50** each, £1 carr.

VARIAC TRANSFORMERS: Input 115V, output 0-135V at 2 Amps. **£3** each 75p post. Input 115V, output 135V at 5 Amps. **£5** 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, £2·50 Carr. OR 4 ft. high × 23 in. wide × 19 in. deep, with rear door. **£8·50** each, £2 Carr.

FUEL INDICATOR Type 113R: 24V complete with 2 magnetic counters 0-9999, with locking and reset controls mounted in 3in. diameter case. Price **£2** each, 30p post.

TS-418/URM49 SIGNAL GENERATOR: Covers 400-1000MHz range. **CW** Pulse or AM emission. Power Range 0-120 dbm. **£125** each. Carr. £1·50.

TN/130/APR.9 UHF TUNING UNIT: Freq. 4300-7350MHz. IF Output 160MHz with bandwidth of 20MHz and is electrically tuned by a d.c. reversible motor. **£27·50** each. Carr. £1.

APR-4 AM RADIO RECEIVER: 90-1000MHz. This receiver is suitable for monitoring and measuring frequencies as well as relative signal strength. Power Supply 115V 50c/s. **£100** each. Carr. £2.

R-361 RECEIVER: 225-400MHz. 1 preset channel crystal controlled. Superheterodyne, voice and CW. 230V 50c/s input. **£35** each. Carr. £1·50.

TS-130 TEST SET: Complete with RF Probe type 1019 Freq. 0·9-12·5KHz, and RF Probe type 1020 Freq. 0·3-1KHz. Also slotted line attenuator 1M-34/U. Freq. 0·3-4KHz; and connectors. **£45** each. £1 carr.

CLASS "D" WAVEMETER NO. 2: Crystal controlled heterodyne frequency meter covering 2-8MHz. Power supply 6V d.c. Good secondhand cond. **£7·50** each. Post 60p.

RCA TE-149 HETERODYNE WAVEMETER: V-cut, 1MHz crystal (0·005%). Accuracy better than 0·02%. Dial directly calibrated every 1KHz from 2·5-5MHz. Useful harmonics up to 20MHz. Provision for fitting internal dry batteries. "As new" complete with Manual and Spares. **£14** each. Carr. 75p.

POWER UNIT TYPE 24: (for R.216 Receiver) A.C. operated 100-125V or 200-250V, 50c/s. "As new" **£10** each. Carr. 75p.

FILTER VARIABLE BAND PASS NO. 1: Dual channel unit, each channel has variable slot frequency of 500-900Hz, 1200-1600Hz and band pass facility. 600Ω input/output, monitor input and high impedance output jacks. Standard rack mounting 3½in. deep panel. Mains operation 200-250V 50c/s. "As new" **£6·50** each. Carr. 75p.

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. £1·50.

POWER SUPPLY: 230V a.c. input; 3000V @ 2·5mA; 4v @ 1 Amp, 300-0-300 200mA; 6V @ 7 Amp; 6V @ 3 Amp. With smoothing capacitors etc. **£10·00** each. £1·50 carr.

GEARED MOTOR: 24c. D.C., current 150mA, output 1 rpm, **£1·50** each, 30p post. **ASSEMBLY UNIT** with Letcherbar Tuning Mechanism and potentiometer, 3 rpm, **£2** each 30p post. **SYNCHROS:** and other special purpose motors available. List 3p.

ACTUATOR UNIT: With 115V d.c. geared motor; o/put 12·5 rpm; torque 16 ins. oz; reversible; microswitches and potentiometer. **£3·50** ea. + 40p post.

DALMOTORS: 24-28V d.c. at 45 Amps, 750 watts (approx. 1hp) 12,000rpm. **£5** each, 60p post.

GEARED MOTOR: 28V d.c. 150 rpm (suitable for opening garage doors). **£4** each, 60p post.

MOTOR: 240V single phase, 2,400 rpm. 1/40 H.P. approx. Price **£1·75** each, 30p post.

CONDENSERS: 30 mfd 600 v wkg. d.c., **£3·50** each, post 50p. 15 mfd 330 v a.c., wkg., **75p** each, post 25p. 10 mfd 600 v. **43p** each, 25p post. 8 mfd 2500 v. **£5** each, carr. 63p. 8 mfd 600 v. **43p** each, post 15p. 8 mfd. 1% 300 v. **D.C. £1·25**, post 25p, 4 mfd 3000 v. wkg. **£3** each, post 37p. 4 mfd 2000 v. **£2** each, post 25p. 4 mfd 600 v., 2 for **£1**. 0·25 mfd, 2Kv, **20p** each, post 10p. 0·01 mfd MICA 2·5Kv, **£1** for 5, post 10p. Capacitor 0·125 mfd, 27,000 v. wkg. **£3·75** each, 50p post. 2·25 mfd 25 Kv. wkg. **£20** each, £3 carr.

CONTROL PANEL: 230 v. A.C., 24 v. D.C. @ 2 amps, **£2·50** each, carr. 75p.

OHMITE VARIABLE RESISTOR: 5 ohms, 5½ amps; or 40 ohms at 2·6 amps; 500 ohms, 0·55 amps. Price (either type) **£2** each, 30p post each.

TX DRIVER UNIT: Freq. 100-156 Mc/s. Valves 3 × 3C24's; complete with filament transformer 230 v. A.C. Mounted in 19in. panel, **£4·50** each, carr. 75p.

AR88 RECEIVER: List of spares, 5p.
TELEPRINTER EQUIPMENT, REPERFORATORS, READERS, and AUTO TRANSMITTERS ETC. Send for list, 5p.

If wishing to call at Stores, please telephone for appointment.

W. MILLS

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Phone: 01-808 9213 and Wilstead 605 (STD. 023 044)

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TRANSISTORS Brand new and fully guaranteed. PLEASE NOTE:—Matching charge (Audio Transistors only) 15p extra per pair. Many more semi-conductors in stock. Please enquire for types not listed.

2G301	0·15
2G302	0·15
2G303	0·25
2G306	0·30
2G309	0·30
2G344A	0·25
2G345B	0·25
2G371	0·15
2G374	0·15
2G381	0·22
2G417	0·20
2N109	0·49
2N174	1·40
2N176	0·75
2N274	0·75
2N335	0·75
2N351	0·95
2N376	1·00
2N384	0·93
2N388A	0·40
2N404	0·20
2N456	0·75
2N456A	0·75
2N457A	0·80
2N491	3·25
2N584	0·26
2N591	0·34
2N696	0·15
2N697	0·15
2N698	0·25
2N699	0·29
2N706	0·10
2N706A	0·12
2N708	0·13
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2N916	0·17
2N918	0·30
2N919	0·20
2N929	0·14
2N930	0·14
2N1090	0·23
2N1091	0·24
2N1131	0·20
2N1132	0·20
2N1184	1·27
2N1302	0·16
2N1303	0·16
2N1304	0·20
2N1305	0·20
2N1306	0·22
2N1307	0·22
2N1308	0·25
2N1309	0·37
2N1483	0·90
2N1507	0·24
2N1613	0·20
2N1631	0·35
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2N1638	0·27
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2N1701	1·10
2N1702	2·15
2N1711	0·17
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2N2147	0·70
2N2148	0·60
2N2192	0·40
2N2192A	0·40
2N2193	0·40
2N2193A	0·42
2N2194	0·27
2N2194A	0·30
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2N2913	0·75
2N2923	0·12
2N2924	0·12
2N2925	0·12

2N2926	
Green	0·10
Yellow	0·10
Orange	0·10
2N3053	0·31
2N3054	0·46
2N3055	0·60
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2N3391	0·20
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2N3393	0·12
2N3394	0·12
2N3402	0·17
2N3403	0·19
2N3404	0·24
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2N3708	0·70
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2N3710	0·90
2N3711	0·90
2N3712	0·95
2N3713	1·08
2N3714	1·15
2N3715	1·23
2N3716	1·30
2N3773	3·00
2N3774	3·33
2N3775	4·19
2N3776	5·95
2N3777	4·84
2N3778	2·25
2N3779	3·15
2N3780	4·50
2N3781	3·67
2N3782	3·37
2N3789	1·76
2N3790	1·90
2N3791	2·06
2N3792	2·20
2N3794	0·10
2N3819	0·26
2N3820	0·48
2N3823	0·97
2N3824	0·75
2N3826	0·23
2N3854	0·16
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2N3855	0·16
2N3855A	0·16
2N3856	0·16
2N3856A	0·16
2N3858	0·16
2N3858A	0·16
2N3859	0·16
2N3859A	0·16
2N3860	0·16
2N3866	0·70
2N3877	0·25
2N3877A	0·26
2N3878	1·22
2N3879	1·91
2N3900	0·20
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2N4061	0·11
2N4062	0·11
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2N4914	0·87
2N4915	0·95
2N4916	0·11
2N4917	0·17
2N4918	0·50
2N4919	0·53
2N4920	0·60
2N4921	0·50
2N4922	0·55
2N4923	0·60
2N4926	0·90
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2N4928	1·80
2N4929	2·23
2N4930	2·25
2N4931	2·70
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2N5174	0·22
2N5175	0·26

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2N5191	0·96
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3N140	0·76
3N141	0·69
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3N154	0·74
3N159	1·00
3N187	1·30
3N200	2·07
3N201	1·05
40050	0·78
40251	0·81
40309	0·33
40310	0·50
40360	0·46
40361	0·48
40362	0·44
40363	0·88
40389	0·46
40394	0·56
40395	0·50
40406	0·44
40407	0·33
40408	0·50
40409	0·52
40410	0·53
40411	2·00
40467A	0·69
40468A	0·44
40600	0·69
40601	0·67
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40636	1·10
40673	0·56
AC107	0·35
AC113	0·16
AC115	0·16
AC117	0·20
AC121	0·13
AC126	0·20
AC127	0·20
AC128	0·20
AC141K	0·30
AC142K	0·25
AC151V	0·14
AC152V	0·17
AC153	0·22
AC153K	0·25
AC154	0·20
AC176	0·18
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AC187K	0·20
AC188K	0·26
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ACY18	0·15
ACY19	0·20
ACY20	0·10
ACY21	0·18
ACY22	0·13
ACY28	0·18
ACY30	0·42
ACY39	0·47
ACY40	0·17
ACY41	0·17
ACY44	0·31
AD136V	0·96
AD140	0·49
AD142	0·50
AD143	0·45
AD149V	0·66
AD150	0·63
AD161	0·49
AD162	0·51
ADZ11	1·50
ADZ12	1·75
AF106	0·27
AF109R	0·40
AF114	0·25
AF115	0·24
AF116	0·25
AF117	0·20
AF118	0·50
AF121	0·22
AF124	0·24
AF125	0·20
AF126	0·19
AF126	0·20
AF139	0·38
AF170	0·25
AF172	0·25
AF178	0·55
AF179	0·65

AF180	0·50
AF186	0·40
AF200	0·35
AF211	0·55
AF239	0·41
AF240	0·72
AF279	0·54
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AFY42	0·74
AL012	0·75
AL103	0·70
ASY26	0·30
ASY27	0·36
ASY28	0·28
ASY29	0·30
ASY50	0·20
ASY55	0·35
ASZ21	0·55
AU103	1·25
BC107	0·14
BC108	0·13
BC109	0·14
BC113	0·13
BC114	0·12
BC115	0·15
BC116	0·15
BC116A	0·18
BC117	0·21
BC118	0·11
BC119	0·27
BC121	0·23
BC123	0·29
BC125	0·15
BC126	0·20
BC132	0·50
BC134	0·11
BC135	0·11
BC136	0·15
BC137	0·15
BC138	0·20
BC140	0·34
BC141	0·39
BC142	0·24
BC143	0·21
BC144	0·24
BC145	0·21
BC147	0·11
BC148	0·10
BC149	0·13
BC153	0·18
BC154	0·18
BC157	0·14
BC158	0·13
BC159	0·14
BC160	0·11
BC167B	0·13
BC168B	0·11
BC168C	0·11
BC169B	0·11
BC169C	0·13
BC170	0·11
BC171	0·13
BC172	0·11
BC182	0·10
BC182L	0·10
BC183	0·09
BC183L	0·09
BC184	0·11
BC184L	0·11
BC186	0·25
BC187	0·25
BC204	0·11
BC205	0·10
BC206	0·11
BC207	0·10
BC208	0·09
BC209	0·10
BC211	0·30
BC212K	0·10
BC212L	0·12
BC213L	0·12
BC214L	0·14
BC236	0·16
BC237	0·09
BC238	0·09
BC239	0·09
BC251	0·20
BC252	0·18
BC253	0·23
BC257	0·09
BC258	0·09
BC259	0·13
BC261	0·20
BC262	0·18
BC263	0·23
BC300	0·42
BC301	0·34
BC302	0·27
BC303	0·54
BC304	0·43
BC307	0·09
BC307A	0·09
BC307VI	0·09
BC308	0·08
BC308A	0·08
BC308B	0·08
BC309	0·09
BC309A	0·09
BC309B	0·09
BC313	0·30

BC327	0·21
BC328	0·19
BC337	0·17
BC338	0·17
BCY30	0·27
BCY31	0·30
BCY32	0·50
BCY33	0·25
BCY34	0·30
BCY38	0·40
BCY39	0·60
BCY40	0·50
BCY42	0·15
BCY43	0·15
BCY58	0·18
BCY59	0·19
BCY66	0·58
BCY67	0·82
BCY70	0·15
BCY71	0·20
BCY72	0·13
BCY87	3·47
BCY88	2·40
BCY89	0·80
BCZ10	0·27
BCZ11	0·40
BD115	0·75
BD116	0·75
BD121	0·65
BD123	0·80
BD124	0·60
BD130	0·50
BD131	0·75
BD132	0·75
BD135	0·38
BD136	0·44
BD137	0·47
BD138	0·55
BD139	0·62
BD140	0·73
BDY10	1·25
BDY11	1·50
BDY17	1·50
BDY18	1·75
BDY19	1·97
BDY20	0·92
BDY38	0·65
BDY60	0·90
BDY61	0·85
BDY62	0·75
BF115	0·23
BF117	0·43
BF119	0·58
BF121	0·25
BF123	0·27
BF125	0·25
BF127	0·27
BF152	0·20
BF153	0·29
BF154	0·16
BF158	0·15
BF159	0·27
BF160	0·23
BF161	0·35
BF163	0·20
BF166	0·35
BF167	0·18
BF173	0·19
BF177	0·25
BF178	0·25
BF179	0·30
BF180	0·35
BF181	0·32
BF182	0·30
BF183	0·40
BF184	0·17
BF185	0·17
BF194	0·14
BF195	0·15
BF196	0·15
BF197	0·15
BF198	0·15
BF199	0·18
BF200	0·35
BF224J	0·14
BF225J	0·19
BF237	0·22
BF238	0·22
BF244	0·16
BF245	0·33
BF246	0·43
BF247	0·49
BF254	0·14
BF255	0·15
BF257	0·41
BF258	0·46
BF259	0·48
BF261	0·23
BF264	1·45
BF270	0·25
BF271	0·21
BF272	0·53
BF273	0·25
BF274	0·28
BF457	0·46
BF458	0·57
BF459	0·57
BFS21	2·10
BFS21A	2·30
BFS28	0·92

BFS61	0·27
BFS98	0·28
BFW10	0·61
BFW11	0·61
BFW45	0·75
BFX13	0·23
BFX29	0·25
BFX30	0·25
BFX37	0·30
BFX44	0·33
BFX63	2·48
BFX68	0·30
BFX84	0·24
BFX85	0·29
BFX86	0·24
BFX87	0·25
BFX88	0·20
BFX89	0·45
BFY10	0·35
BFY11	0·45
BFY17	0·90
BFY18	0·25
BFY19	0·25
BFY20	0·50
BFY29	0·40
BFY37	0·20
BFY41	0·43
BFY43	0·62
BFY50	0·16
BFY51	0·16
BFY52	0·16
BFY53	0·15
BFY56	0·34
BFY64	0·41
BFY75	0·40
BFY76	0·22
BFY77	0·24
BFY78	0·36
BFY90	0·55
BRY39	0·30
BSX19	0·13
BSX20	0·14
BSX21	0·20
BSX26	0·34
BSX27	0·34
BSX28	0·25
BSX29	0·47
BSX30	0·68
BSX59	0·78
BSX60	0·54
BSX61	0·42
BSX76	0·15
BSX77	0·20
BSX78	0·25
BSW70	0·28
BSY24	0·20
BSY25	0·15
BSY26	0·17
BSY27	0·15
BSY28	0·15
BSY38	0·15
BSY39	0·15
BSY51	0·25
BSY52	0·25
BSY53	0·25
BSY54	0·30
BSY56	0·79
BSY65	0·15
BSY78	0·40
BSY79	0·40
BSY790	0·45
BSY95A	0·09
BU104	1·42
BU105	2·25
C111	0·53
C407	0·18
C424	0·15
C425	0·36
C426	0·25
C428	0·25
C444	0·26
D40N1	0·55
D40N3	0·62
GET111	0·45
GET113	0·20
GET114	0·20
GET115	0·50
GET119	0·35
GET120	0·25
GET535	0·20
GET536	0·20
GET538	0·20
GET873	0·12
GET880	0·30
GET883	0·20
GET887	0·20
GET890	0·22
GET895	0·25
MA8001	0·16
MA8002	0·47
MA8003	0·47
MC140	0·25
MD7000	0·82
MD8001	0·94
MD8002	1·11
MD8003	1·26
ME0401	0·18
ME0402	0·20
ME0404	0·13
ME0411	0·17
ME0412	0·18
ME0413	0·14

PANEL METERS
38 Series—FACE SIZE 42 × 42 mm. All prices for 1-9 pieces. All meters D.C. £

50	Microamp	2·30
100	,,	2·10
200	,,	1·95
500	,,	1·75
50-0-50	,,	2·10
100-0-100	,,	1·95
500-0-500	,,	1·75
1	Milliamp	1·60
5	Milliamp	1·60
10	,,	1·60
50	,,	1·60
100	,,	1·60
500	,,	1·60
1	Amp	1·60
5	,,	1·60
10	Volts	1·60
20	,,	1·60
50	,,	1·60
300	,,	1·60
500	,,	1·60

WIDE RANGE OF HEATSINKS

PRESETS Carbon Miniature and Sub miniature. Vertical and Horizontal. 0·1 watt, 0·2 watt, all at 0·06 each. 0·3 watt 0·075.

CARBON POTENTIOMETERS £
Log. or Lin. Less switch .. .. 0·16
Log. or Lin. With switch .. .. 0·25
Wire-wound Pots (3 watts) .. .. .. 0·38
Twin-Ganged Stereo Pots. (Log. and Lin.) Less Switch 0·40

HEAT SINKS £
4·8" × 4" × 1" Finned for Two TO-3 Trans. .. 0·48
4·8" × 2" × 1" Finned for One TO-3 Trans. .. 0·33
For SO-1 0·05 P For TO-5 0·05 Finned
For TO-18 0·05 Finned For TO-1 0·05 Finned

ZENER DIODES £
400 mW (from 3·3v to 33v) .. .. 0·15
1 Watt (from 2·7v to 200v) .. .. 0·22
10 Watt (from 3·9v to 100v) .. .. .. 0·40
20 Watt BZY93 Series (from 7·5v to 75v) .. 0·52

Antex 15W. Soldering Iron .. .. 1·70

POSTAGE AND PACKING CHARGES
U.K. .. .. 0·13
EUROPE .. .. 0·25 (minimum)
OVERSEAS (AIR) .. LETTER 0·65; PARCEL £1·90

SILICON RECTIFIERS

PIV	50	100	200	400	600	800	1000	1200	1400
	£	£	£	£	£	£	£	£	£
1A	0·08	0·09	0·10	0·11	0·12	0·15	0·20	—	—
3A	0·15	0·17	0.20	0·22½	—	0·30	—	—	—
6A	—	—	0·25	0·30	0·32½	0·35	0·50	—	—
10A	0·30	0·35	0·40	0·47	0·56	0·66	0·75	—	—
15A	0·36	0·45	0·48	0·55	0·65	0·75	0·87	—	—
35A	0·70	0·80	0·90	1·00	1·40	1·70	2·75	—	—

1 amp and 3 amp are plastic encapsulation.

DIODES AND RECTIFIERS

IN914	0·07	AAZ15	0·12	BAY18	0·17½	OA5	0·17
IN916	0·07	AAZ17	0·10	BAY31	0·07	OA9	0·10
IN4007	0·22½	BA100	0·15	BAY38	0·25	OA10	0·20
IS44	0·07	BA102	0·25	BY100	0·15	OA47	0·08
IS113	0·15	BA110	0·25	BY103	0·22	OA70	0·07
IS120	0·12	BA115	0·07	BY124	0·15	OA73	0·10
IS121	0·14	BA141	0·32½	BY126	0·15	OA79	0·07
IS130	0·08	BA142	0·32½	BY127	0·17	OA81	0·08
IS131	0·10	BA144	0·12½	BY164	0·57½	OA85	0·10
IS132	0·12	BA145	0·20	BYX10	0·22½	OA90	0·07
IS940	0·05	BAIS4	0·12	BYZ10	0·35	OA91	0·07
AA119	0·07	BA156	0·15	BYZ11	0·32	OA95	0·07
AA129	0·15	BAX13	0·05	BYZ12	0·30	OA200	0·07
AAZ13	0·12	BAX16	0·12½	BYZ13	0·25	OA202	0·10
						TIV307	0·50

WIDE STOCK OF COMPONENT FOR MAGAZINE PROJECTS

MAINS TRANSFORMERS £
1 amp Charger. Sec. 0-3·5-9-18v *Post and packing 0·22½* 1·12
2 amp Charger. Sec. 0-3·5-9-18v *Post and packing 0·22½* 1·44
1 amp (Douglas) MT103 Sec. tappings from 6v to 50v .. 2·00
2 amp (Douglas) MT104 Sec. tappings from 6v to 50v .. 3·10
Post and packing 0·28.
6 amp (Douglas) MT107 Sec. tappings from 6v to 50v .. 7·47
Post and packing 0·37½.
Various other Transformers ranging from ½A to 5A in stock.

TRIACS

SC35D ..	1·00	SC51D ..	1·95	**DIACS**	
SC36D ..	1·00	40430 ..	0·91	MPT20 ..	0·40
SC40D ..	1·25	40486 ..	0·86	MPT28 ..	0·37½
SC41D ..	1·20	40528 ..	0·63	MPT32 ..	0·37½
SC45D ..	1·50	40430 ..	1·30	MPT36 ..	0·37½
SC46D ..	1·42½	40432 ..	1·37	ST2 ..	0·18
SC50D ..	2·00	40512 ..	1·53	40583 ..	0·18

Economy Range Triacs
TC4/10 (Pressfit) 4 amp 100 PIV .. .. 0·65
TC4/20 (Pressfit) 4 amp 200 PIV .. .. 0·75
TC4/40 (Pressfit) 4 amp 400 PIV .. .. 0·87½

ENCAPSULATED FULL-WAVE RECTIFIER
1·8A 100P.I.V. **25p ea.**

THYRISTORS

PIV	50	100	200	300	400
1A	0·25	0·27½	0·37½	0·40	0·47½
4A	0·40	0·45	0·55	—	0·60
7A	—	0·87½	0·92½	—	1·12½

TIC47 0·6 amp. 200 PIV 0·55. TIC44·0 6 amp 50 PIV 0·29
Also 12 amp 100 PIV 0·75; 2N3525 at £1·12½.
2N4444 £1·91

VEROBOARD

	0·15 Matrix	0·1 Matrix
2½" × 3¾"	0·18	0·25
2½" × 5"	0·27	0·25
3¾" × 3¾"	0·25	0·27
3¾" × 5"	0·32	0·31
2½" × 17"	0·58	—
3¾" × 17"	0·80	1·02
5" × 17"	—	1·31
3¾" × 17" (Plain)	—	0·64
5" × 17" (Plain)	0·83	—
2½" × 17" (Plain)	0·57	—

Vero Pins (Bag of 36) £0·20. (0·1 or 0·15 Matrix)
VeroCutter £0·45. Pin Insertion Tools (0·1 and 0·15 matrix) at £0·58
Many more sizes Veroboard in stock

RESISTORS ¼ W. & ½ W. E24 Series.
Carbon Film ⅛ W., 1 W., 2 W. E12. Series.

¼ watt 5%	0·01	1 watt 10%	0·02½
½ watt 5%	0·01½	½ watt M/Oxide 2%	0·04
2 watt 10%	0·06	⅛ watt 5%	0·01

Wire Wound £
2½ watt 5% (up to 270 ohms only) .. .. 0·07
5 watt 5% (up to 12k ohms only) .. .. 0·09
10 watt 5% (up to 25k ohms only) .. .. 0·10

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Capacitor discharge ignition system. (as published in *Practical Electronics*, Nov. 1971).
COMPLETE KIT £10·00 P. & P. 50p.

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MINITRON 7 SEGMENT INDICATOR TYPE 3015F .. £2·00
DRIVER FOR ABOVE (SN7447) .. .. .. £1·30
Light Emitting Diode. TIL209 £0·35 (Texas)

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SINGLE GANG LINEAR or LOG from 1k to 1M
£0·40 each
TWIN GANG LINEAR or LOG from 5k to 500k
£0·60 each

THERMISTORS **MULLARD**

R53 (STC) 1·27½	VA1010 0·12	VA1039 0·15	VA1077 0·20
K151 (Siemens) 1K 0·12	VA1015 0·19	VA1040 0·12	VA1091 0·13
VA1005 0·15	VA1033 0·12	VA1053 0·20	VA1096 0·13
	VA1034 0·22	VA1066 0·20	VA1097 0·13
	VA1037 0·13	VA1074 0·13	VA3705 0·95
	VA1038 0·13		

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STANDARD GPO DIAL TELEPHONE (black) with internal bell, **87p** ea. P. & P. 50p. Two for **£1·50. P. & P. 75p.**
All telephones complete with bell and dial.

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G.E.C. Sealed Relays High Speed 24V. 2m 2b—**17p** ea.

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12v **35p** ea. 2,500 ohm (okay 24v)—**13p** ea.
S.T.C. Brand New 2 pole c/o 6800 ohm coil—**15p** ea.

CARPENTERS polarised Single pole c/o 20 and 65 ohm coil as new, complete with base **37p** ea.
Single pole c/o 14 ohm coil **33p** ea.; Single pole c/o 45 ohm coil **33p** ea.
Varley VP4 Plastic covers 4 pole c/o 5K—**30p** ea. 15K—**33p** ea.

POLARISED Relay 2 pole c/o 250 ohm and 250 ohm coils.—**25p** ea.

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COLVERN 3 watt. Brand new, 5; 10; 25; 500 ohms; 1; 2.5; 5; 10; 25; 50k all at **13p** ea.

MORGANITE Special Brand new, 2·5; 10; 100; 250; 500K; 2·5 meg. 1 in. sealed, **17p** ea.

BERCO 2½ Watt. Brand new, 5; 10; 50; 250; 500 ohms; 1; 2·5; 5; 10; 25; 50K at **15p** ea.

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RELIANCE P.C.B. mounting: 270; 470; 500 ohms; 10K at **35p** ea. ALL BRAND NEW.

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VISCONOL EHT CAPACITORS

Size 1×2¼ ins.			Size 1½×5½ ins.		
0·05mfd	2·5kV	**50p** ea.	0·01mfd	10kV	**50p** ea.
0·01mfd	5kV	**40p** ea.	0·002mfd	15kV	**65p** ea.
0·001mfd	10kV	**50p** ea.	0·0005mfd	20kV	**60p** ea.
Size 2½×6½ ins.			0·1mfd	4kV	**35p** ea.
0·05mfd	8kV	**50p** ea.			

DUBILIER 0·1mfd 5 KV; 0·1mfd 7·5 KV; 0·25mfd 7·5 KV; 0·5mfd 5 KV all at **50p** ea. P. & P. 15p.

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2200MFD 100V
10A (50°C)
70p each
BRAND NEW BOXED
10 off — 60p each
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Up to 250mA **63p.** P. & P. 35p.
Large quantity LT, HT, EHT transformers.

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ONLY £18·00

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TB 2 c/s-750 kc/s. Band width 5·5 Mc/s. Sensitivity 33 Mv/cm. Calibration markers 100 kc/s and 1 Mc/s. A completely reliable general purpose oscilloscope. Supplied with CIRCUIT DIAGRAM and Mains lead. Carr. £1·50.

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PANEL mounting lamp holders. Red or green. **9p** ea. Miniature
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Standard **240V MOTORS** by **CITENCO** reduction gearbox to 19 r.p.m. reversible, **£5** ea.
Also 57 r.p.m. and 114 r.p.m.

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KELVIN & HUGHES 4-channel multi-speed recorders complete with amplifiers. **£45.**

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ELECTRONICS TIMER UNITS—wall or bench mounting—2 Hybrid timer boards may be removed leaving excellent 12 Volt battery charger; DC Power supply etc. Information supplied. Price ONLY **£3·25** incl. carriage.

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SELECTED B.C. 221 Recalibrated to Ministry Specification in brand new condition, complete with circuit, only **£27·50.** Carr. £1·50.

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E.H.T. TRANSFORMERS (Standard Mains) 3 KV 600 MA. **£20·00** ea. Carr. £1·50.
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Brand new 38p each

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Tinsley 4524A slide wire **£55**
Tinsley 52058 precision **£55**
Tinsley A.C. coordinate 3150 **£65**

RECORDERS

Single Pen

Elliott 8½" 0-1 MA right hand zero. Chart speeds 1 & 6 ins/hour. **£25**
Record 3" 0-1MA right hand zero. Chart speeds 1 & 6 ins/hour. **£49.50**
Elliott Emrec 400 0-10MA chart width 4" speed 1 in/hour. **£65**
Evershed & Vignoles recording wattmeter max current 38 amps. Chart drive 8 day clockwork speed 1 in/hour. **£25**
Evershed & Vignoles Recording Ammeter A.C. 0-5 amps. Chart width 4½ins speeds 1 ins/min & 1 ins/hr. **£25**
Kelvin Hughes Freq. range D.C. to 100Hy chart width 2 ins. speeds 6 and 24 ins/min. **£25**
Evershed & Vignoles true KVA (A.C.) range 0-1500KVA chart width 4½" speeds 1 ins/min. and 1 in/hr. **£28**
Evershed & Vignoles D.C. milliameter 0-5MA. Chart width: 4½" speeds 1 in/min. & 1 in/hr **£25**
Honeywell potentiometric -5.5 to 14.5MV response time 25 sec. Chart width 11 ins speeds 1, 1½, 2, 3, 4 ins/hr. **£45**

WELMEC 7 AND 8 HOLE ELECTRO-MECHANICAL PUNCHES & READER
Models S110 and R82C. 17 char. per sec. Available from stock. **£49**

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Evershed & Vignoles D.C. voltmeter 0-10V chart width 8" (4 ins per pen) speeds various **£35**
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Record 3" Duplex 0-1MA chart width 3 ins per channel. Speeds 1 and 6 ins/hr. Drive 30 day clock. **£75**

Four Pen

Kelvin Hughes quick response recorders D.C. to 100Hy. Multi speeds. complete with amplifiers. **£43**

Five Pen

Sefram RP5 1RX5 0-6MA, D.C. — 14Hy. 9 chart speeds from 1 min/sec to 50 min/sec. Chart width 4 cm/channel. two 24V event makers. **£75**

Eight Pen

Kelvin Hughes quick response recorder D.C. to 100Hy multi speeds. **£65**

Twelve Pen

Kelvin Hughes MK4 mod. 1. **£85**

TEMPERATURE RECORDERS

Cambridge 50-300 C on 10½ ins diam. 24 hr. chart. Complete with temperature sensor and 6ft. of capilliary tubing. **£25**
Ether Xactrol chart width 7 ins. Ranges 0-200 C. 0-600 C. **£42**
Electroflo Pyrograph 0-1000 C chart width bins. **£35**
Elliott 51568 0 to ± 60 C **£35**
Fielden Servograph RL41. 0-60 micro A on an 11 ins diam. 24 hr. chart. **£35**
Negretti & Zambra Mersteel 2 channel 0-200 C 24 hour circular chart. Complete with two temperature sensors and capilliary tubing. **£45**
Rototherm 50-300 C on 7 day circular chart. **£22.50**

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Dawe 1406A high speed A.F. level recorder chart speeds 1, 10 and 50 min/sec. **£25**
Everett Edgecumbe Event recorders 20 channels. Event markers operated by 24V D.C. **£75**
Holgate event recorder 6 channels on teledeltos paper. Chart speeds 1 and 10 ins/sec. **£25**

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N.E.P. 1160 12 channels. Chart speeds 2, 6, 20 and 60 ins/sec. **£95**
N.E.P. 1050 6 channel chart speeds 2, 6, 20 and 60 ins/sec. Chart width 4½ins. **£95**
Honeywell 906s. 14 channels on 7 ins wide paper. Chart speeds 4.2, 8.3, 17 and 21 ins/sec. Complete with 6-240Hy galvos. **£115**

Photographic Recorder

N.E.P. 1000 6 channels on 6 ins photographic paper. Chart speeds 0.4, 1.2, 4 and 12 ins/sec. complete with 6 BB 130 galvos. **£55**

POWER SUPPLY UNITS

O/P Volts	O/P Amps	Manuf.	Type	Price
6	4	Advance	DC2	£6
2-7.6	500MA	Roband	T98	£12
+4 +8		Ediswan	R2030	£15
0-8DC	5	Ediswan	R2030	£29.50
0-8AC	250MA	Ediswan		
2-8 5	500MA	Roband	T98	£12
8.7	10	I E	DS369	£19.50
2 9	500MA	Roband	T98	£12
9	10	Farnell	S126	£24
0-10	2	BPL	086	£9
12 Twin	1 twin	Coutant	KD100	£36
±12	3	Plessey	V3174	£22.50
12	3	I.B.M.	4117312	£18
12	4	I.B.M	4117312	£20
2.6-12	10	Roband	6x6x13	£35
12	20	I.B.M.	473381	£24
12	26	I.B.M.	730480	£25
14	2	Roband	T100/14	£18.50
4X15	1.5			£27.50
12-15	5	Advance	DCR12/2	£30
17	6	Farnell	55V17/6	£24.50
4.5	4	Lower Elect	SP110	£25
-10	4	Lower Elect	SP110	£25
20	4 5	Lower Elect	SP110	£25
+10	300MA	Lower Elect	SP110	£25
20	9	Lower Elect	SP135	£27.50
10	4	Lower Elect	SP135	£27.50
10	300MA	Lower Elect	SP135	£27.50
+-12	500MA	Livingstone	LM050	£9.50
-24	500MA	Livingstone	LM050	£9.50
1-22	40 Watts	APT	1777	£9.50
100	5	Solatron	AS755	£35
175-260	80MA	S Smith	CHX/8065	£25
240-320	500	Solatron	AS755 2	£40
6.3C.T.	5	Solatron	AS755.2	£40
3350C		Farnell	PU335	£10
200-400	200MA	Ediswan	R1103A	£29.50
0-500	50MA	Elliott	B700/775	£40
200-500	250MA	APT	501	£35
0-500	250MA	APT	504	£45
200-500	350MA	APT	506	£37.50
0-500	350MA	APT	508	£49
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1000	250MA	APT	7249	£42
24		A.P.T.	TSU1030	£25
24	5	Advance	OC6	£28.50
24	5	Advance	OC22	£28.50
25	7	Roband	T100/25	£20
28		APT	TSU1012	£26
-28V	2			£26
12	2			£26
12	600MA			£26
-20	300MA	B.P.L.		£32.50
+30	300MA			£32.50
±6	1	Coutant		£38
28	2.5			£38
±12	5	Roband	P198	£35
-18	20	Roband	P198	£35
±30	100MA	Roband	P198	£35
0-30	500MA	Startronic	119S	£37
0-30	1	APT	5994	£35
0-30	1	Advance	PP3	£45
0-30	1	Advance	PP3	£45
0-30	2	Coutant		£38
0-30	3	Solatron	As870	£38
30	7	I B M.	210080	£19
32	2	APT	10459/14	£23
25-33	1	Roband	T109	£27
40	8	Advance	DC188	£27.50
48	2	Advance	DC122	£27.50
55-60	1	Roband		£25
48	4	Advance	DC8	£29.50
150	100MA	Farnell	SPU150	£14
150	200MA	Farnell	SPU150	£15
150MA	220-250	Roband	B101/200	£19.50
220	3	Solatron	AS755	£35
±		Solatron	AS1104 2	£35
280-320	500	Solatron	AS755.2	£40
6.3.	C.T.10	Solatron	AS755.2	£40
6.3AC		Farnell	PU335	£10
0-500	200MA	Solatron	SRS1522	£47.50
1K-24	K18MA	Airmec	6988	£45
0-500	250MA	APT	503	£39
0-500	250MA	APT	505	£35
200-500	350MA	APT	507	£47.50
0-500	350MA	APT	509	£52.50
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7 TRACK DIGITAL MAGNETIC TAPE STORAGE 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. Frequency response approximately 30 Kc/s. to 50 Kc/s. Bit density 557 b.p.i. ½ in., 10½ in. spools 230 V. to 380 V. A.C. Capstan Motor speed 1,500 r.p.m. 48 V. D.C. Rewind motors complete with vacuum Assembly. Finished in brush aluminium and matt-black. Size 27 in. x 26 in. x 8 in. Weight 90 lb. Price **£72.50.**

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Memory Core Stores

Plessey ferrite memory stores many types available from stock 8K, 16K bits etc. **£45**
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Muirhead D-652-A L.F. Freq. Range 2-20Hy. Accuracy ±0.1Hy. Input volts 1MV-3V output volts 10MV for extending the range of the D-489-G wave analyser. **£25**
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DL96	0·45
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DY86	0·33
DY87	0·32
DY802	0·48
E88CC/01	1·20
E180CC	0·42
E181CC	0·90
E182CC	1·20
EA50	0·20
EABC80	0·30
EAF42	0·52
EB91	0·18
EBC33	0·50
EBC41	0·50
ECC81	0·31
EBF80	0·40
EBF83	0·40
EBF89	0·30
ECC81	0·30
ECC82	0·28
ECC83	0·30
ECC84	0·30
ECC85	0·40
ECC86	0·45
ECC88	0·37
ECC189	0·52
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ECF82	0·35
ECF83	0·75
ECF801	0·62
ECF802	0·62
ECH35	0·90
ECH81	0·28
ECH83	0·40
ECH84	0·45

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ECH200	0·62
ECL80	0·42
ECL82	0·35
ECL83	0·70
ECL86	0·40
EF36	0·45
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EF83	0·55
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EF91	0·30
EF92	0·35
EF95	0·35
EF183	0·30
EF184	0·35
EFL200	0·75
EL34	0·50
EL41	0·53
EL84	0·24
EL85	0·42
EL86	0·40
EL90	0·35
EL95	0·35
EL500	0·85
EM31	0·25
EM80	0·40
EM84	0·35
EM87	0·70
EY51	0·40
EY86	0·40
EY81	0·40
EY88	0·40
EZ41	0·50
EZ80	0·25
EZ81	0·27
GZ34	0·58
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PCF80	0·30
PCF82	0·33
PCF84	0·60
PCF86	0·57
PCF200	0·73
PCF201	0·73
PCF801	0·45
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PCF805	0·80
PCF806	0·70
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PCH200	0·70
PCL81	0·47
PCL82	0·35
PCL83	0·60
PCL84	0·42
PCL85	0·42
PCL86	0·43
PFL200	0·61
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PL84	0·35
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U25	0·72
U26	0·72
U27	0·50
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U801	0·80
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UAF42	0·55
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UBF80	0·40
UBF89	0·35
UCC85	0·40
UCF80	0·55
UCH42	0·70
UCH81	0·33
UCL82	0·35
UCL83	0·60
UF41	0·50
UF80	0·36
UF89	0·40
UL41	0·63
UL84	0·40
UU5	0·55
UY41	0·43
UY85	0·40
VR105/30	0·35

	£
VR150/30	0·35
Z801U	2·00
Z803A	1·25
Z900T	0·95
1L4	0·15
1R5	0·40
1S4	0·30
1S5	0·30
1T4	0·22
1X2A	0·40
1X2B	0·50
2K25	7·50
3A4	0·35
3D6	0·15
3Q4	0·45
3S4	0·35
3V4	0·45

	£
5B254M	2·20
5B/255M	2·00
5R4GY	0·75
5U4G	0·35
5V4G	0·45
5Y4G	0·40
5Y3GT	0·35
5Z3	0·55
5Z4	0·75
5Z4GT	0·40
6AB7	0·30
6AC7	0·30
6AH6	0·50
6AK5	0·30
6AK8	0·32
6AL5	0·15
6AL5W	0·40
6AM6	0·30
6AN8	0·50

	£
6AQ5	0·35
6AQ5W	0·50
6AS6	0·37
6AS7G	0·80
6AT6	0·30
6AU6	0·25
6AX4GT	0·60
6AX5GT	0·70
6B7	0·40
6BK7	0·60
6BA6	0·25
6BE6	0·30
6BG6G	0·55
6BJ6	0·45
6BQ7A	0·40
6BR7	0·85
6BW6	0·85
9BW7	0·80

	£
6C4	0·30
6C6	0·25
6CH6	0·55
6CL6	0·49
6D6	0·20
6EA8	0·55
6F23	0·75
6F33	1·50
6H6M	0·20
6J4WA	0·75
6J5	0·40
6J5GT	0·25
6J6	0·20
6J7G	0·35
6J7M	0·40
6K6GT	0·56
6K7	0·32

	£
6K7G	0·20
6K8GT	0·40
6K25	0·70
6L6M	1·50
6SA7	0·40
6SA7GT	0·32
6SC7GT	0·25
6SG7	0·35
6SJ7	0·37
6SJ7GT	0·32
6SK7	0·46
6SL7GT	0·32
6SN7GT	0·32
6SQ7	0·39
6SQ7GT	0·35
6V6G	0·17
6V6GT	0·40
6X4	0·30
6X5G	0·30
6X5GT	0·37
6Y6G	0·60
6-30L2	0·80
6Z4	0·36
7B7	0·45
7Y4	0·60
9D6	0·37
11E2	2·80
12AT6	0·30
12AT7	0·30
12AU7	0·29
12AV6	0·38
12AX7	0·30
12BA6	0·37
12BE6	0·40
12BH7	0·27
12C8	0·32
12E1	2·70
12K5	0·55
12K7GT	0·40
12K8GT	0·45
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30FL14	0·83
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30P12	0·80
30P19	0·77
30PL1	0·75
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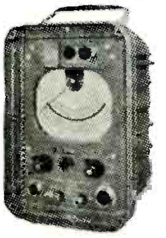

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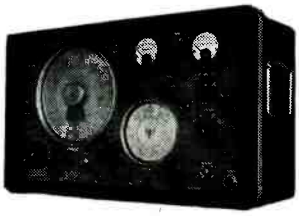

Spec. as for TF 801D/1/S except for minor circuit changes e.g. 1 and 2 MHz switched calibrator. P.O.A.

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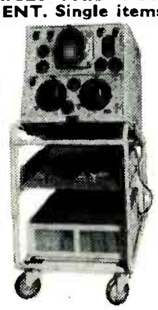

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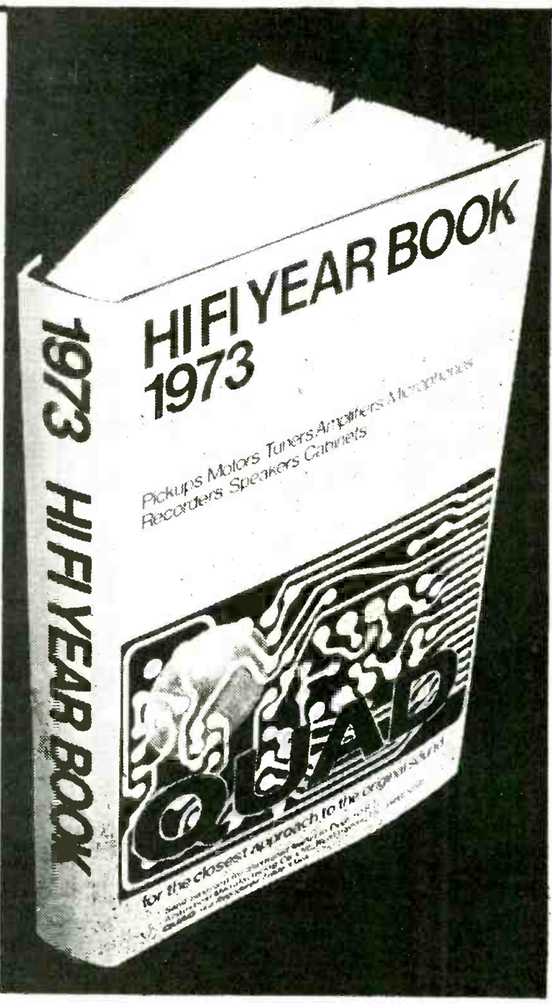

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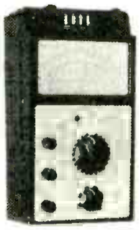

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1N5GT	0·55
1Q5GT	0·60
1R4	0·50
1R5	0·45
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1S5	0·30
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6BR8	0·75
6BS7	1·35
6BW6	0·90
6BW7	0·90
6BX6	0·25
6BX7GT	0·90
6BZ6	0·45
6C4	0·35
6CB5A	1·50
6CB6	0·40
6CD6GA	1·30
6CG7	0·60
6CH6	0·60
6CL6	0·60
6CL8	0·80
6CU6	0·80
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6DS4	1·25
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6EH7	0·30
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6EW6	0·70
6F5	0·75
6F6G	0·45
6F11	0·50
6F13	0·50
6F14	0·70
6F15	0·65
6F17	0·75
6F18	0·50
6F22	0·30
6F23	0·90
6F24	0·80
6F25	1·00
6F28	0·70
6GK5	0·60
6GK6	0·60
6J4	0·60
6J5GT	0·40
6J6	0·30
6J7	0·45
6K6GT	0·75
6K7	0·43
6K8G	0·45
6K8GT	0·50
6K23	0·75
6K25	0·75
6L7	0·45
6L18	0·50
6LD20	0·50
6M11	1·50
6N7GT	0·55
6P28	0·65
6Q7	0·50
6R7G	0·55
6S2	0·40
6S4A	0·70
6SA7	0·45
6SC7	0·80
6SG7	0·45
6SH7	0·45
6SJ7	0·50
6SK7	0·50
6SL7GT	0·45
6SN7GT	0·45
6SQ7	0·50
6SR7	0·50
6SS7	0·40
6T8	0·38
6U4GT	0·70
6U5	0·75
6U8A	0·48
6V6GT	0·45
6X4	0·40
6X5GT	0·45
6X8	0·65
6Y6G	0·80
6Z4	0·50
7B5	0·75
7B6	0·75
7B7	0·70
7F8W	1·00
7F7	1·00
7Z4	0·75
10C2	0·60
10D1	0·65
10D2	0·55
10F1	0·75
10F9	0·65
10F18	0·60
10L1	0·60
10LD11	0·70
10P13	0·75
11D3	0·60
11D5	0·60
11E2	4·00
11E3	4·80
12AB5	0·70
12AC6	0·60
12AD6	0·60
12AH7GT	0·40
12AL5	0·55
12AQ5	0·50
12AT6	0·40
12AT7	0·40
12AU6	0·45
12AU7	0·33
12AV6	0·45
12AV7	0·70
12AX4GTB	0·70
12AX7	0·33
12AY7	0·75
12B4A	0·65
12BA6	0·45
12BA7	0·50
12BE6	0·50
12BH7	0·50
12BY7	0·65
12C8	0·40
12E1	3·00
12E14	4·30
12H6	0·35
12J5GT	0·35
12J7GT	0·60
12K5	1·00
12K7GT	0·50
12Q7GT	0·45
12SC7	0·45
12SG7	0·45
12SH7	0·45
12SJ7	0·50
12SL7GT	0·55
12SN7GT	0·55
12SQ7	0·50
12SR7	0·50
12X4	0·50
20D1	0·60
20F2	0·70
20L1	1·10
20P1	0·50
20P3	0·60
20P4	1·10
20P5	1·20
25L6GT	0·50
25Z4G	0·35
25Z6GT	0·70
30A5	0·60
30AE3	0·40
30C1	0·30
30C15	1·00
30C17	1·10
30C18	0·90
30F5	1·00
30FL1	0·80
30FL12	1·10
30FL14	0·90
30L1	0·40
30L15	0·95
30L17	0·95
30P19	0·95
30PL1	0·95
30PL13	1·10
30PL14	1·25
30PL15	1·25
35B5	0·65
35C5	0·60
35D5	0·75
35W4	0·40
35Z3	0·75
35Z4G	0·40
35Z5GT	0·70
42	0·60
50A5	0·80
50B5	0·70
50C5	0·60
50CD6G	1·20
50EH5	0·65
50L6GT	0·60
52KU	0·45
53KU	0·75
75B1	0·50
75C1	0·50
80	0·60
83	1·35
85A2	0·55
85A3	0·60
90AG	2·40
90AV	2·50
90C1	0·75
90CG	2·40
90CV	2·40
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150B3	1·50
150C1	1·50
150C4	0·65
305	0·75
310A	1·75
311A	2·00
328A	2·00
329A	2·00
715A	3·00
715C	6·00
723A/B	7·00
725A	25·00
805	11·00
807	0·50
812A	3·50
813	4·00
829B	4·00
833A	17·00
837	1·00
866A	0·85
927	4·00
931A	5·00
955	0·40
991	0·50
4378	2·00
4687	2·90
5551A	18·00
5557	5·60
5670	0·60
5751	0·70
5763	0·80
5796	12·00
5814A	0·70
5842	3·00
6072	0·90
6080	1·75
6146	1·60
6146A	2·00
6146B	2·50
6360	1·25
6883	3·00
6922	0·70
6939	2·25
7025	0·50
7109	0·65
7551	2·00
7591A	1·00
7895	1·50
9002	0·45
9003	0·50
A1834	0·85
A2293	2·20
AC/HL/DD	0·70
AC/TH1	0·60
AX50	2·50
AZ31	0·55
BT5	9·00
C1166	26·00
CBL1	0·90
CBL31	1·00
CL4	7·50
CL33	1·50
CY31	0·50
DAF91	0·30
DAF92	0·75
DAF96	0·50
DC90	0·60
DF91	0·30
DF92	0·25
DF96	0·50
DH76	0·50
DH81	0·70
DH101	0·70
DK40	0·65
DK91	0·45
DK92	0·70
DK96	0·60
DL66	1·25
DL68	0·70
DL91	0·30
DL92	0·40
DL93	0·45
DL95	0·60
DL96	0·55
DM70	0·60
DM71	0·60
DY51	0·55
DY86	0·35
DY87	0·36
E80CC	1·10
E80CF	1·50
E80L	1·10
E83F	1·10
E84L	0·60
E86C	1·90
E88C	1·10
E88CC	0·70
E88CC/01	1·10
E90CC	0·45
E91H	0·70
E180F	1·00
E182CC	1·20
E186F	1·25
E188CC	1·10
E280F	2·10
E810F	2·90
EA50	0·25
EA52	4·50
EABC80	0·38
EAF42	0·60
EAF801	0·50
EB34	0·25
EB91	0·22
EBC33	0·60
EBC41	0·65
EBC81	0·33
EBC90	0·38
EBC91	0·40
EBF80	0·40
EBF83	0·40
EBF89	0·32
EBL21	0·60
EBL31	1·50
EC53	0·50
EC86	0·60
EC88	0·60
EC90	0·35
EC92	0·45
EC93	0·60
EC8010	2·25
ECC34	0·50
ECC35	1·00
ECC40	0·70
ECC70	1·25
ECC81	0·40
ECC82	0·33
ECC83	0·33
ECC84	0·30
ECC85	0·40
ECC86	0·80
ECC88	0·40
ECC89	0·50
ECC91	0·30
ECC189	0·65
ECC2000	1·50
ECC807	1·00
ECC2000	1·50
ECF80	0·35
ECF82	0·35
ECF86	0·70
ECF200	0·85
ECF801	0·60
ECF804	1·65
ECH42	0·75
ECH81	0·30
ECH83	0·45
ECH84	0·45
ECL80	0·50
ECL81	0·50
ECL82	0·35
ECL83	0·70
ECL84	0·55
ECL85	0·55
ECL86	0·40
ECLL800	2·20
EF9	0·90
EF36	0·60
EF37A	0·85
EF40	0·50
EF41	0·65
EF42	0·70
EF80	0·25
EF83	0·60
EF85	0·35
EF86	0·30
EF89	0·28
EF91	0·37
EF92	0·35
EF93	0·28
EF94	0·30
EF95	0·40
EF96	0·25
EF97	0·65
EF98	0·75
EF183	0·30
EF184	0·35
EF804	1·25
EF811	1·00
EF812	0·90
EF814	0·80
EH90	0·50
EK32	0·60
EK90	0·32
EL5	0·60
EL12	1·00
EL34	0·50
EL35	0·50
EL36	0·50
EL37	1·70
EL41	0·75
EL81	0·55
EL83	0·50
EL84	0·25
EL85	0·43
EL86	0·40
EL90	0·42
EL91	0·40
EL95	0·35
EL360	1·15
EL821	0·60
EL822	1·40
ELL80	0·75
EM34	1·00
EM71	0·80
EM80	0·45
EM81	0·60
EM84	0·35
EM85	1·00
EM87	0·70
EN10	6·00
EN11	5·00
EN32	1·50
EN91	0·40
EY51	0·40
EY80	0·75
EY81	0·40
EY83	0·55
EY84	0·60
EY86	0·40
EY87	0·43
EY88	0·43
EZ35	0·45
EZ40	0·50
EZ41	0·75
EZ80	0·28
EZ81	0·29
EZ90	0·40
FG17	5·50
FW4/500	0·75
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GN4	1·50
GR10M	1·50
GS10C	5·50
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GS10H	4·50
GS12D	8·00
GS47X	4·00
GT1C	3·00
GU50	3·00
GY501	0·70
GZ30	0·45
GZ31	0·40
GZ32	0·50
GZ33	0·75
GZ34	0·60
HABC80	0·55
HBC90	0·40
HBC91	0·45
HF93	0·45
HF94	0·45
HK90	0·50
HL23	0·50
HL23DD	0·55
HL42DD	0·70
HL92	0·60
HL94	0·60
KT8	2·50
KT36	1·20
KT44	0·70
KT45	2·00
KT66	2·35
KT71	0·60
KT76	0·60
KT88	2·25
KTW61	1·00
ME91	0·65
ME1400	1·30
MH4	0·75
ML6	0·60
MSPEN/7	0·70
MT17	5·50
MU12/14	0·75
N78	1·60
NSP1	5·00
NSP2	6·00
PABC80	0·40
PC86	0·60
PC88	0·60
PC92	0·50
PC96	0·45
PC900	0·48
PCC84	0·40
PCC85	0·40
PCC88	0·55
PCC89	0·50
PCC189	0·60
PCC805	0·95
PCC806	0·95
PCE800	0·80
PCF80	0·30
PCF82	0·35
PCF84	0·60
PCF86	0·60
PCF87	1·10
PCF200	0·75
PCF201	0·75
PCF800	1·00
PCF801	0·50
PCF802	0·50
PCF805	0·90
PCF806	0·75
PCF808	0·90
PCH2000	0·70
PCL81	0·50
PCL82	0·35
PCL83	0·65
PCL84	0·45
PCL85	0·50
PCL86	0·45
PCL88	1·25
PCL200	0·75
PCL800	1·10
PCL801	0·95
PCL805	0·50
PD500	1·30
PEN4DD	0·70
PEN36C	0·75
PEN45	0·75
PEN45DD	0·75
PEN46	0·50
PEN383	0·75
PEN384	0·75
PEN453DD	0·75
PF86	0·70
PF818	1·00
PFL200	0·65
PL33	0·40
PL36	0·55
PL38	0·65
PL81	0·50
PL82	0·45
PL83	0·45
PL84	0·40
PL302	0·95
PL504	0·75
PL508	0·90
PL509	1·10
PL802	0·85
PLL80	0·70
PM84	0·65
PX4	3·00
PY31	0·35
PY33	0·63
PY80	0·40
PY81	0·30
PY82	0·35
PY83	0·38
PY88	0·40
PY500	1·00
PY800	0·47
PY801	0·50
PZ30	0·38
QQV02-6	2·25
QQV03-10	1·25
QQV03-20A	5·25
QS83/3	0·55
QU37	6·50
QV03-12	0·80
QY3-125	9·00
QY4-250A	14·50
QY4-400A	16·50
R18	0·60
RG3-250A	0·85
RL18	0·50
S130	1·75
S130P	1·75
SP2	0·85
SP4	0·70
SP61	0·75
TP22	0·80
TP25	0·65
TT21	3·40
TT22	3·50
TY2-125	11·00
U18/20	0·75
U19	3·50
U20	0·75
U25	0·65
U26	0·65
U31	0·70
U37	6·50
U50	0·45
U52	0·40
U76	0·40
U78	0·40
U191	0·75
U201	0·50
U281	0·55
U282	0·55
U301	0·55
U403	0·70
U404	0·70
U801	0·80
UABC80	0·40
UAF41	0·70
UAF42	0·60
UB41	0·65
UBC41	0·55
UBC81	0·45
UBF80	0·40
UBF89	0·40
UBL1	0·70
UBL21	0·70
UC92	0·45
UCC85	0·45
UCF80	0·70
UCH21	0·60
UCH42	0·70
UCH81	0·40
UCL81	0·60
UCL82	0·35
UCL83	0·65
UF9	0·65
UF11	0·60
UF41	0·65
UF42	0·65
UF43	0·65
UF80	0·35
UF85	0·40
UF89	0·40
UL41	0·65
UL84	0·43
UM4	0·60
UM84	0·30
UU5	0·75
UY1N	0·50
UY11	1·00
UY41	0·48
UY82	0·50
UY85	0·40
VL8631	2·30
VP41	0·75
VP133	1·00
VR75/30	0·48
VR105/30	0·40
VR150/30	0·40
VU33	0·75
VU39A	0·75
VU111	0·75
VU120	1·00
VU133	0·75
W729	0·75
X65	0·60
X66	0·60
X76M	0·60
XC11	1·00
XC15T	0·50
XC23	0·80
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[2359

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[2373

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[2323

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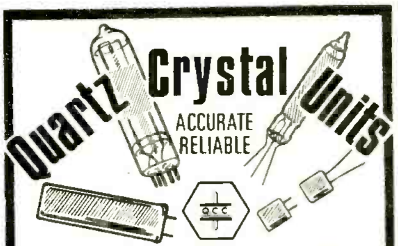

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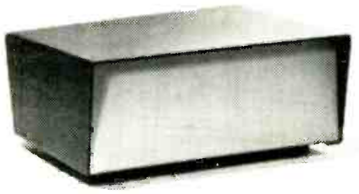

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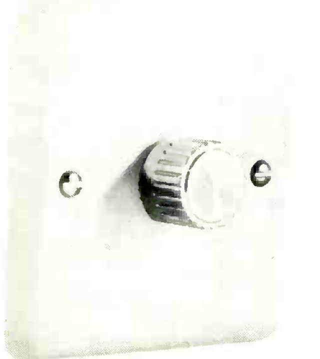

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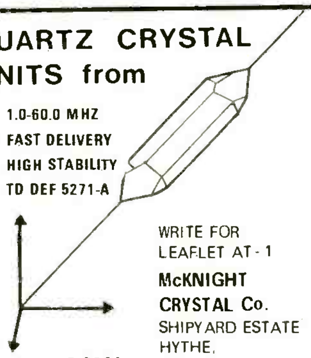

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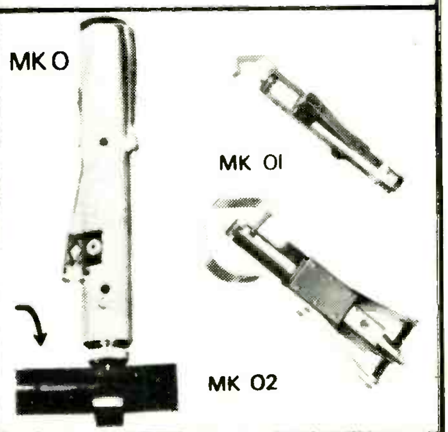

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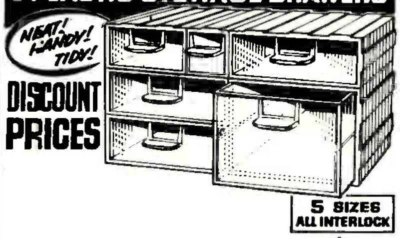

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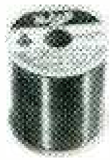
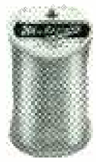
The first oxide free high purity extruded solder. Available in 1 lb. and 2 lb. bars, also Extrusol pellets for use in printed circuit soldering machines, baths and pots, polythene protected.



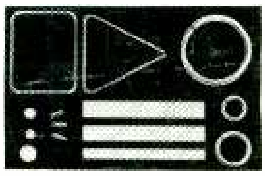
7 LB. REELS Available in standard wire gauge from 10-22 swg., on strong plastic reels.



1 LB. REELS Available in all standard wire gauges from 10-34 swg., on unbreakable plastic reels. (From 24-34 swg. only ½ lb. is wound on one reel).

GALLON CONTAINERS
All liquid chemicals and fluxes supplied in 1 gallon polythene 'easy pouring' containers, with carrying handle.

SOLDER TAPE, RINGS, PREFORMS, WASHERS, DISCS & PELLETS
Made in a wide range solid or cored alloys. Tape, rings and pellets are the most economical to use.



STANDARD ALLOYS INCLUDE

TIN/LEAD	B.S. GRADE	LIQUIDUS MELTING TEMP. °C	°F
60/40	K	188	370
Savbit No. 1	–	215	419
50/50	F	212	414
45/55	R	224	435
40/60	G	234	453
30/70	J	255	491
20/80	V	276	529

HIGH & LOW MELTING POINT ALLOYS

ALLOY	DESCRIPTION	MELTING TEMP. °C	°F
T.L.C.	Tin/Lead/Cadmium with very low melting point	145	293
L.M.P.	Contains 2% Silver for soldering silver coated surfaces	179	354
P.T.	Made from Pure Tin for use when a lead free solder is essential	232	450
H.M.P.	High melting point solder to B.S. Grade 5S	296–301	565–574

Over 400 specifications used in more than 80 countries

SOLDERING HANDBOOK

The most comprehensive book on soldering for industrial use, containing 120 pages with 100 illustrations and invaluable reference charts. Features practical methods of soldering in electronics and allied industries, and is divided into three headings; Published by Iliffe Books and available from Technical Bookshops.

ERSIN Multicore 5 CORE SOLDER

Should you have any soldering problems, or require details on any of our products, please write on your company's note paper to:

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