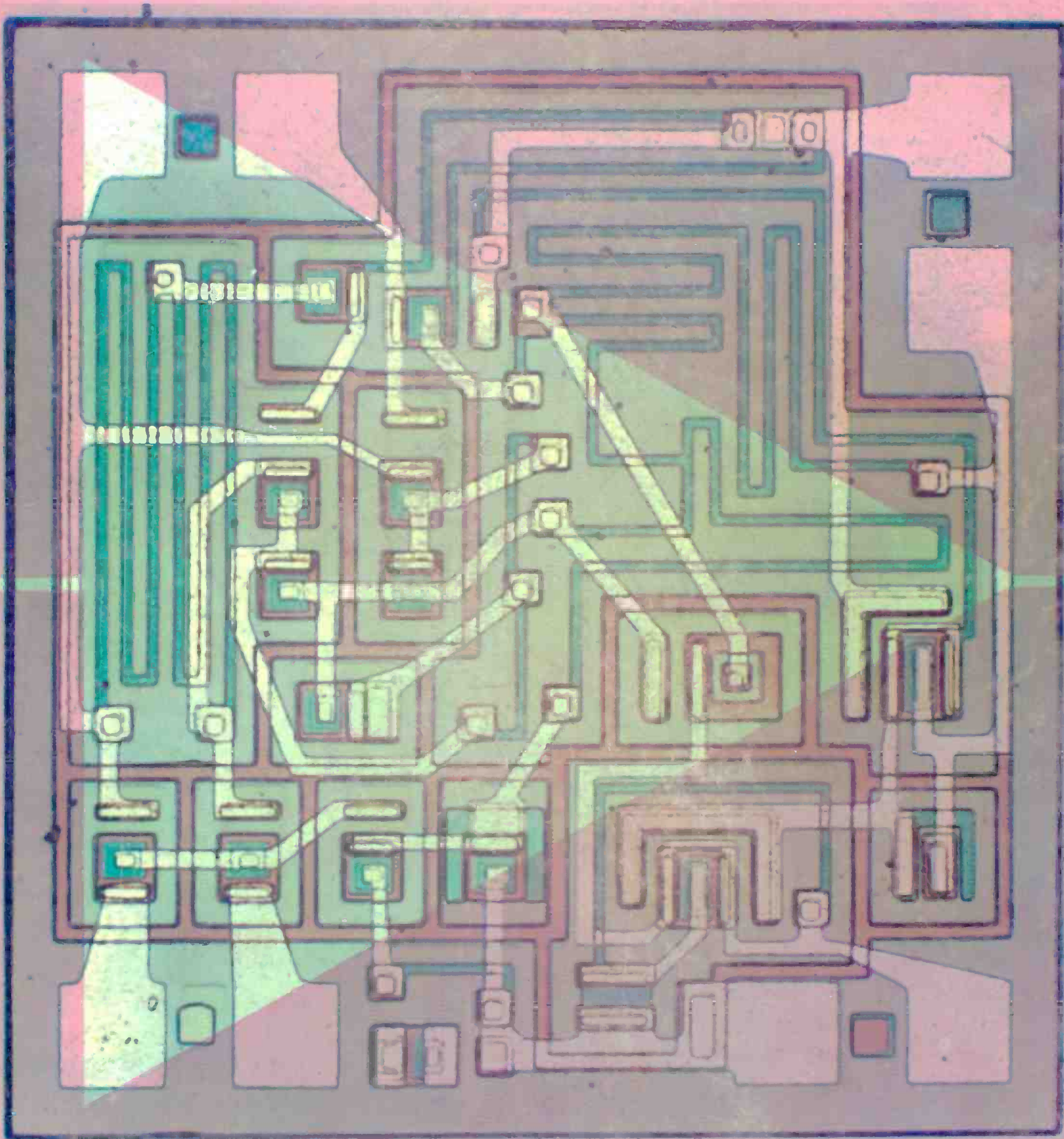
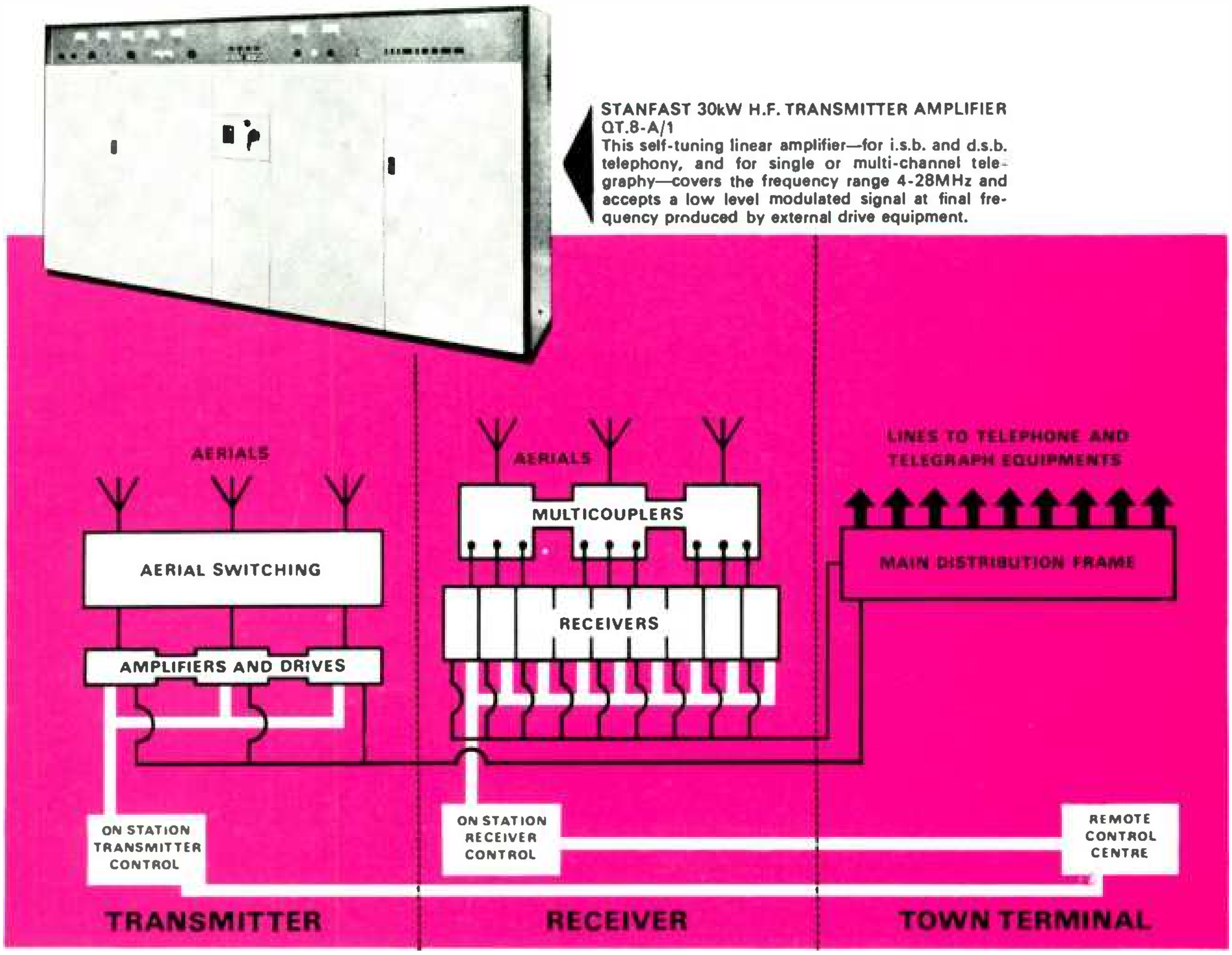
Wireless World

February 1969 Three Shillings

Operational amplifiers

Multimeter construction





STANFAST 30kW H.F. TRANSMITTER AMPLIFIER QT.8-A/1
This self-tuning linear amplifier—for i.s.b. and d.s.b. telephony, and for single or multi-channel telegraphy—covers the frequency range 4-28MHz and accepts a low level modulated signal at final frequency produced by external drive equipment.

Cut the operational and maintenance costs of your HF radio station right now –with STANFAST

Here's how

STANFAST Systems—the STC concept of automated h.f. radio stations—permit transmitting and receiving installation to be controlled completely by one man from a central location.

STANFAST Systems provide high speed frequency changing, automatic performance monitoring and rapid fault location affording optimum traffic handling capability and maximum revenue.

STANFAST Systems use the latest techniques in radio design, demand smaller sites and require less maintenance than hitherto. Initial capital cost is lower and return on investment is greater.

Standard Telephones and Cables Limited, Communications Division, New Southgate, London N.11. Telephone: 01-368 1200. Telex: 261912.

world-wide telecommunications and electronics **STC**

WW—001 FOR FURTHER DETAILS

Ferrograph Series 7 - a lifetime of recording

Ferrograph Tape Recorders have been famous ever since 1949. A lifetime's experience of making fine recorders goes into every one of Ferrograph's brilliant new Series 7.

And there is a lifetime's recording *in* every Ferrograph instrument. Many of the earliest Ferrographs are giving perfect service today, nearly twenty years later. You can be sure your Ferrograph will do the same for you. It will give dependable service for many, many years to come. It will keep its value. It will need the minimum of service. Spare parts will remain available for a lifetime's recording. That's how Ferrograph got its name.

Available in Mono, and in Stereo with and without end amplifiers; combining a unique range of 30 recording facilities, including:

- **All silicon solid-state electronics with FET input stages and wide input overload margins.**
- **Vertical or horizontal operation.**
- **Unit construction: The 3 individual units i.e. tape deck, power unit and amplifier complex are mounted on a single frame easily removable from cabinet for service or installation in other cabinets or racks.**
- **3 motors (no belts). 3 tape speeds.**
- **Variable speed spooling control for easy indexing and editing.**
- **Electrical deck operation allowing pre-setting for time-switch starting without need for machine to be previously powered.**
- **Provision for instantaneous stop/start by electrical remote control.**
- **Single lever-knob deck operation with pause position.**
- **Independent press-to-record button for safety and to permit click-free recording and insertions.**
- **8¼" reel capacity.**
- **Endless loop cassette facility.**
- **Internal loud speakers (2)—1 each channel on stereo, 2 phased on mono.**
- **4 digit, one-press re-set, gear-driven index counter.**
- **2 inputs per channel with independent mixing (ability to mix 4 inputs into one channel on stereo machine).**
- **Signal level meter for each channel operative on playback as well as record.**
- **Tape/original switching through to output stages.**
- **Re-record facility on stereo models for multi-play, echo effects etc, without external connections.**
- **Meters switchable to read 100 kHz bias and erase supply with accessible preset adjustment.**
- **Three outputs per channel i.e. (1) line out—level response. (2) line out—after tone controls. (3) power output—8-15 ohms.**
- **Power output 10W per channel.**
- **Independent tone controls giving full lift and cut to both bass and treble each channel.**
- **Retractable carrying handle permitting carrying by one or two persons.**

U.K. Retail prices from £150 incl. P.T.

See and hear Ferrograph Series 7 recorders at your local Ferrograph stockist, or post coupon for details and address of nearest Ferrograph specialist (or ring 01-589 4485)

FERROGRAPH

To the Ferrograph Co Ltd, Mercury House, 195 Knightsbridge, London SW7
Please send me FREE brochure on Ferrograph Series 7 Tape Recorders ☐ *Please tick*
OR send me the new Ferrograph Manual, for which I enclose £1 ☐

NAME ....

ADDRESS ....

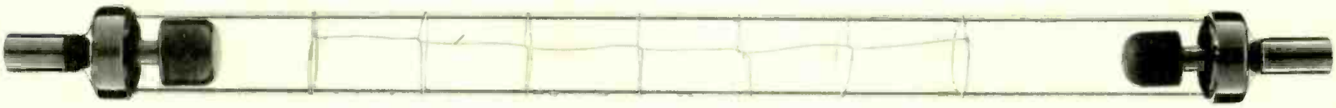
.... WW

WW—007 FOR FURTHER DETAILS

Outstanding in quality, reliability and performance

Don't take our word for it—test EEV flash tubes against the equivalents you're now using and learn why other users think so highly of those made by EEV. Incorporating extra heavy duty electrodes, EEV flash tubes are renowned for their reliability, long life (up to 10^6 flashes) and high conversion efficiency. EEV liquid-cooled and air-cooled xenon flash tubes for pumping laser rods offer a wide range of input energy levels and they are capable of operation at high repetition rates.

Full details of the range are available on request—but if your application calls for a flash tube that is not in the present range, tell us your requirement because we can probably make it for you.



EEV flash tubes

Type	Energy input per flash max. (J)	Arc length (mm)	Bore diameter (mm)	Typical operating conditions Voltage (kV)	Series inductance (μH)	Flash rate	Trigger voltage (kV)
XL615/7/3	600	76	7.0	2.5	400	1 per 15 sec.	12–16
XL615/9/4	1500	102	9.0	2.5	400	1 per 30 sec.	12–16
XL615/10/5.5	3500	140	10.0	2.5	400	1 per 30 sec.	16–20
XL615/10/6.5	5000	165	10.0	2.5	800	1 per 2 min.	20–25
XL615/13/6.5	10000	165	13.0	2.5	800	1 per 2 min.	25

Send for full details of the complete range of EEV flash tubes.

English Electric Valve Co Ltd
Chelmsford Essex England Telephone : 61777
Telex : 99103 Grams : Enelectico Chelmsford

I am interested in EEV flash tubes for .... (application).
Please send me data sheets on your full range.

NAME POSITION

COMPANY

ADDRESS

TELEPHONE NUMBER EXTENSION

WW1

AP 356

REPEAT PERFORMANCE FROM GARDNERS

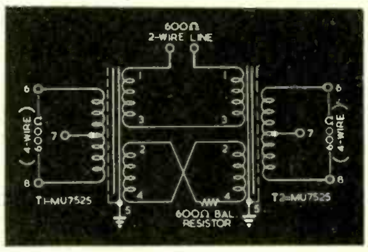
Exceptionally wide band microphone and audio line matching transformers

FREQUENCY RANGE
100 K.ohm models ±1 dB 30 c/s to 20 kc/s.
All other models ±0.5 dB 30 c/s to 20 kc/s.
MAXIMUM AUDIO LEVEL +12 dBm (16mW).
INPUT IMPEDANCE maintained to within ±10% (±20% j) at all frequencies within the range 50 c/s to 8 kc/s (to 5 kc/s only for 100 K.ohm models).
MAGNETICALLY SCREENED
—50 dB reduction in hum pick up.

For professional recording and broadcast transmission equipment, these Octal-based plug-in transformers have a frequency response extending well beyond the audio range. The design achieves dynamic performance with minimum distortion at all levels

Type No.	Input Z Ohms	Pin Nos.†	Output Z Ohms	Pin Nos.	Sec./Pri. Turns Ratio	Applications
MU.7521	3·75/15*	1-3, 2-4	600 (C.T.)	6-7-8	6·32 :1/12·64 :1	Low Z. Mic/Line
MU.7522	3·75/15*	1-3, 2-4	100K.	6-8	82 :1/164 :1	Low Z. Mic/Grid
MU.7523	75/300*	1-3, 2-4	600 (C.T.)	6-7-8	1·41 :1/2·82 :1	Line/Line
MU.7524	150/600*	1-3, 2-4	600 (C.T.)	6-7-8	1 :1/2 :1	Mixing : Bal./Unbal.
MU.7525	600 (C.T.)	6-7-8	300/1·2K*	1-3, 2-4	1+1 :1·41 (C.T.)	Mixing : Hybrid‡
MU.7526	600 (C.T.)	6-7-8	2·5k/10k.*	1-3, 2-4	2·04 :1/4·08 :1	Line/Grid
MU.7527	150/600*	1-3, 2-4	100K.	6-8	13 :1/26 :1	Line/Grid
MU.7528	7·5/30*	1-3, 2-4	600 (C.T.)	6-7-8	4·47 :1/8·94 :1	Low Z. Mic./Line
MU.7529	50/200*	1-3, 2-4	600 (C.T.)	6-7-8	1·73 :1/3·46 :1	Mic. or Line/Line
MU.7530	10K. (C.T.)	6-7-8	10K.	1-4	1 (C.T.) :1	600 Line Bridging
MU.7532	7·5/30*	1-3, 2-4	100K.	6-8	58 :1/116 :1	Low Z. Mic./Grid
MU.7534	50/200*	1-3, 2-4	100K.	6-8	22·4 :1/44·8 :1	Mic. or Line/Grid

Type MU.7525 may be used in "Hybrid" circuits, as shown, to establish 2 to 4 wire operation in telephony. Accurate balancing of the windings enable guaranteed rejection of better than — 55 dB from 50 c/s to 10 kc/s. Up to — 75 dB may be expected for normal rejection levels.



Gardners

WRITE FOR A.F. BROCHURE GT.4
giving full details of these and other types of A.F. transformers

GARDNERS TRANSFORMERS LIMITED
Christchurch, Hampshire BH23 3PN. Tel. Christchurch 2284
TELEX 41276 A. B. GARDNERS CHRISTCHURCH

WW—009 FOR FURTHER DETAILS

EEV thyratrons-for better high speed switching

EEV glass and ceramic hydrogen thyratrons are extensively used to provide more precise and efficient high speed switching. Here are some of the reasons why:

1 Their short anode delay time of between 20 and 120 nanoseconds depending on triggering method.
2 Low jitter generally of 1 to 2 nanoseconds but down to less than ½ nanosecond depending on heater supply.
3 The negligible change in anode delay time—typically only 10 nanoseconds over a long period of use.
4 A high peak inverse voltage capability of 20kV immediately following pulse.
5 The low trigger power required.
6 The wide operating voltage range of 1kV-120kV with four tubes.
7 The ability to control anode delay time and rise time of current, using reservoir.
8 The wide reservoir range for maintenance of gas pressure typically 4.5V to 5.7V.

The standard range plus EEV's ability to meet special requirements means that virtually any high speed switching application can be met.
Here are a few:
Radar modulators with a system output power of 10kW – 10MW.
Medical linear accelerators with RF accelerating powers up to 15MW.
Particle linear accelerators with RF accelerating powers up to 50MW. They may also be used in first-stage particle beam choppers.
Particle beam benders where a network of stored energy needs to be discharged into a deflection coil or other device somewhere on the the accelerating ring.
Spark chambers
For pulsing light shutters such as Kerr or Pockel cells.
Electronic crowbars and energy diverters

Brief data on some of the ceramic types available.

Type	Peak power output max (MW)	Heating Factor (V.A.p.p.s.)	Peak forward voltage max (kV)	Peak anode current max (A)	Mean anode current max (A)
CX1154	50.0	30×10^9	40	2500	3.0
CX1157	3.5	7×10^9	20	350	0.35
CX1168	100.0	70×10^9	80	2500	2.5
CX1171	150	70×10^9	120	2500	2.5
CX1174	120	60×10^9	40	6000	6.0
CX1175	200	140×10^9	80	5000	6.0
CX1180	12.5	9×10^9	25	1000	1.25

Send for full details of the complete range of EEV thyratrons.

English Electric Valve Co Ltd
Chelmsford Essex England Telephone: 61777
Telex: 99103 Grams: Enelectico Chelmsford

I am particularly interested in using a thyratron with the following parameters:

Application

Peak power output

Peak forward voltage

Peak anode current

Please send me full data on your complete range of glass and ceramic hydrogen thyratrons

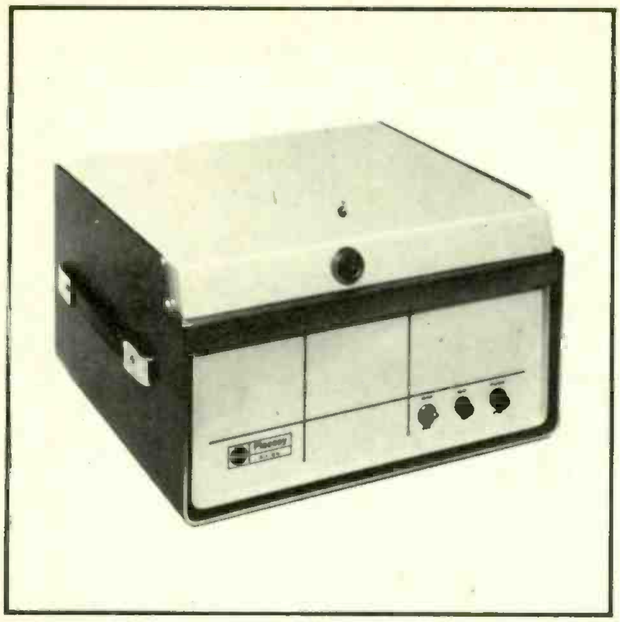
NAME POSITION

COMPANY

ADDRESS

TELEPHONE NUMBER EXTENSION WW2

AP 359



Now Plessey cartridge recorders

offer 48 Volt DC operation

The CT85 is the latest model to be added to the wide range of Plessey endless loop cartridge recorders. This unit provides emergency interception services in Telephone Exchanges and other special services where 48 Volt D.C. operation is required.
The CT85 is suitable for continuous or intermittent service. Audio output is 2 watts into 50 ohms for multiple telephone line distribution. A second track is used for stop cues together with an auxiliary cue for other functions such as redirecting telephone traffic from non-operative numbers. Start can be local or by an external earth signal.
In common with all CT80 cartridge recorders the CT85 operates from an exclusive integral direct drive capstan motor, solenoid and puck wheel assembly. For long term reliability the motor is an AC type driven through an electronic switching module. Solid state silicon devices are utilized throughout.
The CT85 is supplied in a portable cabinet that can be locked to prevent access to the cartridge, circuit boards and operating controls by unauthorised personnel. The unit can also be supplied for desk top, built-in and rack mounting.
For full details of Plessey broadcast standard CT80 recorders contact your local Plessey office now.

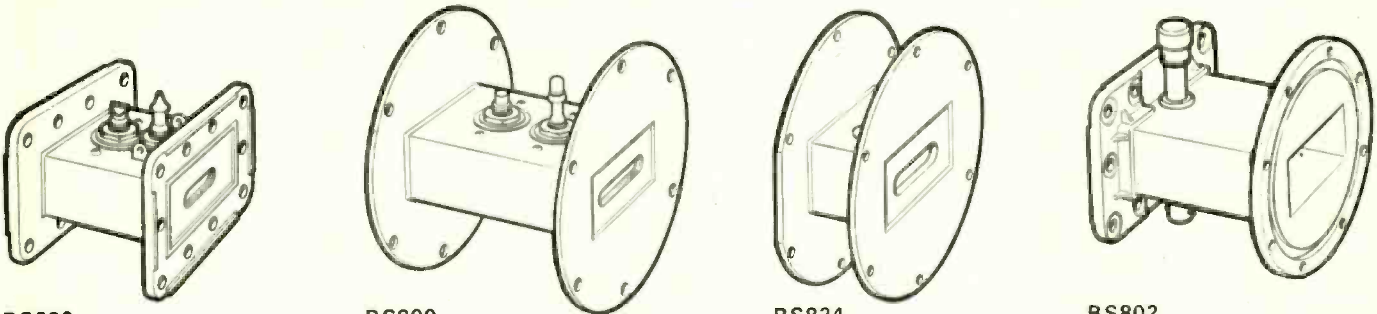
PLESSEY
Electronics

Sales and Service — Rola Recording Products Department|Garrard Engineering Limited Newcastle Street Swindon Wiltshire Telephone Swindon 5381 Telex 44271|or the manufacturer Plessey Australia Rola Unit The Boulevard Richmond Australia 3121 Telex 30383 Cables ROLA Melbourne

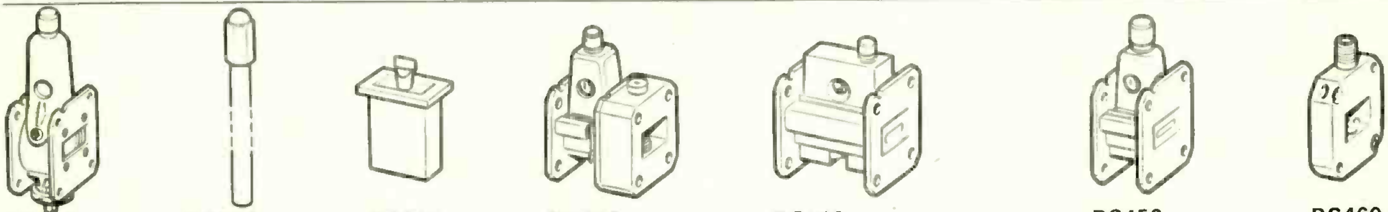
WW—013 FOR FURTHER DETAILS

120-AR9

Choose your duplexer devices from EEV's extensive range



BS390 BS800 BS824 BS802



BS332 BS834 BS310 BS814 BS458 BS452 BS460

Brief data on some of the many types available.

Product	Type No	Band	Frequency range (MHz)	Peak power (kW)
Pre TR cells	BS834	—	2000-12000	2500
	BS870	—	1240-1365	2500
TR cells	BS390	S	2925-3075	1250
	BS800	S	2840-3100	1250
	BS824*	S	2700-3100	250
	BS156	X	9000-9600	200
	BS452	X	9310-9510	100
	BS810	X	9250-9550	75
	BS850	X	9300-9500	50
TB cells	BS310	X	9375	5-200
TR limiter cells	BS814	X	9000-9700	200
	BS828	X	9325-9425	50
Solid state microwave switches	BS392	S	2925-3075	0.5
	BS460	X	8500-12000	0.5

*For protection of travelling waveguide amplifiers

Send for this booklet giving full details of the complete range of EEV duplexer devices and waveguide switches.

English Electric Valve Co Ltd
Chelmsford Essex England Telephone: 61777
Telex: 99103 Grams: Enelectico Chelmsford

Please send me a copy of "Duplexer Devices". I am interested in a tube with the following parameters:

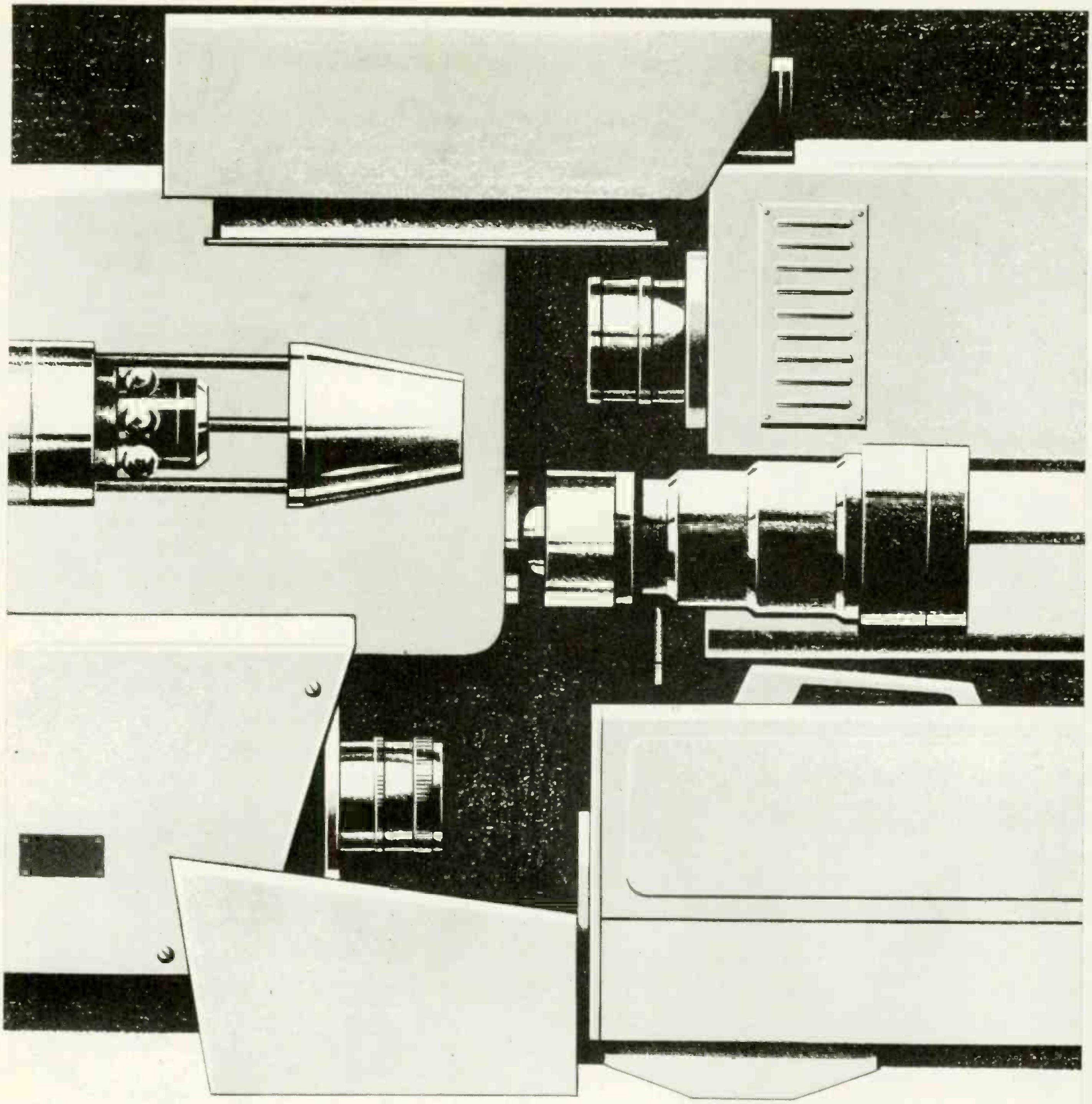
Frequency range Power Type of cell

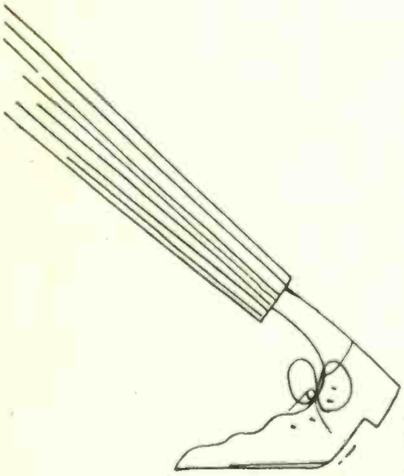
NAME POSITION

COMPANY

ADDRESS

TELEPHONE NUMBER EXTENSION





going places? -don't!

GEC–AEI Remote Control and Telemetry Systems are helping industry's key personnel to stay put while controlling distant out-stations.

The equipment covers transmission of information between out-stations and control rooms by various forms of telemetry, including: Teledata; Teleshift; Telecode and Teleducer, and provides visual presentation of conditions of controlled equipment on mimic diagrams, using the well-known GEC–AEI Modular Mimic Systems.

Write today for telemetry literature/modular mimic systems literature.

Communications Division

GEC

Information Centre. GEC-AEI (Electronics) Limited Communications Division Spon Street Coventry CV1 3BR
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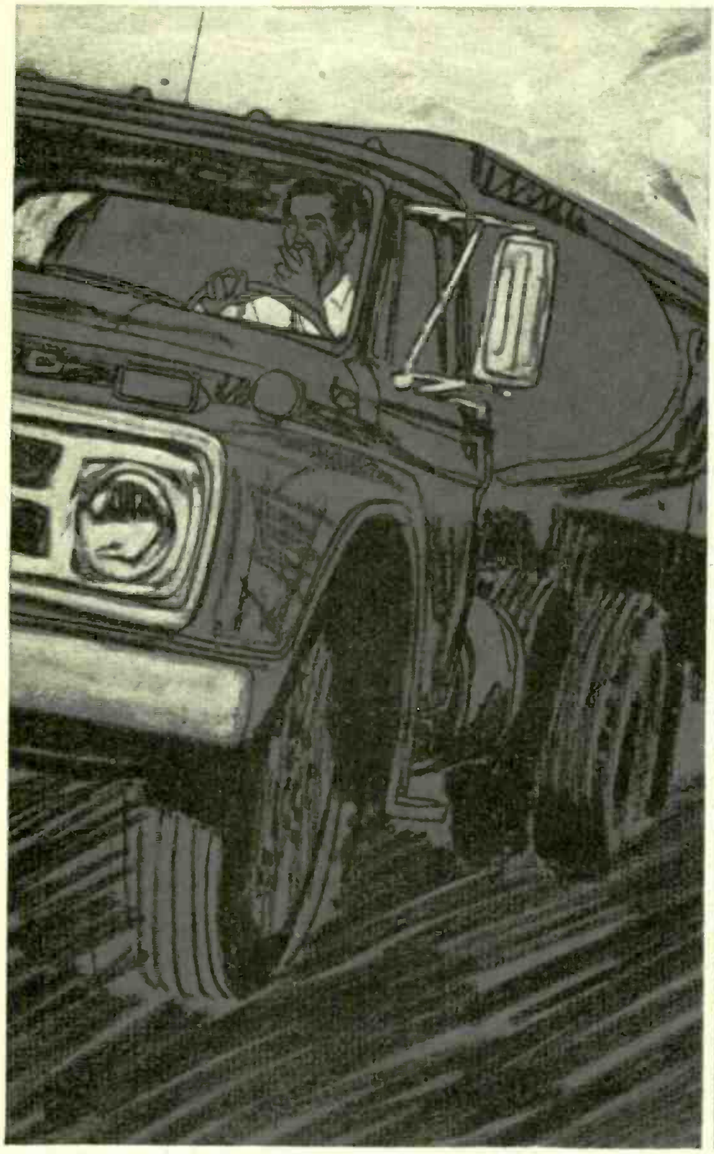
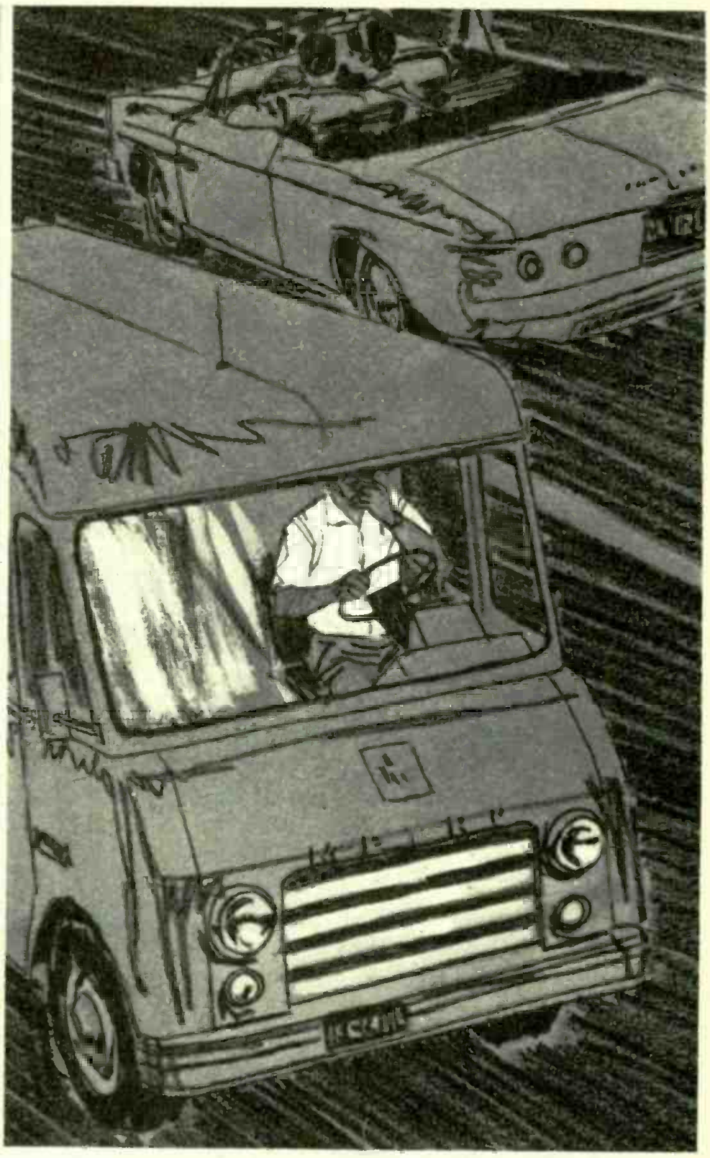
WW—016 FOR FURTHER DETAILS

BREAK THE SOUND BARRIER





MODEL 488 SONO-BAR

MODEL 419 RANGER II

WITH PROVED **SHURE** SETTING THE WORLD'S STANDARD IN SOUND

NOISE CANCELLING MICROPHONES

When the chips are down, and noise levels are high, Shure Noise Cancelling microphones with their exclusive Controlled Magnetic cartridges, distance-discrimination design, and specially tailored response get the message through . . . *even when noise level is so high the operator cannot hear himself!* They have been field-tested and proved in such ear-shattering environments as: drop forges, helicopters, police power boats, "hard surface" gyms among cheering crowds, motorcycles, jets revving up, fire engines, etc.

SHURE MODEL 488 SONO-BAR

Rugged, impact resistant "Armo-Dur" case. Four types: High or low impedance; transistorized for direct replacement of carbon microphone; and FAA Certified Transistorized Aircraft version.

SHURE MODEL 419 RANGER II

New small size. Only about half the size and weight of conventional mobile communications microphones. Unsurpassed for use with portable or miniaturized equipment.

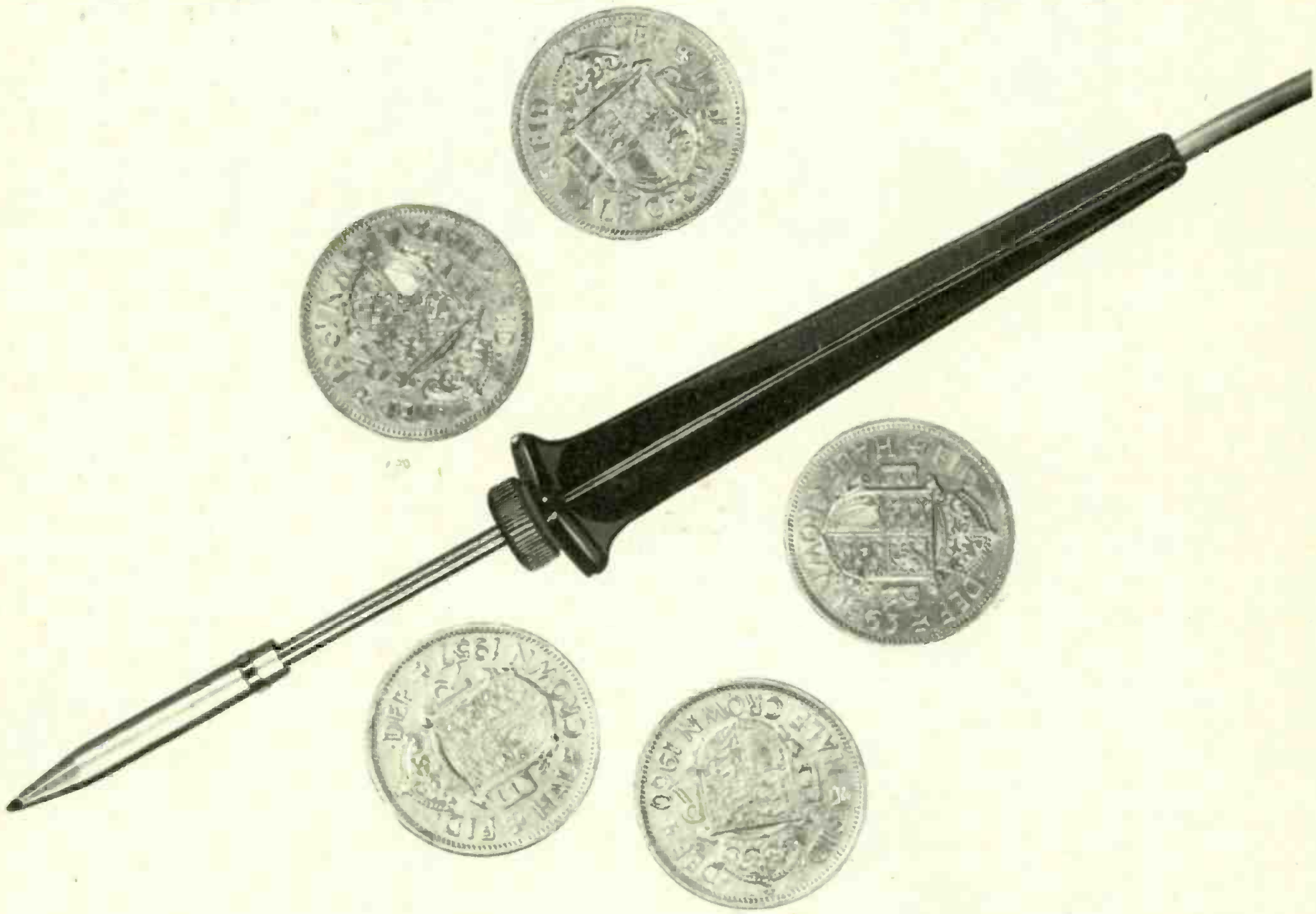
SHURE MICROPHONES—WORLD STANDARD WHEREVER RELIABILITY AND SOUND QUALITY ARE PARAMOUNT

SHURE

SHURE ELECTRONICS · 84 BLACKFRIARS ROAD · LONDON · SE1 Tel: 01-928 3424

WW—017 FOR FURTHER DETAILS

ALL CHANGE..



THE ELREMCO SUB-MINIATURE SOLDERING IRON TYPE MS1

- Revolutionary heating element design – 1″ long, fitting into 1/10″ dia. hole. Long life. High efficiency.
- Easily interchangeable bits.
- Bit tips down to 1/32″ diameter.
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- Inputs up to 240 V.
- Outstanding performance – will solder up to 14 swg. Copper conductors.
- Weight, less than 3/4 ozs.
- Low cost.

For further details send for List ADS.601 from

ELECTRICAL REMOTE CONTROL COMPANY LIMITED

ELREMCO

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Standardise on ±5% tolerance

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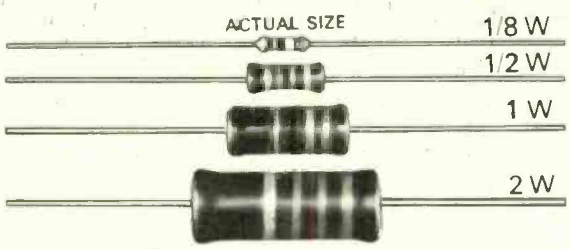
for all your requirements



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1/8 W ± 5%	5.1Ω to 330KΩ	—	2/2d	4/9d	16/-
1/2 W ± 5%	10Ω to 10MΩ	—	2/2	4/9	16/-
1 W ± 5%	10Ω to 10MΩ	—	3/3	7/6	23/-
2 W ± 5%	10Ω to 10MΩ	3/-	5/9	14/-	45/-

FULL SPECIFICATION OF WAYCOM CARBON FILM RESISTORS IS CONTAINED IN OUR NEW 150 PAGE ELECTRONIC COMPONENTS CATALOGUE. COMPLETE COUPON FOR YOUR COPY.

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To: COMBINED ELECTRONIC SERVICES LTD. *(formerly R T S)*
Queensway, Waddon Factory Estate, CROYDON, CR9 4DR
Please send me your new catalogue of components available 'by return'

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ADDRESS ....

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WW—020 FOR FURTHER DETAILS

Has red tape been complicating your procurement of electronic components from the U.S.A.?

Let us help you cut through it!

Procurement of American-made electronic components used to be thought of as a complex, time-consuming procedure with a myriad of red tape details and problems. Not anymore — now you can join the growing list of companies that rely on the technical skills and services of Milo International, world-wide distributors of electronic components. Our team of experienced specialists will process your order with speed and efficiency from start to finish — immediate price and availability quotations, product information, application data, import certificates, export licenses, declarations, export packaging, delivery expediting, etc. And this all-inclusive service is provided for each order, no matter how small or large.

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Amphenol	Electrons, Inc.	Raytheon
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Cinch-Jones	J.F.D.	Superior
Clarostat	Kings	Sylvania
Cornell-Dubilier	Littelfuse	Texas Instruments
Corning	Mallory	Transitron
Dale Electronics	Oak	United Transformer
Delco Radio	Ohmite-Allen Bradley	Vector
	Potter & Brumfield	Xcelite

For immediate price and delivery quotations, contact Milo by mail, phone, cable or International Telex.

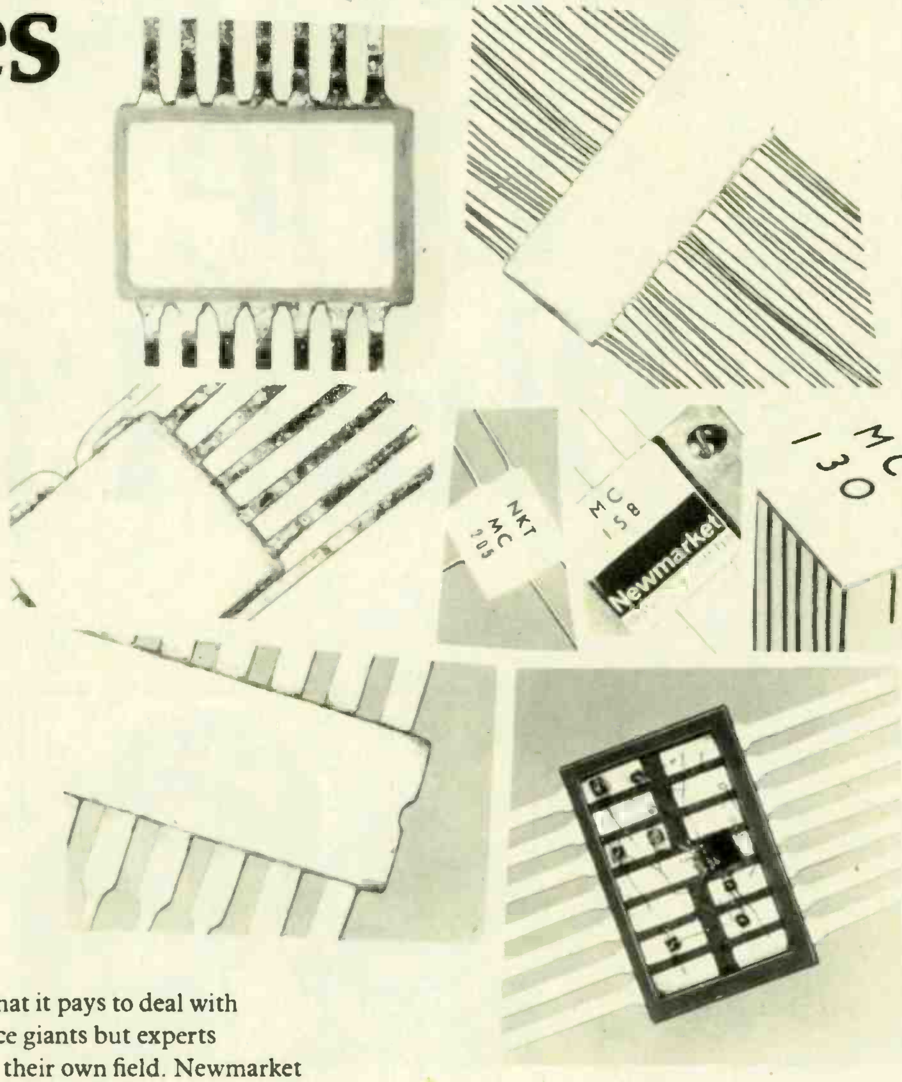
MILO International

World-Wide Electronic Component Suppliers

325 Hudson St., New York, N.Y. 10013/Tel 212-924-5000/Cable MILOLECTRO, N.Y./Int'l. Telex 62528 or 620715

WW—021 FOR FURTHER DETAILS

Newmarket microcircuits have several distinguishing features



Rational production
the *only* UK custom-built thickfilm hybrid microcircuit manufacturer also producing the active devices for hybrids in house.

Reliable delivery
12 actual weeks from first enquiry to delivery of custom-built batches for full production (only 6 weeks to prototype production).

Reasonable quantities
typical annual requirement is 500—5,000 off: no multi-million runs required.

Radical costing
just enquire—you'll probably find the complete Newmarket microcircuit costs no more than your own real discrete component assembly costs.

Newmarket Transistors prove again that it pays to deal with specialists. Not every-electronic-device giants but experts constantly contributing to progress in their own field. Newmarket are the experts in industrial semiconductors and have led the field for two years in custom-built microcircuits. So deal with the team (and the distinguished distributors) in tune with tomorrow.

face tomorrow's pace with Newmarket Transistors

the specialist semiconductor engineers with the distinguished personal service network:

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COVENTRY Coventry Factors Ltd., Coronet House, Upper Well Street. Call 21051/5
GLASGOW James Scott (Electronic Agencies) Ltd., 90 West Campbell Street, C.2. Call CENtral 3866
HARLOW Standard Telephones & Cables Ltd., Electronic Services Division, Edinburgh Way. Call 26777
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HOUNSLOW Eastern Aero Electrical Services Ltd., Building 44, London (Heathrow) Airport, North. Call SKYport 1314
PORTSMOUTH S.D.S. (Portsmouth) Ltd., Hilsea Industrial Estate. Call 62332

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TRANSISTORS LIMITED

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Force Three/Cambridge

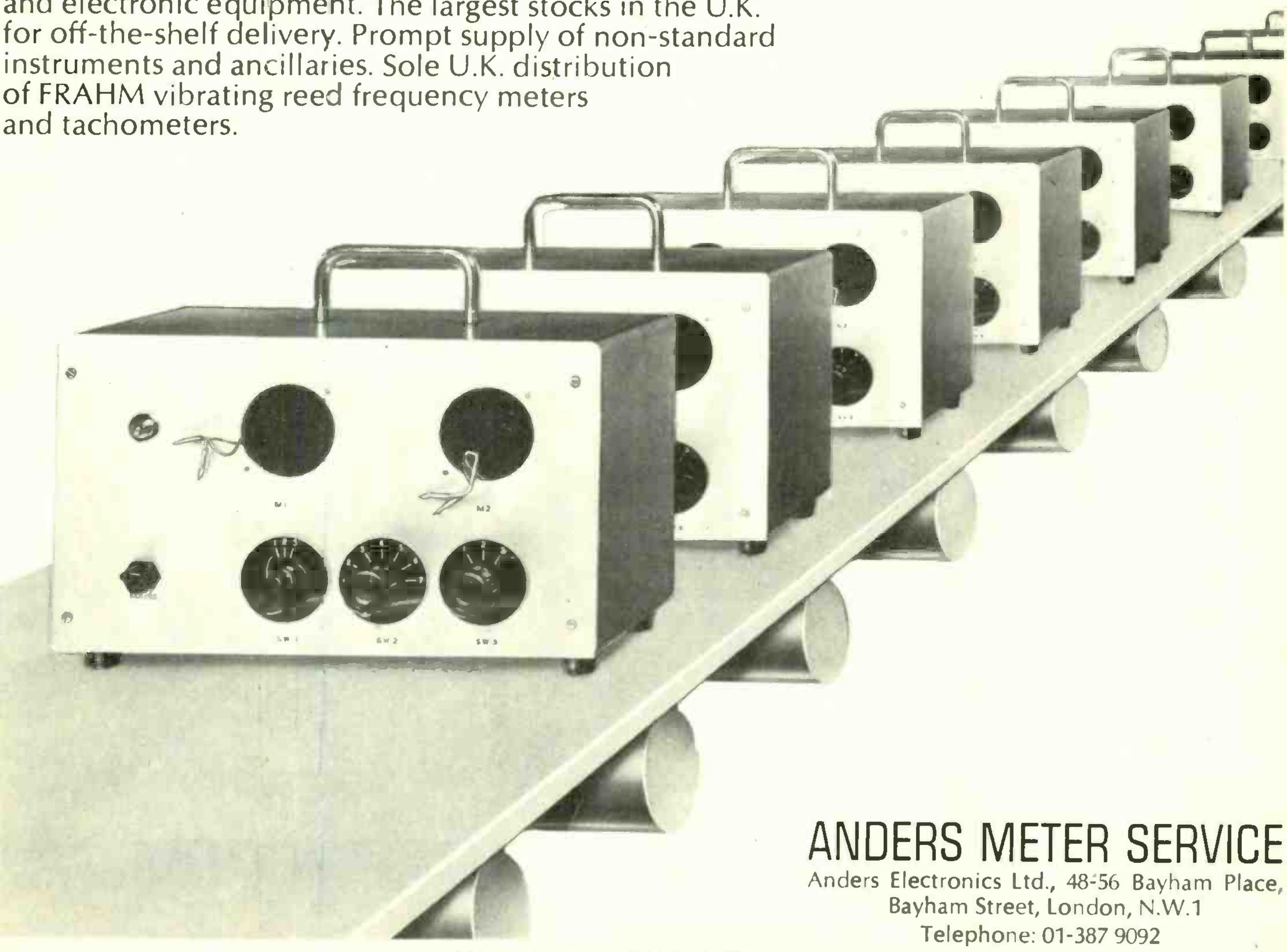
WW—023 FOR FURTHER DETAILS

METERS MISSING?

Whether your products are individually assembled or on a flow line, missing components spell loss of time, delayed deliveries – and maybe tied-up capital. When it comes to meters, there's no excuse. Anders carry the largest stocks of meters in the U.K. Standard meters are off-the-shelf and on their way to you within 24 hours of your order. Non-standard instruments take very little longer. Anders have a fast moving production team of well-equipped specialists in assembly, calibration, and even hand-lettering of dials. In fact the only things missing from the Anders' service are excuses: we take care to see that we don't have to make them. So when it comes to meters, come to Anders.

N.B. The variety of meters in our new catalogue is a revelation – and now we've got extensive new centralised premises for a better-than-ever service.

Manufacture and distribution of electrical measuring instruments and electronic equipment. The largest stocks in the U.K. for off-the-shelf delivery. Prompt supply of non-standard instruments and ancillaries. Sole U.K. distribution of FRAHM vibrating reed frequency meters and tachometers.



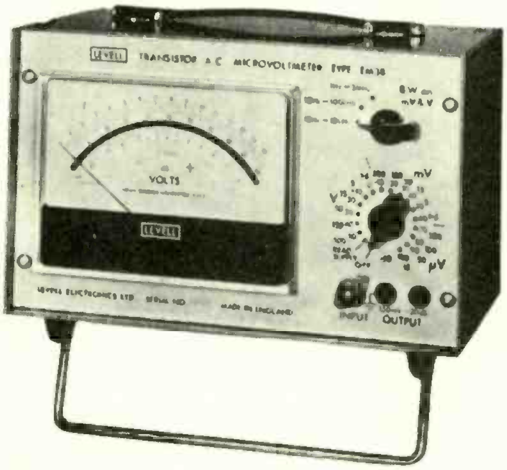
ANDERS METER SERVICE

Anders Electronics Ltd., 48-56 Bayham Place,
Bayham Street, London, N.W.1
Telephone: 01-387 9092

LEVELL VOLTMETERS measure μV's from 1Hz to 450MHz

TRANSISTOR A.C. MICROVOLTMETERS

Response from 1Hz to 3MHz with amplifier output available. Two versions differ only in meter size and bandwidth switch on type TM3B.



TYPE TM3A

£49

Complete with battery and input lead.

OPTIONAL EXTRAS
Leather case £4/10/-.
A.C. Power Unit £7/10/-.

TYPE TM3B

£63

Complete with battery and input lead.

OPTIONAL EXTRAS
Leather Case £5.
A.C. Power Unit £7/10/-.

VOLTMETER RANGES

15μV, 50μV, 150μV . . . . 500V f.s.d.
Accuracy $\pm 1\%$ $\pm 1\%$ f.s.d. $\pm 1\mu$V at 1kHz.

dB RANGES

-100dB to $+50$dB in 10dB steps. Scale -20dB to $+6$dB. 0dB = 1mW into 600Ω.

FREQUENCY RESPONSE

Above 500μV: ± 3dB from 1Hz to 3MHz.
$\pm 0{\cdot}3$dB from 4Hz to 1MHz.
On 500μV: ± 3dB from 2Hz to 2MHz.
On 150μV: ± 3dB from 4Hz to 1MHz.
On 50μV: ± 3dB from 7Hz to 500kHz.
On 15μV: ± 3dB from 20Hz to 200kHz.

AMPLIFIER OUTPUT

150mV at f.s.d. on all ranges. Will drive a load of 200kΩ and 50pF without loss.

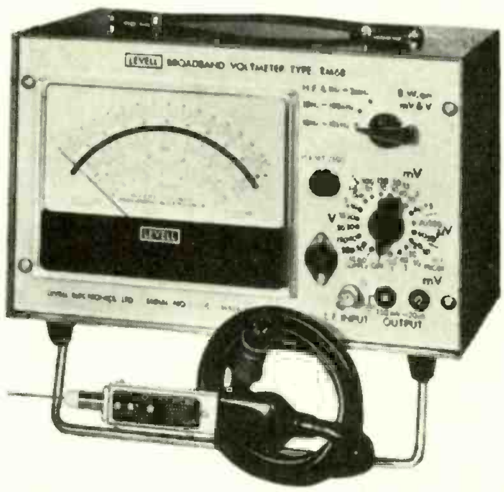
POWER SUPPLY

One type PP9 battery, life 1000 hours; or. A.C. mains when Power Unit is fitted.

★ ★ ★ ★ ★ ★ ★ ★ ★ ★

BROADBAND VOLTMETERS

As A.C. Microvoltmeters plus H.F. probe to extend response to 450MHz. Two versions differ only in meter size and L.F. bandwidth switch on type TM6B.



TYPE TM6A

£85

Complete with battery and input lead.
OPTIONAL EXTRAS

Leather Case £4/10/-.
A.C. Power Unit £7/10/-.

TYPE TM6B

£99

Complete with battery and input lead.

OPTIONAL EXTRAS

Leather Case £5.
A.C. Power Unit £7/10/-.

H.F. VOLTAGE RANGES

1mV, 3mV, 10mV . . . . 3V f.s.d. Square law scales. Accuracy $\pm 4\%$ of reading $\pm 1\%$ of f.s.d. at 30MHz.

H.F. dB RANGES

-50dB, -40dB, -30dB . . . . $+20$dB. Scale -10dB to $+3$dB. 0dB = 1mW into 50Ω.

H.F. RESPONSE

$\pm 0{\cdot}7$dB from 1MHz to 50MHz.
± 3dB from 300kHz to 400MHz.
± 6dB from 400MHz to 450MHz.

L.F. RANGES

As TM3A and TM3B except for the omission of 15μV and 150μV.

POWER SUPPLY

One type PP9 battery, life 1000 hours on L.F. ranges and 400 hours on H.F. ranges; or, A.C. mains when Levell Power Unit is fitted.

LEVELL

PORTABLE INSTRUMENTS

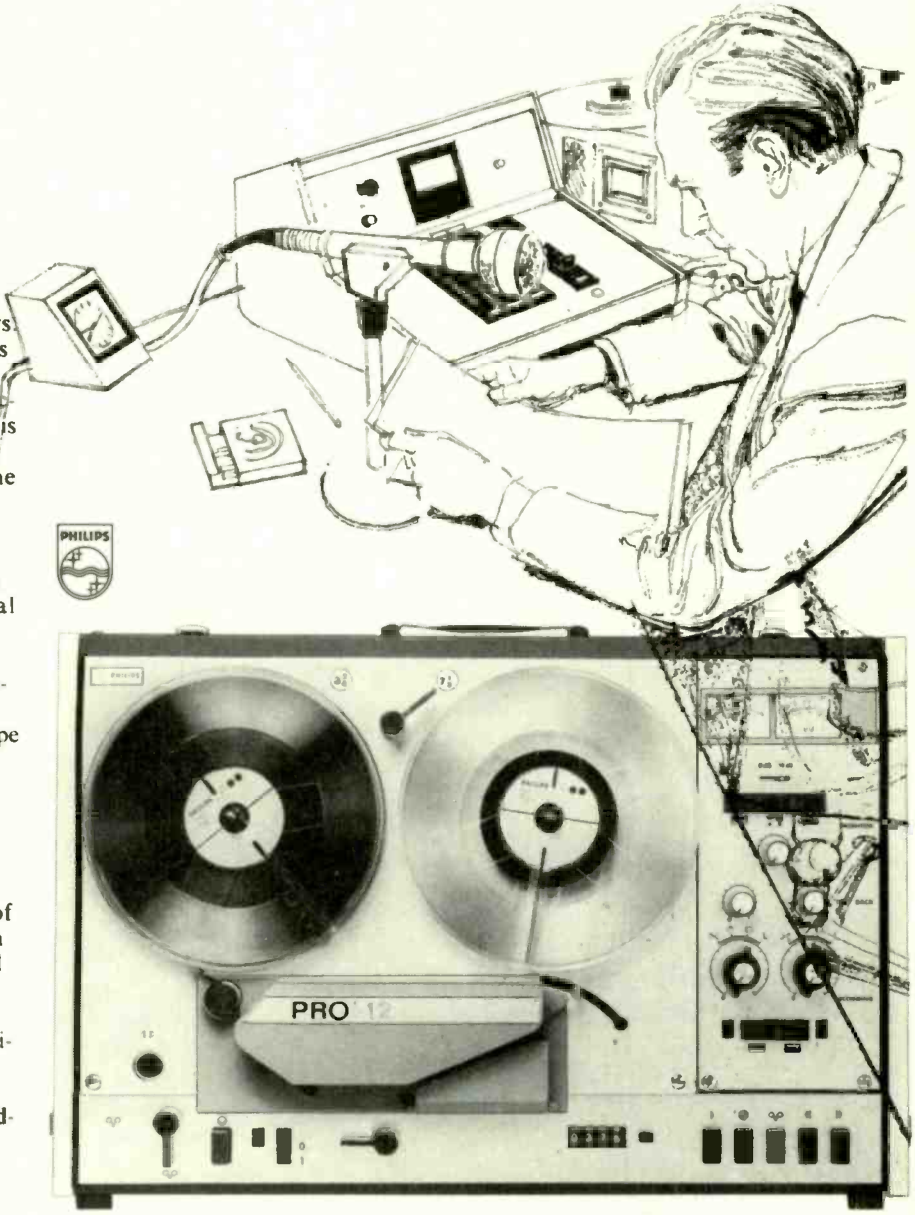
Fully detailed leaflets are available on our complete range of portable instruments

LEVELL ELECTRONICS LTD., Park Road, High Barnet, Herts. Tel.: 01-449 5028

WW—025 FOR FURTHER DETAILS

Sounds exactly what you want

Here's a professional tape recorder that you can use in the studio and in outside broadcast vans.
Philips Pro'12 meets a long standing requirement of studio sound engineers. This portable two-channel recorder is designed to meet the high standards of sound quality and versatility expected of professional equipment, yet it is small and competitively priced.
Recording and playback quality of the Pro'12 is of a very high standard. Tapes prepared on a Pro'12 are suitable for immediate broadcasting.
Even at the lowest tape speed of 3 3/4 in/s, the sound quality is at least equal to the DIN 45511 studio equipment specification.
It features: • Twin-track stereo, twin-track mono and dual-track mono operation on 6.25 mm (1/4 in) wide tape (standard version). • Extra quarter-track stereo (special version). • Tape speeds of 9.5 and 19 cm/s (3 3/4 and 7 1/2 in/s). • Unique "constant load" tape transport. • Microphone, diode and line inputs for each channel. • Facilities for mixing input signals of both channels. • Multiplay, sound on sound and echo effect. • Fade in and out and dubbing facilities. • Cueing and pause keys. • Line and monitoring outputs for each channel. • Monitoring with stereo headset or built-in loudspeaker, before or after tape. • VU-control of either channel. • End-of-tape switch. • Remote control connection. • Horizontal or vertical operation.



Technical data
Tape speeds
3 3/4 and 7 1/2 in/s (9.5 and 19 cm/s)
Tape
longplay (1800 ft — 540 m) or doubleplay (2400 ft — 720 m)
Reels
Ciné type, max. 7 in (180 mm)
Playing time
for longplay tape on 7-inch reel:
at 7 1/2 in/s: 45 min
for doubleplay tape on 7-inch reel:
at 7 1/2 in/s: 60 min
Deviation on absolute tape speed
less than 0.8%
Wow and flutter
measured acc. to DIN 45507 with EMT 420,
at 7 1/2 in/s: 0.08%
at 3 3/4 in/s: 0.1%
Frequency response
acc. to DIN 45511, playback
at 7 1/2 in/s: 60 . . . 12000 Hz, 0-1.5 dB
at 7 1/2 in/s: 40 . . . 18000 Hz, 0-2.5 dB
at 3 3/4 in/s: 60 . . . 10000 Hz, 0-1.5 dB
at 3 3/4 in/s: 40 . . . 15000 Hz, 0-2.5 dB
overall at 7 1/2 in/s:
60 . . . 12000 Hz, 0-3 dB
overall at 7 1/2 in/s:
40 . . . 18000 Hz, 0-5 dB
overall at 3 3/4 in/s:
60 . . . 10000 Hz, 0-3 dB
overall at 3 3/4 in/s:
40 . . . 15000 Hz, 0-5 dB
Signal-to-noise ratio
acc. to DIN 45405, weighted,
at 7 1/2 in/s: — 56 dB
at 3 3/4 in/s: — 52 dB
Inputs
a. line: 100 mV, 100 kΩ
b. microphone: < 1 mV (unbalanced), suitable for microphones from 50 to 2000 Ω
c. diode: 2-40 mV, 20 kΩ
Other inputs are available optionally
Outputs
a. line:
nom. 0.775 V, max. 4 V, 10 000 Ω
b. monitor (stereo):
nom. 0.775 V, max. 4 V, 10 000 Ω
c. diode: 0.5 — 2 V, 100 k Ω
Other outputs available optionally.
Power supply
110-117-127-220-245 V, 50 or 60 Hz
Power consumption: 80 W
Dimensions and weight
52 x 34 x 24 cm
(20 5/8 x 13 3/4 x 9 3/8 in);
23 kg (50.6 lb)

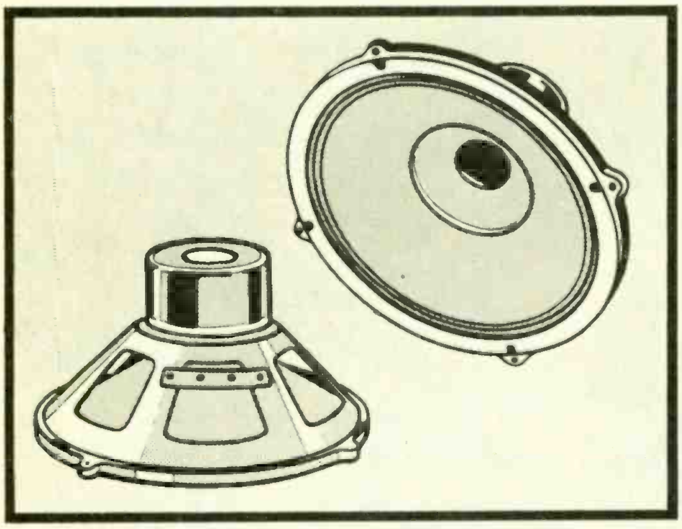
For detailed information please write for our 8 page Pro'12 brochure.

Electro-acoustics Division of
Philips Industries,
N.V. Philips' Gloeilampenfabrieken,
Eindhoven, the Netherlands

PHILIPS

WW—026 FOR FURTHER DETAILS

Faithful Reproduction



with the Grampian TC12 loudspeaker

The Grampian TC12 loudspeaker is a high quality twin cone unit at a reasonable price. The loudspeaker is built of high quality materials to a rigid specification and is eminently suitable for good quality sound reproduction. Let us send you full details or better still go and hear one at your local dealers now.

Design for suitable cabinet available.

Grampian manufacture high grade microphones, parabolic reflectors, windshields and accessories, also mixers and amplifiers.

Grampian SOUND EQUIPMENT
Integrity that you hear

Send for leaflet giving full details

GRAMPIAN REPRODUCERS LTD
Hanworth Trading Estate, Feltham, Middlesex
Tel: 01-894 9141/3 Cables REAMP. FELTHAM

WW—027 FOR FURTHER DETAILS

Litesold

SOLDERING INSTRUMENTS

as selected for the DESIGN CENTRE LONDON

Have a look at your present soldering irons. Are they really giving you the performance and service you're paying for? Is there really a model suitable for your size of work? Or are you making do with a tiny bit in a big iron? Or vice versa? Do they have the cool, comfortable feel, the elegance, of a LITESOLD? Drop one on a concrete floor—does it survive? Can you easily and cheaply replace the bits? Can you service it yourself? Are the models you want available for any voltage? Are they listed at 32 shillings or so each, with discounts for quantity?

Yes? Then we must be preaching to the converted, for you are surely a LITESOLD user already.

Well, if you are, or even if you're not, you may be interested in the new PHILIPS ELECTROLYTICALLY IRON COATED BITS. They last up to 75 times longer than copper, and are a big advance on all previous iron coatings.

Please ask for colour catalogue L5.

LIGHT SOLDERING DEVELOPMENTS LTD

28 Sydenham Road, Croydon, CR9 2LL
Telephone 01-688 8589 and 4559

WW—028 FOR FURTHER DETAILS

PHILIPS

Every aspect of microphone manufacture is covered by the makers of ten million of them—Philips. Presentation and directivity are made to suit requirements. In fact, whatever your needs, there's one in ten million for you. Please ask for full information.

PYE TVT LIMITED

PHILIPS SOUND
Addlestone Road, Weybridge
Tel: Weybridge (97) 45511. Telex: London 262319

TVT 23

WW—033 FOR FURTHER DETAILS

Armstrong
the high fidelity sound

A STEREO TUNER-AMPLIFIER for the BUDGET SYSTEM

127 STEREO TUNER-AMPLIFIER £43-13-9
OPTIONAL CASE As illustrated £3-17-0

If you want high fidelity in the highest class don't buy the 127 Tuner-Amplifier; it isn't meant for you. But if you want a good quality system that is a great deal better than the average radiogram, and your power requirements, as well as your budget, are of modest proportions, then this is meant for you.

The 10 watts power output, 5 from each channel, won't fill a hall, but it is more than adequate for most domestic purposes. The AM-FM Tuner incorporated is doubly attractive because, as well as covering the medium waveband, it has a performance on FM which is good enough to give excellent results on stereo radio once you add the optional M5 stereo radio decoder.

There are of course the usual facilities; pickup and tape inputs, tape recording outputs, bass and treble tone controls.

As we said at the outset, if you are after top-class hi-fi you don't want the 127, what you want is the Armstrong series 400 or series 500 models.

For details and technical specifications of all models, plus list of stockists, post coupon or write, mentioning 2WW69.

ARMSTRONG AUDIO LTD., WARLTERS ROAD N.7
Telephone 01-607 3213

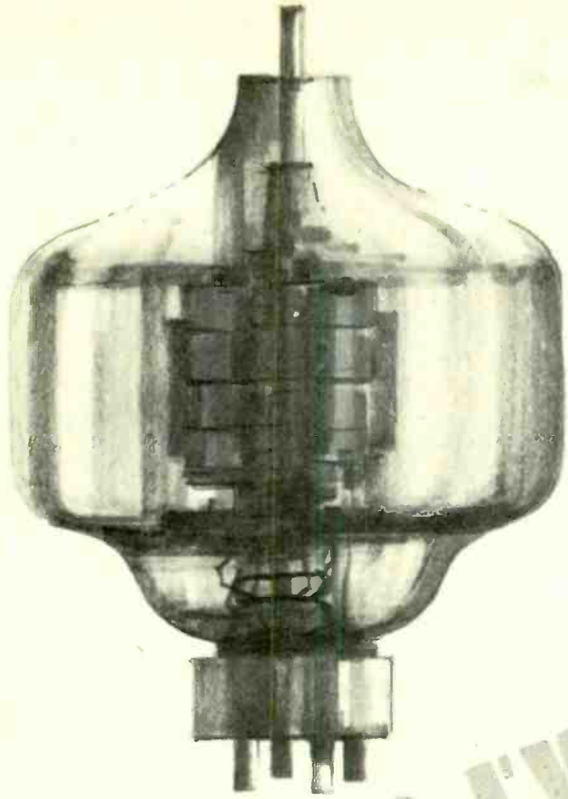
name ....

address ....

....

2WW69

WW—034 FOR FURTHER DETAILS



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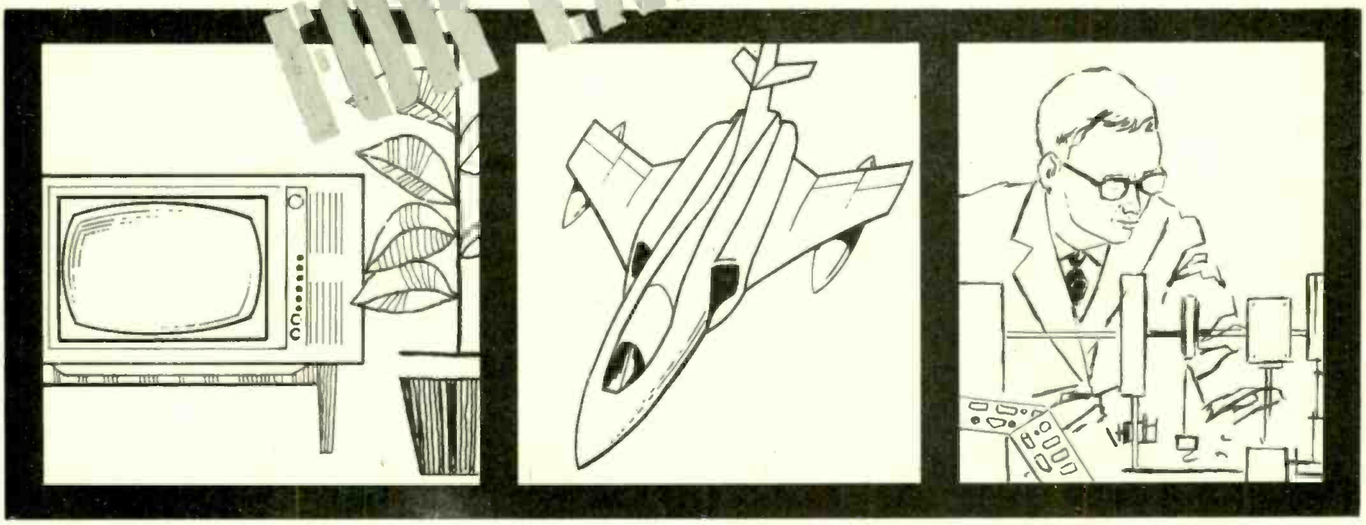

FOR QUALITY, RELIABILITY AND WORLD-WIDE AVAILABILITY, RELY ON HALL ELECTRIC'S SPEED, INTELLIGENCE AND REPUTATION

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Air Registration Board Approved Inspection.

HALTRON
RADIO VALVES & TUBES

All enquiries to:
Hall Electric Ltd., Haltron House, Anglers Lane, London, N.W.5.
Telephone: 01-485 8531 (10 lines). Telex: 2-2573. Cables: Hallectric, London, N.W.5.

WW—035 FOR FURTHER DETAILS

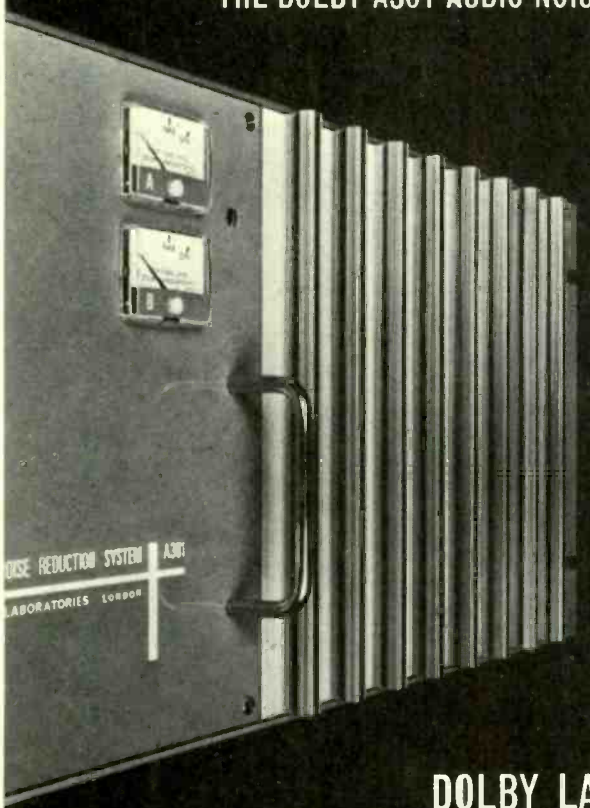
The Goldring caress... we call it transduction seduction

Smooth, breathing, open and graceful that's the sound of Goldring True Transduction. The ability of a cartridge to track properly at low forces is only the first stage of design, and from that point Goldring engineers continued development through to achieve their *True Transduction.* A micro-element of tubular permeable material lies in a 'Free-Field' generated from a fixed source away from the removable stylus assembly. It is as light as the cantilever itself—no massy magnets or coils to move! This design approach provides a texture of sound transparency previously associated with direct-coupled pickups. Excessive de-coupling techniques are rendered unnecessary and tight coupling is employed to ensure that every motion of the sensing element is identical to that of the stylus—at all frequencies.

Full technical details of these new era cartridges from Desk HF, Goldring Manufacturing Co. (Great Britain) Ltd., 486-488 High Road, Leytonstone, London, E.11, or from your nearest dealer.

WW—036 FOR FURTHER DETAILS

THE DOLBY A301 AUDIO NOISE REDUCTION SYSTEM



Making the Master Recordings of the Future

DOLBY LABORATORIES INC.

Already in use in eighteen countries, the Dolby system is making master recordings which will withstand the test of time.

The system provides a full 10 dB reduction of print-through and a 10 – 15 dB reduction of hiss. These improvements, of breakthrough magnitude, are valid at any time—even after years of tape storage. This is why record companies with an eye to the future are now adopting this new revolutionary recording technique.

A301 features: Easy, plug-in installation · solid state circuitry · modular, printed circuit construction · high reliability, hands-off operation. Performance parameters such as distortion, frequency response, transient response, and noise level meet highest quality professional standards.

NEW Remote Changeover option cuts costs, enables one A301 unit to do the work of two.

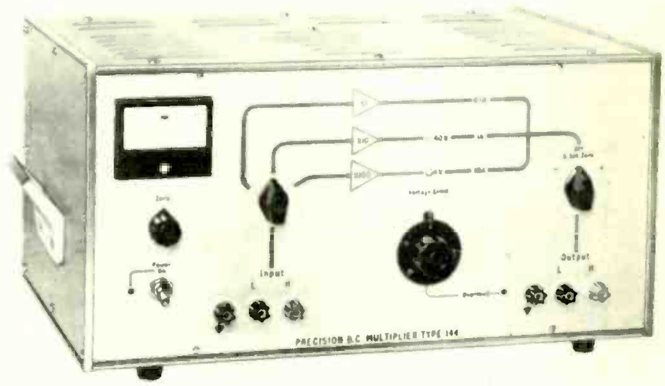
NEW NAB and DIN level setting meters simplify recorder gain calibration.

333 Avenue of the Americas · New York · N.Y. 10014
(212) 243-2525 Cables: Dolbylabs New York

WW—037 FOR FURTHER DETAILS

DO YOU NEED TO CALIBRATE CURRENT SENSITIVE INSTRUMENTS?

DO YOU NEED AN ACCURATE CURRENT SOURCE FOR SEMI-CONDUCTOR TESTING?



The Bradley D.C. Current Calibrator 132 provides an extremely stable D.C. current source up to 100 milliamperes at an accuracy of 0.05%. An add-on unit, the Current Multiplier 144, extends the range to 10 amperes.

The 132 is used extensively by meter manufacturers because of its high accuracy and ease of use—just dial up the current required—and also because of its unique percentage deviation measuring device. Semi-conductor and thin film component manufacturers have found it invaluable for the evolution and production line testing of their products . . . Further the 132–144 combination with its unrivalled output of 10 amperes covers the testing of most types of meters.

We shall be pleased to send further details.

BRADLEY INSTRUMENTS

G. & E. Bradley Ltd., Electral House, Neasden Lane, London, N.W.10. Tel: 01-450 7811. Telex: 25583

WW—038 FOR FURTHER DETAILS

TIMERS MICRO SWITCHES

IMMEDIATE DESPATCH

NEW

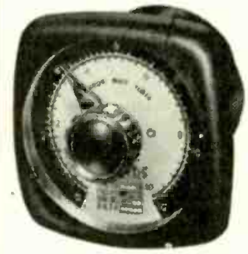
Solid State Process Timer type TDS

LATEST CIRCUIT PROVIDES PROLONGED ACCURACY

- 1% REPEAT ACCURACY
- OCTAL BASE PLUG-IN
- CIRCUIT CONTAINS BUILT-IN VOLTAGE STABILISER
- CONTACTS: Timed out 5 amp C/O Instantaneous 0·15 amp normally open

30 sec and 60 sec Linear dials
110 and 240 VAC operated
Approximately £10 dependent on quantity

SYS MINI-TIMER



SYNCHRONOUS MOTOR & CLUTCH

★ 10 MILLION OPERATIONS

★ Instantaneous & Timed out 3 AMP contacts.

★ Repeat Accuracy $\pm\frac{1}{2}\%$. 10 secs to 28 Hrs. May also be used as impulse start and automatic reset.

£11.0.0 approx. dependent on quantity.

NEW

TEMPERATURE CONTROLLER TYPE THP

- THERMISTOR OPERATED
- OCTAL BASE PLUG IN
- COMPACT

Temperature ranges up to 280°C
Output contacts .4 amp
Repeat Accuracy 3% full scale
Complete with Thermistor
Approximately £15 dependent on quantity

VV-15-1A

★ 15/10 AMPS. c/o
★ 100,000 ops.

1/11 each per 1,000
Single Throw 1/6 each

FLOATLESS LIQUID LEVEL CONTROL

★ 5 amp. OUTPUT CONTROL CONTACTS
★ Solid State
★ Octal Base plug-in

The most compact unit available, measures only 2¼" × 2¼" × 3".

Approx. **£4.0.0.**

dependent on quantity.

SINGLE AND TREBLE STAINLESS ELECTRODES AVAILABLE.

STP Sub-Mini Process Timer SYNCHRONOUS MOTOR & CLUTCH

Matchbox size frontal area.
Automatic re-set.
★PLUG-IN OCTAL BASE
★INSTANTANEOUS AND TIMED OUT 2 AMP CONTACTS
★RANGES: 10 SECS. TO 36 MINS.

approx. **£5.0.0** each.

PROXIMITY SWITCH

YL2 GPA

★ For Batching, Conveyors, Machine Tool Control, Packaging, Sorting, etc.
★ Senses ferrous objects.
★ Needs no mechanical force or pressure to operate.
★ Solid state sensing head includes constant voltage circuit.
★ Mains operated.

approx. £12.10.0 dependent on quantity.
OTHER INDUCTIVE AND CAPACITY TYPES AVAILABLE

SLB CAPACITY PROXIMITY SWITCH

Senses any object :

PACKETS BOTTLES
CARTONS BOXES
CANS

empty or full, ferrous and non-ferrous materials.

STAINLESS PROBE

remote from 240v AC Power Pack which
Incorporates own 5 amp relay.

Suitable for
CONVEYOR SYSTEMS
PACKING MACHINERY
PRESS GUARDS

and level control of
GRANULES
POWDERS
LIQUIDS

Approximately £20.0.0 complete dependent on quantity.

S5G

★ I MILLION OPS.
5 amp. c/o Sub-miniature Micro-switch.

2/6 each per 1,000

VAQ

★ 10 amp. c/o PUSH BUTTON
Panel mounting.
Buttons in six colours.

4/4 each per 1,000.

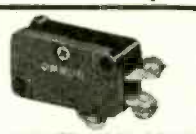
LIMIT SWITCH

WL 10 FNJ

★ 10 AMP 2 CIRCUIT
★ 5 INCH FLEXIBLE ACTUATOR AS ILLUSTRATED

AS LOW AS **53/9** EACH.

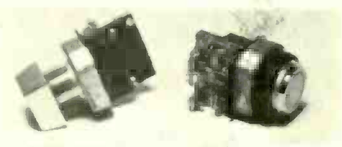
FIVE OTHER STANDARD TYPES AVAILABLE



V-10-1B
★ I MILLION OPERATIONS.
★ 10 amp. c/o.
★ COMPARE OUR SPEC. & OUR PRICES WITH OTHER SIMILAR TYPES.

Screw Terms. **3/1** each per 1,000

V-10-1A Solder Tags 2/3 each per 1,000
VV-15 IC2 187 Amp Tags 2/6 each per 1,000



PUSH-BUTTON SWITCHES

Chrome rimmed flush square and flush round. Up to 4 switch blocks can be fitted. Slow break and make. 10 amps. Latest addition—Illuminated version.

U.L. APPROVED (Appr. No. 32667) - - - U.S. MILITARY SPECIFICATION

Stockists: B.P.G. Ltd., Leicester 61460; Edmundsons Electronics Ltd., London, New X 9731; A. C. Farnell Ltd., Leeds 35111; Gordon Wilson Ltd., Blackburn 59921; G.D.S. Ltd., Bucks. Slough 30211
DISTRIBUTORS FOR EIRE: SOUTHERN ELECTRONICS LTD. CORK 26488

OMRON PRECISION CONTROLS

DIVISION OF I.M.O. PRECISION CONTROLS LTD.

(Dept. W.W.9), 313 Edgware Road, London, W.2 Tel. 01-723 2231

WW—044 FOR FURTHER DETAILS

The Microphone with a Message

EV 635A

. . . a simple message. If you're looking for professional results, use a professional microphone.
Radio and TV media, film units and recording studios throughout the world demand the best and get it – in an EV 635A Omnidirectional dynamic microphone. It can be used on a stand, hand-held or as a lavalier and is practically indestructible under normal conditions of use. An internal shock absorber greatly reduces the pick-up of cable or other noises generated by external contact, and the steel casing provides excellent magnetic shielding. Used outdoors, the 635A withstands the effects of high humidity and temperature extremes, salt air and severe mechanical shocks. A four-stage pop and dust filter eliminates the need for an external windscreen.

Specifications

Element:	Dynamic	Finish:	Non-reflecting matt satin nickel
Frequency response:	80-13,000 Hz	Net weight:	6 ounces without cable
Polar Pattern:	Omnidirectional	Cable connector:	Cannon XLR-3-12 complete with 18′ 2-conductor shielded broadcast type cable
Impedance:	Low (150 ohms)	Accessories:	Lavalier neck cord assembly and model 310 clamp
Output level:	55 dB (O dB = 1 mw/10 dynes/cm²)		
EIA sensitivity rating:	149 dB		
Diaphram:	EV Acoustalloy		
Case material:	Steel		
Dimensions:	6″ x 1⅜″ dia.		

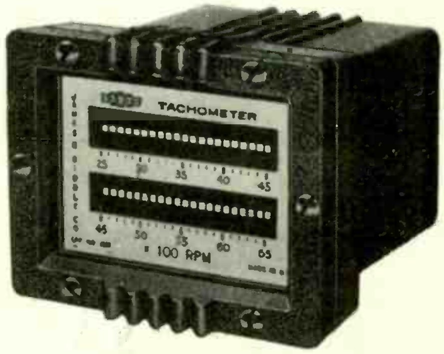
For more information about the EV 635A, write the sole U.K. distributors:

KEF

KEF Electronics Ltd.
Tovil · Maidstone · Kent
Telephone Maidstone 57258

WW—045 FOR FURTHER DETAILS

Accurate and direct measurement of speed without coupling to moving parts



FRAHM

Resonant Reed TACHOMETERS

for hand use or permanent mounting.

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

Descriptive literature on FRAHM Tachometers and Frequency Meters is freely available from the Sole U.K. distributors:

ANDERS METER SERVICE

ANDERS ELECTRONICS LTD. 48/56 BAYHAM PLACE, BAYHAM STREET LONDON NW1 TEL: 01-387 9092.

WW—046 FOR FURTHER DETAILS

TRANSIREG ®

(Patents Pending, Registered Trade Mark)

SOLID STATE, CONSTANT VOLTAGE HIGH POWER FLOAT BATTERY CHARGERS WITH AUTOMATIC CURRENT LIMITING

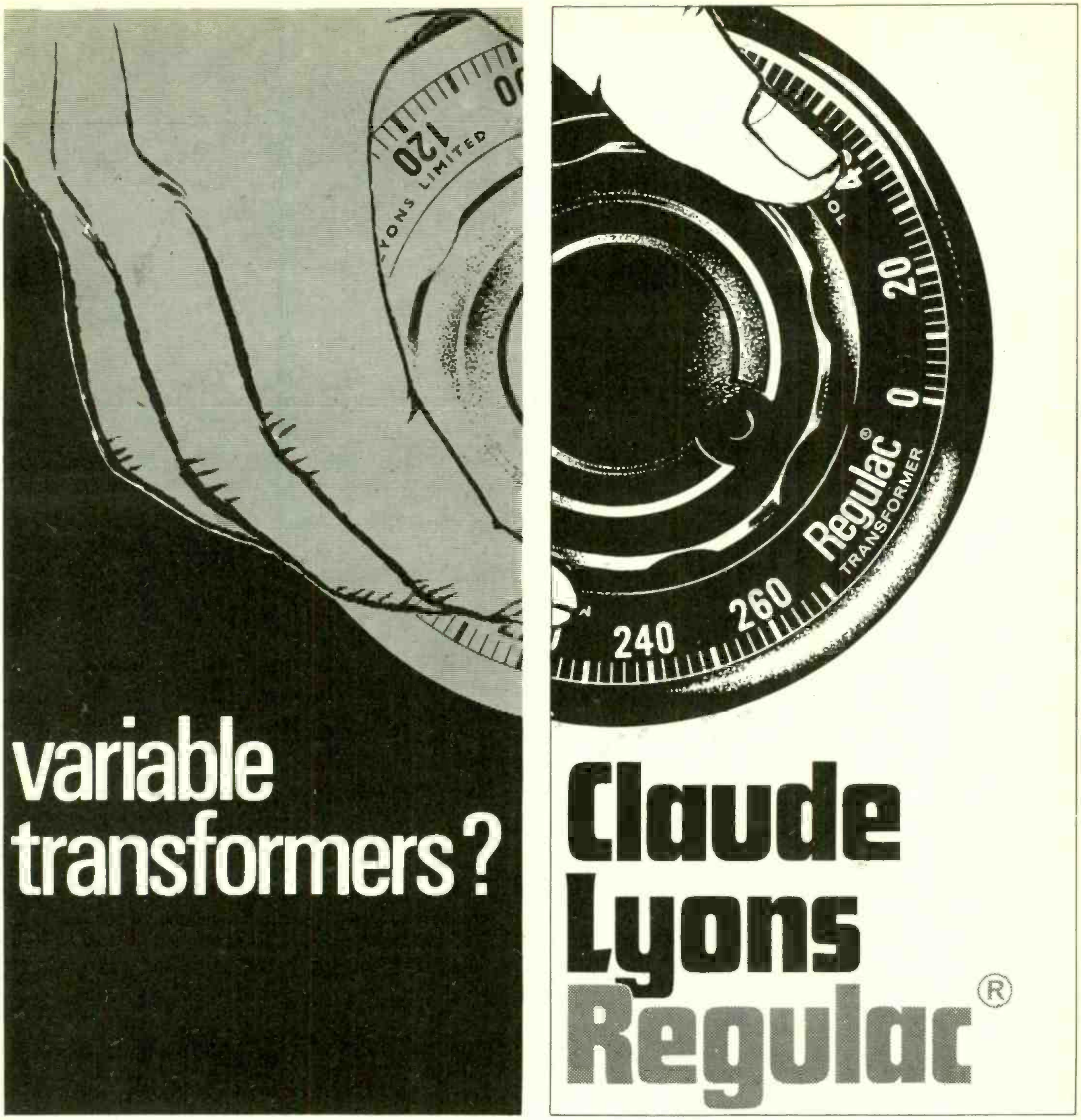
- ★ Will charge batteries and feed external DC loads such as telemetry, logic, instrumentation, data processing.
- ★ Wide range of units, up to 400V. and 1000 amp.
- ★ Sealed space for accumulators provided.
- ★ Will act as DC emergency power supply.
- ★ Prevents overcharging.
- ★ Accumulator life prolonged.
- ★ Float or boost charging.
- ★ Ideally suitable for use with Transipack Inverters as emergency AC supply.

Typical Transireg with accumulator space.

INDUSTRIAL INSTRUMENTS LIMITED STANLEY RD., BROMLEY, KENT

Tel: 01-460 9212 *Grams:* Transipack Bromley

WW—047 FOR FURTHER DETAILS



From Claude Lyons – leaders in voltage control for over 30 years – an extensive new range of variable transformers employing the latest design techniques and providing unit ratings from 0·5 to 40 amperes.

The Regulac® range of hundreds of models includes ganged assemblies for parallel and three-phase operation, dual-output, portable and oil-immersed models plus many high-frequency and special types, for manual operation or with motor drive.

Rapid delivery from Southern or Northern works. *Send now for comprehensive new catalogue and rating guide to Publicity Department, Hoddesdon.*

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CLAUDE LYONS

Claude Lyons Limited
Hoddesdon, Herts. *Hoddesdon 67161 Telex 22724*
76 Old Hall Street, Liverpool L3 9PX. *051-227 1761 Telex 62181*

WW—048 FOR FURTHER DETAILS

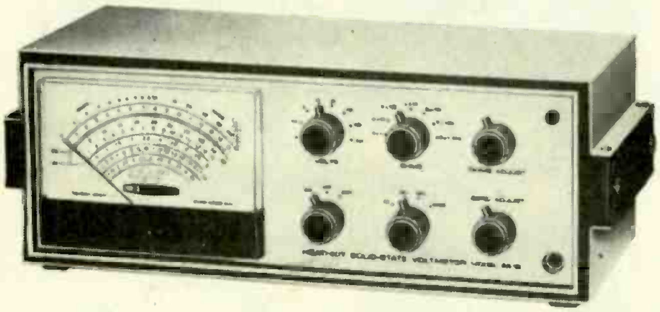
CL65

Choose HEATHKIT instrumentation

(Heathkit models available Ready-to-use, as well as in easy-to-build kit form)

KIT K/IM-25
£48.10.0 P.P. 10/6

Ready-to-use A/IM-25
£59.0.0 P.P. 10/6



KIT K/IM-16
£28.8.0 P.P. 10/6

Ready-to-use A/IM-16
£35.8.0 P.P. 10/6

KIT K/IP-17
£37.4.0 P.P. 10/6

Ready-to-use A/IP-17
£46.0.0 P.P. 10/6

KIT K/IP-27
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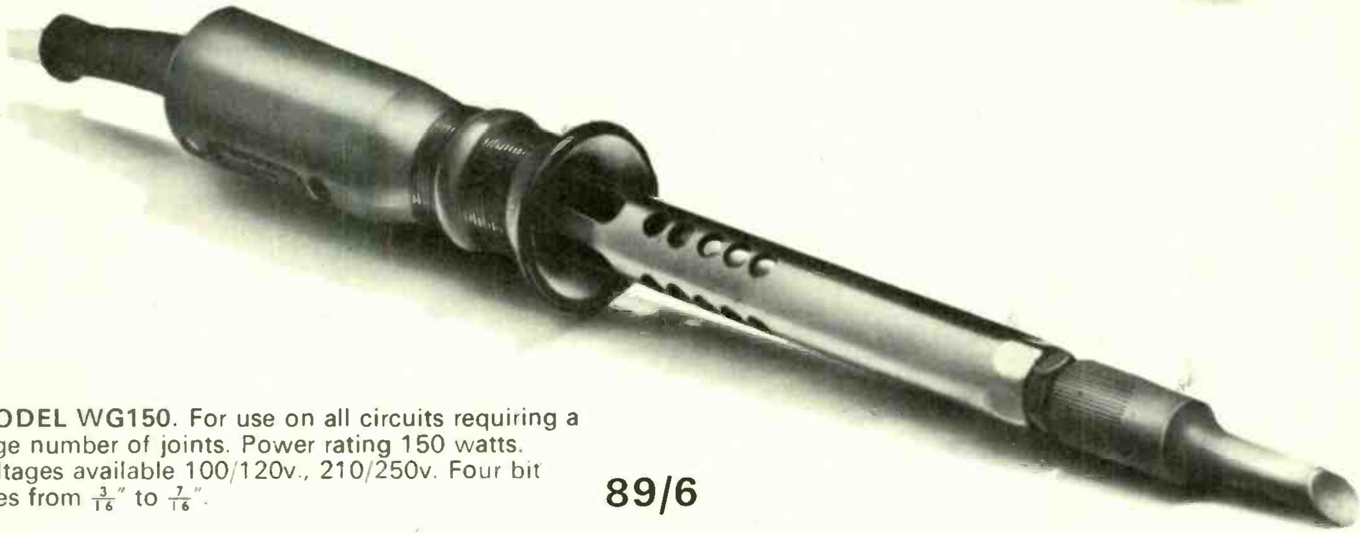

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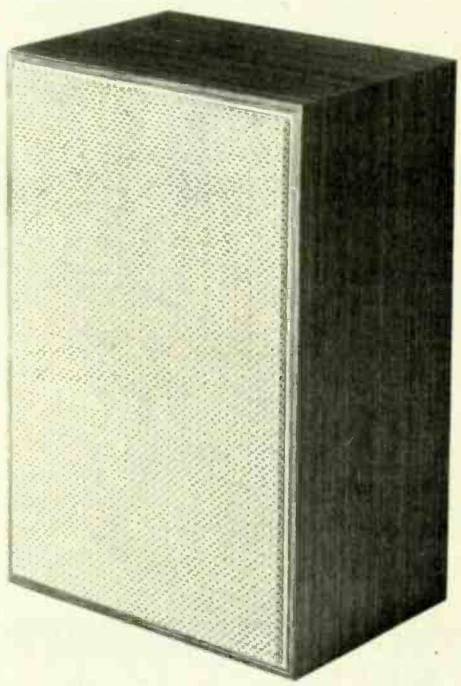

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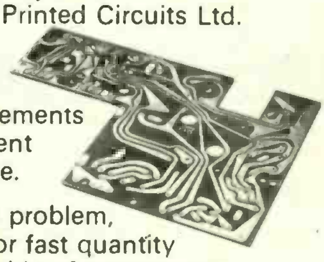

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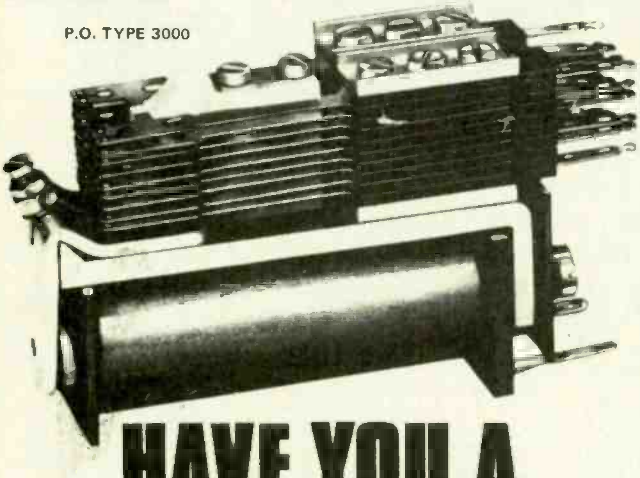

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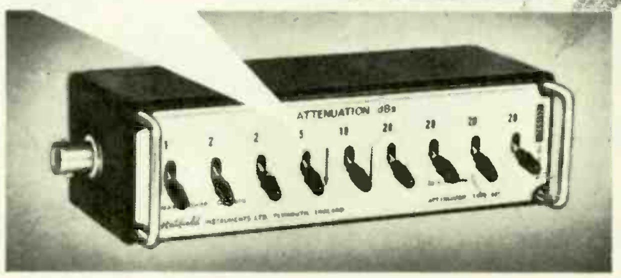

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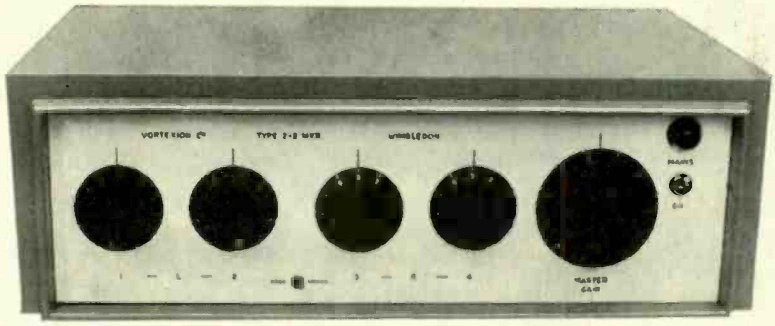

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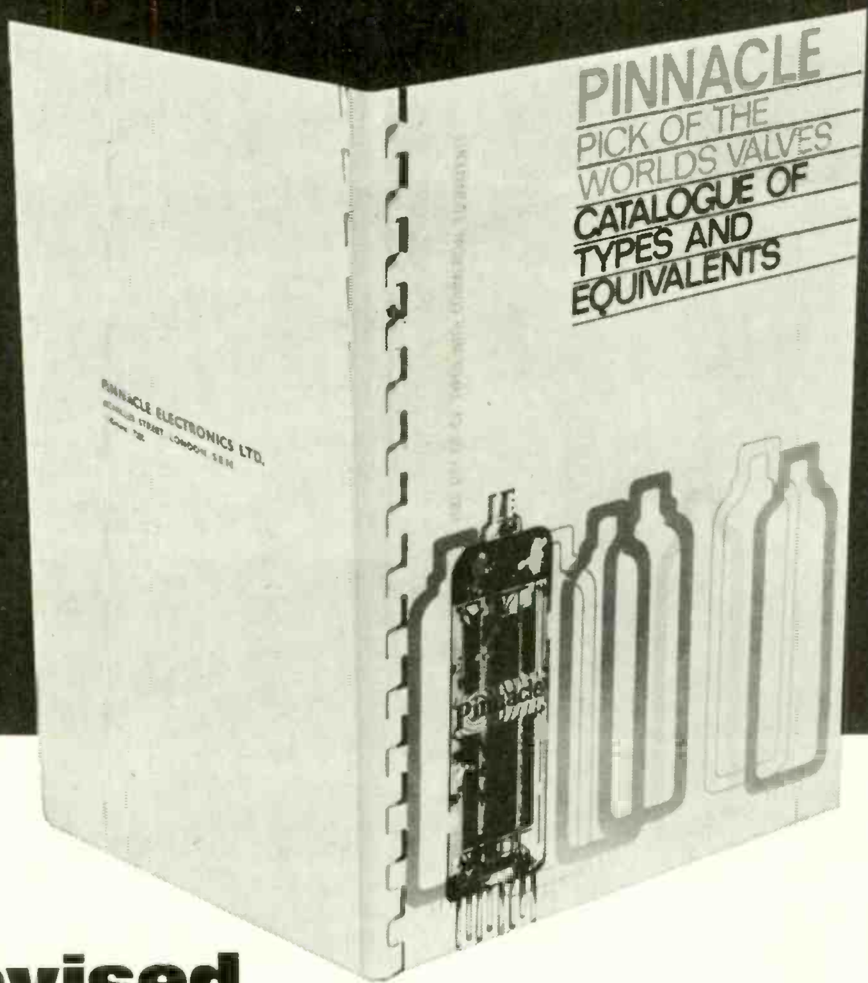

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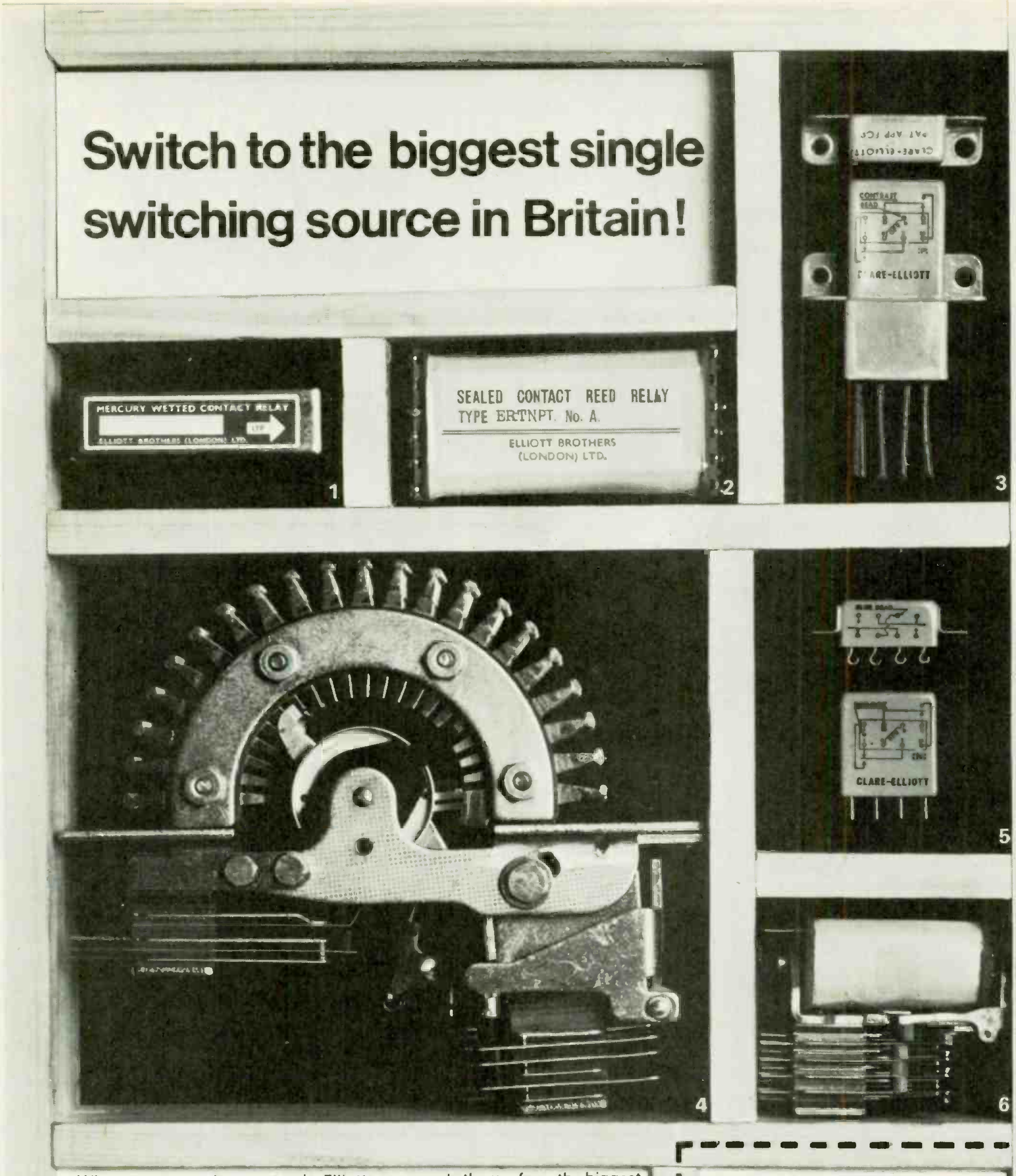

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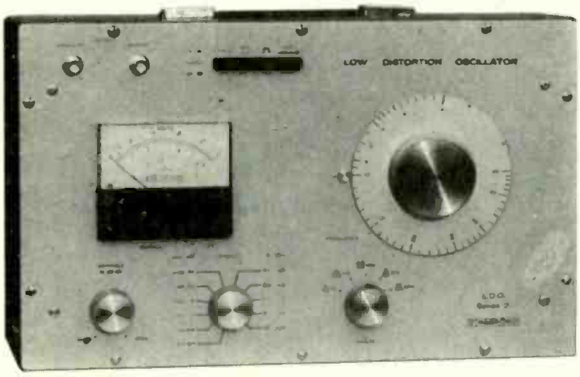

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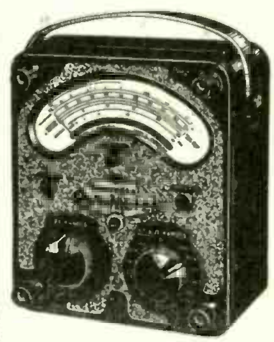

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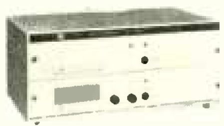

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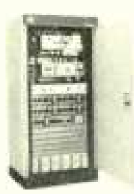

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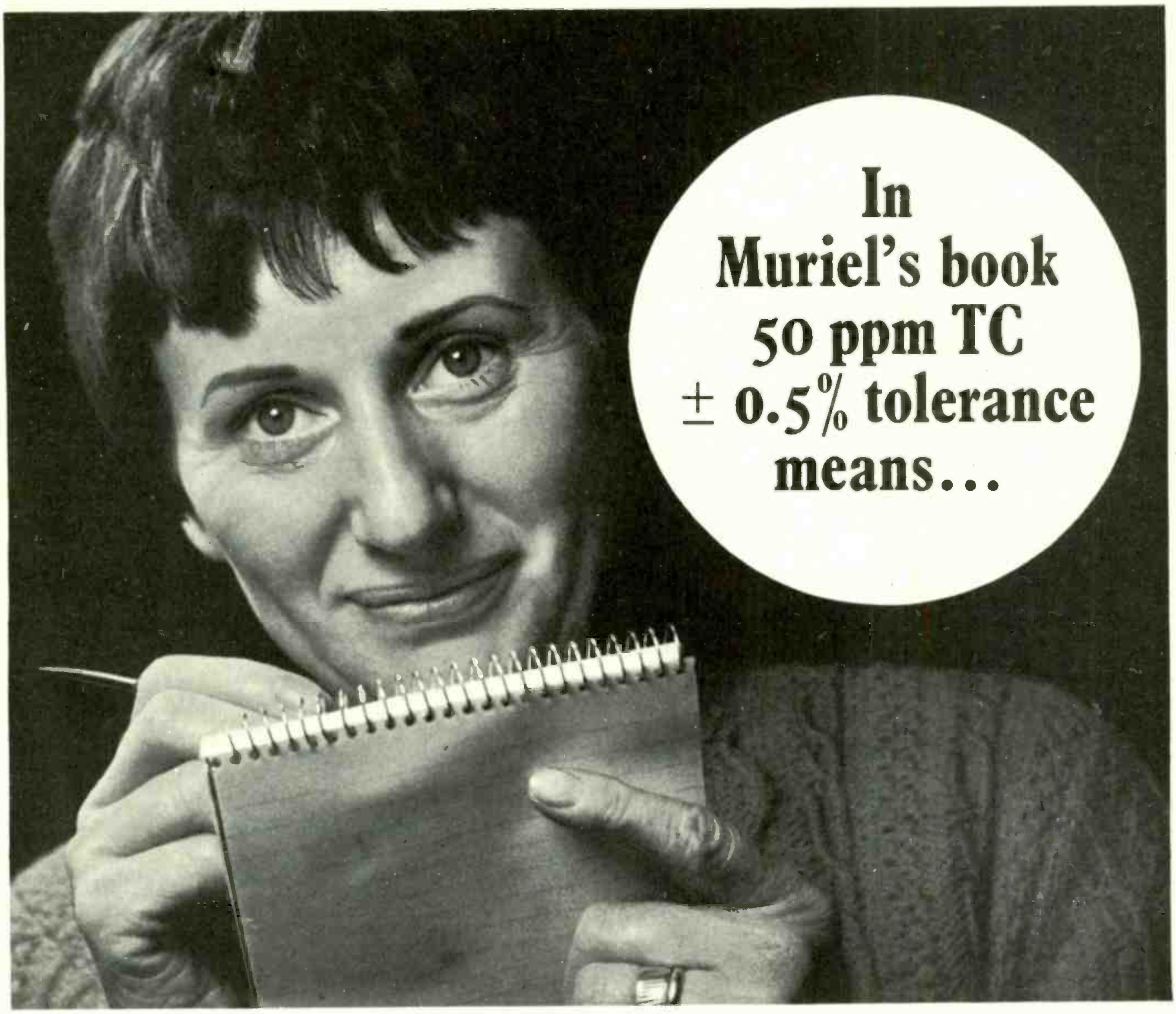

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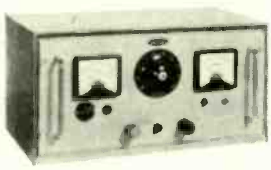

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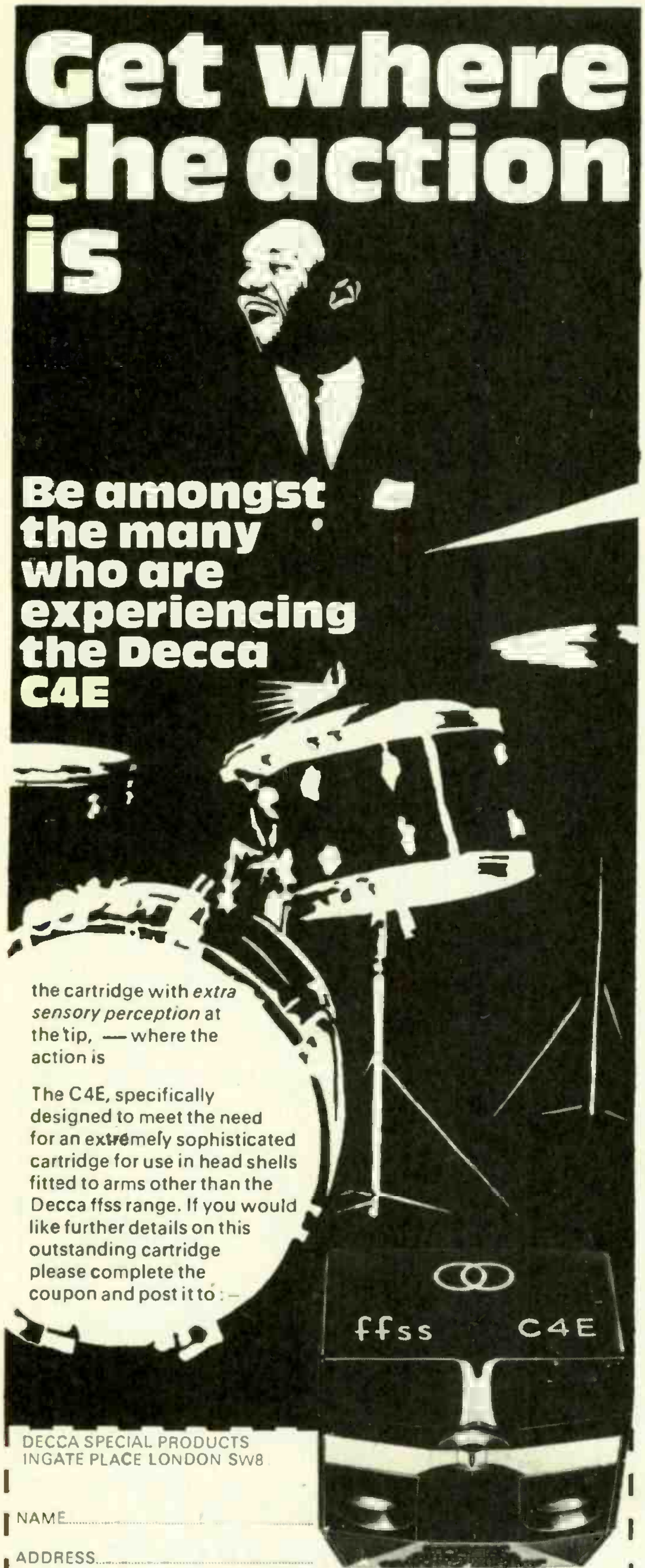

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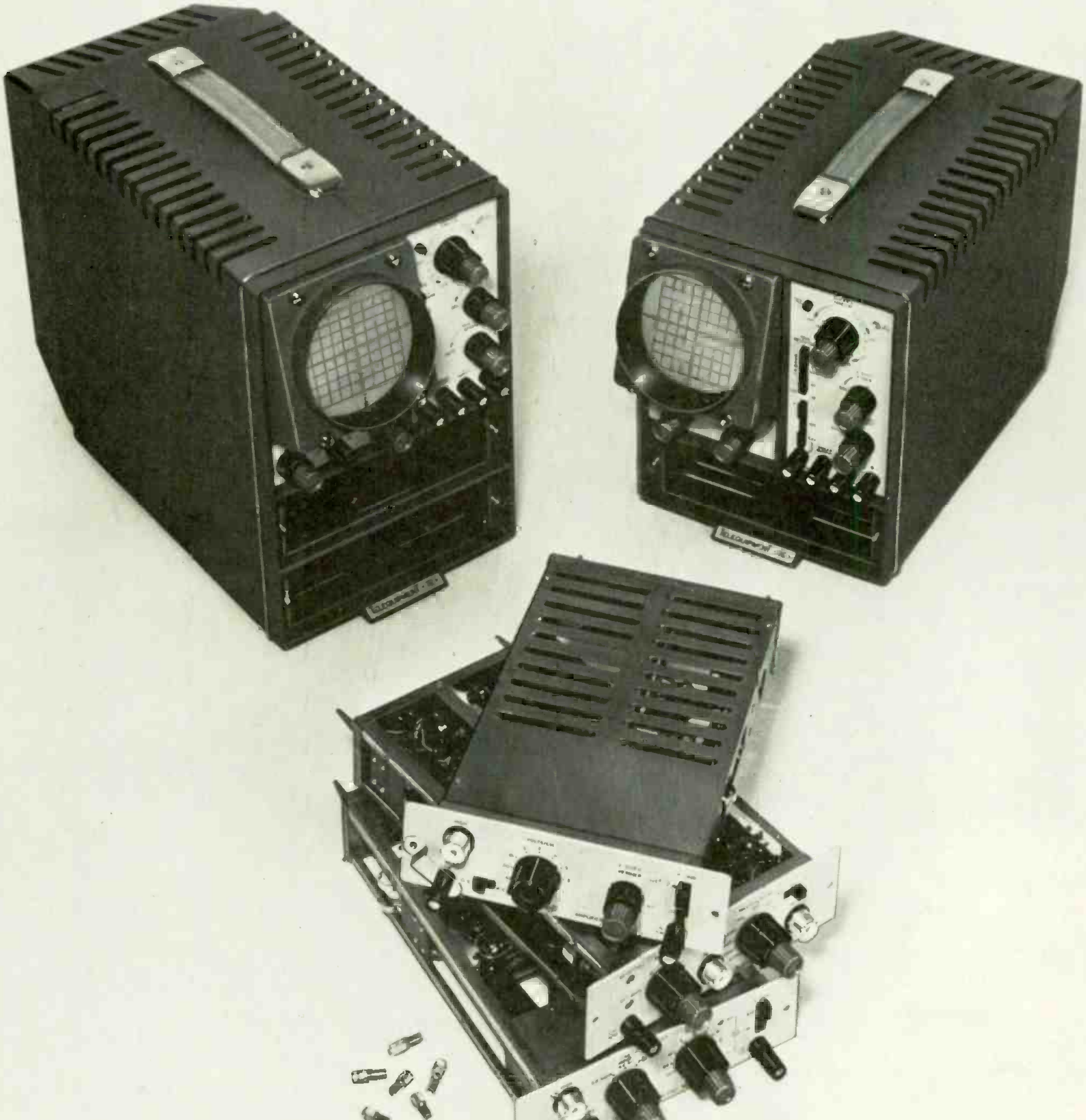

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Wireless World

Electronics, Television, Radio, Audio

Fifty-eighth year of publication **February 1969** **Volume 75 Number 1400**

The front cover design introduces a short series of articles on operational amplifiers, beginning in this issue. Combined with the familiar triangular graphical symbol for an operational amplifier is a magnified photograph of the semiconductor chip of an integrated-circuit type of op.amp.—actually the ZLD709 made by Ferranti. This d.c. linear amplifier has differential inputs and a Class B output stage.

Iliffe Technical Publications Ltd.,
Managing Director: Kenneth Tett
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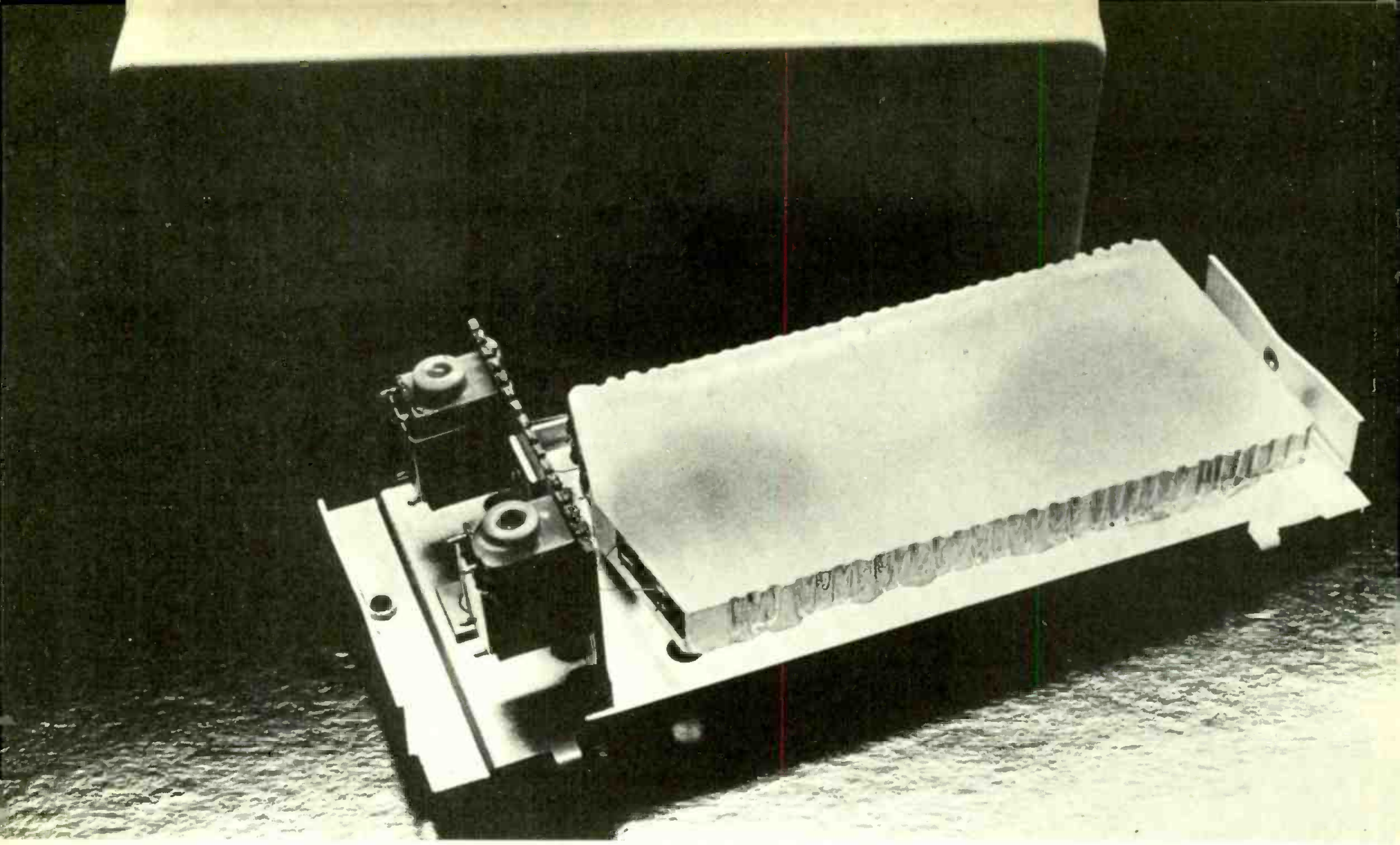
Dorset House, Stamford Street, London, SE1

Contents

PUBLISHED MONTHLY (3rd Monday of preceding month). *Telephone:* 01-928 3333 (70 lines). *Telegrams/Telex:* Wiworld Iliffepres 25137 London. *Cables:* "Ethaworld, London, S.E.1." *Annual Subscriptions: Home;* £2 15s 0d. *Overseas;* 1 year £2 15s 0d. *Canada and U.S.A.;* $6.75; 3 years £7 0s 0d. *Canada and U.S.A.;* $17.50 Second-Class mail privileges authorised at New York N.Y. Subscribers are requested to notify a change of address four weeks in advance and to return wrapper bearing previous address. BRANCH OFFICES: *BIRMINGHAM:* 401, Lynton House, Walsall Road, 22b. *Telephone:* 021-356 4838. *BRISTOL:* 11 Marsh Street, 1. *Telephone:* 0272 21491/2. *COVENTRY:* 8-10, Corporation Street. *Telephone:* 0203 25210. *GLASGOW:* 3 Clairmont Gardens, C.3. *Telephone:* 041-332 3792. *MANCHESTER:* 260, Deansgate, 3. *Telephone:* 061-834 4412. NEW YORK OFFICE U.S.A.: 300 East 42nd Street, New York 10017. *Telephone:* 867-3900.



Why we decided to make every part in this PAL delay line

The PAL delay line is a precision item. But it also has to be inexpensive, and therefore mass-produced. The problems involved in getting the delay time of 63·94μs—an adjustment to a few thousandths of a microsecond—for just one, are quite formidable. To achieve it on an assembly line is practically impossible, unless you have everything under your own control.

When the PAL system was being developed, we found ourselves in an excellent position to develop the special glass delay line needed for the chrominance decoder. Delay lines weren't new to us. For the previous five years we'd been producing them for the computer industry. We therefore had considerable experience. Experience which few others in the television industry had and which enabled us to develop our delay line in parallel with the development of colour television itself.

Critical factors. The set designer's demands pose problems in design and in production (remember we're concerned with price too!). Our considerable experience gained in the computing industry made the design problems relatively easy to overcome. But marrying them to mass-production was something quite new. Again we were fortunate in having vast experience in mass producing complex items for other areas of the electronics industry.

Any old glass? The Mullard delay line is made of glass and works on an electromechanical principle.

The glass is specially compounded to ensure consistent behaviour propagation velocities and good stability with changes in temperature. The blocks are cast to ensure complete uniformity and an absence of any internal stressing. One end is ground with two optically flat faces which are at a slight angle to each other and to which two transducers are connected. The electrical television colour signal enters one transducer and is converted into vibrations. These vibrations travel through the glass until they are reflected back from the end face to the second transducer. This converts them back into an electrical signal. In this way we halve the size of the delay line and help save space within the set.

Ground away. The end of the glass block opposite the transducers is then ground away under automatic control until the response is exactly right. We have found that this construction—apart from saving space—greatly simplifies the problem of delay time. adjustment to 63·943μs at 4·433619MHz.

Insertion loss. While the glass has some effect on the insertion loss, the major loss is in the transducer and the coupling to the glass. The transducers themselves have been developed from ceramics selected for their long term stability as well as good mechanical properties. We have further reduced insertion loss by developing a new metal deposition technique and adhesives which create an intimate bond. As a result the overall insertion loss is only about 13dB over the bandwidth 3·43 to 5·23MHz.

The final step is the assembly of the delay line on its mounting plate with the associated input and output coils before final testing and inspection.

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Closer collaboration between the three "components" trade associations (R.E.C.M.F., V.A.S.C.A. and B.V.A.) is foreseen by the announcement elsewhere in this issue that they are now together under one roof (even if not the same ceiling!). With the Electronics Components Board overlord, Sir Alan Dudley, in the role of matchmaker it augers well for an eventual marriage. With the increasing use of integrated circuits and therefore a gradual decline in the number of discreet components used in equipment it would seem a logical step. Otherwise we can foresee a situation arising calling for a judicial pronouncement on "what is a component?"

It is not without significance that Dr. F. E. Jones is the current chairman of three of the four bodies mentioned, i.e. E.C.B., R.E.C.M.F. and V.A.S.C.A. He certainly has some strong views on many of the problems which beset our industry (and indeed the whole country) and, since the publication of the report on the manpower committee, of which he was chairman, his knowledge and advice is much sought after.

He recently had some trenchant things to say about the reasons for the "technological gap" which exists between this country (and indeed the whole of Europe) and the U.S.A. This gap is not, in fact, due to our inability to create new and worthwhile technical advances in the various fields of technology, but because of our apparent inability to make full use of them industrially. This, says F.E.J., is why the average output of, or wealth created by, each employee in this country in 1967 was only £1,300 whereas in the United States it was four times this figure.

An instance of our tardiness to make capital out of new ideas is mentioned by one of our contributors in this issue (p. 85) who comments on the fact that although Piccolo—the refined teleprinter transmitting system—was developed by the Diplomatic Wireless Service ten years ago it is only just being exploited commercially.

To get back to the title we have given to this month's leader. One of the major factors affecting our industry today, and not ours only, is the vast expenditure on R & D which in many instances appears to bear little relationship to the eventual profitability of the end product. It is interesting to note that the cost of R & D in both the U.K. and the U.S.A. over the past ten years or so has increased threefold, but, the overall figure in America is in fact some six times the U.K. total of £1,000M. However, the wealth created per employee in America makes the return on this expenditure considerably higher than in this country. What then is the answer? Dr. Jones has stressed that the only way of obtaining effective correlation between the cost of R & D and the creation of wealth, is to ensure that research is "conducted under pressure from the market". This problem has already been explored by the Central Advisory Council for Science and Technology of which Dr. Jones is a member. In the Council's report "Technological Innovation in Britain" it recommends "the direct linkage of R & D, production and marketing into a single interacting operation, and, planned programmes of innovation related to market opportunities".

No longer is it practicable, as in the past, to have one or two backroom boys "on the strength" in the hope that one day they will come up with a bright idea. R & D must be geared to production. Over the past few years the curve for R & D has risen sharply in this country but that for the gross national product is fairly flat.

Operational Amplifiers

Device characteristics and what they mean: Methods of testing commercial units

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

An operational amplifier is basically a very high gain d.c. coupled amplifier which makes use of feedback to control its response characteristics. The term 'operational amplifier' was in fact originally introduced by workers in the analogue computer field to denote an amplifier circuit which performed various mathematical operations such as integration, differentiation, summation and subtraction. Operational amplifiers are still widely used for analogue computation but their range of applications has now been vastly extended to include a great number of other fields, for example in the many branches of instrumentation and control. Non-linear applications of operational amplifiers are also now quite common; voltage comparators, non-linear function generators, and ultra linear rectifiers are but a few examples of their use in this last category.

Early operational amplifiers used thermionic valve circuitry, but these have now largely been replaced by solid state circuits. A wide range of solid state amplifier modules is commercially available, including f.e.t., chopper stabilized, and parametric amplifiers in discrete-component, thin-film hybrid integrated circuit, thick-film hybrid integrated circuit and monolithic integrated circuit forms.

Discrete-component amplifiers are assembled on printed circuit boards and are often supplied in epoxy encapsulated modules which may be either soldered directly to a printed circuit board or plugged into a suitable mating socket. They can be economically produced in small quantities. In general thin-film hybrid integrated circuits are used for highly complex, close tolerance analogue applications requiring extreme resistor stability. Thick-film hybrid integrated circuits are widely used for high production requirements where a large number of circuit types is needed but where the quantity of circuits produced per type may be small.

Semiconductor integrated circuits find most applications where highly repetitive requirements exist and where relatively few circuit types are involved.

The manufacture of electronic systems in integrated form dates from about 1959 and attention was initially focused on digital systems; it is only comparatively recently that a variety of linear integrated circuits have become available at moderate prices. An important characteristic of the i.c. manufacturing process is that the tooling cost for each individual circuit is high and circuits can only be produced economically if large numbers of the same circuit are made. The electronic designer accustomed to selecting individual components that exactly meet his requirements must now adopt rather a different approach if he is to make use of i.cs. He must accept the available mass-produced circuits and modify them as necessary to fulfil his requirements by connecting external discrete components to them.

One may well ask the advantages of making this change over to i.cs and the reasons that may be put forward are those of reliability, cost, performance, size and weight—all quite formidable reasons. The improved reliability results from factors such as fewer connections of dissimilar materials, therefore less connection failure, and less handling of individual component parts and therefore more uniformity of product. The cost advantage is not always immediately apparent. The actual cost of an i.c. may be more than the cost of the discrete components that would be required to make a similar circuit; however, if one takes into account the reduction in design and construction time the i.c. usually turns out to be the more economical. The superior performance characteristics of i.cs result from the close matching of components and the very short interconnections between components that are possible in these circuits. Size and weight reductions that are obtained are obvious although not always necessary.

The actual silicon chip on which an integrated-circuit operational amplifier is formed (see front cover) is very little bigger than a single transistor chip, one millimetre square being fairly typical. There are several different methods of packaging the chip. Mounting in a transistor-type metal can is one method (Fig. 1(a)), another is the ten-lead flat pack (Fig. 1(b)), and more recently the dual-in-line plastics package has been introduced (Fig. 1(c)). Many manufacturers produce economy versions of their amplifiers in the last style of package. The dual-in-line plastics pack has fourteen pin-like connections arranged to mate up conveniently with a printed circuit board although once these pins are soldered into position it is somewhat difficult to remove the amplifier. To overcome this difficulty it is often convenient to use one of the dual-in-line sockets that are available, and these eliminate the need for soldering the i.c. leads. The sockets themselves may be printed-circuit or chassis mounted; they are made with solder or wire wrap terminations.

It is not essential that the user of i.c. op. amps be familiar with the intricacies of the internal circuit details of the amplifier (he can't get at them!), but he must understand the function of the external connections provided by the manufacturer and he must understand the terms used to specify the amplifier's performance if he is to be able to select the best device for a particular application. The desired response of an op. amp. is normally obtained by connecting feedback components externally to the input terminals of the amplifier. An amplifier with a differential input allows a greater flexibility in the choice of feedback configuration and most i.c. op. amps are made with differential input and single-ended output. In fact most direct coupled amplifiers invariably use the differential configuration because of the superior drift performance that can be obtained by the matching of characteristics. Op. amps are generally designed to operate from symmetrical positive and negative power supplies to permit an output voltage which may be positive or negative with respect to earth and a frequency response extending down to zero. The functions mentioned require five external connections to the amplifier. Most amplifiers are provided with several other external connections, the purpose of which will be discussed later. It is possible to operate the amplifiers with a single power supply if the particular application does not require a d.c. response[1].

I.C. op. amp. characteristics

The graphical symbol commonly used for an op. amp. is a triangle indicating the direction of signal flow (Fig. 2(a)). Ignoring certain important errors which will be discussed later the output of the amplifier is related to its inputs by the transfer curve shown in

* Liverpool College of Technology

1. Motorola Information Note AN-403.

Fig. 2(b), and with open loop gains greater than 10^3 being quite typical only a very small voltage between the two input terminals is needed to cause saturation of the amplifier output.

The open loop voltage gain, A_{VOL}, is defined as the ratio of the change in output voltage Δe_O to the change in voltage Δe_ϵ between the two input terminals; it is normally specified for d.c. and may be determined from the slope of the non-saturated portion of the transfer curve.

Op. amps are in fact seldom used open loop, but are used with negative feedback to improve accuracy. The significance of the open loop gain is that it determines the accuracy limits in such applications. The two basic feedback configurations are the inverting (Fig. 3) and non inverting (Fig. 4) circuits.

The closed-loop voltage gain, A_{VCL}, of the inverting amplifier is defined as the ratio of the change in output voltage to the change in the input voltage applied to the input resistor R_1. If the amplifier is considered to be ideal, i.e. infinite input impedance, zero output impedance, infinite open-loop gain and bandwidth, feedback maintains the error voltage e_ϵ between the two input terminals zero at all times and a simple analysis shows that the closed-loop gain

$$A_{VCL} = -\frac{R_2}{R_1}$$

If the amplifier is ideal except for finite open-loop gain, the closed-loop gain,

$$A_{VCL} = -\frac{R_2}{R_1}\left\{\frac{1}{1+\dfrac{1}{\beta\, A_{VOL}}}\right\} \quad \ldots (1)$$

(see Appendix 1)

where

$$\beta = \frac{R_1}{R_1 + R_2}$$

The quantity $\beta\, A_{VOL}$ is called the **loop gain,** and it is a most important factor in determining closed-loop performance. The error in closed-loop gain due to finite open-loop gain may be expressed by the error factor

$$\frac{1}{1+\dfrac{1}{\beta\, A_{VOL}}}$$

which is approximately

$$1 - \frac{1}{\beta\, A_{VOL}}$$

for $\beta\, A_{VOL}$ much greater than 1. The percentage error due to finite open-loop gain thus $\dfrac{100}{\beta\, A_{VOL}}$%, which is a direct function of loop gain. The error in closed-loop gain is not in itself very significant since the ratio R_2/R_1 can always be adjusted to compensate for this error, but the closed-loop gain stability, the closed-loop output impedance and closed-loop distortion are all directly related to loop gain.

Closed-loop gain stability:

$$\frac{\Delta A_{VCL}}{A_{CL}} = \frac{\Delta A_{VOL}}{A_{VOL}} \cdot \frac{1}{\beta\, A_{VOL}}$$

Closed-loop output impedance:

$$Z_{OCL} = \frac{Z_{OOL}}{\beta\, A_{VOL}}$$

Closed-loop distortion;

$$D_{CL} = \frac{D_{OL}}{\beta\, A_{VOL}}$$

The closed-loop gain of the non-inverting amplifier assuming ideal amplifier performance, is

$$A_{VCL} = 1 + \frac{R_2}{R_1}$$

If the amplifier is ideal except for finite open-loop gain

$$A_{VCL} = \left\{1+\frac{R_2}{R_1}\right\}\left\{\frac{1}{1+\dfrac{1}{\beta\, A_{VOL}}}\right\} \quad \ldots (1)$$

(see Appendix 2)

where again

$$\beta = \frac{R_1}{R_1 + R_2}$$

and as in the case of the inverting amplifier the loop gain $\beta\, A_{VOL}$ plays an important part in determining closed-loop characteristics.

In the case of both amplifier configurations if the closed-loop gain is greater than one, i.e. if $R_2/R_1 > 1$ then β is approximately equal to R_1/R_2 and the loop gain

$$\beta\, A_{VOL} \approx \frac{A_{VOL}}{A_{VCL}}$$

If as is usual gains are measured in dB we have the relationship: loop gain (dB) = open-loop gain (dB) − closed-loop gain (dB).

The maximum output voltage swing, V_{Omax}. This is the maximum output voltage swing (positive and negative) measured with respect to earth that can be achieved without clipping of the signal waveform.

An ideal differential amplifier with equal voltages applied to its input terminals would give zero output voltage, but under these circumstances real amplifiers are found to give a non-zero output voltage called an 'offset voltage'. In many amplifiers provision is made for zeroing the amplifier output voltage with an external trim potentiometer.

Input offset voltage, V_{io}. This is the difference in the d.c. voltages which must be applied to the input terminals to obtain a zero quiescent output. It is indicative of the degree of matching in the differential amplifier stages of the integrated circuit, and in general represents the main source of offset error when the amplifier is used with low source impedances. Integrated-circuit op. amps with the smallest input offset voltages in general exhibit the smallest output drift with temperature variations.

All i.c. op. amps require some small and relatively constant current at each input.

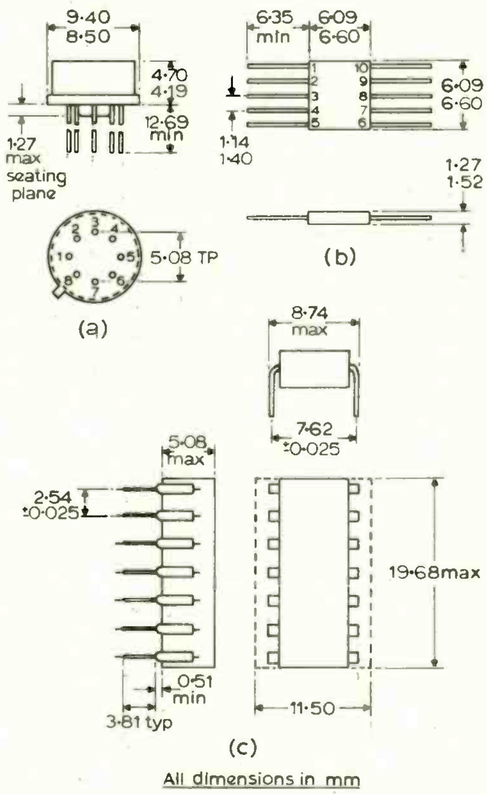


Fig. 1. Types of encapsulation for integrated-circuit operational amplifiers: (a) "transistor outline", (b) "flat-pack", (c) "dual-in-line".

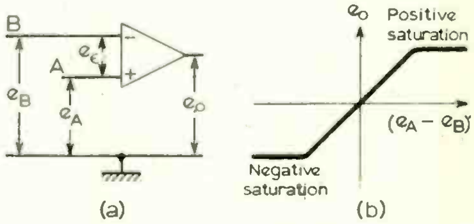


Fig. 2. (a) Graphical symbol for an operational amplifier; (b) ideal transfer curve for an op. amp.

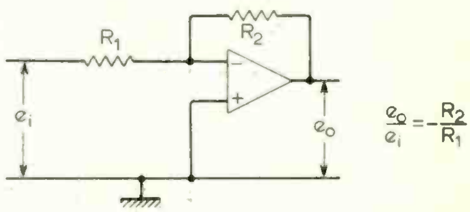


Fig. 3. Inverting amplifier feedback configuration.

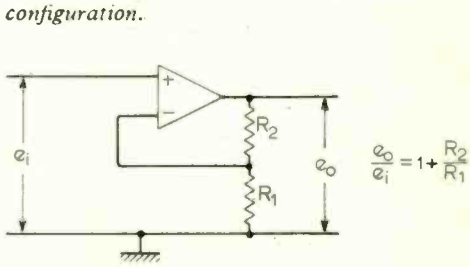


Fig. 4. Non-inverting amplifier feedback configuration.

Input bias current, I_b, is defined as the average value (half the sum) of the currents at the two input terminals with the quiescent output voltage zero. It constitutes the bias currents drawn by the transistors in the differential input stage of the i.c. and if these were perfectly matched the two currents would be equal. It is normal practice to use balanced impedances at each input so that offset due to bias current is cancelled at the output. In practice some degree of mismatch always exists.

Input offset current, I_{io}, is defined as the difference in the input bias currents into the two input terminals. With equal source impedances connected to the two inputs it is only this mismatch or difference current which causes an offset error. The effects of I_{io} tend to overshadow the effects of input offset voltage when the input source impedances are high.

Temperature drift. The output voltage of all d.c. coupled solid-state amplifiers changes or 'drifts' from its initial value if the temperature changes. The temperature drift of i.c. op. amps is specified by the temperature coefficients of input offset voltage, input bias current and input offset current.

Supply voltage sensitivity. The output voltage of an i.c. op. amp changes if the supply voltages are changed. The effect is usually specified by the effect of supply voltages on input offset voltage, input bias current, and input offset current. With well regulated power supplies offset errors due to this effect are usually negligible compared to temperature drift.

It is very instructive for the new user of i.c. op. amps to gain an initial familiarity with the devices by wherever possible setting up test circuits to measure their characteristics. A simple test circuit for measuring the transfer curve of an op. amp. is shown in Fig. 5.

An oscilloscope with d.c. coupled X and Y channels is used to obtain a visual display of the transfer curve. The same signal is used to drive both the input of the amplifier and the horizontal sweep. Op. amps will normally be found to have gains in excess of 1000 and a resistive divider is placed at the input of the amplifier in order that the amplitudes of the X and Y inputs presented to the oscilloscope shall be of the same order. A low frequency sinusoid (f < 20 Hz) may be used as the drive signal. If a low frequency signal generator is not available or if the amplifier under test shows appreciable hysteresis effects it may be found convenient to use a low frequency ramp as the drive signal. A circuit that has been found quite suitable for producing a ramp drive is shown in Fig. 6. If this ramp drive is used it will be found that the retrace sweep rate is so much faster than the trace rate that the retrace is effectively blanked off from visual presentation.

In order to obtain the display the oscilloscope inputs are initially earthed and the spot centred in order to establish the vertical and horizontal references. The oscilloscope is then connected into circuit and the

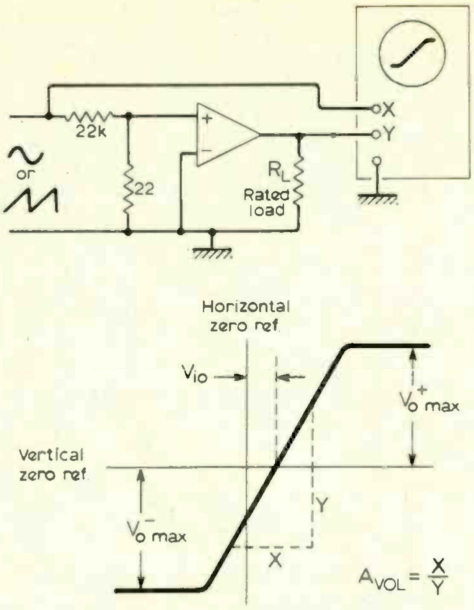


Fig. 5. Test circuit for obtaining a transfer curve; significant parameters of the transfer curve.

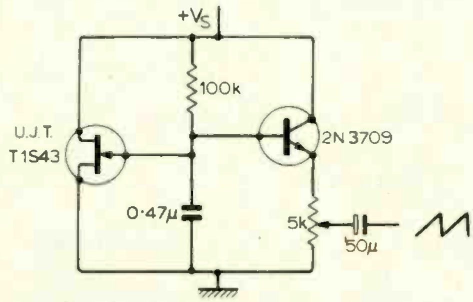


Fig. 6. Circuit for generating a ramp function for test purposes.

amplitude of the input drive is turned up until the amplifier is in saturation. The maximum positive and negative output voltage swing ($V_{o\,max}$) is read directly from the trace; A_{VOL} is calculated from the slope of the transfer curve. The horizontal displacement from the horizontal zero reference to the point where the curve crosses the vertical zero reference gives the input offset voltage V_{io}. Any departure from linearity shown by the device is also readily apparent from the display. If supply voltages are changed the dependence of these parameters on supply voltages can be measured. The oscillograms (Fig. 7) were obtained using the test circuit and show the transfer curve of R.C.A. type CA3029 amplifier for different values of supply voltage.

A circuit suitable for the measurement of input bias current I_b, and input offset current I_{io} is shown in Fig. 8. The effects of input offset voltage are swamped by the use of the large input source resistors (100 kΩ). The measurement procedure consists of adjusting the voltage V_b to bring the output voltage of the amplifier to zero and then measuring the voltages V_{in_1} and V_b with a high input resistance d.c. voltmeter. The bias current is calculated from $I_b = \frac{V_{in_1}}{10\,k\Omega}$ amperes; the input offset current is calculated from $I_{io} = \frac{V_b}{100\,k\Omega}$ amperes.

Maximum voltage between inputs. The voltage between the input terminals of an op. amp. is maintained at a very small value under most operating conditions by the feedback circuit in which the amplifier is used. If the application is such that the voltage between the input terminals might be appreciable care must be taken to ensure that it does not exceed the maximum allowable value for the particular amplifier, otherwise permanent damage may be caused. The connection of parallel back-to-back diodes across the input terminals is one way of protecting the circuit.

Maximum common mode voltage. The voltage at both inputs of a differential amplifier can be raised above earth potential. The input **common mode voltage** (e_{cm}) is defined as the voltage above earth at each input when both inputs are at the same voltage. The maximum common mode voltage E_{cm} is the maximum value of this voltage which can be applied without producing clipping or excessive non-linearity at the output.

If an amplifier is to be used under conditions in which excessive common mode voltage might cause permanent damage, protection can be provided by the use of a suitable pair of zener diodes. The circuit of Fig. 9 illustrates protection both against excessive voltage between inputs and excessive common mode voltage.

Common mode rejection. An ideal differential amplifier responds only to the difference in the voltages applied to its input terminals and produces no output for a common mode voltage. In practical amplifiers, because of slightly different gains between the inverting and non-inverting inputs, common mode input voltages are not entirely subtracted at the output. The gain of an amplifier for common mode voltages is known as the **common mode response** and the ratio of the gain with the signal applied differentially to the common mode response is called the **common mode rejection ratio (c.m.r.r.).** It is often expressed in dB by taking 20 times log (base 10) of the ratio. An alternative way of defining c.m.r.r. is as the ratio of input common mode voltage e_{cm} to the output common mode error voltage referred to the input $e_{\epsilon cm}$ (divided by the differential gain). A little consideration will show that the two definitions are of course identical.

Common mode rejection presents no problems in the case of amplifiers used in the inverting configuration (Fig. 3), for with one input earthed the input common mode voltage e_{cm} must be zero. In the case of the non-inverting circuit (Fig. 4) feedback causes the voltage at the inverting input to follow that at the non-inverting input. The input common mode voltage thus varies directly with the input signal. This introduces a basic error which affects the overall circuit accuracy. For example, consider an amplifier with c.m.r.r. of 1000, used in the non-inverting configuration. With an input signal of say 1 V, the input common mode voltage e_{cm} would also be

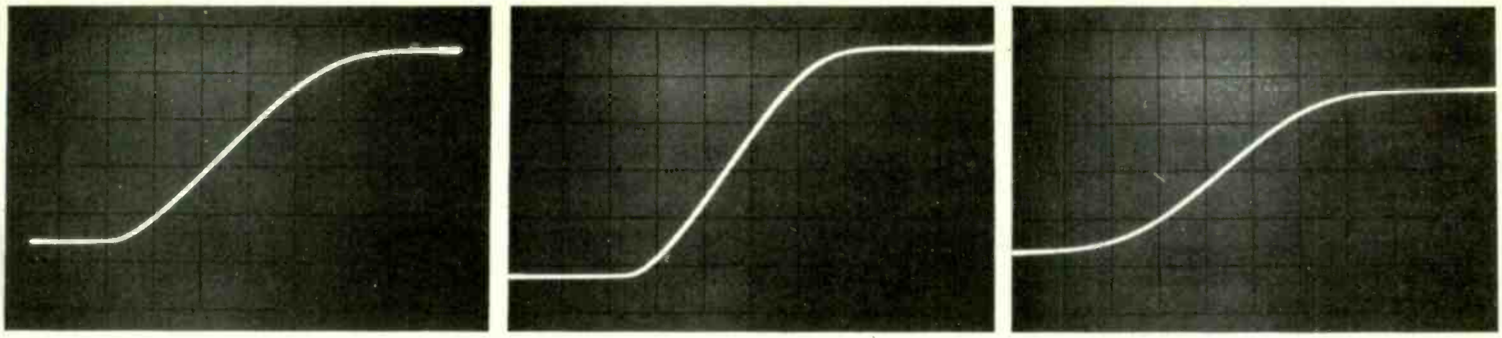


Fig. 7. Illustrating supply voltage sensitivity: transfer curves of CA3029 i.c. amplifier with different supply voltages. Left: positive supply +4V, negative supply −4V. Middle: +4V, −5V. Right: +3V, −4V. (Vertical scales: 1V/division. Horizontal scales: 1mV/division).

1 V and the common mode error voltage (referred to the input) would be $e_{\epsilon cm} = e_{cm}$/c.m.r.r. equals 1mV and representing a 0·1% measuring error. If common mode error voltage $e_{\epsilon cm}$ varies linearly with common mode voltage this error is not very important, since it can be compensated for by adjustment of closed-loop gain (adjustment of R_2/R_1). Linearity of common mode error voltage with common mode voltage is thus in many applications more important than the value of c.m.r.r., and a graph of the type shown in Fig. 10 is particularly useful in specifying the common mode behaviour of an amplifier.

A suitable test circuit for practically obtaining such a graph is shown in Fig. 11. An oscilloscope with d.c. coupled X and Y channels is used for the visual display; the

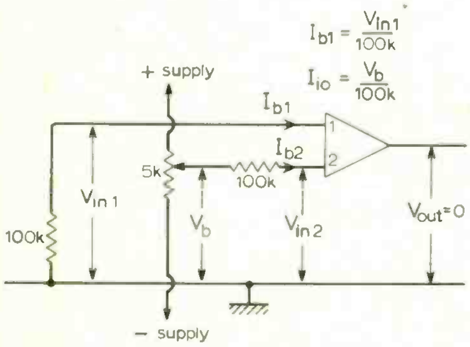


Fig. 8. Test circuit for determining input bias current and input offset current.

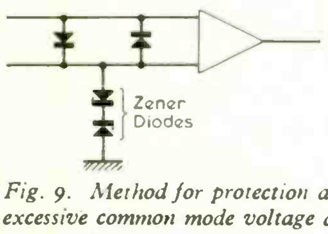


Fig. 9. Method for protection against excessive common mode voltage and excessive input voltage

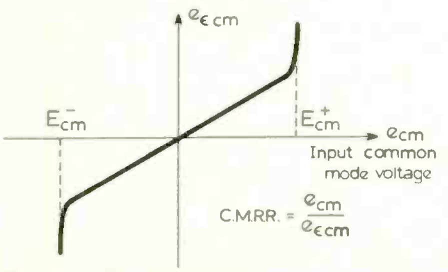


Fig. 10. Graph of input common mode input voltage vs. input common mode voltage.

oscilloscope may be single-ended provided, as shown in the diagram, the power supply is floated. A low frequency signal generator is used to provide both the input common mode voltage and the oscilloscope horizontal sweep. The amplifier output, which is equal to the closed loop gain multiplied by the equivalent input common mode error voltage

$$\left[1 + \frac{R_2}{R_1}\right] . e_{\epsilon cm}$$

provides the oscilloscope vertical sweep. A variable d.c. bias is included in addition to the signal generator to provide the common mode input voltage e_{cm} for amplifiers in which the positive and negative values of maximum common mode voltage differ appreciably. To allow a measurement of this parameter to be made directly from the trace the horizontal zero reference is established by earthing the oscilloscope horizontal input and aligning the trace with the central vertical graticule line. The vertical position of the trace is not of significance in the measurements. The oscillogram shows a result obtained with the test circuit; the polarity of the horizontal scale has the opposite sense to that of the graph in Fig. 10. For the particular amplifier tested, positive and negative values of maximum common mode voltage are seen to be +1 V and −2·5 V respectively. The trace is fairly linear between these limits; its average slope is used to give the c.m.r.r. from the relationship

$$\text{c.m.r.r.} = \frac{X}{Y} \cdot \left(1 + \frac{R_2}{R_1}\right)$$

The effects of power supply voltage on c.m.r.r. and maximum common mode voltage can easily be measured by changing the power supply voltages and observing any changes in the trace.

Open loop bandwidth and frequency response. The importance of open-loop gain A_{VOL}, and loop gain $\beta\, A_{VOL}$ in determining the closed-loop performance of an op. amp. has already been discussed, but the assumption was made that the amplifier had an infinite bandwidth. Practical amplifiers have, of course, a finite bandwidth, and the effect of this on closed-loop performance must be taken into account. The **open loop bandwidth** is defined as the frequency at which the open-loop gain

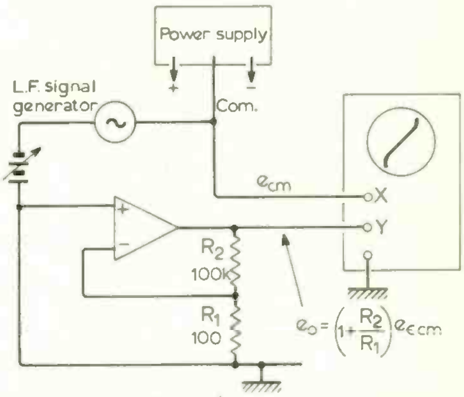
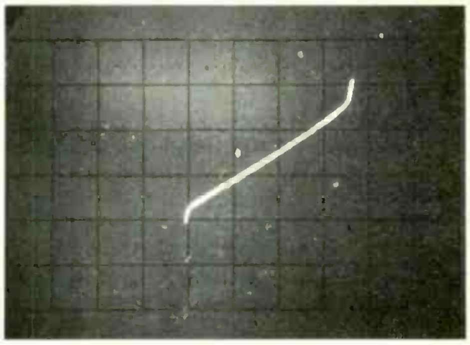


Fig. 11. (a) Test circuit for determining common mode rejection ratio. (b) Oscillogram showing result obtained with test circuit. Vertical scale(0·1V/division) represents $100e_{\epsilon cm}$. Horizontal scale (1V/division) represents e_{cm}.



is 3 dB down on its value at low frequencies. Many applications of op. amps require closed-loop gains over bandwidths of only a few hundred hertz, nevertheless the open-loop gain characteristics at much higher frequencies are of great importance. Amplifier gain attenuation with frequency is always accompanied by phase shift and because of this phase shift a negative feedback circuit may in fact provide positive feedback at high frequencies resulting in peaking of closed-loop gain or in high frequency oscillations.

A typical operational amplifier open-loop frequency response together with a closed loop response for a gain of 40dB is shown in Fig. 12. A response of this type can be represented mathematically by the equation:

$$A_{VOL(\omega)} = \frac{A_{VOL}}{1 + j\dfrac{\omega}{\omega_o}} \quad . . . (3)$$

This equation describes what is known as a first order high frequency response; ω_o

is called the break frequency. The function is conveniently approximated by its asymptotes (see Appendix 3) and this approximation has been made in Fig. 12. An amplifier having an open-loop response of this form with a 6 dB per octave (20 dB per decade) roll off will be stable (will not oscillate) for all values of resistive feedback, for the amplifier phase shift never exceeds 90° and the feedback is negative at all frequencies. An expression showing the effect of the frequency dependence of open-loop gain on closed-loop gain is obtained by inserting equation (3) into the equation for closed loop gain (eq. 1), thus

$$A_{VCL(\omega)} = -\frac{R_2}{R_1}\left\{\frac{1}{1+\dfrac{1}{\beta\, A_{VOL(\omega)}}}\right\}$$

$$A_{VCL(\omega)} = -\frac{R_2}{R_1}\left\{\frac{1}{1+\dfrac{1+j(\omega/\omega_o)}{\beta\, A_{VOL}}}\right\} \quad \ldots (4)$$

The closed loop 3 dB frequency is obtained by equating real and imaginary parts of the denominator, giving

$$\omega_{oCL} = (1+\beta\, A_{VOL})\,\omega_o \quad \ldots (2)$$

The closed-loop bandwidth is greater than the open-loop bandwidth by the amount $\beta \,.\, A_{VOL} \,.\, \omega_o$ At frequencies higher than ω_{oCL}, closed-loop and open-loop gains become equal. This may be seen from inspection of eq. (4) remembering that $\beta \approx R_1/R_2$. These points are illustrated in Fig. 12 and also the fact that loop gain in dB is the difference between open-loop gain and closed-loop gain. Loop gain decreases with increase in frequency because of the attenuation of open-loop gain, and consequently closed-loop gain stability, linearity and other parameters that depend on loop gain are degraded at higher frequencies.

Not all op. amps are designed with a 6 dB per octave attenuation. Some are designed with a much faster roll-off, and these fast roll-off amplifiers allow an improved closed-loop performance at the higher frequencies, but without compensation they are not stable under all conditions of resistive feedback. Consider an amplifier having an open-loop response of the form shown in Fig. 13, with a 6 dB per octave roll-off breaking at ω_{o1}, and a second break at ω_{o2} followed by a 12 dB per octave roll-off. Mathematically this is represented by a combination of two first-order high frequency response functions with break frequencies ω_{o1} and ω_{o2}; where the slope reaches 12 dB per octave the amplifier phase shift approaches 180°. With resistive feedback this amplifier would give stable closed-loop operation for closed-loop gains in excess of 60 dB, and at frequencies above the closed-loop bandwidth open-loop and closed-loop gains would become equal as before. If feedback components were changed in order to obtain a closed-loop gain less than 60 dB instability would occur. The criterion for stable closed-loop operation is simply that the rate of closure between the open-loop and closed-loop response curves should be less than 12 dB per octave.

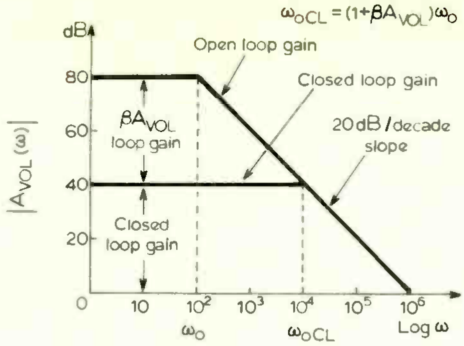


Fig. 12. Amplifier with 6dB/octave of open-loop gain.

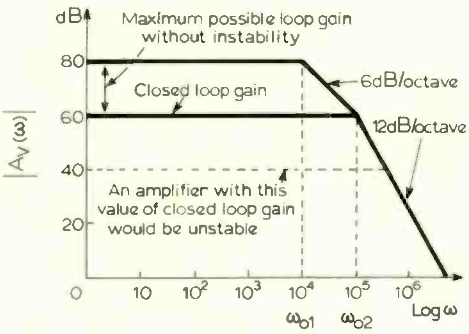


Fig. 13. Amplifier with attenuation of open-loop gain greater than 6dB/octave.

Appendices

1. Inverting amplifier

With ideal amplifier, i.e., infinite input impedance, infinite open loop gain, infinite bandwith, zero output impedance

$$e_\epsilon = -\frac{e_o}{A_{VOL}} = 0,$$

and $\quad i_i = i_f$

But $\quad i_i = \dfrac{e_i}{R_1} \quad$ and $\quad i_f = -\dfrac{e_o}{R_2},$

which gives

$$A_{VOL} = \frac{e_o}{e_i} = -\frac{R_2}{R_1}$$

With ideal amplifier except for finite open loop gain

$$i_i = \frac{e_i - e_\epsilon}{R_1} = \frac{e_i + \dfrac{e_o}{A_{VOL}}}{R_1}$$

$$i_f = \frac{e_\epsilon - e_o}{R_2} = -\frac{\dfrac{e_o}{A_{VOL}} - e_o}{R_2}$$

$$= -\frac{e_o\left\{\dfrac{1}{A_{VOL}}+1\right\}}{R_2}$$

As before $i_i = i_f$, and substitution and rearrangement gives,

$$A_{VOL} = \frac{e_o}{e_i} = -\frac{R_2}{R_1}\left\{\frac{1}{1+\dfrac{R_1+R_2}{A_{VOL}\,R_1}}\right\} \quad \ldots (A1)$$

2. Non inverting amplifier

With ideal amplifier, $e_\epsilon = 0$ and

$$e_i = e_o\,\frac{R_1}{R_1+R_2}$$

which gives

$$A_{VOL} = \frac{e_o}{e_i} = 1 + \frac{R_2}{R_1}$$

With ideal amplifier except for finite open loop gain

$$e_i - e_\epsilon = e_o\,\frac{R_1}{R_1+R_2}$$

but $\quad e_\epsilon = \dfrac{e_o}{A_{VOL}}$

Substitution and rearrangement gives

$$A_{VCL} = \frac{e_o}{e_i}$$

$$= \left\{1+\frac{R_2}{R_1}\right\}\left\{\frac{1}{1+\dfrac{R_1+R_2}{A_{VOL}\,R_1}}\right\} \quad \ldots (A2)$$

3. First order systems

Consider the function

$$A_{V(\omega)} = A_{V(O)}\,\frac{1}{1+j\dfrac{\omega}{\omega_c}}$$

At low frequencies the straight line given by $|A_{V(\omega)}| = A_{V(O)}$ is an asymptote and at high frequencies the curve is asymptotic to

$$|A_{V(\omega)}| = A_{V(O)}\,\frac{\omega_c}{\omega}$$

The high frequency asymptote has a slope of 20 dB per decade, i.e. if the frequency is increased ten times $|A_{V(\omega)}|$ is reduced by 20 dB. (If the frequency is doubled $|A_{V(\omega)}|$ is reduced by 6 dB, i.e. 6 dB per octave.)
The asymptotes intersect at ω equals ω_c and here

$$|A_{V(\omega c)}| = \frac{A_{V(O)}}{1+j1}$$

which gives

$$|A_{V(\omega c)}| = A_{(VO)}\cdot\frac{1}{\sqrt{2}}$$

$|A_{V(\omega c)}|$ is 3 dB down on $A_{V(O)}$ The angle (phase) as well as the magnitude of $A_{V(\omega)}$ is of importance. It may be sketched as a function of ω by noting the following: 1. As $\omega \rightarrow 0$, $A_{V(\omega)} \rightarrow A_{V(O)}$, which is real, therefore the phase shift produced by the amplifier is zero at low frequencies 2. As $\omega \rightarrow \infty$, $A_{V(\omega)}$ becomes imaginary corresponding to a 90° phase lag.
3. At $\omega = \omega_c$, $A_{V(\omega c)}$ has real and imaginary parts equal, and the phase shift is thus 45°.

The two plots of magnitude and angle of $A_{V(\omega)}$ are referred to as the Bode plot. The magnitude of $A_{V(\omega)}$ is usually expressed in dB and is plotted against a log (base 10) scale of frequency.

The Notion of "State"

A unifying concept in the diverse world of electronics

by James Franklin

Some of the older readers of *Wireless World* tend to be worried by the fact that the contents of a typical 1960s issue do not seem to reflect a well-defined area of technology—say "radio" as it was in the '20s and '30s. To them, and perhaps some younger people too, it is disturbing to find articles on computers and switching circuits cheek-by-jowl with articles on receivers and audio amplifiers. It is not enough to say "well, all these things are embraced by electronics" and explain that there is now one body of engineering theory which is equally relevant to television sets and industrial process-control systems. Within electronics the techniques, and the languages used by their practitioners, often seem worlds apart, and it may certainly be difficult for a particular reader to understand two adjacent articles in *Wireless World*.*

One of the fundamental divisions in electronics is, of course, between what we call continuous or analogue techniques and digital techniques, and this has arisen largely because analysis and design is done mainly in the frequency domain for the first and in the time domain for the second. In reality, of course, all events take place in the time domain, and the frequency approach, depending on the convention that all signals are made up of pure sine waves, is a specialized, blinkered view which avoids the direct handling of time relationships because it is convenient to do so. At the basis of the frequency approach, however, are differential equations which express the behaviour of circuits and systems with respect to time. It is these differential equations which enable us to predict what will happen after a specified interval of time in, say, an *LCR* circuit with the same sort of certainty that we can predict what will happen after a specified interval of time in, say, a shift register of a digital computer (given the initial conditions and input signals in both cases, of course).

In Fig. 1 this common dimension of time is used to compare the action of an analogue circuit with that of a digital circuit. This diagram may be rather obvious and elementary, but it is intended to bring out the fact that both the behaviour of the analogue circuit and the behaviour of the digital circuit can be considered in terms of their having a *state* which changes from instant to instant (indicated on the two graphs by the dots at t_1 t_2 . . . . . t_n). As another example imagine the mechanical "system" of a ball being propelled through the air by the foot of a small boy (see Fig. 2). The state of the system can be defined as the position of the ball with respect to a three-dimensional frame of reference, and the x, y and z distances giving this position are a set of variables—the *state variables*—which, of course, change from instant to instant during the flight of the ball.

In an electrical system the principal variables which define its state are, of course, the charges, voltages and currents at various points. Again, the values of these variables change from instant to instant during the operation of the system. In Fig. 1(a) we have selected for examination one state variable which tells us practically everything we want to know about the behaviour of the circuit—the voltage across the capacitor, V_c. This variable has a sequence of values, each of which is different from the previous ones. In Fig. 1(b) a significant state variable is the voltage V_B representing the binary condition at the output of the register. Here again the state variable has a sequence of values at t_0, t_1 . . . . . . t_n but at each instant it can be only one or the other of two possible values.

In more complex dynamical systems the number of state variables necessary to describe behaviour will obviously be greater. For example, in an *LCR* circuit one must know about the movement of charge through the inductor (e.g. current through it) and the accumulation of charge in the capacitor (e.g. voltage across it). It is not necessary, however, to know anything about any variable associated with the resistance because R is non-reactive and has no memory and does not *itself* produce any change with time in the flow of charge through it. What are significant as state variables in systems, then, are variables associated with elements producing operations in the time domain—stores or delays in digital systems, reactive or energy-storing elements in continuous systems.

This view of system behaviour as a state which changes from moment to moment is by no means new. For example, Newton talks about the state of rest or state of uniform motion of a body in the laws of motion he propounded in the 17th century. A more conscious use of state, in analysing dynamical systems, was made in the 19th century by the French mathematician and philosopher Henri Poincaré who introduced the whole mathematical basis of what are now called state space techniques in his three-volume work "Les Méthodes Nouvelles de la Mécanique Céleste". Also in the 19th century the Russian mathematician Liapunov (well known to students of control theory) used the concept of state in analysing the conditions for stability in a dynamical system. During the past decade there have emerged various methods for applying these ideas to engineering systems. The remainder of this article is intended to provide no more than an introduction to the many learned works that have been written on the subject.

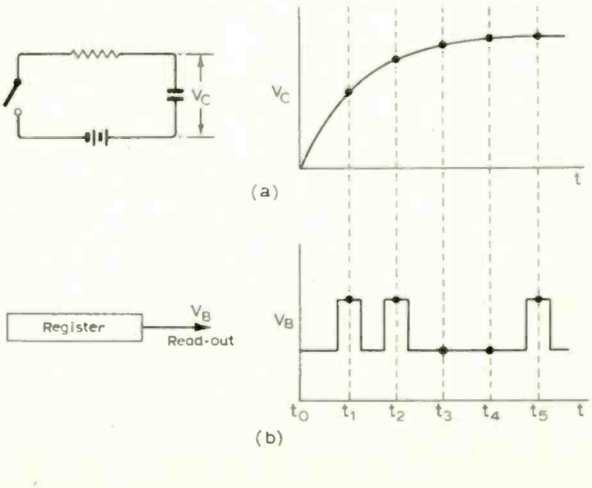


Fig. 1. Illustrating the idea that any system—here an analogue one in (a) and a digital one in (b)—can be considered as having a state, which changes with successive instants of time, t_0, t_1, t_2 . . . . . . etc.

* Although we do our best to find a *lingua franca* that will help matters.—ED.

Fig. 3 is a block diagram of an electrical or mechanical system. As already explained its state can be represented by a set of variables, which here we shall call x_1, x_2, $x_3 \ldots\ldots x_n$. Similarly, its input will consist of another set of variables which we shall call u_1, u_2, $u_3 \ldots\ldots u_n$ and its output yet another set of variables $y_1, y_2, y_3 \ldots y_n$. (In many electronic systems, of course, there is only one input variable, u_1, and one output variable, y_1.) For convenience these sets of variables are represented by single symbols in heavy type, **x**, **u** and **y**, on the diagram.

Now if Fig. 3 is an analogue system we are interested in its state (and input and output) continuously, and in graphical representations we use a continuous time scale t as in Fig. 4(a). But if Fig. 3 is a digital system, although time is still a continuum we are only interested in what happens at particular instants on the Fig. 4(a) scale, t_0, t_1, $t_2 \ldots\ldots$ etc. We will call these discrete instants of time t_k, where k ranges over the integers. In most digital systems the interval between the discrete instants t_k is constant, and here we will call it T. Thus the actual time at which an event takes place in the digital system is given by a value kT (with respect to t_0). But since T is a constant it is k which is the significant factor and we can then use a discrete-time scale as in Fig. 4(b). Of course, the scale in Fig. 4(b) could also be used for a continuous system if it is assumed that T is infinitesimally small.

We can now use the symbology of Figs. 3 and 4 to write down generalized equations for the two types of system. In the case of the continuous or analogue system we can say first that the state **x** is a function of time, which is expressed formally as $\mathbf{x}(t)$. At any instant the state of a system depends on its initial condition when switched on or otherwise started—an instant we shall define as t_0—and on the input during the period between t_0 and the present instant, t. This can be written in algebraic form as

$$\mathbf{x}(t) = f[\mathbf{x}(t_0); \mathbf{u}(t_0, t)] \quad \ldots (1)$$

where f is some function.

The output of the system can be considered as one or more of the internal state variables which have been made available externally for observation, measurement or further use in some way. Thus $\mathbf{y}(t)$, the present output, depends on $\mathbf{x}(t)$ the present state, and algebraically we can write

$$\mathbf{y}(t) = g[\mathbf{x}(t)] \quad \ldots (2)$$

where g is some function.

Equations (1) and (2) are what are called the "state equations" for a continuous system.

With a digital or discrete-time system we are concerned with the state **x** in Fig. 3 at particular instants of time, so using the symbology of Fig. 4(b) the present state is represented by $\mathbf{x}(k)$. Consider, for example, a simple digital system such as a bistable, with an input consisting of a triggering voltage and an output consisting of a voltage taken from one side of the circuit. It has two possible states, expressible in binary symbols as "0 1" and "1 0". Which state it occupies at any given instant depends on (a) its state at a previous time and (b) the presence or absence of a triggering voltage at that instant. Thus $\mathbf{x}(k)$ depends on $\mathbf{x}(k-1)$ and $\mathbf{u}(k)$. This can be expressed algebraically as

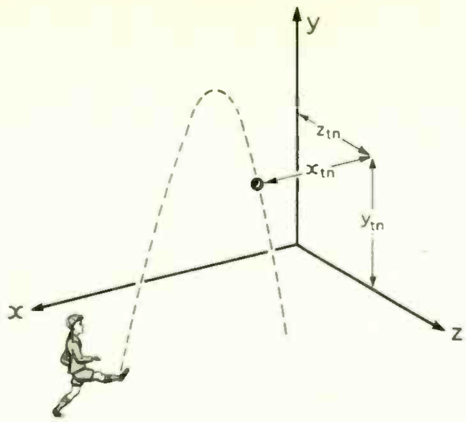


Fig. 2. The state of this mechanical "system" is the position of the ball within the frame of reference—given here by the distances x_{tn}, y_{tn} and z_{tn} which fix it at the instant t_n "frozen" in the picture.

Fig. 3. Block schematic of any system. Each of the symbols **u**, **x** *and* **y** *represents a complete set of variables. In many electronic systems there is only one input variable and one output variable.*

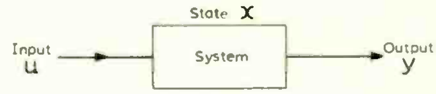
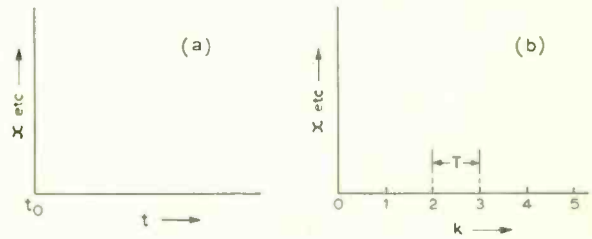


Fig. 4. Two scales for representing events in the time domain graphically: (a) for a continuous system; (b) for a "discrete-time" system, where we are only interested in what happens at particular instants.



$$\mathbf{x}(k) = q[\mathbf{x}(k-1); \mathbf{u}(k)] \quad \ldots (3)$$

where q is some function. And since the present output $\mathbf{y}(k)$ is an observable part of the present state

$$\mathbf{y}(k) = r[\mathbf{x}(k)] \quad \ldots (4)$$

where r is some function.

Equations (3) and (4) are the corresponding state equations for the discrete-time system.

At this point the reader may have become rather lost in the abstractness and generality of this form of system representation, so a look at some concrete examples may be helpful. Let us, for an example, consider the simple *LCR* system in Fig. 5 in terms of the state concept. Here the input is a single variable, a voltage e_1. The output is also a single variable, the voltage e_2 developed across R. We must now decide how the state of the system is to be represented and what are the state variables. Earlier it was stated that the state variables are those variables associated with the elements which cause changes in the time domain—in particular energy-storage elements in continuous systems. Here, then, the state variables are clearly linked with L and C. In an inductance the energy stored is given by $\frac{1}{2}Li^2$, so an obvious variable to choose as a state variable is the current i flowing through the inductance. Similarly with the capacitance, the energy stored is given by $\frac{1}{2}Cv^2$ and the most obvious state variable is the voltage v across the capacitor. A further, practical, reason for choosing these two particular variables is that when the differential equations for such circuits are being solved the initial conditions necessary for solution are usually most readily obtainable in terms of inductor current or capacitor voltage. But in practice other variables can be chosen, provided that they are linearly related to the basic state variables, the i and v in this case. For example, another possible pair of state variables in Fig. 5 would be e_2, which is obviously derivable from i, and de_2/dt which is related to v.

Since we wish to examine the state of the Fig. 5 system in the time domain, we must use differential equations to represent the rates of change of the variables concerned. In fact the general rule for expressing the behaviour of continuous dynamic systems in "state" form, developed from Poincaré's work, is to derive from the system equation a set of first-order differential equations which express the behaviour of the energy-storage elements. In this case we have chosen i and v as the state variables, so the relevant rates of change to be used in the differential equations are

$$\frac{di}{dt} \quad \text{and} \quad \frac{dv}{dt}$$

The system equation for Fig. 4, set up from Kirchhoff's voltage law, is

$$e_1 = L\frac{di}{dt} + Ri + v$$

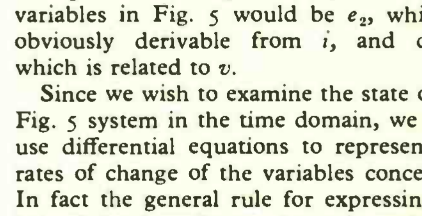


Fig. 5. A continuous system consisting of a simple LCR circuit. Considering it in terms of the "state" concept, one set of state variables can be the current through the inductance and the voltage across the capacitance.

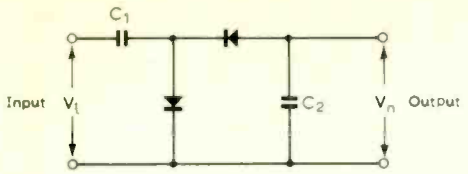


Fig. 6. Diode "pump" circuit used as an example of a discrete-time system. The input is a sequence of pulses of amplitude V_i.

From which

$$\frac{di}{dt} = -\frac{R}{L}i - \frac{1}{L}v + \frac{1}{L}e_1 \quad . . . (5)$$

The charge on the capacitor $q = Cv$, so $v = q/C$

$$\therefore \frac{dv}{dt} = \frac{d(q/C)}{dt} = \frac{1}{C}i \quad . . . (6)$$

(Since rate of change of charge, q, is current, i).

Equations (5) and (6), then, are the required first-order differential equations. It will be noted that these have been obtained from what can be considered as a second-order differential equation if the system relationships are expressed in terms of charge:

$$e_1 = L\frac{d^2q}{dt^2} + R\frac{dq}{dt} + \frac{1}{C}q$$

The same principle could be applied to third, fourth or higher order differential equations—all can be reduced to sets of first-order equations.

It is now possible to bring the particular state equations (5) and (6) into a form corresponding with the generalized state equations (1) and (2). For this purpose we can present the set of first-order differential equations (only two in this case) in matrix algebra form, thus

$$\begin{bmatrix} \frac{di}{dt} \\ \frac{dv}{dt} \end{bmatrix} = \begin{bmatrix} -\frac{R}{L} & \frac{1}{L} \\ \frac{1}{C} & 0 \end{bmatrix} \begin{bmatrix} i \\ v \end{bmatrix} + \begin{bmatrix} \frac{1}{L} \\ 0 \end{bmatrix} e_1$$

Reverting to the original terminology of expressing state variables as x_1, x_2, x_3 . . . . . etc. and input variables as u_1, u_2, u_3 . . . . . . etc., this becomes:

$$\begin{bmatrix} \frac{dx_1}{dt} \\ \frac{dx_2}{dt} \end{bmatrix} = \begin{bmatrix} -\frac{R}{L} & \frac{1}{L} \\ \frac{1}{C} & 0 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} \frac{1}{L} \\ 0 \end{bmatrix} \mathbf{u}_1$$

And if we label the two matrices containing the *LCR* constants as *A* and *B*, we can express this in generalized matrix form as

$$\frac{d\mathbf{x}}{dt} = A\mathbf{x} + B\mathbf{u}$$

or

$$\mathbf{x} = \int [A\mathbf{x} + B\mathbf{u}]\,dt \quad . . . (7)$$

which is the particular version of equation (1) for the particular system Fig. 5.

As a concrete example of a digital or discrete-time system, consider a situation where a capacitor is not charged continuously, as in Fig. 1(a), but only at particular instants of time. This occurs in the familiar diode pump circuit, an example of which is shown in Fig. 6. There is no need to describe the action of this circuit in detail here,‡ suffice to say that when pulses are applied to the input the capacitor C_2 becomes charged in steps, the actual voltage across C_2 being determined by the *number* of pulses that have already occurred (assuming the pulse amplitude to be constant). To be more precise the C_2 voltage after the *n*th pulse will depend partly on the amplitude of the *n*th pulse and partly on the number of previous pulses (of the same amplitude) that have occurred, $n - 1$. The electrical formula expressing this condition is:**

$$V_n = V_iA\,(1 + B + B^2 + \ldots + B^{n-1}) \quad . . . (8)$$

where V_n is the voltage across C_2 after n input pulses, V_i is the amplitude of the input pulses, and A and B are the following constants:

$$A = C_1/(C_1 + C_2);\ B = C_2/(C_1 + C_2)$$

Looking at this system in terms of its state, we can see that the state variables will be associated with the energy (and information) storage elements C_1 and C_2. The state variable which is of greatest interest to us (because it is used as the output) is V_n, so this will be called $x(k)$—remembering that k is an integer. Similarly the exponent $n - 1$ in equation (8) will be called $k - 1$. The input pulse amplitude V_i, again in accordance with the earlier terminology, becomes u, and because the voltage is not a function of continuous time but of particular instants (see Fig. 4(b)) it becomes $u(k)$. Thus from this "state" point of view equation (8) would be expressed as

$$x(k) = u(k)\,A\,[1 + B + B^2 + \ldots B^{k-1}] \quad . . . (9)$$

which is a particular version of the generalized expression for a discrete-time system given in equation (3).

This, then is the kind of symbolical language that is being used for describing systems in a precise manner in terms of the "state" concept. As such it does no more than sharpen and solidify the concept, just as verbalizing a vague idea in speech or writing sharpens and solidifies it. Are there any practical ends to served by analysing systems in this manner? It seems there may be, although it is too early yet to be certain. The process of breaking down the mathematical descriptions of complicated continuous systems into sets of first-order differential equations is particularly useful when one realizes that computers, both analogue and digital, can be used to solve these sets of first-order equations quite easily, whereas the original equations would be relatively difficult to handle. So there may be some applications in computer-aided design of electronic circuits. In addition state variable analysis avoids the problems which arise when one tries to apply classical linear theory to non-linear systems—the point being of course, that it is a form of analysis based on the time domain instead of the frequency domain. The method may also be particularly useful in dealing with complicated control systems with a multiplicity of inter-related inputs and outputs, as occur in process control and flight control. Some idea of these more practical aspects can be gathered from references 4 and 5. For the average *Wireless World* reader, however, the state concept must be at present little more than a way of looking at things. But, because it is a fresh view through another window, it may be helpful to the understanding.

‡ See "The Diode-transistor Pump" by D. E. O'N. Waddington. *Wireless World*, July 1966 for a full explanation.

** Adapted from a formula given in the above article.

Acknowledgement. I would like to thank Dr. A. G. J. MacFarlane, of the University of Manchester Institute of Science and Technology, for his kind help in the preparation of this article.

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Corrections

"Test Your Knowledge—8": As a result of a printing error, question No.1 in the set on Electromagnetic Radiation (January, p.47) was presented incorrectly. The first two possible answers should read: (a) α radiation, (b) X radiation.

"Digital Exposure Timer": The following corrections should be made to three diagrams published in the January issue. The pulse outputs B and C in Fig. 6 should be relabelled A and B to key them with Fig. 3. (The related text on page 25 should also be amended.) In Fig. 5 the collector of Tr_2 should be marked V as this is the input for the output of NAND gate G_3 shown in Fig. 3. Switch S_5 drawn at the top left of Fig. 3 should be labelled start, not stop. The diode between point *C* and switch S_{4_b} in Fig. 3 should be marked D_{23}.

Some other Measuring Rectifiers

by 'Cathode Ray'

Last month we considered the very simple-looking rectifier circuit shown here as Fig. 1, as used for measuring alternating voltages. To recap., C charges up through D to very nearly the positive input peak voltage, and R allows it to discharge slowly enough not to lose voltage significantly between one cycle and the next, but fast enough to make the voltmeter ready for another reading. The unidirectional output voltage, which is thus a close approximation to the peak input, can be indicated either by a microammeter in series with R or by a less delicate meter via a stable amplifier. There is a more often used variety of this rectifier in which D and C in Fig. 1 change places.

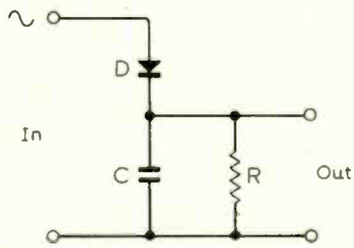


Fig. 1. One variety of the simple peak rectifier circuit considered last month.

What we found was that the behaviour of these circuits is a good deal less simple than their appearance, or than it is represented to be in some of the specifications of electronic a.v. voltmeters in which such a rectifier comes at the front end. In particular, the quoted input resistance is valid only when applied to resonant circuits and is seriously misleading when applied to resistive circuits. What might look like an instrument suitable for measurements in quite high-impedance circuits could in fact be worse for that purpose than an ordinary metal-rectifier voltmeter, with the additional disadvantage of causing an unpleasant form of distortion.

Most ordinary a.v. voltmeters for power and audio frequencies use a bridge rectifier as shown in Fig. 2 in which R is the range-setting resistance. During positive half-cycles, current flows through the moving coil milliammeter M via D_1 and D_4, and during negative half-cyles in the same direction through M via D_3 and D_2. The forward resistances of the diodes are normally negligible compared with R, so the behaviour of the instrument conforms to the simple pattern in Fig. 3, which shows that the deflection will be proportional to the mean (average) value of the input voltage, regardless of polarity. Almost always such instruments are calibrated in 1·11 × mean value, which directly indicates r.m.s. values *so long as the waveform is either sine or square*. Unless the Fig. 1 type is specifically called a peak-reading voltmeter, it too is usually calibrated in what are correctly r.m.s. volts with the same proviso. Both types are misleading when used on other waveforms.

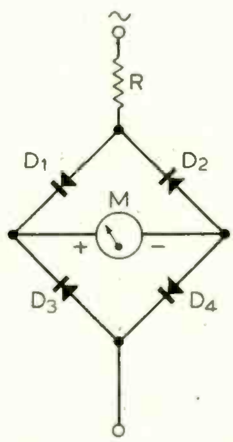


Fig. 2. Bridge type of rectifier circuit used in many multirange a.v. voltmeters.

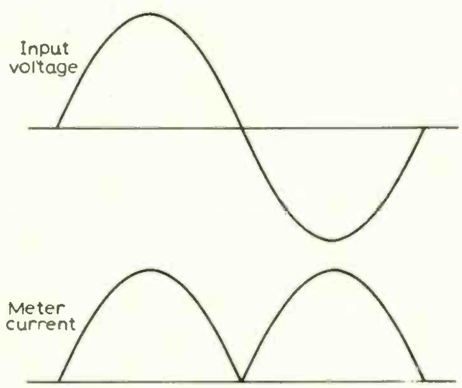


Fig. 3. Voltage and current waveforms for the Fig. 2 circuit.

There is no doubt about input resistance with the Fig. 2 type—except perhaps on the lowest range—because the diode and meter resistance is normally made small compared with R. On any ranges, and whatever kind of circuit one is measuring, one can be sure that the resistance of the instrument is at least R. And it remains practically constant throughout the cycle, so there is not the distortion one gets with the Fig. 1 type as a result of its drawing a sharp pulse of current at each positive (or negative) peak. But Fig. 2 is limited, as I said, more or less to power and audio frequencies and perhaps the lower radio frequencies, owing mainly to the shunting effect of unwanted capacitances.

Another circuit that has been coming into use is usually drawn as in Fig. 4, which suggests that it is akin to Fig. 2. Sometimes it is even called a half-bridge rectifier circuit. But really it is a pair of Fig. 1 type, with diodes connected oppositely so as to give outputs of opposite polarity. It is therefore a voltage-doubling rectifier, which Fig. 2 is not. In fact, because its output is nearly peak-to-peak whereas Fig. 2 yields the mean value, with a sine wave it gives π times as much.

Instead of having two separate leak or load resistors, we can connect them in series between the output terminals to make one. The potential of their junction or centre point varies only slightly with respect to that of the bottom terminal ('earthy'), so the behaviour is practically the same as that of two separate Fig. 1 rectifiers, without the necessity for connecting the half-loads across C_1 and C_2, so one gets the advantage of the modified Fig. 1 (R across D) without its disadvantage (a.v. in the output as well as d.v.). Because C_1 and C_2 can be large, the output device is all nearly at earth potential so far as the a.v. is concerned. All the same, if this circuit is used for high radio frequencies (and at least one commercial example is rated up to 1·5GHz) it would be asking for trouble to connect a microammeter quite so near the input terminal, and for this and other reasons a high-input-impedance amplifier is used. The fact that it has to be a balanced one is no real disadvantage, because that would be preferred anyway for stability and interference rejection.

But there is still the same complaint that we had about its single-phase prototype, Fig. 1—unless you think the fact that both peaks equally have to provide capacitor-

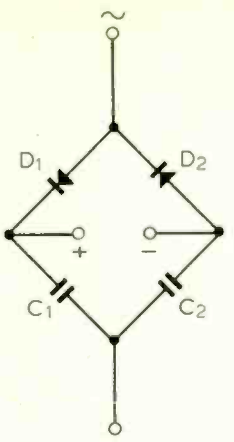


Fig. 4. Voltage-doubling rectifier circuit, which behaves either like Fig. 1 or Fig. 2 according to how it is operated.

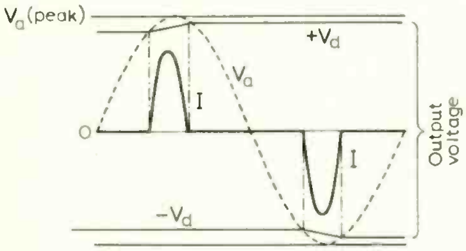


Fig. 5. If voltage-operated, the Fig. 4 circuit behaves as a pair of Fig. 1 type rectifiers, giving voltage and current waveforms like these.

charging current pulses is any mitigation. Some might regard it as an aggravation!

However, although we cannot be particularly enthusiastic about this kind of rectifier at the front end, it is interestingly different in the class of electronic voltmeter in which the amplification comes first. Here the amplifier must not only be very constant—that goes without saying in a measuring instrument—it must also be so over the full frequency range of the voltages to be measured. That rules out the hertz to gigahertz specification that is possible with the front-end rectifier, and concentrates design skill on the amplifier. Negative feedback is essential, of course. Usually one doesn't think of including a rectifier in a feedback system, because rectification is a drastic kind of distortion, which negative feedback would do its best to iron out. However, this is not necessarily so with a full-wave rectifier such as Fig. 2 or Fig. 4. The current through R in Fig. 2, and therefore the voltage across it, has the same waveform as the input, except to the extent that the non-linear diode forward resistance is appreciable compared with R. So if this rectifier circuit were fed from an amplifier, the voltage across R could be used for negative feedback. It would be current feedback, because that voltage is proportional to the amplifier output current. One effect of negative current feedback is to increase the apparent output resistance of the amplifier, making it more like a constant-current source. So the non-linearity of the diodes is made even less significant than it was, and the rectifier more nearly ideal.

The same technique works with Fig. 4. However, making the diodes more like perfect on-off switches is not the most significant or interesting effect of current feedback in this case. Without feedback, the voltage and current diagram is something like Fig. 5, which is the full-wave voltage-doubling counterpart of the one we studied last month in connection with Fig. 1. Here the current waveform is obviously drastically distorted. If however Fig. 4 is worked from a source impedance which, owing to the use of current feedback or otherwise, is very large compared with the load resistance connected to its + and − terminals, and also linear, the current waveform is forced to be that of the source. The impedance of the rectifier as a whole is too relatively small to distort it. Clearly the operation of the rectifier must be quite different from that represented in Fig. 5, which applies to a more or less constant-voltage source.

Let us continue to assume that the applied waveform is sinusoidal, but we must begin again on the basis of current instead of voltage. In Fig. 6, then, we draw a sine wave for current, I. The corresponding equivalent circuit diagram is shown as Fig. 7, where the diodes are represented by a two-way switch, S. Let us suppose that the capacitances of C_1 and C_2 are equal to one another and large enough to maintain their charges almost constant between switch movements (half cycles). Then point *a* will be at an almost constant positive voltage which we can represent approximately in Fig. 6 by the horizontal line marked V_a, and *b* is at an equal but negative voltage represented by the line marked V_b. The nearly constant voltage between *a* and *b* drives a nearly constant current, i_L, through the load resistance R, and this current is approximately represented by the horizontal line i_L. During the first half-cycle, when the switch is to the left, i_L and i_b are necessarily identical. During the same period $i_a = I - i_L$. So we can draw i_a as a positive half-cycle, lower than I by the amount i_L. During the other half-cycle everything is reversed: i_a is constant and negative, and i_b has the same form as I but is more positive by i_L. Because the current through (more correctly, into and out of) a good capacitor can have no d.c. component, the i_a and i_b waveforms must enclose equal areas above and below the zero-current line. That fact fixes i_L. And if you use any of the various methods for equalizing the areas, you should arrive at the result that $i_L = I_{(peak)}/\pi$. (Students of duality will note with pleasure that this corresponds to the voltage relationship, already mentioned, between the voltage output in Fig. 5 and that in Fig. 3.)

We can now get a better approximation to the voltages at *a* and *b*. At the start of the cycle I is zero, so the current i_L is kept going by the discharge of C_1, i_a being negative. This phase lasts only a short time and soon i_a goes positive and remains so for most of the remainder of the half-cycle, positive current being a charging current. These charges and discharges cause the voltage at *a* to vary in the manner shown rather exaggeratedly by the dotted line marked v_a; V_a is now the *mean* voltage at *a*. The v_b waveform is arrived at in the same way, and we now see that the voltage across the load, v_L, varies even less than v_a and v_b separately. Except near the low-frequency end of the range, v_a and v_b should be hardly distinguishable from V_a and V_b. And the voltage, V, of the top terminal, being v_a during the first half-cycle and v_b during the second, is a near-square wave.

As the Fig. 4 circuit used in this way as a current instrument produces readings proportional to mean values, that fact must be kept in mind if it has an r.m.s. calibration and is used to measure non-sinusoidal and non-square waveforms. An example of this type of instrument was described by D.E.O'N. Waddington in the March 1966 issue.

There is another variety in which resistors are used in place of the capacitors C_1 and C_2, but it seems to lack any advantages.

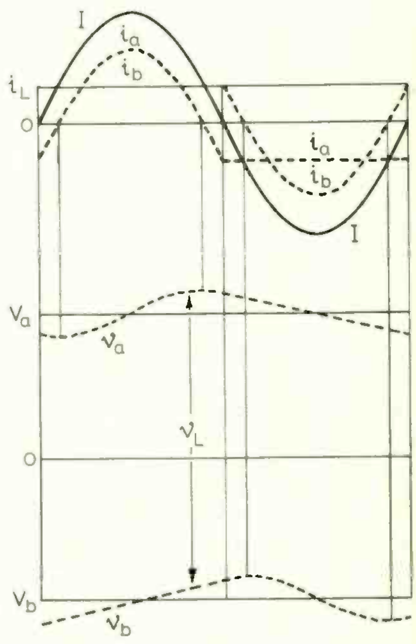


Fig. 6. If Fig. 4 is current-operated, its voltage and current waveforms are like this. The overall voltage V, not shown, is a near-square wave, the first half-cycle being like v_a and the second like v_b.

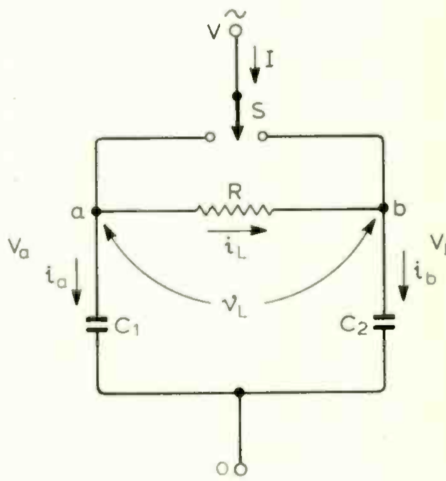


Fig. 7. Equivalent circuit diagram corresponding to Fig, 4, the diodes being simulated by a switch. The symbols correspond to those in Fig. 6.

News of the Month

Giant electronics merger

A company with an electronics turnover in excess of £100M has resulted from the move to bring together the electronics interests of G.E.C.-A.E.I., English Electric and Elliott Automation. The new company, called G.E.C. Marconi Electronics Ltd will have Robert Telford as managing director. Robert Telford also continues as managing director of the—Marconi Company.

The new company has interests in defence and broadcasting equipment and communications and navigational equipment for land, sea, air and space.

G.E.C.-Marconi Electronics Limited will be responsible for the management of the following units:—

from Marconi Company:

The Marconi Company Limited (Chelmsford and district, Basildon, Billericay, Gateshead, Hackbridge and Wembley); including Marconi Instruments Ltd. (St. Albans and Stevenage).

Marconi-Elliott Microelectronics Ltd. (Witham and Glenrothes).

Eddystone Radio Ltd. (Birmingham).

and including all Marconi subsidiary companies overseas;

from G.E.C.-A.E.I.:

G.E.C.-A.E.I. (Electronics) Ltd. Radar, Aerospace and Defence Division (Stanmore, Portsmouth, Leicester and Watford).

G.E.C.-A.E.I. (Electronics) Limited, Communications Division, (Coventry);

from Elliott-Automation:

Elliott Flight Automation Limited (Rochester).

Elliott-Automation Radar Systems Ltd. (Borehamwood, Hillend).

Elliott Space and Weapon Automation Limited (Frimley, Borehamwood, and Hillend).

E.-A. Space and Advanced Military Systems Limited (Camberley).

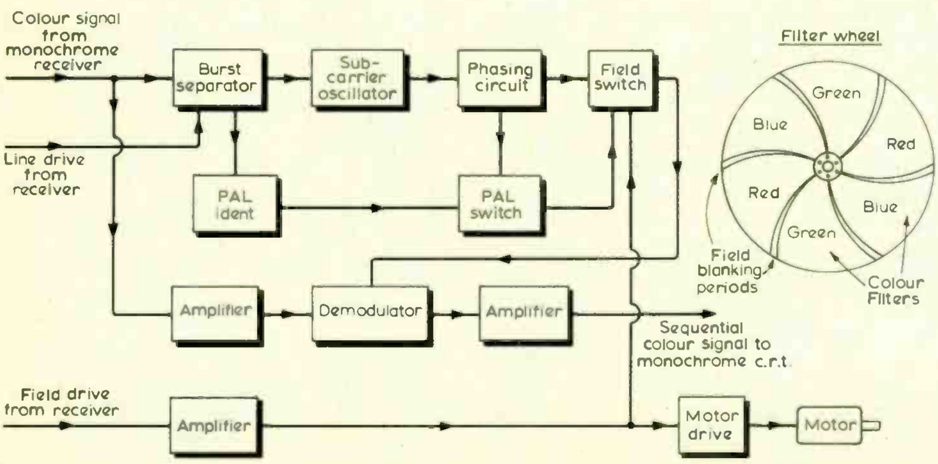
Domestic monochrome-to-colour converter

A converter that enables colour pictures to be viewed on a standard monochrome receiver has been built by A. Becker of Scottish Television. The operating principles of the converter are not new, in fact they can be traced back to Baird's experiments.

The electronics of the converter consist of about a dozen transistors mounted on a small board that in most cases would fit into the cabinet of the monochrome receiver. The unit converts a chroma signal from the receiver's video stage into a sequential $R-Y$, $B-Y$, $G-Y$ signal which is fed to the grid of the receiver c.r.t. The picture on the screen is viewed through a rotating optical filter which, in its simplest form consists of two tri-colour filter groups rotating at 500 r.p.m. in synchronism in phase and frequency with frame drive. A block diagram of the system is shown in the accompanying drawing.

Mr. Becker tells us that in the kit form the system would cost less than £30 and he is seeking commercial exploitation of the idea.

A block schematic of the colour converter



Watt output convention ?

It would appear that manufacturers of amplifiers are going to have to watch the watts they claim that their products will produce. The Association of Public Address Engineers point out that the figures used to express the output power of amplifiers would seem to be covered by the new Trade Description Act.

The correct method of expressing the power output of audio amplifiers is given in BS 3860:65. This states that two power ratings should be given, these are rated and maximum. The rated power is the output an amplifier will provide continuously at some value of harmonic distortion lower than is claimed for the amplifier. The maximum power output is the power developed across the load when the level of harmonic distortion equals that specified for the amplifier. In both cases the input is a 1kHz sine-wave.

It is difficult to see why some amplifiers are rated using the American I.H.F.M. convention. Is it because this figure is about 50% higher than the continuous rating and that the less informed members of the public may be deceived?

U.K. Audio Engineering Society?

As a result of a meeting of some 70 former members of the defunct British Sound Recording Association an approach is being made to the American Audio Engineering Society with a view to forming an affiliated society in the U.K. The meeting, held at the Hotel Russell on December 10th, set up a small working committee, comprising R. E. Cooke, J. C. G. Gilbert, J. Maunder, R. Baldock and N. Leevers, all members of the A.E.S. John Gilbert, who convened the meeting, has been assured of the financial support of some 20 audio manufacturers. Readers interested in this proposal may obtain further information from 10 Museum Street, London W.C.1. Letters should be marked "Audio Engineering Society".

Hospital computer system

The Department of Health & Social Security, the Birmingham Regional Hospital Board and International Computers Limited are co-operating in the development of a large hospital information system and communication network. The system will employ remote access terminals connected to a central system 4-50 computer and will be installed at the North Staffordshire Hospital Centre. Initially the equipment will handle out-patients' bookings and clinical records and will be followed by the development of similar facilities for in-patients. In addition to the computer, 12 video terminals and 4 teleprinters, will be installed in a new building in Stoke-on-Trent in April 1970. Further remote terminals will be added to the system as the project develops.

Video terminals located in the outpatient clinic areas will be used for making appointments, requesting tests, displaying test results, entering patients on hospital bed waiting lists, and also to book patients for examination in other clinics.

In addition summary clinical information on patients, such as diseases diagnosed, test results, operations performed and drugs prescribed, will be printed out by the computer for the doctor.

In the first instance video terminals will be installed in the admission offices of the Hospital Centre, the North Staffordshire Royal Infirmary and the City General Hospital. These terminals will be used for admission and bed allocation procedures.

The next stage will involve the extension of the system into selected wards of the two main hospitals by the installation of teletypewriter terminals at strategic points to serve groups of wards.

The terminals in wards will primarily be used to make requests and receive reports on investigations, to aid the prescription and administration of drugs and for putting patients on operating lists. They will also help to establish the existence and location of all records relating to a patient. In certain cases, for instance, the reporting of biochemical tests, the computer will detect and draw to the attention of the medical staff any abnormal results. A further use of ward teleprinters will be the recording of diagnoses.

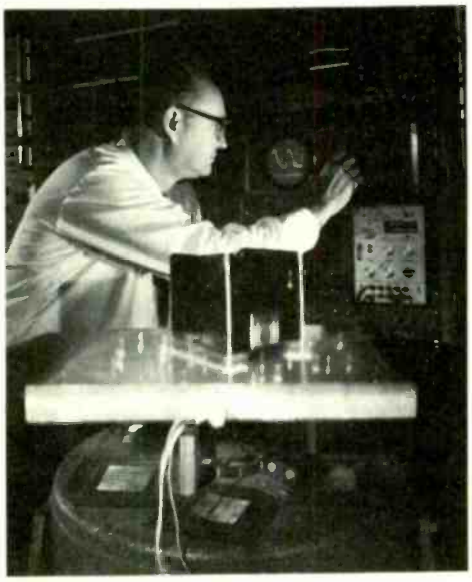
Detecting loose articles

Foreign particles left in equipment after manufacture can be detected with the aid of a device developed by the General Electric Company of U.S.A. The presence of particles that may be too small to be seen with the naked eye can be detected.

The equipment to be tested is placed on a standard vibration machine and a very sensitive listening device enables one to hear foreign particles bouncing.

Accelerometers mounted to the vibrating table feed signals into the electronic listening device so that unwanted sounds are cancelled.

The signals detected by the listening system can be monitored over a loudspeaker system or on an oscilloscope. It is asserted that different articles can be identified by the nature of the bounce or by their "sound signature" to use the jargon coined by G.E.



Showing the loose article detector in operation.

Racal expands

The £8.9M bid made by Racal Electronics for Controls and Communications has been favourably received. At the time of going to press a spokesman for Racal said that his company had succeeded in obtaining more than 50% of C and C's shares. Racal's offer follows the breakdown of talks between Plessey and C and C. Subsidiaries of C and C are Airmec, British Communications Corporation; Modern Aerials, Thermionic Products and Vectron Electronics.

British sensing equipment in HEOS-A

ESRO's highly eccentric orbit satellite (HEOS-A) which was successfully launched on December 5th, from the Kennedy Space Centre has an apogee of about 225,000km (two-thirds of the distance to the moon) and an orbital period of 4.5 days. Because of the vast distance from the earth during orbit it was necessary to employ two methods of attitude measurement to ensure that the satellite is aligned correctly to the earth. The first, for close-range alignment, depends on infrared sensors which use the earth's horizon as a reference. The second, for long-range alignment, uses a unique sensor to measure the reflection of sunlight from the face of the earth. A solar aspect sensor measures the attitude of sunlight striking the satellite enabling it to be aligned correctly with respect to the sun. The scientific mission of HEOS-A is to study interplanetary physics, particularly magnetic fields, cosmic radiation and solar winds outside of the earth's atmosphere. The attitude sensing and control system was designed by British Aircraft Corporation.

U.S.A. to have Pay-TV

America's Federal Communications Commission has recently authorized subscription television operations on a national scale, the rules governing this type of operation to become effective on June 12th, 1969. This announcement is in direct contrast to the state of affairs in this country. After the Government's decision to refuse the British Pay-TV experiment to expand the company was run-down as rapidly as possible, as reported in *Wireless World*, December 1968, page 444.

Canada's own satellite

Canada could have its own communications satellite by 1971 if proposals resulting from a study are accepted by the Department of Industry. The study was carried out under a six-month contract by the Northern Electric Company Ltd, with Canadair and the Hughes Aircraft Company as sub-contractors.

A mock-up of the proposed Canadian communications satellite.

The proposed six-channel satellite would be placed in a high synchronous orbit and would have a total capacity of 6,000 one-way voice circuits or six colour television channels. Primary power source would be formed by 18,780 solar cells. During times when the satellite is in eclipse power would be provided by a battery of nickel-cadmium cells.

Component Associations, more co-operation

Closer integration between the various trade associations concerned with active and passive components has been achieved since Sir Alan Dudley was appointed director of the Electric Components Board last year. In January, 1969, the Radio and Electronic Manufacturer's Association moved into premises at Mappin House, 4 Winsley Street, London, WIN ODT., where the British Radio Valve Manufacturers Association, the Electronic Valve and Semiconductor Manufacturers Association and the Electronic Components Board are already accommodated.

Although each Association will continue to deal separately with matters of specialist interest, matters concerning the electronic components industry as a whole will be handled by the Board.

Radio and space research report

In the recently published first triennial report of the Radio and Space Research Station (H.M.S.O. 7s 6d) some details are given of studies being carried out on investigating the mechanism of solar flares. It is thought that it may be possible to predict their occurrence. This would be of great value to operators of supersonic aircraft, such as the *Concorde*, who would be able to predetermine whether or not dangerous levels of radiation are likely to exist at high altitudes.

Studies of the physics of the ionosphere have continued using data obtained from the

Canadian satellites Alouette 1 and 2 received by telemetry at the Radio and Space Research Stations situated at Winkfield, Berks, and Singapore. Work done in this connection, derived from satellite drag data, has indicated that it is atmospheric winds at heights between 100 and 700km that are responsible for the many ionospheric anomalies.

More work has been done on relating meteorological data to the characteristics of u.h.f. signals propagated in the troposphere. This work will be extended with the aid of the Chilbolton Tracking station.

In anticipation of the commercial use of millimetre waves for communications investigations of their transmission characteristics have begun. The scintillation of signals arising from variations in atmospheric refractive index has been studied and measurements made of attenuation caused by rain on 2.9mm waves propagated over a path of 300m.

Research at 0.793mm has been concerned with generation and detection and absorption by water vapour.

The Station's experiment to measure high-frequency radio noise distribution over the world, started in May 1967 in Ariel 3, has progressed well. Noise intensities above major storm areas are in broad agreement with expectations and much new information has been obtained from areas not covered by ground stations.

Libyan television

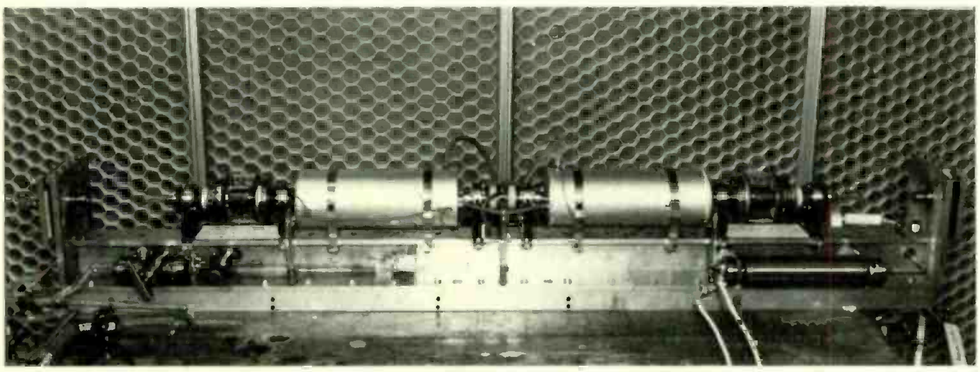
The television service of Libya was inaugurated on December 24th 1968 by the Crown Prince. The B.B.C., which was represented at the opening ceremony by a twelve-man outside broadcast team, has been associated with the project since 1964 and will have seventeen engineers seconded to the service for a year.

The service is operating on 625-line standard G* which differs very slightly from the U.K. standard. For colour the PAL system is employed and we understand that experimental colour broadcasts have already begun using a 16mm telecine machine as the source of programme material.

* Standard G: 625 lines; channel width 8MHz; vision bandwidth 5MHz; sound separation + 5.5MHz; vision modulation negative going; sound f.m.

Powerful ion laser

A powerful gas laser system which emits beams of the three primary colours has been developed by the Japanese Hitachi Company. Coherence and power of the beams are of sufficiently good quality to enable the system to be used to produce full-colour holograms or to project coloured images on to a screen. The system comprises a krypton laser which emits red light and an argon laser which emits blue and green light, a single blue or green line being selected by a mirror in the optical resonator. Outputs are of the order of 5-6W.



Gas laser developed by Hitachi of Japan emits beams of the three primary colours.

"WIRELESS WORLD" INDEX

The Index to Volume 74 (March-December 1968) is now available price 2s. 6d. (postage 4d.). Cloth binding cases with index cost 11s. 6d., including postage and packing. Our publishers will undertake the binding of readers' issues, the cost being 40s. per volume including binding case, index and return postage. Copies should be sent to Associated Iliffe Press Ltd., Binding Department, c/o 4 Iliffe Yard, 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 the Publishing Department, Dorset House, Stamford Street, London, S.E.1.

Colour TV in Sweden

When Sweden's colour television service starts in 1970 a major role will be played by a British equipment manufacturer. Twenty-three of the existing black and white v.h.f. television stations in Sweden incorporate Marconi transmitters and these will all be modified to enable them to transmit colour pictures as part of that country's first colour TV service.

DX listeners' award

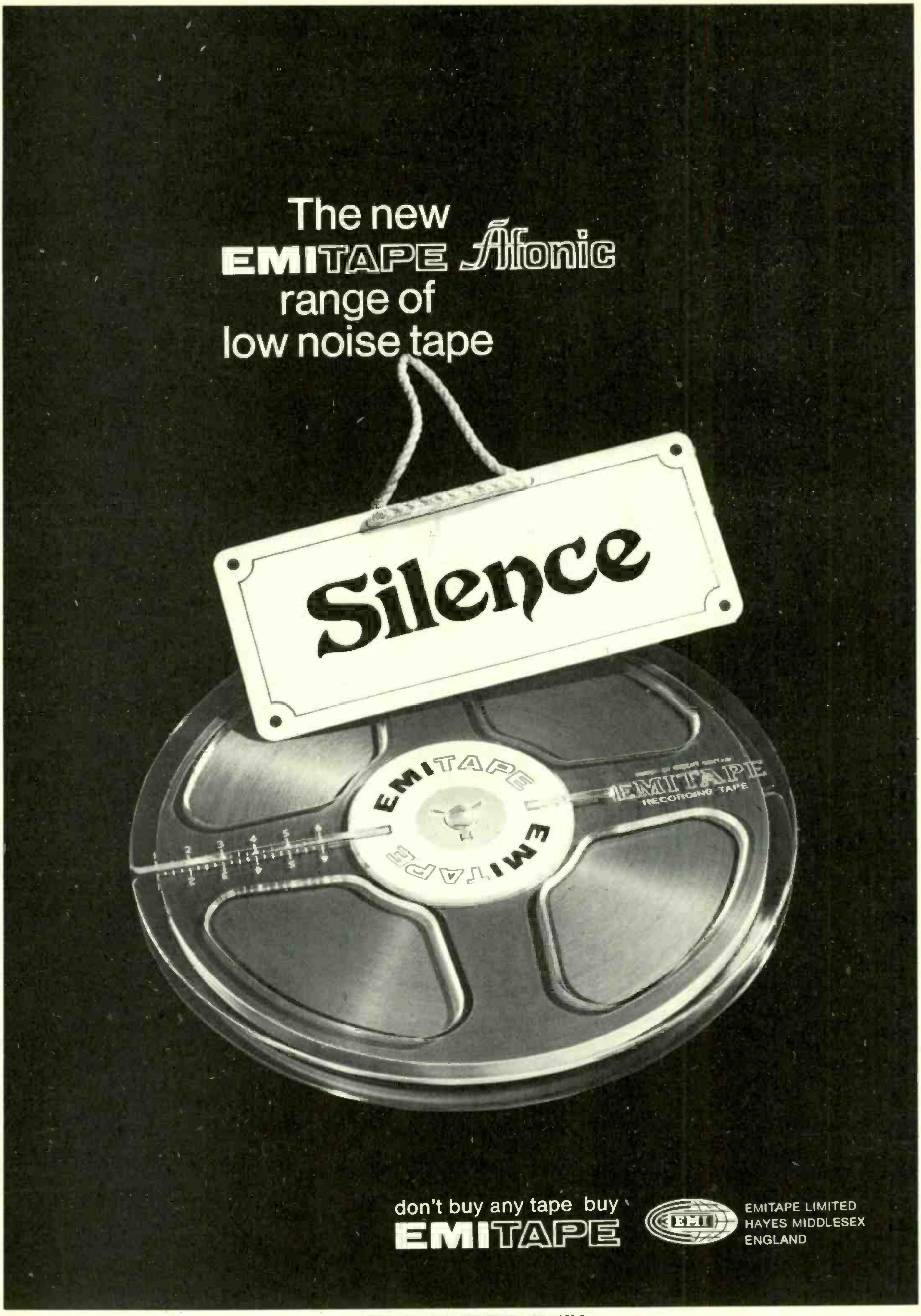
The B.B.C. is offering a certificate award (called World Radio Club Award) to listeners who correctly report on a number of B.B.C. transmissions received from different locations. It applies to one frequency schedule period only, from March 2nd to May 3rd. To qualify for the award, listeners must be members of the World Radio Club run by the B.B.C. and must give evidence of reception of three B.B.C. transmissions from each of the following areas: Great Britain and the Atlantic, east Mediterranean and Far Eastern relay stations. Membership of World Radio Club can be obtained by writing to B.B.C., Bush House, London W.C.2.

U.H.F. transmitters

The following table gives, alphabetically, B.B.C. and I.T.A. u.h.f. television stations with the channels allocated for the three proposed programmes. Those transmitters already in operation (to date BBC-2 only) are shown in heavy type. Relay stations are shown after the main station of the group. For extended coverage, further relay stations are, of course, planned. It is intended that individual BBC-1 and I.T.A. stations will "come on the air" simultaneously, using the 625-line standard, and they will transmit programmes in colour from the start. This list is provisional and the information it contains is subject to alteration.

	BBC-2	BBC-1	ITA
Angus (H)	63	57	60
BELMONT (H)	**28**	22	25
Bilsdale West Moor (H)	26	33	29
BLACK HILL (H)	**46**	40	43
Caradon Hill (H)	28	22	25
Craigkelly (H)	27	21	24
CRYSTAL PALACE (H)	**33**	26	23
Guildford (V)	**46**	40	43
Hemel Hempstead (V)	44	51	41
Hertford (V)	**64**	58	61
High Wycombe (V)	62	55	59
Reigate (V)	**63**	57	60
Tunbridge Wells (V)	**44**	51	41
DIVIS (H)	**27**	21	24
Larne (V)	45	39	49
DOVER (H)	**56**	50	66
DURRIS (H)	**28**	22	25
EMLEY MOOR (H)	**51**	44	47
Chesterfield (V)	26	33	23
Halifax (V)	27	21	24
Keighley (V)	64	58	61
Sheffield (V)	27	21	24
Hannington (H)	45	39	42
Heathfield (H)	52	49	64
Newhaven (V)	45	39	—
Limavady (H)	62	55	59
Londonderry (V)	44	51	41
LLANDDONA (H)	**63**	57	60
Betws-y-Coed (V)	27	21	24
Mendip (H)	64	58	61
Bath (V)	28	22	25
Bristol (V)	46	40	43
West Sussex (H)	55	61	58
Moel-y-Parc (H)	45	52	49
OXFORD (H)	**63**	57	60
PONTOP PIKE (H)	**64**	58	61
Fenham (V)	27	21	24
Newton (V)	26	33	—
Weardale (V)	44	51	41
ROWRIDGE (H)	**24**	31	27
Brighton (V)	63	57	60
Salisbury (V)	**63**	57	60
Ventnor (V)	**45**	39	49
Sandy Heath (H)	27	21	24
SUDBURY (H)	**44**	51	41
SUTTON COLDFIELD (H)	**40**	46	43
Brierley Hill (V)	**63**	57	60
Bromsgrove (V)	**27**	21	24
Fenton (V)	27	21	—
Kidderminster (V)	**64**	58	61
Lark Stoke (V)	**26**	33	23
Malvern (V)	62	56	66
TACOLNESTON (H)	**55**	62	59
Aldeburgh (V)	**26**	33	23
West Runton (V)	**26**	33	—
WALTHAM (H)	**64**	58	61
WENVOE (H)	**51**	44	41
Aberdare (V)	**27**	21	24
Kilvey Hill (V)	**26**	33	23
Merthyr Tydfil (V)	28	22	25
Mynydd Machen (V)	26	33	23
Pontypridd (V)	**28**	22	25
Rhondda (V)	**26**	33	23
WINTER HILL (H)	**62**	55	59
Darwen (V)	45	39	49
Haslingden (V)	26	33	23
Pendle Forest (V)	28	22	25
Saddleworth (V)	45	52	49
Skipton (V)	**45**	39	49
Todmorden (V)	45	39	49

H = Horizontal polarization
V = Vertical polarization



WW—107 FOR FURTHER DETAILS

transient conditions. These outputs operate the printer or other mechanism, and at the same time set stage C, which then is set again on every cycle, thus inhibiting the striking of, say, B. As soon as the glide finishes this inhibition is automatically removed and normal operation resumed. The other actions can be followed easily.

Recognition of words

The main grouper (Fig. 4) discussed above can, by itself, and without the VC-L circuits act as a recogniser for words carefully chosen to match its capabilities. For instance consider the words of command shown in Table 5, where they have been broken down into their basic constituents. At first sight it might appear a reasonably satisfactory selection, but closer inspection shows some defects. For instance, apart from the beginnings, 'not' and 'right' are identical and both 'r' and 'n' tend to be somewhat ill-defined phonemes; moreover if an attempt were made to add 'left' as another control action, the difficulties would be increased to an impossible extent. The solution here would be to replace 'right' and 'left' by, for instance, 'starboard' and 'port'. Alternatively manufactured words of well defined photenic content could be used. Table 6 lists suitable phonemes for constructing strong words from.

However, with the equipment in the form described, values for A, B, C, and G are available, and the next step is to use them. Thus instead of saying that a phoneme was a vowel, it could be specified as a vowel-A1; or in further detail as VC-V: A_1: B_1: C_3—thus identifying itself as 'a' from Table 1 in Part 1. This approach will be considered in more detail below, but meanwhile the digits 0-9 may be examined using the main groupings and A values only (Table 7). It will be seen that separation appears to be quite good, except for '2' and '3', which can however be very easily separated on the value of B. However the position is not as simple as this, because the weak phonemes, show in brackets, may or may not be detected. Thus '5' can easily be confused with '9', and perhaps also with '1'. However, in spite of troubles such as these, a recogniser for the spoken digits can be built along these lines and will give some 90% correct responses for well enunciated speech.

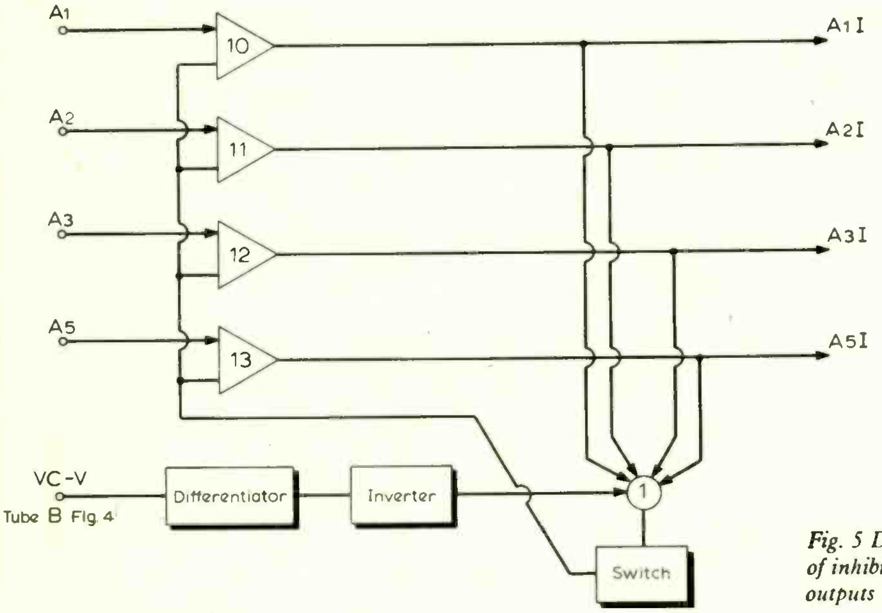


Fig. 5 Derivation of inhibited A outputs

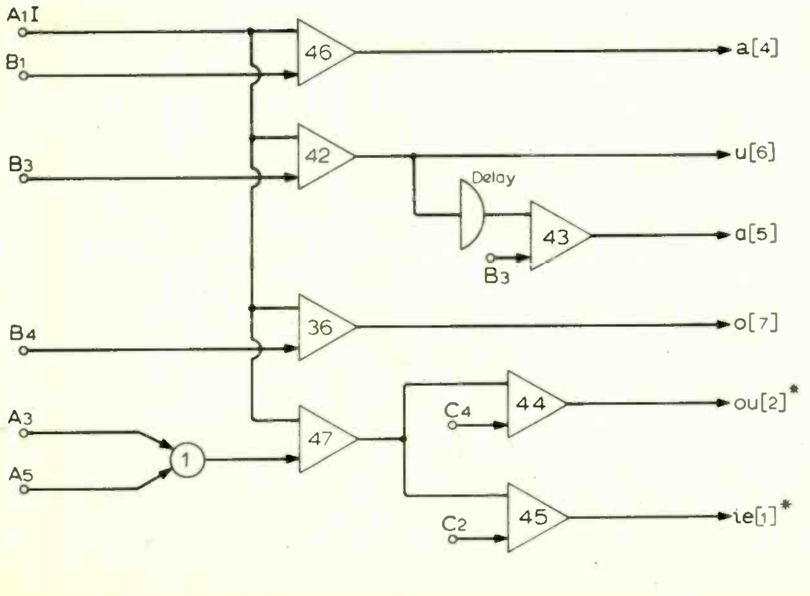


Fig. 6 Vowel and diphthong coding: group A1

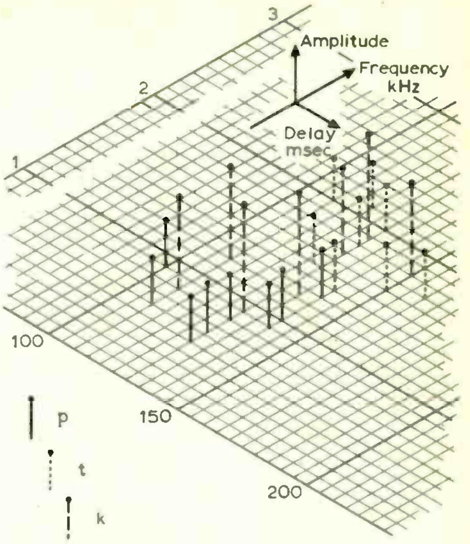


Fig. 7 Delay, burst frequency, and amplitude for unvoiced stops

It is perhaps unfortunate that it seems to be a feature of languages generally that opposites are very often phonetically or actually similar. Thus is Latin 'altus' means both high and low. In English we have 'left' and 'right' which are phonetically close, or 'starboard' and 'larboard' which are even closer. The tendency is however for separation to occur: thus 'larboard' has become 'port' and 'yea' and 'nay' have become 'yes' and 'no', and later 'affirmative' or 'negative'.

Recognition of phrases

In a machine for identifying words, the gaps between the words are marked and are unlikely to be confused with other gaps, as those in stopped utterances. Moreover, if a single word is missed, the machine can demand an immediate repetition. In a machine designed to recognise phrases, however, doubtful gaps and missed phonemes can very quickly ruin the most perfect identification scheme. Under these conditions the machine is best arranged to operate as the brain is believed to—that is to compare the incoming message with the most likely of the repetoire of possible messages, on the basis of what has gone before, and to mark off points of resemblance as they occur. The problem is made more difficult by the inclusion in any worthwhile practical situation (such as air traffic control) of variable data, the position of which in the message is known, but not the content, and which must be detected accurately for the message to be effective. There are clearly many more problems here than those of phonetics only.

Recognition of phonemes

The recognition of phonemes is a useful study in itself, for it could lead to a machine producing a phonetic script from a spoken input, and possibly ultimately to an orthographically correct script. It also has other uses, such as determining which phonemes can be most reliably detected. Using the coder of Fig. 1 and the main grouper of Fig. 4 to supply inputs as before, about half the phonemes can be identified with accuracies of 80% or above in carefully enunciated connected speech, and of the remaining phonemes many of the errors are near misses. So far the resulting script has proved barely intelligible if the subject matter is unknown, but moderately intelligible if the subject is familiar. Much further work is needed before a commercial machine can be made, but the remainder of the article will be devoted to a description of the method used in one system. The same nomenclature as that used above is employed.

The first piece of additional equipment is a circuit designed to select the appropriate A value at the start of a vowel or diphthong. In Fig. 5, as soon as bistable B (Fig. 4) is set, the four bistables 10–13 (Fig. 5) are primed, and whichever output from the averaging A stages is effective fires the appropriate bistable which is reset only on the resetting of bistable B. Once one of the group is set, all are inhibited. The output from this group are labelled A_1I, A_2I, etc.

As an example of the subsequent processing the coding for Group A_1 vowels and diphthongs (Fig. 6) may be considered. All the bistables shown are reset when the printer or other display apparatus receives a command to print. All the outlets are scanned in the order given in square brackets after the symbol, and the first one found energized is printed, the remainder being reset. This enables subsequent characters to be selected whilst a relatively slow display is acting. The command to print is given whenever the main grouper (Fig. 4) changes state, or on the receipt of a valid ending to a diphthong, indicated by an asterisk(*) on the diagram. In the latter case the print command on the next change of state of the main grouper is inhibited. In Fig. 6, the setting of A_1I (Fig. 5) primes bistables 46, 42, 36, and 47, which can thereafter be set by B_1, B_3, B_4, and A_3 or A_5 (uninhibited). Assume that B_1 is firing: then 46 will set—this represents 'a' or the first stage of the diphthong 'ie'. If the former condition, then 'a' will be printed when the main grouper changes state. If the input is the diphthong, though, as soon as the first formant period increases to energize A_3, then 44 and 45 will be primed, and in the case quoted, 45 will set, thus energizing the 'ie' print line, and immediately executing the print command, as described above.

Similar groups of bistable elements deal with the other vowel groups. Fricatives are handled similarly. Stops require a more complex arrangement as several features need to be taken into consideration. As a fully satisfactory coding arrangement has not yet been found, a full description will not be given. The factors involved are:

(a) The amplitude of the fricative burst formed on the release of pressure. This is greatest for 'k'.
(b) The high frequency content of the burst.
(c) The duration of the silent period.

Fig. 7 shows the relationship between the length of silent period and the peak high frequency (C channel) response for the voiced and unvoiced stops. Using the additional parameter of high energy, 'k' can be separated from 't' and 'p', which can be separated between themselves by high frequency level. With the voiced stops ('b', 'd', and 'g') however, separation is much more difficult, and is perhaps impossible to achieve except on a syllabic basis which would take account of the context.

In conclusion it may be said that the field of speech recognition is only just beginning to be explored. It is of the greatest interest and is not so complicated that an individual worker cannot make useful progress. What are needed at present are more good ideas to make for simpler and more direct precoding. The remaining operations are then perhaps better done on a general purpose computer.

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Announcements

"Advances in microwave applications of semiconductors" is the title of a course of ten lectures to be given on Wednesday afternoons commencing January 15th at the Borough Polytechnic, Borough Road, London S.E.1. There is also a course of nine lectures entitled "Transistors in communication circuits" to be held on Tuesday evenings commencing January 21st. Fees are 3gns and £2 10s respectively.

A course of eight laboratory sessions for students who have attended a course on transistor theory and wish to gain practical experience will be held at **Hendon College of Technology,** The Burroughs, Hendon, London N.W.4, on Thursday evenings commencing February 27th. There is also a nine-lecture course on hi-fi sound reproduction on Wednesday evenings from January 29th.

The Electronics Division of the I.E.E. is organizing a **vacation school on aerials** to be held at the University of Birmingham from July 7th to 19th.

A lecture course entitled **"Semiconductor devices and circuit techniques"** will be held at Bournemouth College of Technology commencing February 4th for eight weeks.

Show cancelled. The Electronic Production Equipment Exhibition arranged for March 10th-14th at Earls Court (see list of 1969 Conferences and Exhibitions in our January issue) will not now be held.

Welwyn-Berco agreement. British Electric Resistance Company and Welwyn Electric have agreed to exchange know-how and commercial interests in the areas of fixed and variable power vitreous enamelled units. By 1st April this year Welwyn will stop making rheostats (Berco taking responsibility for any of Welwyn's outstanding commitments) and Berco will stop manufacturing fixed vitreous enamelled resistors (Welwyn taking over their outstanding commitments).

The Westinghouse Electric International Company of New York, and Ferranti Ltd., jointly announced a **technical exchange agreement** involving Westinghouse electro optical systems and Ferranti air-to-surface radar systems. For the past three years both companies have been working on avionics and navigation systems for the Phantom F-4 aircraft purchased by the United Kingdom.

Audio equipment hire. Carston Electronics have formed a new division to provide long- or short-term hire for a range of tape recorders, microphones, and other studio sound equipment as well as audio test equipment. Hire periods may be from a week up to three years or longer and equipment will be maintained throughout the hire period at no extra charge. Carston Electronics Ltd., 71 Oakley Road, Chinnor, Oxon (Tel. Kingston Blount 8561).

SGS-Fairchild have changed the name of the company to "SGS (United Kingdom) Ltd".

Honeywell Controls Ltd of Brentford, Middlesex, have changed the name of the company to **Honeywell Ltd.**

R.E.C.M.F. move. The Radio & Electronic Component Manufacturers' Federation have moved from 6 Hanover Street, W.1, to Mappin House, 4 Winsley Street, Oxford Street, London, W1N ODT. (Tel: 01-580 8562.)

The address of Mullard's Order Department (Distributor Sales), is now New Road, Mitcham, Surrey, CR4 4SR. (Tel: 01-648 3471.)

The southern sales and export offices of **F. C. Robinson & Partners Ltd** are now at Bilton House, Uxbridge Road, London W.5. (Tel: 01-579 2041.)

E.M.I. Ltd, have completed an agreement with **B. & F. Instruments Inc.,** an electronic instrument company of Philadelphia, U.S.A, in which they are taking an equity investment, with the option to acquire a majority interest, to direct the marketing of their own instrument range, particularly the products of their subsidiary S.D. Laboratories.

Guest Electronics Ltd., Nicholas House, Brigstock Road, Thornton Heath, Surrey CR4 7JA, have acquired the exclusive marketing rights within the U.K. of **Luft Instruments Inc.,** U.S.A.

Rastra Electronics Ltd., 275 King Street, Hammersmith, London W.6, have been appointed official agents for part of the **Redpoint** range of small heat sinks.

A contract valued at £125,349 has been placed with Marconi Instruments, for the supply of 127 **signal generators,** Type TF 2002AS, by the Canadian Department of Transport. This instrument covers the carrier frequency range 10kHz to 72 MHz with provision for a.m. up to 100% at modulating frequencies from 20Hz to 20kHz.

Orders worth over £½ million have been placed by the G.P.O. with S.T.C's Microwave and Line Division, Basildon, for 6GHz equipment to provide up to seven **broadband radio links** between Carlisle and Belfast, Carlisle and Manchester, and Leeds and Newcastle.

The Indonesian Government have placed an order valued at £55,000 with Racal for a large quantity of the **"Squadcal" Manpack** h.f. transmitter-receiver together with other mobile radio and ancillary equipment.

The Industrial Products Group of British Aircraft Corporation's Guided Weapons Division have been awarded a **product on contract** valued at almost £200,000 by the G.P.O. The contract is for semi-automatic test set equipment, known as TRT 116.

Labgear Ltd, a member of the Pye of Cambridge group, have received an order valued at £60,000 from the Iraq mobile police force for **s.s.b. packset transceivers.**

Circuit Ideas

Readers' tricks and trifles

Power supply with overload trip/current limiter

This simple module with a built-in overload trip was designed as a power supply for a 20-W amplifier. The user has a choice, either of a latching overload trip, in which the power is disconnected from the load a microsecond or so after the current drain exceeds a certain pre-set value, or, alternatively, by substituting a high-voltage bipolar transistor for the low-current thyristor, the circuit behaves as a simple current limiter. In both cases, the range with the component values shown is from 1 amp to about 5 amps. To reset the latch version, the mains supply is disconnected for not less than 8 seconds, to allow time for the charge in the smoothing capacitors to drain away, and for the current through the thyristor to fall below the "hold" level. (If a shorter reset time is required, the circuit can be modified for pulse reset by the addition of a capacitor, a resistor and a press-to-make switch. These components are shown within the dotted lines, and marked Reset 2.) Overload indication is provided by a low-current lamp.

REGINALD WILLIAMSON,
Norwich.

Rumble and acoustic-feedback filter for stereo pickup

On some gramophone equipment acoustic feedback and rumble occur at frequencies below 100Hz on stereo, but not on true mono. Rumble and low-frequency feedback are very often vertical and therefore the output from the two channels of the pickup are in anti-phase. If added together as in mono there is no output and therefore no rumble etc. As low frequencies do not contribute much to the stereo effect, it would be useful to have a

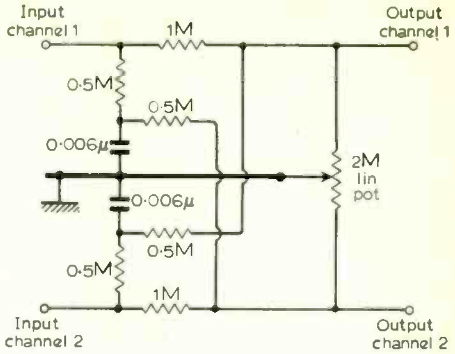


Fig.1. Circuit for rumble suppression.

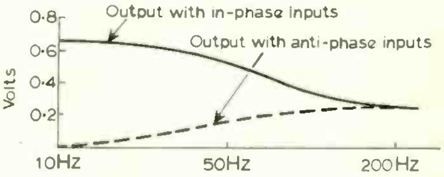
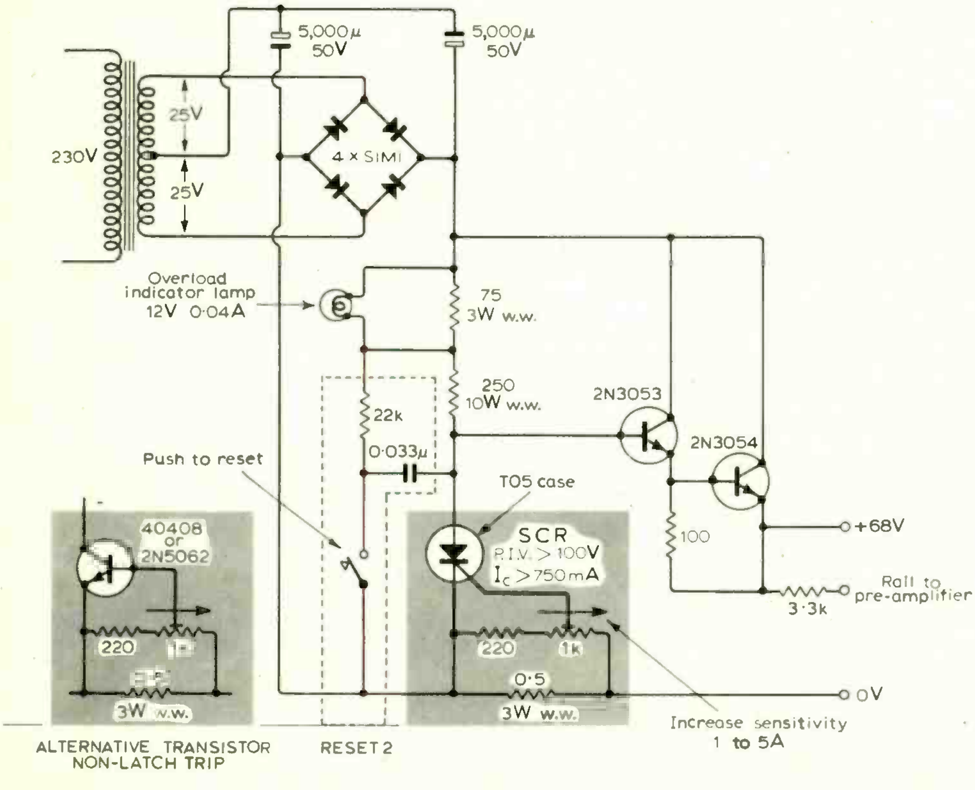


Fig.2. Output voltage with respect to frequency for 1V signal level to each channel.

circuit which effectively gives mono at low frequencies and allows for signal separation at frequencies above say 200Hz.

The circuit given (Fig.1) allows for such action and also boosts the bass frequencies. The 2MΩ potentiometer across the two outputs allows balance to be controlled. The main filtering action of the circuit is slightly disturbed when the balance control is off-centre. The potentiometer can be replaced by fixed resistors if the two inputs are equal. The effect of the filter is shown in Fig. 2.

DAVID RALPH,
Northfleet,
Kent.

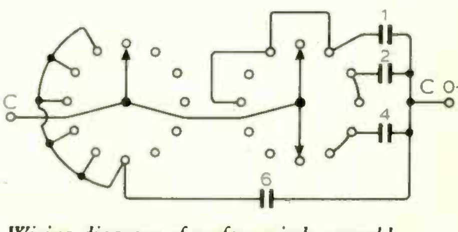


Power supply with overload trip or current limiter.

Switching decades of capacitance

In order to switch decades of capacitance with a single control it might seem that the alternatives are either a single wafer specially made, or a rather bulky 4-wafer switch (Radio Lab. Handbook 7th edition, pp.188-190). However, the following solution presented itself using two dissimilar Oak wafers. The 2-pole 5-way wafer repeats its pattern twice in a revolution. Similar results can be obtained using a 3-pole 3-way switch to repeat the 0, 1, 2, 3 pattern (switching 1 and 2 units) and a 1-pole 11-way switch to bring in 4 and 8 units as required.

R. MASSEY,
Planet Instrument Co. Ltd.,
Leeds.



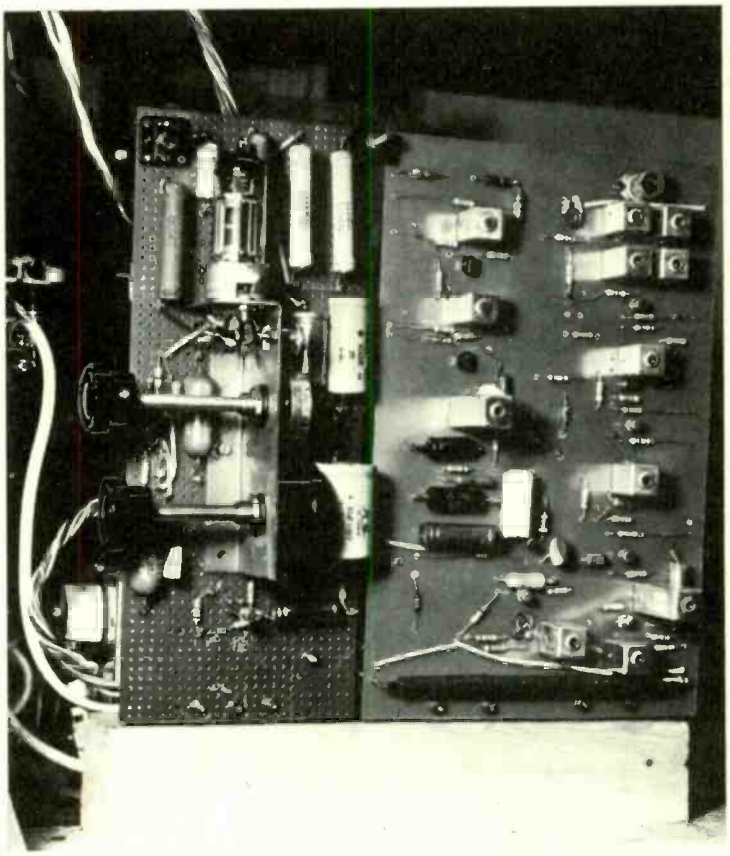
Wiring diagram of wafer-switch assembly.

Wireless World Colour Television Receiver

9. Miscellaneous

Except for a few matters, which will be dealt with in this article, details of the receiver have now been given with but one important omission, the colour decoding circuits. To most people these circuits are probably the most interesting of all for there is nothing like them in an ordinary monochrome receiver. The rest of the apparatus bears a superficial likeness to a black-and-white set, the differences being chiefly those dictated by the use of a colour tube.

It was pointed out at the beginning of these articles that the first essential to the attainment of a good colour picture is a good monochrome one. It is quite hopeless to attempt to get the colour circuits working until the receiver, as so far described, is working well and reliably. The picture obtained should compare well with that given by an ordinary black-and-white set. In a comparison between the two, the monochrome picture of the colour set will normally have a somewhat lower maximum brightness and the horizontal definition may not be quite as good as that of the best black-and-white sets, but may be better than that of the poorer ones. In addition, there may be some colour fringing towards the corners of the picture, due to the impossibility of obtaining perfect convergence.



This photograph shows the video and i.f. amplifier boards mounted side by side. Both are hinged for ready access to their other sides and also to permit the convergence magnets to be reached from the front.

Delay line

So far no details have been given of the 0.6μsec delay line in the luminance channel which is shown in Fig. 1, Part 7. The purpose of this is to equalize the transit times of the monochrome and colour components of the complete signal. What may be variously termed the luminance signal, the Y signal, or the monochrome signal passes through equipment with an overall bandwidth of some 4.5MHz. The chrominance components are picked out of the first video stage and pass to the tube through a separate chrominance channel which has a bandwidth of about 1.2MHz only. Because of this narrower bandwidth, the chrominance components of the signal take longer to pass through the circuits and reach the tube than do the luminance components. Therefore, a delay line must be inserted in the luminance amplifier to make up for the difference in transit times. Without it, the colour would appear on the tube displaced to the right relative to the picture detail.

Since it is included in the i.f. unit, it would be logical to deal with the construction of the line at this point. However, it is not necessary for a good monochrome picture, and we are regarding it as a special colour part, and shall deal with it in the colour section of these articles.

So far little or nothing has been said about grey-scale adjustments. These are important for a good colour picture; they are also important for a good monochrome picture, but the effect of poor adjustment is usually less noticeable.

We normally think of grey as a kind of colour in its own right. In reality, however, it is not; it is merely white of a low brightness. This is easily seen if we consider a normal monochrome tube and gradually increase the grid bias so that a blank raster passes from peak white to black through all depths of grey. There is clearly no change of colour involved (except possibly and undesirably for small changes in the spectral efficiency of the phosphor with excitation). This same result is required with a colour tube, but here white is obtained by combining the effect of three guns exciting red, green, and blue phosphor dots on the screen.

The characteristics of the three guns are unlikely to be identical nor are the relative efficiencies of the three phosphors. As a result, if adjustments are made to produce white at maximum brightness then as the tube bias is increased to give grey the balance between the three colour components may alter and give a colour cast to the grey. Typically, the grey may become brownish, but it might equally well become greenish or bluish. The result on a colour picture, of course, is to make the hue dependent on brightness.

There are five controls which affect grey-scale tracking.

These are the three potentiometers R_{17}, R_{18} and R_{19} (Fig. 1, Part 5) mounted in the convergence unit which control the first-anode voltages of the three guns, and the two potentiometers R_1 and R_2 (Fig. 2, Part 2) which control the signal drive to the green and blue cathodes. The first three are adjusted to give a pure grey at a very low brightness level; the second two are then adjusted for a pure white at maximum brightness.

A signal is needed for proper adjustment. If possible this should be from a colour signal generator which provides a set of standard colour bars. In monochrome these reproduce as a set of vertical bars varying in steps from black to white. These bars are broadcast by BBC-2 during the trade test transmissions only and have the drawback that they are not always there when one wants them or for as long as one wants. There is also a grey scale in the Test Card D which is also broadcast and more frequently than the colour bars.

First of all set the brightness and contrast controls so that all steps of the grey scale are clearly visible, but without defocusing on peak white. The red anode voltage control R_{17} should normally be set at little below maximum. Then adjust the green and blue controls R_{18} and R_{19} for a pure grey in the darkest tone value for which changes of colour can be observed. If it happens that either of these comes to its maximum setting, turn down the red control a bit and start again.

Having done this leave these controls alone and adjust R_1 and R_2 on the tube base for a pure white on the brightest tone step. The proper white is one which is much less blue than that of the ordinary monochrome tube, one which may appear brownish by comparison but which should not really be brownish at all.

Provided that the anode voltages are adjusted first, adjustment of the drive to the cathodes does not affect the first set of adjustments.

These adjustments provide two-point tracking and some errors may still exist away from these points. These are quite unimportant at very low brightness levels, for the eye there loses its sensitivity to colour, and levels above peak white should never occur. If examination of the grey scale between the levels used for adjustment of the grey scale shows any appreciable colouration, it probably means that the characteristics of the guns of that particular tube differ from each other more than usual. There is not much that can be done about it, but it may prove better to adopt one grey tone brighter for adjustments of the anode voltages. This will reduce the error between the tracking points at the expense of increasing it on the darker tones. As the eye is there less sensitive the net result may be better.

The drive potentiometers R_1 and R_2 (Fig. 2, Part 2) have capacitors C_1 and C_2 associated with them. These are for the purpose of equalizing the frequency responses of the green and blue drives with the red. If they are not properly adjusted some slight colouration of a vertical edge may appear because the step responses of the three cathode inputs will not be alike. For this to be observable it is, of course, necessary that the vertical edge be in a part of the picture at which the convergence is perfect.

In practice, the effect of these capacitors is quite small and on an ordinary moving picture may not be detectable.

A.F. amplifier

Turning now to the sound channel, as so far described this terminates in an audio output from a ratio detector in the i.f. unit. An a.f. amplifier and loudspeaker are naturally required additionally. Compared with colour television this is very much bread and butter stuff! It seems unnecessary to give much detail but a suitable circuit is shown in Fig. 1. This can be tucked away in any convenient place, but the loudspeaker magnet must, of course, be kept away from the tube.

In view of past correspondence in *Wireless World* many readers will doubtless deplore the fact that so little attention is being paid to the sound side and would expect that, at the least, provision would be made for feeding an external high-quality sound system. This is, however, a very difficult thing to do and, because we feel that there is this expectation, we shall go into the matter in some detail.

The difficulty arises because, in common with almost all modern television receivers, colour or not, no isolating mains transformer is used. Series-connected heaters must be used for the valves because there are no suitable types available for parallel connection. This in itself does not preclude the use of a mains transformer, of course, but the heater supply is 72 watts. The h.t. supply is of the order of 200 watts, so that the transformer would have a rating approaching 300 watts. This would not be cheap and it would be quite heavy. Much more important, however, is the fact that it would not be at all easy to dispose without its stray field affecting the picture tube. This can be very troublesome with a black-and-white tube; it will obviously be more so with a colour tube, where screening against the effect of the earth's magnetic field is needed!

When there is no isolating transformer the circuits of the receiver are live to the mains. This at once raises difficulties in connecting an external audio amplifier. A high-quality audio amplifier will normally have a mains transformer and so be itself isolated from the mains. It is, therefore, really only practicable to connect an audio output from a set which is not

Line-Scan Transformer

Terminals	L (mH)	Q	R (Ω)
3–4	5.6	50	0.3
4–5	1.42	41.5	0.25
6–7	12.5	64	0.6
8–9	3.4	44	0.8
9–10	265	49	6.5
10–13	45.1	68	3.2
13–12	69	64	4
3–5	12.5	68	0.8
3–7 (5 & 6 joined)	50	74	1.4
6–12 (7 & 8 joined)	1350	60	14.9

Inductance and Q measurements at 10kHz. Resistance measurements with model 8 Avometer on ÷ 100 range.

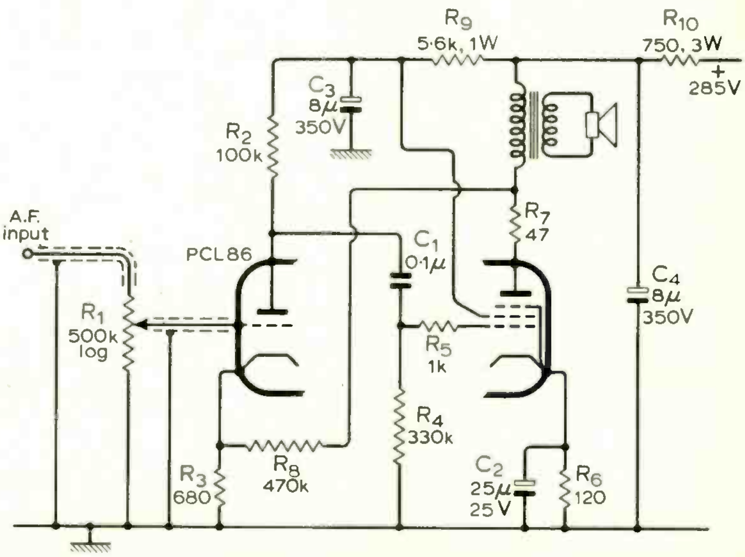


Fig. 1. Circuit diagram of simple a.f. amplifier. Screened leads for the triode grid and input connections are essential. The transformer ratio must be chosen to give a load of 5.6 k Ω on the pentode

so isolated via a double-wound audio transformer which is insulated to withstand the full mains voltage.

We have not investigated this, but it is quite likely that there is no suitable component commercially available. In any case, the purist will object to the use of an a.f. transformer in high-quality equipment; we shall not argue whether this is a valid objection.

The use of isolating capacitors will doubtless be suggested. This is not so easy as it sounds because they must pass 50Hz from the quality point of view and if they do they will hardly be isolating at mains frequency! In addition, there would almost certainly be serious hum problems.

We can, in fact, think of only one way in which an external quality amplifier can be used safely and successfully with a television receiver which is live to the mains. This is to take the output, not at audio, but at the sound i.f. To do this, the sound i.f. amplifier would have to be split at its middle, only the first stage remaining in the receiver, with the second stage and the ratio detector forming an external unit which is mounted close to the a.f. amplifier and which is fed either from this amplifier's h.t. supply or from its own separate supply through a mains transformer.

The problem of insulation is now transferred to an r.f. transformer at 6MHz and is relatively easy. In fact, the transformer installation could be supplemented by capacitors since these need now pass only radio-frequency.

These are our ideas on the subject. Quite a lot of development would be needed, no doubt, to produce a practicable scheme and we do not intend to do this unless there is a considerable demand for it. This is because we do not think that the use of a separate sound system is usually right for television. We agree entirely that it is desirable to have high-quality sound, but there is a factor which most critics of television sound quality overlook. This is the fact that for natural results the sound must appear to originate at the picture. If the sound comes from a loudspeaker which is separated some distance from the picture the effect is quite unpleasant. In our view high-quality sound from a loudspeaker which is appreciably distant from the picture is far less pleasing than ordinary television sound which seems to come straight from the picture.

It is normally impracticable to build high-quality audio equipment into a television set; the size of the loudspeaker alone prevents that. The nearest that one can get to it is to have the loudspeaker mounted behind the television set to minimize the effect of its displacement from the set. In a normal living room this may well be impracticable.

Some measurements

Before concluding this article, we give some miscellaneous notes on the complete equipment as so far described. First, we give some measurements made on a Marconi Instruments Universal Bridge type TF868B at 10kHz for inductance and Q between various terminals of the line output transformer. These refer to a particular sample but they at least give an indication of the order of magnitude which may be useful if one suspects a defective component. Short-circuited turns, for instance, would reduce inductance and particularly Q, but because of the tight coupling between the sections, probably all the figures would be considerably affected. Such a fault could happen but is not likely. More probable is a high-voltage flash over between parts of the windings which does not show up at all on such a test but which makes itself very evident in operation.

It can happen that the anode of the PL509 gets red hot. This is a sign of greatly excessive anode dissipation and the valve will be damaged if it is operated for any length of time in this condition. It means that the anode current and/or voltage is much too high. One cause may be the wrong grid drive waveform. It should be a negative pulse of some 200V amplitude and some 20μsec duration with a fairly slow exponential recovery.

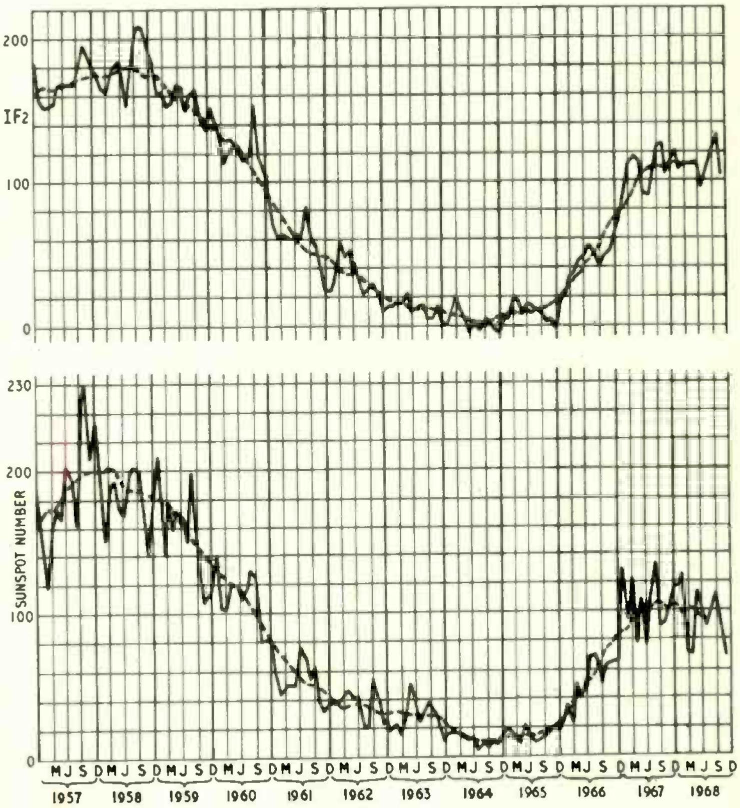
The dissipation will be too great if for any reason the scan amplitude is much too small; in this case the back e.m.f. on the anode will be too small, so that the anode voltage during the scan will be too high.

Measurements on the line output stage are difficult because there are so few earthy points. Referring to Fig. 1, Part 3, it is useful to disconnect C_{19} and R_{26} from the chassis, together with which ever of L_1 or terminal 6 of the transformer is normally connected to the chassis. Connect all three to chassis through a 1Ω resistor. This should be wire-wound and adjusted to 1Ω within 1%. If desired it can be included permanently. The total mean cathode current can be checked by measuring the voltage across this resistor and is normally 390mA. The waveform can be checked with an oscilloscope and the peak cathode current measured; this should be 880mA.

Some indication of the deflector-coil current can be obtained by connecting a 1Ω resistor between terminal 5 and chassis, the line convergence circuit being disconnected. An oscilloscope connected across it indicates the current in the transformer, which is not necessarily exactly that in the deflector coils, but the two are not very different.

In the field timebase it has been found desirable to connect a capacitor of 0.01μF between chassis and the junction of R_{13} with the output transformer primary. This reduces the line-frequency voltages fed into this circuit and improves interlacing.

Point-to-Point Review (see opposite)



Monthly figures and smoothed values of the ionosphere index (IF_2) and of the number of sunspots for the past 12 years.

Point-to-Point Review, 1968

by David Wilkinson, B.Sc., M.I.E.E.*

On the whole, 1968 was a good year for h.f. radio communications. Solar activity was sufficient to ensure maximum usable frequencies (MUFs) high enough for all practical purposes and yet conditions remained fairly stable. The efficiency of most h.f. circuits remained good, a monthly average commercial time of 99.1% being maintained on three representative circuits received in the U.K.

For a year of peak solar activity, however, 1968 was remarkably uneventful, due to comparatively low values of sunspot number and ionospheric index (IF2). There seems to be some justification in relating the present solar cycle to that of 1878/1882 (minimum/maximum), both of which have been very quiet and followed by a maximum of enhanced activity.

In order to align their figures with those of Zurich Observatory, the Royal Observatory, Greenwich, twice adjusted their sunspot 'k' factor; from 0.8 to 0.7 in September 1967 and from 0.7 to 0.75 in November 1968. (The Zurich sunspot number is given by $k(f + 10g)$, where g is the number of sunspot groups and f is the number of spots within those groups. k is a factor to allow for variations between observers and telescopes.) These alterations have not been taken into consideration when calculating smoothed values, which has resulted in the peak of solar activity being slightly masked and offset. They do account, however, for the apparent drop in the Greenwich provisional monthly mean sunspot number for the first eleven months of the year from 103.2 in 1967 to 94.8 in 1968. The peak of solar activity is represented more accurately by the smoothed IF2 curve† which indicates that the maximum probably occurred early in 1968. It is interesting to note from the latest figures available at the time of writing, however, that a second upsurge took place during more recent months, resulting in a plateau effect from the end of 1967 to June 1968.

Forty-five sunspot groups of area greater than 500 millionths of the visible solar hemisphere were reported. Seven were over 1000 millionths, the largest of which grew to 3100 millionths (approximately 3600 million square miles) before splitting in two. It was the largest group since 1947, but caused only partial Dellinger fade-outs and little magnetic disturbance during its passage from June 24th to July 6th. One of the most active sunspots was only 400 millionths in area, flares from which resulted in several Dellinger fade-outs and a magnetic disturbance from October 29th to November 4th, which was more severe than any since May 1967.

Dellinger fade-outs totalled 27 and were evenly distributed throughout the year although it is worth noting that none occurred during March, April or May.

Magnetic activity remained at a comparatively low level during the year, the monthly mean "C" value of readings recorded every three hours at Hartland, Devon, being 0.75, which represents a small increase on the 1967 figure of 0.62. The activity was fairly evenly spread and, apart from the above-mentioned storm, those magnetic disturbances which did occur were not severe and had little effect on h.f. circuit performance.

Satellite communications

There was considerable activity in the field of satellite communications during the year. The first of the Intelsat III satellites was scheduled to be put into orbit on September 18th but, due to a launcher failure, the spacecraft had to be destroyed a few minutes after launch. The subsequent enquiry disclosed that one of the rate gyros on the launch vehicle had failed; there was every reason to expect that the Intelsat III spacecraft was itself perfectly satisfactory. It was fortunately possible to provide coverage of the Mexico Olympic games by employing the NASA experimental satellite ATS III. (The replacement for Intelsat III was successfully launched over the Atlantic Ocean on December 18th). It is intended that additional satellites be launched in 1969, to cover the Pacific and Indian Oceans and also a second over the Atlantic, to cater for the rapidly increasing traffic.

In September, the contract for the Intelsat IV satellites was placed with the Hughes Aircraft Corporation. The satellites should be ready for launch in 1970. A significant part of the later satellites will be built by the British Aircraft Corporation, under a contract worth £2.8 million. This new generation of satellites will have some twelve times the capacity of Intelsat III.

More earth stations were completed during the year, including those in Moree (Australia), Chile, Mexico, Panama, Spain, Etam and Jamesburg (U.S.A.), Puerto Rico, Thailand and the Philippines. The second paraboloid at Goonhilly was completed; this is now the first earth station to have two large aerials, though second aerials are under construction in Germany and France. The stations in Hong Kong and Bahrain are expected to be complete in mid-1969.

The Piccolo system seems, at last, to have achieved some measure of success, having been commercially produced and installed in the QE2. This system is designed to carry teleprinter channels over noisy h.f. circuits and employs a different tone frequency for each character (32 in all). The first patents of this system were taken out, by members of the Diplomatic Wireless Service, in 1957 and, other than a mention in an I.E.E. Convention in 1963, little interest seems to have been shown until the 1968 R.S.G.B. Exhibition ‡. This seems to be another example of the much-publicised British inability to see the commercial possibilities of an invention.

The year seems to have been relatively quiet in the fields of trunk waveguides and optical communications though those working in these fields might not agree.

The author wishes to thank Mr. B. Priestley for collecting all the data on h.f. performance.

* Cable and Wireless Ltd.
† See graphs opposite

‡ See our report on the exhibition, November 1968, p.405—ED.

Personalities

Alan L. Gray, B.Sc., A.Inst.P., for the past 20 years with the Plessey organization, has joined Allied Research Laboratories Ltd., of Luton, as chief engineer. After graduating in physics at Kings College, London, in 1941, Mr. Gray, who is 45, gained a commission in the R.A.F.V.R. and specialized in radar, serving in 60 Group. He joined Plessey's Braxted Research Laboratory in 1948 and later transferred to the Caswell Research Laboratory where he was concerned with the development of ceramic piezoelectric materials and semiconductors. From 1956 until joining Allied Research Laboratories he was with Plessey Nucleonics, latterly as technical manager.

Roderick McInnes, Grad.Inst.P., aged 30, is appointed applications manager of Philbrick-Nexus Research, the Chichester, Sussex, subsidiary of Teledyne Inc., of Los Angeles. He spent twelve years at the Royal Aircraft Establishment, Farnborough, working on the design and construction of instrumentation and control systems for aircraft and missiles. He was latterly, for one year, with Elliott Automation's Space and Guided Weapons Division working on guidance systems.

The City and Guilds of London Institute has recently presented its Insignia Award (C.G.I.A.) to **P. Beckley**, B.Sc., A.M.I.E.E., A.M.I.E.R.E., aged 32, a senior physicist with the Steel Company of Wales Ltd., Newport, for his thesis "Sensors for automation"; to **J. Helszajn**, M.I.E.R.E., aged 34, who is reading for a PhD. degree at the University of Leeds, for his thesis "A general characterisation of the three port ferrite junction circulator"; and to **E. G. Jarvis**, aged 48, an executive engineer with the Post Office Research Laboratory, Backwell, Bristol, for his thesis "Multi-access satellite repeaters".

P. J. Smith has joined the staff of Anglia Transformers Ltd., of Farnham, Surrey, as technical manager. Mr. Smith served his apprenticeship at Foster Transformers with whom he remained for thirteen years before joining Gardners Transformers, where be became chief designer and latterly technical sales engineer.

John Matchett, B.Sc., who is 24 and joined Honeywell Controls Ltd. in 1960 as a craft apprentice, has been selected as the company's "apprentice of the year" and his prize is a three-month trip to the United States to Honeywell's industrial division at Fort Washington. He studied for his degree which he gained with first class honours from Glasgow University, under the company's training scheme. He is now an applications engineer in the industrial products group.

The appointment of two new assistant superintendent engineers in the Transmitter Group was recently announced by the B.B.C. **G.I.F. Tupper**, M.I.E.E., A.M.I.E.R.E., is appointed to the post in Transmitter I department, dealing with v.h.f. and u.h.f. stations and **M. Clough**, M.I.E.E., in Transmitter II Department, which is concerned with l.f., m.f. and h.f. stations in the United Kingdom and overseas. Mr. Tupper joined the B.B.C. in 1943 at Droitwich. In 1960 he transferred to the headquarters staff of Transmitter Department where he has latterly been concerned with the general development of the v.h.f. and u.h.f. transmitter network and the extension of colour television. Mr. Clough also joined the Corporation in 1943 and after service at several transmitting stations joined the headquarters staff of Transmitter Department in 1959. Since 1961 Mr. Clough has been head of the site acquisition section.

Kenneth L. Smith, B.Sc., who is well known in British amateur transmitting circles (his call is G3JIX), has been appointed to a senior research associateship in the department of electronics in the University of Kent at Canterbury. He graduated in physics at London University in 1962 and then did three years' research in infrared spectroscopy at the Northern Polytechnic, London. Since 1965 until his recent appointment he was head of the physics department at Holloway School, North London.

E. Trevor Thomas, formerly managing director of Sound Coverage Ltd., has joined Leevers-Rich Equipment Ltd., of Wandsworth, London, as general manager.

William Logan, a director of Baird and Tatlock (London) Ltd., is the new chairman of the Instruments, Electronics and Automation Exhibition, held biennially in London. Mr. Logan retired, with the rank of major, from R.E.M.E. after fifteen years' service (during which he worked for some time at the Radar Research Establishment at Malvern) and spent 16 years with Avo Ltd., latterly as sales director, before joining Baird and Tatlock two years ago. He was president of the Scientific Instrument Manufacturers' Association from 1964 to 1965 and is a member of the Court of the Worshipful Company of Scientific Instrument Makers.

Maurice Cufflin, B.Sc., has joined English Electric Valve Co. Ltd., at Chelmsford, as sales engineer. He graduated from Queen Mary College, University of London, with an honours degree in physics in 1935 and joined Marconi, working on communications and navigational equipment for aircraft. In 1949 Mr. Cufflin went to the Marconi Research Laboratories at Great Baddow where he was appointed chief of the measurements research group in 1957, in which work ranged from d.c. to millimetric waves. In 1965 he became engineering manager of Marconi's Automation Division.

John Locke, who has been with Marconi Instruments Ltd. since 1950, is appointed service representative and will be particularly concerned with customer liaison with the company's repair and calibration service. Before joining M. I. he was for eight years with E. K. Cole Ltd., working on the test and calibration of airborne telecommunication and direction-finding equipment.

J. H. W. Costin, B.Sc., A.M.I.E.E., recently joined Emihus Microcomponents Ltd., of Glenrothes, Fifeshire, Scotland, as product sales manager (welding and special assemblies). He graduated in electrical engineering from Kings College, London University, in 1959. He then spent two years with Associated Electrical Industries as a graduate apprentice. From 1962 to 1965 he was with Standard Telephones and Cables Ltd. at Footscray as a senior process engineer concerned with the manufacture of semiconductors. Mr. Costin was latterly with Mullard as a specialist semiconductor sales engineer.

V. G. Oastler, London area manager of the Marconi International Marine Co., has retired after nearly 40 years' service with the company. He began his career as a sea-going radio officer and then served on the technical staff of several of the company's depots. In 1966 he was appointed manager, London area, with responsibility for co-ordinating the company's installation and maintenance activities, not only in the vast Port of London, but in all the other ports of south east England from Clacton to Shoreham.

New Year Honours

Among the recipients of life peerages conferred by the Queen in the New Year Honours were **Professor P. M. S. Blackett**, O.M., C.H., president of the Royal Society.

New Knights Bachelor include **Morien Bedford Morgan**, C.B., controller of guided weapons and electronics, Ministry of Technology, and **F. Neil Sutherland**, C.B.E., M.A., F.I.E.E., chairman of the Marconi Company and of the Conference of the Electronics Industry.

C.B.

J. V. Dunworth, C.B.E., M.A., Ph.D., F.I.E.E., director, National Physical Laboratory.

W. Millward, C.B.E., superintending director, Government Communications Headquarters.

C.B.E.

J. Howlett, director, Atlas Computer Laboratory, Science Res. Council.

Col. R. Knowles, F.I.E.R.E., late R.E.M.E.

D. B. Weigall, deputy director of engineering, B.B.C.

O.B.E.

Lt. Col. A. C. Bate, M.B.E., Royal Corps of Signals.

Lt. Col. P. H. Flear, Royal Corps of Signals.

R. M. Billington, T.D., M.Sc.(Eng.), F.I.E.E., inspector of wireless telegraphy, G.P.O.

R. H. W. Burkett, B.Sc., F.I.E.E., managing director, Welwyn Electric Ltd.

B. R. Greenhead, director of studio and engineering, Thames Television.

A. C. Heathcote, director, Posts and Telecommunications, Lesotho.

M. D. Mason, M.B.E., superintending electronic/communications engineer, Government Communications Headquarters.

Lt. Col. F. P. Nurdin, sales director, British Communications Corporation.

F. D. Outridge, director, Scientific Instrument Manufacturers Association.

Lt. Col. J. L. Purdon, F.I.E.R.E., Royal Corps of Signals.

Lt. Col. J. J. H. Swallow, B.Sc.(Eng.), F.I.E.E., Royal Corps of Signals.

J. M. J. Whellens, B.Sc., M.I.E.E., principal engineer, G.E.C.-A.E.I. (Electronics).

R. C. G. Williams, Ph.D., B.Sc.(Eng.), F.I.E.E., chief engineer, Philips' Electronic and Associated Industries Ltd.

M.B.E.

G. F. Budden, M.I.E.R.E., assistant engineer-in-charge, operations, North Region B.B.C.

Royal Victorian Medal

Chief Radio Supervisor L. L. Fuller, Royal Navy.

World of Amateur Radio

Big Increase in "B" Licences

During recent months the rate of increase in the number of current U.K. Amateur (Sound) "B" licences—which do not require the passing of any Morse test but which restrict operation to frequencies above 144 MHz—has risen very rapidly when compared with the issue of new "A" licences. The "A" licences permit operation on all amateur bands after passing a 12-word-per-minute Morse test. Both "A" and "B" licences require that applicants should have passed the written Radio Amateurs' Examination. Callsigns in the sequence G8 plus three letters are issued to "B" licensees. In the three months, August 31 to November 30, 1968, "B" licences increased from 1058 to 1327, a rise of 269 or about 25%. This compared with an increase of 155 in the "A" licences, from 12903 to 13058 or roughly 1.2%. Sound mobile "B" licences are similarly increasing at a rapid rate, the total having risen by almost six times in a year, from 22 to 128. U.K. licences at November 30, 1968, were: Sound "A" 13058; Sound "B" 1327; Sound "A" mobile 2578; Sound "B" mobile 128; Amateur television 186. The position twelve months earlier was: 12597; 693; 2396; 22; and 176. During this period model radio control licences have risen from 12016 to 14978. The marked rise in popularity of the "B" licence follows the concession in spring 1968 when the licence was extended to include operation in the 144 MHz band; it is also similar to the experience of a number of other European countries where it has been shown that non-Morse v.h.f. licences tend to attract a substantial proportion of total applicants. "B" licences thus seem certain to have important repercussions on the future pattern of amateur activity.

Security Risk?

British amateurs have been disturbed at what they believe to have been unduly adverse publicity directed at the hobby following the publication of the official Security Commission report (HMSO, Cmnd 3856) on the circumstances surrounding the case of D. R. Britten, the R.A.F. chief technician who pleaded guilty to offences under the Official Secrets Acts. Britten had held the amateur licence G3KFL since the early 1950s, and admitted to supplying secret information over a long period to Russian intelligence during personal meetings. In view of the opportunities which amateur radio affords for a hostile intelligence service to talent-spot potential agents and to communicate with them, the Commission suggested that the case justifies a reassessment of security risks attaching to amateur radio activities by members of the armed forces and public service. At the same time, although this received far less press and broadcast comment, the report made it clear that the R.A.F. "see great merit in amateur radio clubs, which have a high interest and training value for many on signals work". The report also shows that the widely reported story of Britten being initially hailed by his amateur callsign by a Russian short-wave listener at the Science Museum is not accepted as true by the Commission. Amateur radio circles believe that most enthusiasts have long appreciated the need for reasonable prudence in communicating with overseas stations, and are alert to any possible attempt to use their privileges for purposes of covert communication. Furthermore they can point to the role of amateur operators in assisting military and special communications during World War II.

Open Weekend

An "Open Weekend" at the new R.S.G.B. headquarters at 35 Doughty Street, recently attracted some hundreds of amateurs and friends. Three stations, specially installed for the occasion, made nearly 400 contacts. The R.S.G.B. state that consideration is being given to setting up a permanent headquarters station.

ARRL DX Contest

The 35th ARRL International DX Competition—the doyen of the big amateur long-distance contests—is being held this year, as usual, over four weekends, two for telephony operation and two for c.w. Dates and times are: Telephony, February 1, 00.01 g.m.t. to February 2, 23.59 g.m.t. March 1, 00.01 g.m.t. to March 2, 23.59 g.m.t. C.W. February 15, 00.01 g.m.t. to February 16, 23.59 g.m.t.; March 15, 00.01 g.m.t. to March 16, 23.59 g.m.t.

New Moonbounce Record

A new earth-moon-earth (EME) record for the 1296 MHz (23 cm) band has been established by Peter Blair, G3LTF of Chelmsford who successfully contacted on this mode the Californian amateur station WB6IOM. Blair was using a 15-ft dish aerial and 150-watt transmitter. WB6IOM had 500 watts of power and a 10-ft dish aerial. Both stations used parametric amplifiers and bandwidth was about 75 Hz with signals just audible above the noise level.

"Radio News of 1968"

A new R.S.G.B. 16-mm sound film "Radio News of 1968" was well received at its first showing at the society's a.g.m. in December. This magazine-style film runs for 29 minutes and includes items on amateur radio astronomy, reception of cloud-cover maps from weather satellites on home-constructed equipment, the GB2LO station at the 1968 City of London Festival, glimpses of amateur-operating during National Field Day, moonbounce equipment used by station G3LTF, and the 1968 R.S.G.B. exhibition. A similar film venture, including shots of British radio amateurs and stations, is currently being undertaken by the American Radio Relay League.

Australian Youth Radio Clubs' Scheme

The first national conference of the Youth Radio Clubs' scheme of Australia took place recently at the headquarters of the Victorian Division of the Wireless Institute of Australia, Melbourne. The purpose of the conference was to organise the state groups on a national basis, and to ensure uniformity of syllabuses, certificates and examinations throughout Australia. This was successfully achieved and the scheme has been adopted by the Wireless Institute of Australia (national amateur radio society for that country), as part of its educational activities.

Jamboree-on-the-air

L. F. Jarrett (VE3EWE/G3UXZ/HB9AMS), director of administration at the Boy Scout World Bureau now established at 72 Bd. St. Georges, Geneva, is anxious that amateur radio societies throughout the world shall avoid arranging international contests to clash with future Jamborees-on-the-air. The 1969 event—the 12th—has been fixed for the weekend October 18-19, and it is planned that future J.O.T.A. shall be held during the third full weekend in October each year.

Amateur Radio in Hungary

The Hungarian Amateur Radio Society (M.R.S.) has made application to join the International Amateur Radio Union. Amateur radio in Hungary is organized on lines similar to those in force elsewhere in Europe, licences are issued by the Ministry of Posts and Transport who also arrange Morse code tests and technical examinations. There are 750 licensed amateurs in the country and the address of the society is Magyar Radio-amator Szovetseg, Budapest VI, Gorkij Fasor 6, Hungary.

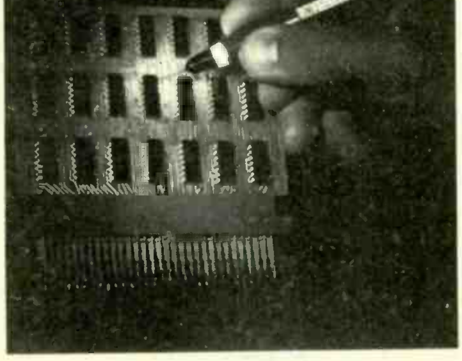
New Products

Signal Recovery Equipment

The third generation of Brookdeal Instruments' signal recovery systems, based on the principle of correlation detection, are devised around their phase-sensitive detector type 411. This instrument has a specified zero stability, linearity and frequency response which are claimed to lead this particular field. Complementary instruments are the type 451 nanovolt pre-amplifier and type 450 low-noise amplifier. A different type of signal recovery system has recently been introduced by this company for plotting the waveform of signals buried in noise such as are found in experiments on fluorescent decay, radar signals and spin-lattice relaxation time. The system is designated Boxcar Detector type 415/425. It is able to plot waveforms with a resolution of 10ns. The range of repetition rate is 0.2Hz to 1MHz and sampling pulse width 0.5s to 10ns. Scan time is 1-2000s and zero drift less than 0.01% deg C^{-1}. Financial backing for expansion has recently been secured by Brookdeal by an agreement with Fulcra Finance Ltd. which has acquired a 33% interest in the company. Brookdeal Electronics Ltd., 2 Myron Place, Lewisham, London, S.E.13.
WW 305 for further details

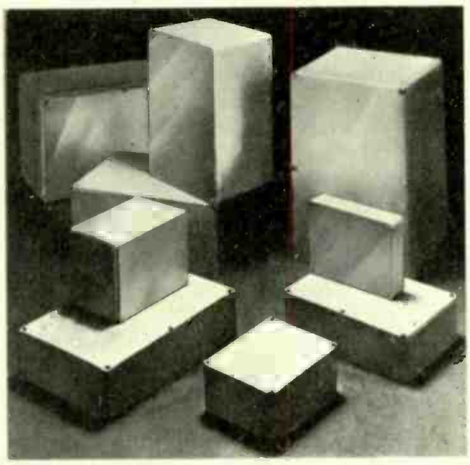
I.C. Logics Circuits Check

The presence of "0" or "1" logic states and the occurrence of single pulses as short as 30ns are indicated when checking the performance of logic circuits with a new hand-held probe by Hewlett Packard. Designed for use with i.c. circuits, the probe, type 10525A, is compatible with t.t.l. and d.t.l. 5V logic systems. Threshold level is + 1.4V. Above this level an indicator light near the tip of the probe is on; below + 1.4V the light is off. No triggering or threshold adjustments are required and protection against accidental overload up to 200V is provided. Input impedance is 10kΩ. Power for the probe can be obtained from an independent supply or from the power line of the circuit under test via a cable with adaptors. Consumption is 75mA at 5V and operating temperature range 0–55°C. Price: £43 12s. Hewlett Packard Ltd., 224 Bath Road, Slough, Bucks.
WW 312 for further details



Die-cast Boxes

Four new die-cast boxes by Electronic Services extend their range to nine sizes from 100 × 75 × 25mm to 280 × 180 × 150mm. The new larger sizes incorporate the slot guide system used on



the original range. The die-cast construction offers ruggedness with lightness and the screening properties may be valuable in some applications. Electronic Services, Edinburgh Way, Harlow, Essex.
WW 313 for further details

Thermally Stable Soldering Irons and Long-life Bits

Two temperature-controlled soldering irons, Litestat 50 and Litestat 70 have been introduced to the range of irons manufactured by Light Soldering Developments Ltd. Of 50 and 70W loading respectively, they have handles moulded of translucent plastics through which an internal indicator lamp shows when the elements are energized, Temperature stability is within $\pm 2\frac{1}{2}$°C during idling and is achieved by a mechanical system operating a micro-switch inside the handle, via a push rod, in response to thermal expansion of the copper element core unit. Close thermal coupling ensures rapid response without temperature overshoot. Operating temperature is continuously variable, without dismantling, between approximately 200 and 420 deg C. Screw-on copper bits are available in four sizes for each model. Basic prices are: £4 16s (50W) and £5 (70W). A range of Philips iron-coated bits are now

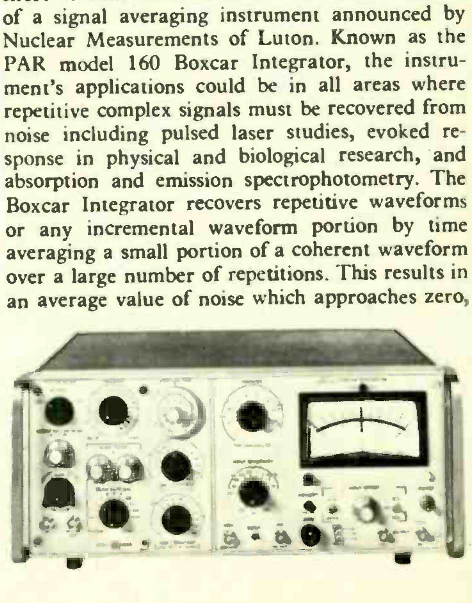
available for Litesold soldering irons giving an estimated life up to 75 times that of copper bits. These new long-life bits are coated with iron to a radial thickness of up to 250μm, covered with a protective coating of nickel, then chromium plated. The coating extends for the full length of the bit but it is not so thick as to impair the heat flow. The bits can be supplied in three standard shapes: chisel (single face), screwdriver and conical. They are not cheap; the price varies from 14s 6d for a 10W version through to £1 12s 3d for a 60W version but this cost is likely to represent a saving in the long term. Light Soldering Developments Ltd., 28 Sydenham Road, Croydon, Surrey, CR9 2LL.
WW 306 for further details

Step Recovery Diode

Reverse recovery transients of diodes, occurring during the brief time following forward conduction, can be used to generate significant amounts of power at microwave frequencies. This is because the very abrupt transient is a strong source of high order harmonics and because high conversion efficiencies can be achieved. The augmented reverse conductivity results from the presence of minority carriers, injected and stored during forward conduction. Diodes which are specially designed to enhance storage and to achieve an abrupt transition from reverse storage-conduction to cut-off are called step recovery diodes. A new step recovery microwave diode announced by Mullard has a cut-off frequency of 150GHz and has been developed for use in high-order frequency multipliers with outputs up to 13GHz. It will provide output powers in the region of 20mW at 13GHz when multiplying by a factor of 8. When tested, with 500mW 1GHz input in a "multiply by ten circuit", the output power at 10GHz is 15mW. The diode, type BXY32, is encapsulated in the standard varactor pill package. Other details are: junction capacitance (V_R = 6V) 0.75pF, transition time (max) 150ps, life time 50ns and V_R max. 20V. Mullard Ltd., Torrington Place, London, W.C.1.
WW 323 for further details

"Boxcar" Integrator

Recovery of repetitive waveforms with pulses as short as 10ns from random noise is the function of a signal averaging instrument announced by Nuclear Measurements of Luton. Known as the PAR model 160 Boxcar Integrator, the instrument's applications could be in all areas where repetitive complex signals must be recovered from noise including pulsed laser studies, evoked response in physical and biological research, and absorption and emission spectrophotometry. The Boxcar Integrator recovers repetitive waveforms or any incremental waveform portion by time averaging a small portion of a coherent waveform over a large number of repetitions. This results in an average value of noise which approaches zero,



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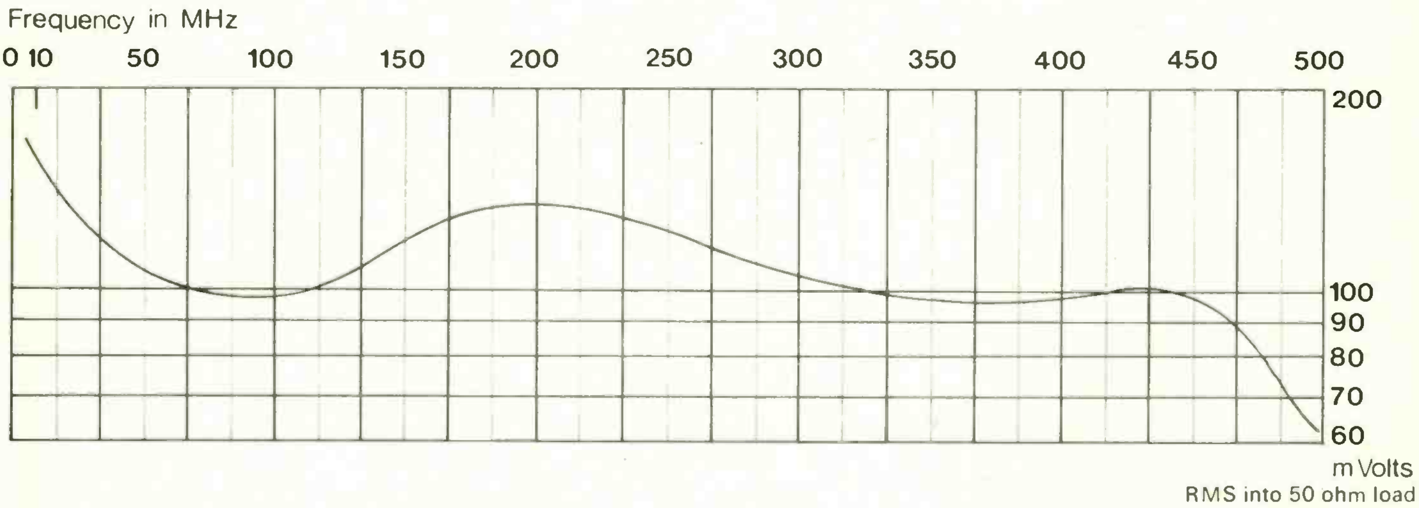

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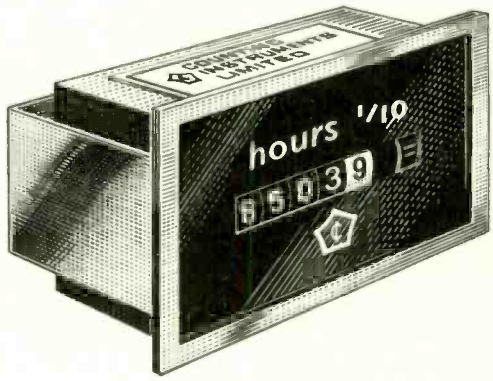

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Here is a new Elapsed Time Indicator from C.I. which, although made to their usual high standards, offers considerable price reductions and higher efficiency through the use of injection moulded components and a very high standard of quality control. A small attractive frontal area combines with large figures which can be read at over ten feet. Motors are self starting and fully protected for dust filled atmospheres and an exceptionally long life, similar to that of an electric clock may be expected.
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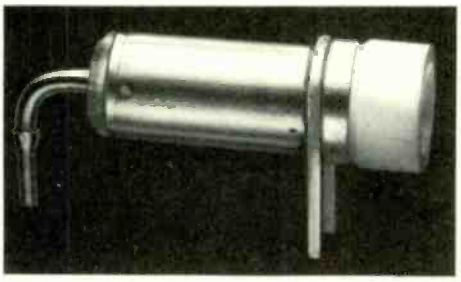
yielding only the output from the coherent content of the sampled portion. The entire waveform is recovered by scanning the interval of interest. The range of aperture times available is 10ns to 0.55s, and variable averaging time constants are from 3ns to 100s. A variable bandwidth prefilter and a.m. limiting circuit are provided. Nuclear Measurements, Dalroad Industrial Estate, Dallow Road, Luton, Bedfordshire.
WW 310 for further details

Miniature Capacitors

A tubular capacitor for mounting on printed boards has been introduced by Oxley Developments. This capacitor employs polytetra-



fluoroethylene (p.t.f.e.) as the dielectric medium. Uniformly smooth adjustment and linear reversal-free tuning is claimed. Capacitance value is 2pF minimum, swing is 5pF and power factor is better than 0.0005 at 10kHz. Temperature coefficient is 50 p.p.m. per deg C and insulation resistance $>16^6 M\Omega$. Oxley Developments Co. Ltd., Priory Park, Ulverston, North Lancashire.
WW 307 for further details

Mains Fuseholders

The irritation of Fuseholders which turn in the panel, twisting the connecting leads, or fuses which defy all attempts to dislodge them from the holder for replacement, has been remedied by Bulgin in three versions of a new panel mounting design to accept $\frac{1}{4}$-in. diameter fuses. A lug prevents the unit turning in the panel, and the fuse is withdrawn with the fuse cap, which is screw fitting. When the fuse is withdrawn the rear (live) contact cannot be reached by the B.S. test finger. Maximum ratings are 15A at 250V or 20A at 32V and the panel hole required is 15.9mm plus a keyway, 2.4mm wide and 1.2mm deep.

Maximum panel thickness is 5.5mm. A. F. Bulgin & Co. Ltd., Bye-pass Road, Barking, Essex.
WW 311 for further details

Radiation Thermometer

Temperature measurements of sea surface, clouds, terrain or any large-scale subjects are made possible by an American radiation thermometer which employs non-contact infrared techniques. The instrument takes the form of a light-weight battery-powered infrared radiometer, type PRT-5, which can be used from aircraft, ships or other platforms. Temperature measurements can be made in any selected range between $-50°C$ and $+150°C$. The standard model comprises an optical head and a separate solid-state control unit. The optical head may be hand-held or tripod-mounted. It has a 2° field of view restricted to the $8-14\mu m$ spectral region. Measurements from $-20°C$ to $+75°C$ are made on three overlapping meter scales. Wavelength region, meter scale and field of view can be modified to suit special measurement requirements. Measurements are independent of distance, provided the target fills the instrument's field of view. Temperature sensitivity is 0.05°C above zero and 0.1°C below zero, and accuracy is $\pm$ 0.5°C. A recorder output is available, of 1V d.c. at $10k\Omega$ or 50mV d.c. at 500Ω impedance. The internal batteries can be re-charged from 115V or 230V 50-400Hz mains supplies. Barnes Engineering Co., Stamford, Connecticut, U.S.A. U.K. enquiries to: B & K Publicity Division, 59 Union Street, London, S.E.1.
WW 316 for further details

Voltage Regulators

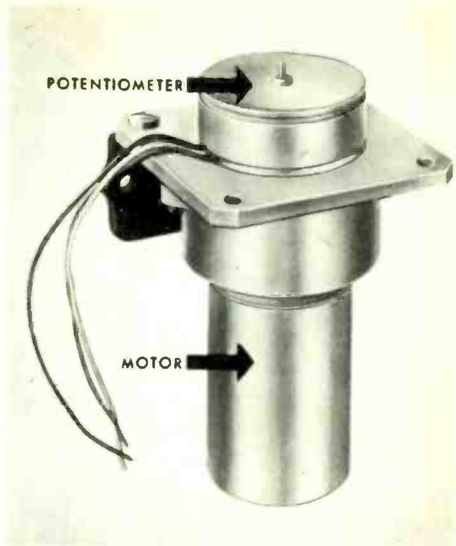
Three silicon monolithic voltage regulators designed for a regulated output at $-15V$ contain their own voltage reference element for voltage regulation to 0.1%. They are types 2103, 2104 and 2105 by Philbrick-Nexus. Internal short-circuit protection is provided and a thermal feedback circuit prevents excessive operating temperature. Type 2103 features an electrical zero adjustment for output voltage in the range -13 to $-17V$ and remote sensing is optional for regulation with respect to voltage at the load instead of at the regulator output pin. Type 2104 provides voltage sensing at the output pin with a preset regulator output. The 2103 and 2104 are housed in a TO–99 case and have a power dissipation of 300mW in free air; one watt with heat sink. Type 2105 also dissipates 300mW and, with only three terminal leads, provides easy installation. It is housed in a TO–105 non-conductive case. Voltage-divider resistors are built into all three regulators and need not be provided by the user. Prices for small quantities are: 2103 £6 2s 6d, 2104 £4 15s and 2105 £1 10s. Philbrick-Nexus Research, 81a North Street, Chichester, Sussex.
WW 315 for further details

Portable R/T

Compact and light-weight is the claim made by Interplanetric for a new 450-490 MHz band transmitter/receiver designed to be worn by the user. The complete unit weighs 2kg and comprises a transmitter, receiver, switchblock, microphone, earphone, batteries and either a quarter-wave or half-wave aerial. It is suspended on the person by an adjustable harness. The system is crystal-controlled and provides good line-of-sight short-range communication. Transmitter power output is 100mW and receiver audio output power 5mW. Modulation is f.m., single channel working, with spurious radiation 25dB down from the power output level. A carrier-operated squelch circuit mutes the audio output during "no signal" periods. The equipment is powered by mercury cell batteries located in the transmitter and receiver casings. Interplanetric, 39-49 Cowleaze Road, Kingston on Thames, Surrey.
WW 343 for further details

Motor-potentiometer

A motor-potentiometer with principal applications in the automatic adjustment of potentiometer circuits and the production of very long time constants for feedback in control loops has been announced by U.C.E. The unit comprises a motor driving a low torque potentiometer through a compact gear train. Motors are of three types, a measuring motor, a stepping motor and a reversible synchronous motor. Gear ratios available are up to 1:500,000 and units with six-speed gearboxes with ratios of up to 1:500 for use with low



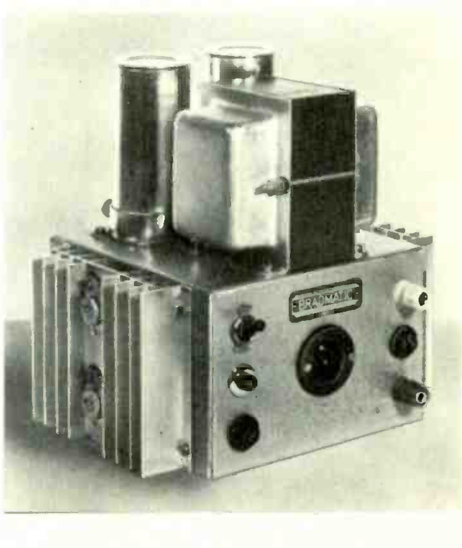
torque potentiometers can be supplied. Special features include wiper reset, limit switches, wired self-balancing potentiometer systems and wired servo systems for position transmission or computing circuits. Universal Control Equipment Ltd., 38 London Road, Stroud, Gloucestershire.
WW 308 for further details

X-band 2W Varactor

The upper frequency limit of Bimode diodes by the Bomac division of Varian has been extended from 8GHz to 10GHz by the introduction of a new type, the VAB-824A. Output power is quoted as being typically 2.5W in a 50% efficient tripler circuit with measurements being taken in the mid-point of the 7–10GHz range. Varian Associates Ltd., Russell House, Molesey Road, Walton-on-Thames, Surrey.
WW 314 for further details

70W Amplifier

A new solid-state power amplifier from Bradmatic provides 70W output into 4Ω with total harmonic distortion of 0.25% at full output. Input sensitivity is 850mV into $10k\Omega$ for 70W output and frequency response is 20Hz – 20kHz. The amplifier, type SSP2, will operate from 220 – 250V 50Hz or 105-115V 6Hz mains input and has a power consumption of 130VA at full output. A 28V 100mA unsmoothed output is available to power auxiliary equipment. The output stage is open- and short-circuit proof. Bradmatic Ltd., 338 Aldridge Road, Streetly, Sutton Coldfield, Warwickshire.
WW 326 for further details



A Folded Exponential Horn Loudspeaker

A design for a bass speaker, and details for building a full-range system

*Abstract of an article by J. Jecklin**

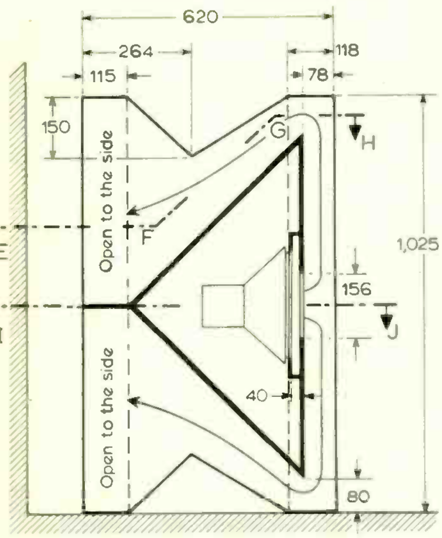
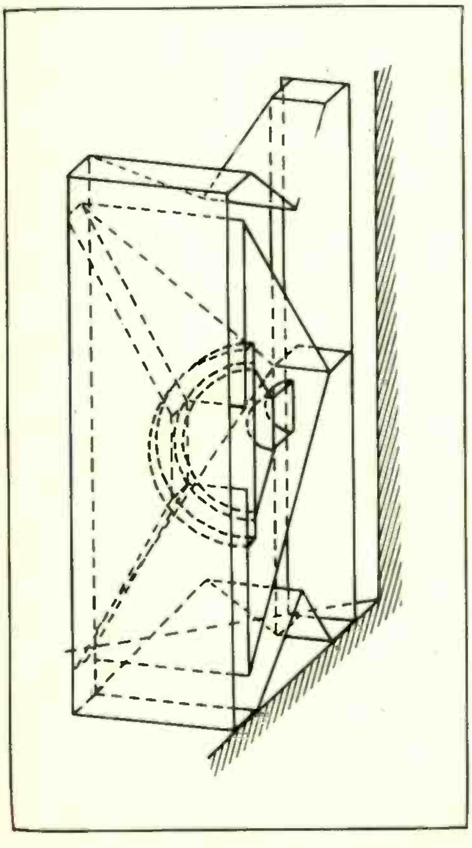


Fig. 1. Side view of half the horn.

Fig. 2. Perspective view of half the horn.



If a horn with a low frequency cut off of 40-50 Hz is to be used in a normal room it must, for aesthetic and space-requirement reasons, be folded. Unfortunately, when a horn is folded, its high frequency response deteriorates, but this can be overcome by a properly chosen combination of bass and medium/high frequency loudspeakers. Moreover, the radiation resistance of a folded horn is not independent of frequency, but rises as the latter is increased. This again is obviated in the system described here* by inserting a flared matching section between the horn proper and an acoustic low-pass chamber situated immediately in front of the loudspeaker unit.

The construction of the horn is based on an ingenious suggestion made by Klipsch in 1941. It is divided throughout its entire length into two symmetrical halves. The outer sides of the final section are constituted by the walls forming the rectangular corner of the room in which the horn is installed. The detailed construction is shown, with dimensions in mm, in Figs. 1-4, it being assumed that $\frac{1}{2}$ in. thick plywood or blockboard is used throughout. The dimensions are determined as explained by the author in *Funk-technik* No. 16 (1967) pp. 591-2.

An even low frequency response is obtained if the stiffness of the air mass in the horn is compensated by the stiffness of the air cushion in the closed housing and a loudspeaker with a very freely suspended diaphragm and low self-resonant frequency is employed.

Among various makes of loudspeakers available, the author has found as a result of listening tests that the Wharfedale W15RS, which proved highly reliable by virtue of its rigid construction, was particularly suitable for the bass section of the system. It is mounted within the front end of the horn assembly behind the rear wall of the closed housing as shown in Figs. 1-4.

For the medium and high frequency section, electrostatic, pressure chamber and cone-type loudspeakers were considered in turn. The first type was rejected owing to its low conversion efficiency and its relatively high bass cut off frequency, the second on the score of its high cost and not detectably superior performance to the cone type. Of

* The original article appeared in *Funk-technik* No. 20 (1967) pp. 783-786.

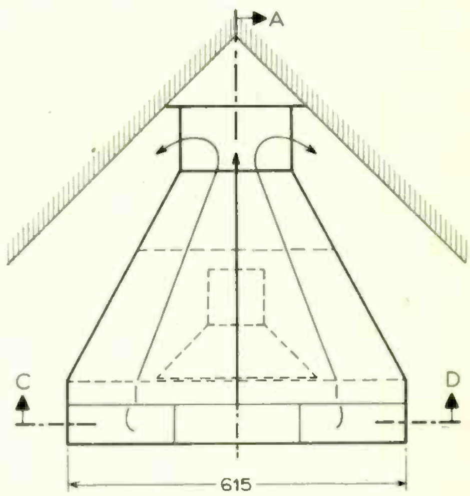


Fig. 3. Section E-H of Fig. 1.

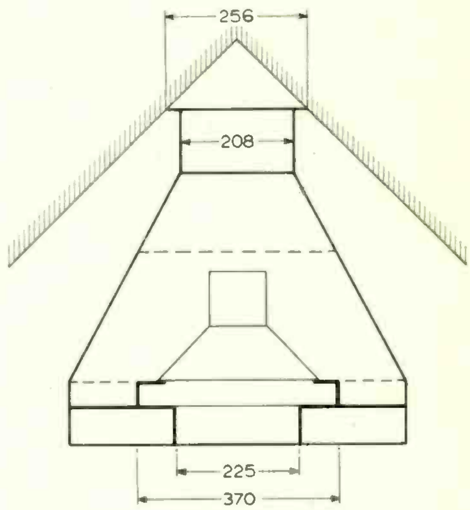
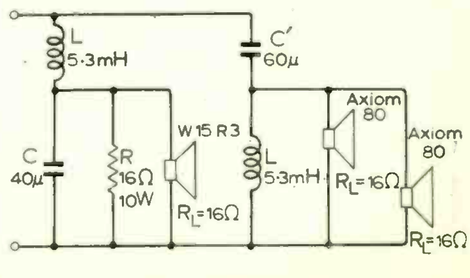


Fig. 4. Section I-J of Fig. 1.

Fig. 5. Crossover circuit for full-range loudspeaker system.



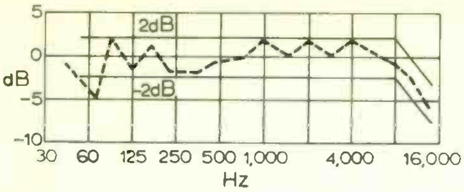


Fig. 6. Frequency response of the full-range system.

the various makes available the author found the Goodman's Axiom 80, which has a double cone and a frequency range of 20 Hz - 20 kHz ± 4 dB the most suitable, mainly on account of its unusual cone suspension system. Owing to the narrowing of the radiated beam at frequencies above about 8kHz, two such loudspeakers must be used in order to fill the 90° angle formed by the walls in the corner of the room. Many tests were made to ascertain the optimal position for these loudspeakers. It was found that for stereo reproduction in normal rooms they are best mounted in the saddle of the horn, radiating at an angle of 20° upwards and 30° outwards, whereas for mono in small rooms angles of 20° upwards and 15° outwards are preferable.

For the combined system, the calculated cross-over frequency comes out at 350Hz, the network and its method of connection being shown, with numerical values of the components, in Fig. 5. The overall frequency response of the complete system was measured in a low-reverberation resonance-free room using a narrow-band noise source and a previously calibrated condenser microphone placed in various positions. The mean of eight measurements is shown in Fig. 6.

Although the response curve is not absolutely level at very low frequencies, the unevenness is due to the horn being folded, and not to any artificial resonances which are virtually unavoidable with cabinets and bass reflex housings, and moreover, as compared with the latter, variations in the furnishings of the room have very little effect on the effective frequency response of the horn system.

The efficiency of conversion of electrical into acoustic energy of the horn described is about 20%, about ten times better than that of a compact box system. The maximum permissable loading is 12W.

Although exponential horns are now out of fashion, both theoretical considerations and the practical results obtained with the system described here clearly show that they can offer unsurpassable performance, particularly in the bass range. The combination described is eminently suitable for the most exacting professional requirements.

'High Performance A.G.C.'

It has been pointed out that the collector of Tr_1 in Fig. 6 (page 18, Jan. 1969) should go to the base of Tr_2 as shown in Fig. 2.

February Meetings

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

LONDON

4th. Inst. Electronics—"Practical aspects of acoustic insulation" by R. G. Monk at 18.45 at London School of Hygiene, Keppel St., W.C.1.

5th. Inst. Railway Sig. Eng.—"Radar for the railways" by Prof. H. M. Barlow at 18.00 at the I.E.E., Savoy Pl., W.C.2.

5th. B.K.S.T.S.—"The importance of colour separation accuracy for films and TV" by B. J. Rogers at 19.30 at Royal Overseas League, St. James's St., S.W.1.

6th. I.E.R.E.—"Radar echo signatures from birds, insects and bats" by Dr. Glen W. Schaefer at 19.00 at 9 Bedford Sq., W.C.1.

7th. R. Instn.—"The hologram" by Dr. D. Gabor at 21.00 at 21 Albemarle St., W.1.

13th. I.P.P.S.—Symposium on "The preparation of thin films by the method of sputtering" at 10.00 at the I.E.E., Savoy Pl., W.C.2.

13th. I.E.R.E.—"M.O.S.T. arrays" by Dr. R. C. Foss at 18.00 at 9 Bedford Sq., W.C.1.

18th. I.E.R.E.—"Instrumentation and control in float glass manufacture" by G. P. Rigby and M. Hilton at 18.00 at 9 Bedford Sq., W.C.1.

18th. Radar & Electronics Assoc.—"The use of radar in meteorology" at 19.00 at B.I.C.C. Ltd., 21 Bloomsbury St., W.C.1.

19th. I.E.R.E.—"New approach to h.f. receiver design" by E. T. Wilson at 18.00 at 9 Bedford Sq., W.C.1.

20th. R.T.S.—"The process of learning—the future role of educational technology in higher education" by D. E. P. Jenkins at 19.00 at the I.T.A., 70 Brompton Rd., S.W.3.

26th. I.E.R.E. & I.E.E.—Colloquium on "Fail-safe techniques for high reliability computer equipment" at 10.30 at the Middx. Hospital Medical School, Cleveland St., W.1.

27th. R.T.S.—"The Yorkshire Television Centre at Leeds" by P. G. Parker and D. J. Whittle at 19.00 at the I.T.A., 70 Brompton Rd., S.W.3.

28th. R. Instn.—"Physics and music" by Prof. C. A. Taylor at 21.00 at 21 Albemarle St., W.1.

BASINGSTOKE

13th. I.E.R.E.—"Management for engineers" by T. G. Clark at 19.30 at the Technical College.

BELFAST

25th. I.E.R.E.—"Engineers must learn to manage" by Harley R. Sykes at 18.30 at the Ashby Inst., Queen's University, Stranmillis Rd.

BIRMINGHAM

11th. Soc. Environmental Engrs.—"Application of random signal analysis to engineering problems" by Dr. C. Ashley at 19.30 at the University.

BOURNEMOUTH

5th. I.E.E.—"Post Office Tower" by D. C. Jones at 18.30 at the College of Technology.

BRIGHTON

18th. I.E.R.E.—"Electronic organs and associated equipment" by L. F. Hawkes at 18.30 at the College of Technology.

BRISTOL

19th. I.E.R.E. & I.E.E.—"Active filters" by F. E. J. Girling and E. F. Good at 19.00 at the University.

CAMBRIDGE

4th. I.E.R.E. & I.E.E.—"Ergonomics in electronic equipment and system design" by B. Shackel at 20.00 at the University Eng'g Labs., Trumpington St.

CARDIFF

12th. I.E.R.E.—"Long-range radio communication" by Dr. G. L. Grisdale at 18.30 at the University of Wales Inst. of Science & Technology.

14th. R.T.S.—"Stereophonic broadcasting" by R. S. C. Gundry at 19.00 at Broadcasting House, Llandaff.

CHELTENHAM

18th. I.E.R.E.—"Computer aided circuit design" by E. Wolfendale at 19.00 at the Government Communications Headquarters, Oakley.

EDINBURGH

11th. I.E.R.E. & I.E.E.—"Electronic signal processing in hospitals" by Dr. J. M. M. Neilson at 18.00 at the Carlton Hotel, North Bridge.

GLASGOW

10th. I.E.R.E. & I.E.E.—"Electronic signal processing in hospitals" by Dr. J. M. M. Neilson at 18.00 at the University of Strathclyde.

LIVERPOOL

19th. I.E.R.E.—"Electrical and electronic devices associated with railway signalling" by F. Bowyer at 19.00 at the University.

LOUGHBOROUGH

11th I.E.R.E. & I.E.E.—"A flexible modular data handling system for satellite use, with particular reference to the Black Arrow programme" by E. K. Crampton at 18.30 at the University of Technology.

NEWCASTLE-UPON-TYNE

12th. I.E.R.E.—"Moire fringe digitization of linear and circular movement" by C. N. W. Reece at 18.00 at the Inst. of Mining & Mech. Engrs., Westgate Rd.

NEWPORT, ISLE OF WIGHT

7th. I.E.R.E.—"Yacht electronics" by Major R. N. B. Gatehouse at 19.00 at the Technical College.

PLYMOUTH

18th. I.E.R.E. & I.E.E.—"Application of microelectronics" by Dr. S. S. Forte at 19.00 at the College of Technology.

READING

18th. I.E.R.E.—"Positional transducers and precision electronic measurement" by P. Wolfendale at 19.30 at the J. J. Thomson Physical Lab., the University.

RUGELEY

6th. I.E.R.E., I.E.E. & I.P.O.E.E.—"The design of high-quality transistor power amplifiers" by Dr. A. R. Bailey at 19.00 at Shrewsbury Arms, Market St.

SHRIVENHAM

4th. I.E.R.E. & I.E.E.—"Modern methods of traffic control" by D. G. Hornby at 18.15 at the Royal Military College of Science.

SWANSEA

12th. I.E.E.T.E.—"Medical electronics" by R. G. Wood at 19.30 at the Applied Sciences Bldg., University College, Singleton Park.

Literature Received

"**Catalogue of Electronic Components and Equipment**" (2nd edition) from G. W. Smith is now available at 7s 6d. About half of the 190 pages are devoted to audio and "Ham" equipment. The rest of the catalogue lists a wide range of electronic components including some that are not to be found easily elsewhere. G. W. Smith & Co. (Radio) Ltd, 3/34 Lisle St, London W.C.2.

Brief details of a **range of relays** are given in a pocket guide we have received from B & R Relays Ltd, Temple Fields, Harlow, Essex. Small conventional relays, heavy contactors and reed relays are included.
WW 401 for further details

Industrial sound equipment, amplifiers, record players, tape recorders, microphones and loudspeakers manufactured by Magneta (B.V.C.). Ltd, Ackmar Works, Parsons Green Lane, Fulham, London S.W.6, are described in a series of leaflets.
WW402 for further details

A bulletin describing a **high-speed transistor tester** (type T217) for classifying semiconductors on the production line or for incoming component testing has just been released. The instrument is an improved version of the T207 with increased range. Teradyne Ltd, 12 Swallow St, London W.1.
WW403 for further details

"**Concise catalogue of Industrial Instrumentation**" contains details of a wide variety of tachometers, counters, electronic relays, frequency sensitive switches, position indicators, temperature measuring equipment and hours-gone indicators. It is produced by Smiths Industries Ltd, Industrial Instrument Division, Kelvin House, Wembley Park, Middlesex.
WW 404 for further details

"**Colour Television Training Courses by E.C.T.T.**" contains 12-pages which are devoted to details of courses covering various aspects of colour television training from servicing to sales. E.C.T.T. Ltd., 45 Walton Rd, East Molesey, Surrey.
WW 405 for further details

The range of **lasers and associated equipment** available from Laser Associates Ltd, 172 Bradford Rd, Slough, Bucks, is briefly outlined in a leaflet. A description of the company is also given.
WW 406 for further details

Switching circuits using a combination of Triacs and gas discharge tubes are presented in a leaflet from Cerberus Ltd, CH-8708 Männedof, Switzerland.
WW 407 for further details

The latest catalogue from Ariel Pressings pictures a range of **pressed components,** switches and connectors. Ariel Pressings Ltd, Wollaton Rd, Beeston, Nottingham.
WW 408 for further details

A folding chart, for pocket or wall use, listing a range of Motorola **semiconductors** held in stock by Celdis Ltd, 43/45 Mifford Rd, Reading, Berks, is now available.
WW 409 for further details

Two new pamphlets from Mullard are (1) **"Introducing Silicon Planar Transistors"** and (2) **"Simple Motor Speed Control using a Thyristor".** Both pamphlets orginate from the Mullard Educational Service, Mullard House, Torrington Place, London W.C.1.
(1) WW 417 for further details
(2) WW 418 for further details

A good deal of information on the types of **microphone** available and advise on their use is contained in a seven-and-half page quarto typescript we have received from Allbeury Coombs & Partners. The report, which is called "Microphone Techniques and Applications", is "written round" Beyer microphones. Allbeury Coombs & Partners, 29 Adam & Eve Mews, London W.8.
WW 411 for further details

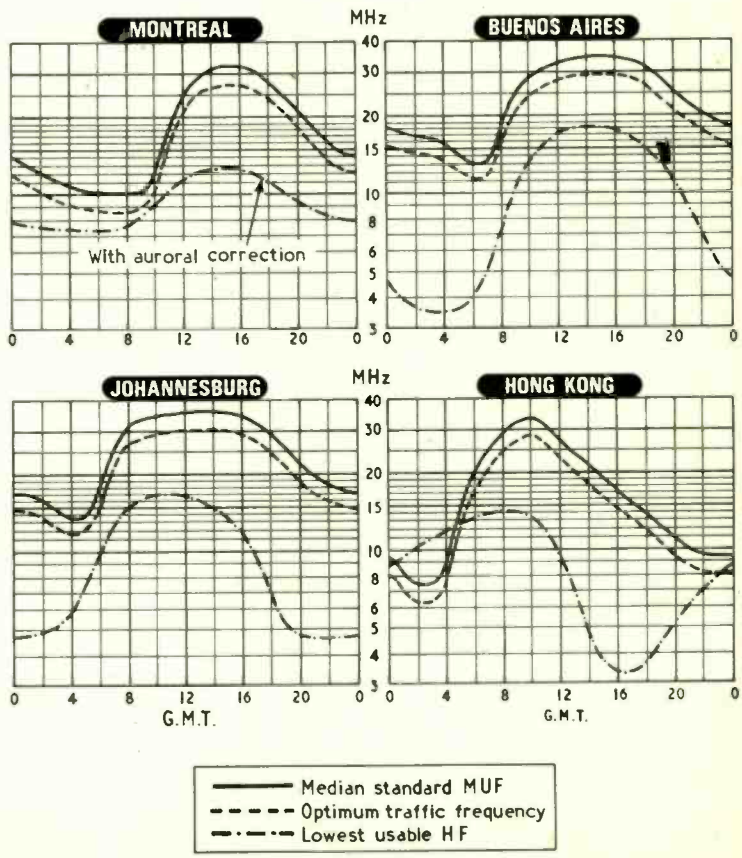
"**Aerosol Aids to Industry**" is the title of a small booklet listing such items as anti-oxidant, anti-corrosion, de-greasants, insulants, coolants, anti-static and colloidal graphite compounds in aerosol cans. These items are distributed by Special Products Distributors Ltd, 81 Piccadilly, London W.1.
WW 412 for further details

Modular power supplies for digital integrated circuits are described in a brochure received from Oltronix. A typical unit, type MB5-10, provides outputs at up to 10A from 4.5 to 5.5V. A 10% change in mains voltage results in about a 0.01% change in output. Oltronix, 99 Bancroft, Hitchin, Herts.
WW 413 for further details

A **picoammeter** that carries out measurements in the range of 10–2 to 3 x 10^{-14} A is described in a leaflet from Keithley Instruments Inc., 28775 Aurora Rd, Cleveland Road, Ohio, U.S.A.
WW 414 for further details

H. F. Predictions—February

MUFs are forecast by the two control point method. Thus, as regards reception in the U.K. from stations beyond about 60° longitude and in the same general direction, MUFs will be the same after sunset for westerly, before sunrise for easterly, routes, duration of the effect increasing with distance. This means that the Montreal and Buenos Aires charts are a good guide to evening reception from the whole of North and South America. An ionospheric index IF2 of 104 has been used to calculate MUFs and a sunspot number of 97 for the LUFs. There is a similarity between recent solar cycles and those of 169 years previously which suggests that the smoothed sunspot number will not exceed 100 for the next 30 years and will be below 50 for two thirds of this period. There is no theoretical support to this observation, so its empirical nature must be borne in mind when considering such long-term predictions.



Test Your Knowledge

*Series devised by L. Ibbotson**, B.Sc., A.Inst.P., M.I.E.E., M.I.E.R.E.

9. Aerials

1. An aerial which will radiate a coherent electromagnetic wave with the same power flux in all directions (an isotropic radiator) is
(a) theoretically impossible
(b) theoretically possible but has never been made
(c) available but never used because of its low gain
(d) used in space communications.

2. A transmitting aerial has a gain of 3dB. This means that:
(a) it radiates twice as much power as is fed into it from the transmitter
(b) it produces in all directions twice the power flux that would be produced by a reference aerial fed with the same transmitter power at the same distance
(c) in some direction it produces twice the power flux that would be produced by a reference aerial fed with the same transmitter power at the same distance
(d) it radiates all its energy towards the receiver thus causing the received power to have twice the value it would have if energy were radiated equally in all directions.

3. The equivalent absorbing area (effective aperture) of a receiving aerial when compared to the physical area presented by the aerial perpendicular to the direction of propagation of the received wave:
(a) is the same
(b) is always greater
(c) is always less
(d) is in some cases greater, in others less.

4. An aerial when used to transmit has a highly directive polar diagram. When used to receive its polar diagram is:
(a) the same
(b) more directive
(c) less directive
(d) shows no directivity.

5. The radiation resistance of a centre-fed half-wave dipole is of the order of:
(a) 13 ohms
(b) 70 ohms
(c) 600 ohms
(d) 1 megohm.

6. From four properties of a half-wave dipole given below select one which does not depend on its thickness:
(a) the radiation resistance
(b) the resonant length
(c) the bandwidth
(d) the gain.

7. A centre-fed dipole which is very much shorter than half a wavelength at the frequency to be radiated has an input impedance which is:
(a) purely resistive with a value much less than that at half-wave resonance
(b) purely resistive with a value much greater than that at half-wave resonance
(c) highly capacitive
(d) highly inductive.

8. A narrow rectangular slot in an infinite conducting sheet when fed between the centres of opposite sides of the slot forms an aerial with similar radiating properties to those of a centre-fed dipole which would just fill the slot. The two differ, however, in certain respects. Select from the four properties below one in which they differ:
(a) the half-wave resonant frequency
(b) the gain
(c) the polar diagram
(d) the plane of polarization.

9. A broadside array of dipoles, fed in phase, is to be built to produce a narrow beam of radiation in a direction perpendicular to the array, the aperture being given. The optimum separation between dipoles is:
(a) as close together as possible
(b) a quarter wavelength
(c) a half wavelength
(d) a wavelength.

10. The driven element of a Yagi array is frequently a folded half-wave dipole. The advantage of using a folded dipole rather than a simple dipole for this purpose is that
(a) it has an input impedance which is four times as great, so that it is much easier to match to the feeder
(b) it is much shorter and requires much shorter parasitic elements thus producing a smaller aerial
(c) it has better directional properties which improve the gain of the array
(d) the amplitude of side-lobes is reduced.

11. A vertical unipole, used to transmit a low frequency signal, usually has a network of buried wires connected to the earth terminal beneath it so as to improve the conductivity of the earth. This is necessary
(a) to reduce the reactive component of the input impedance
(b) to increase the effective height
(c) to reduce the dissipation of transmitter energy in heat
(d) to increase the proportion of the radiated energy radiated in the ground wave.

12. A common aerial for receiving long-wave and medium-wave (vertically polarized) signals consists of a vertical wire a few metres high with a horizontal wire connected to the upper end. The purpose of the horizontal wire is:
(a) to give capacitance to earth thus increasing the effective height of the vertical section
(b) to receive any incoming signal which may have become horizontally polarized
(c) to make the aerial terminal impedance resistive
(d) to increase the gain of the aerial by making it directive.

13. At high frequencies directional aerial arrays, consisting of a number of coplanar half-wave dipoles mounted in front of a reflecting screen, are used. The elements are generally end-fed. They are fed in this way because:
(a) the input impedance is high so that many elements can be connected in parallel with the same feeder
(b) connecting the feeders to the ends of the dipoles causes least disturbance to the polar diagram
(c) this form of feeding reduces the effect of earth reflections on the radiation pattern
(d) end-feeding reduces the effect of mutual impedance between the elements.

14. A rhombic aerial used for transmission is mounted with the plane containing its conductors horizontal. The radiation which it produces is:
(a) entirely horizontally polarized
(b) entirely vertically polarized
(c) horizontally polarized in the main lobe but not in all the side lobes
(d) vertically polarized in the main lobe but not in all the side lobes.

15. Which of the following is normally used to transmit a circularly polarized wave?
(a) a dielectric rod aerial
(b) a helical aerial
(c) a lens-corrected horn aerial
(d) a Franklin aerial.

16. A uniformly illuminated aperture (an ideal radiator to which a number of high frequency aerial systems approximate) can produce a narrow beam of radiation. Under conditions in which it does so the beam width of the main lobe in a given plane containing the axis of the main lobe is:
(a) directly proportional to the width of the aperture in that plane
(b) inversely proportional to the width of the aperture in that plane
(c) directly proportional to the area of the aperture
(d) inversely proportional to the area of the aperture.

Answers and Comments page 95

*West Ham College of Technology, London, E.15.

Letter from America

A recent press conference in a small office at Troy, Michigan, not only stirred up electronic circles but created a flurry of interest in Wall Street. The office in question belonged to one Stamford Ovshinsky of Energy Conversion Devices. The meeting was called to announce the publication of an article by the American Physical Society entitled "A description of an a.c. switch made of homogenous film containing no rectifying elements". Reporters were told about a new glassy compound which could supersede transistors in many areas and there was much talk of flat TV sets that could be. hung on the wall and so on. All this was very exciting to the non-technical press and the *New York Times* had large headlines saying "Glassy Electronic Device May Surpass Transistors" and the solemn *Wall Street Journal* devoted several columns to the Ovshinsky devices saying "Electron microcircuits using semiconductors are the basis of modern computers and the miniatured circuits used in transistorised radios, TV sets and other electronic machines. Mr Ovshinsky has developed an electronic switch with new materials. A microscopically thin layer of the material separates two electrodes which otherwise carry a current. The material blocks off the current until the force of the current hits a specific voltage. Then, in less than 50 trillionths of a second the material becomes a conductor . . . the material continues to conduct the current until the voltage drops. . . . What is exciting the physicists is that Mr. Ovshinsky's materials aren't crystalline in the atomic structure as all other semiconductors are. In a crystal the atoms are in an extremely evenly spaced geometric orderly arrangement. The Ovshinsky materials, however, consist of a variety of different atoms linked together in a disorderly fashion, a structure known to scientists as an 'amorphous' material. They are actually glasses composed of a mixture of tellurium, arsenic, silicon, germanium and other elements. By contrast, conventional semiconductors are crystalline forms of elements such as silicon and germanium. Ovshinsky materials are made fairly cheaply and easily. Common chemicals are weighed on a simple scale, mixed and then placed in a small furnace. There they are heated to 1000 deg for 24 hours until they fuse into a chunk of gray opaque glass . . . a small chip of this glass can be evaporated in a vacuum and laid down as a microscopic film. Or the material can be simply painted on. One advantage of the Ovshinsky devices is that they can operate on alternating current. Conventional semiconductors can pass an electric current in only one direction but the new semiconductors work regardless of which direction the current is flowing. Reporters were shown a memory switch made of the new materials. This memory switch, as with the threshold switch, is a non-conductor until the current flowing through hits a certain voltage; it then becomes a conductor. However, if the current is suddenly turned off the device doesn't revert to a non-conductor. Instead, it will stay in its conducting state indefinitely until it is hit with an electric pulse. An array of these devices, they explained, could permanently store the on-off pattern as long as needed. . . . Thus, they suggested, computer memories could be mailed across the country for example. . . . Mr. Ovshinsky envisioned a picture frame sized TV set. Essentially, it would consist of an array of tiny dots of the new semiconductor behind a coating of phosphors that coat conventional TV screens. These would be sandwiched between a grid of strips of conducting materials in the rear and transparent conductors in the front. As the electronic TV signals swept through the grid of the conductors in the rear it would cause the tiny semiconductors either to block or pass the current. Where it would pass the current the phosphors would glow creating the TV image. . . . Non-exclusive licences for the new materials have already been granted to International Telephone & Telegraph, L. M. Ericsson of Sweden and Danfoss of Denmark."

Publicity of this kind caused a tremendous rise in E.C.D. shares, but, the reaction from the industry was, to say the least, a little cautious. It was pointed out that these devices were not really new and that the first article appeared in *Control* as far back as April 1964. This was entitled "The threshold switch, a new component for a.c. control". Another article was published by *Electronics* in September 1966 and at that time Mr. Ovshinsky said his invention would shake the industry. At the moment the industry is still unshaken. RCA say they have tested the devices and Dr. Webster of the Princeton laboratories says "we have found no significant use for them". Raytheon are said to have found them erratic and Texas Instruments reported some instability problems and expressed doubt that they could be produced in quantities. Dr. Sparks of Bell Telephone said "There are relatively few applications for two-terminal devices, also the materials are more complex than crystalline structures and are less understood". He went on to say "they are not easily controlled and in our experience have exhibited considerable jitter in switching characteristics". Bell have patents for amorphous devices dating back to 1961, but, they stated recently that these devices do not warrant a major development programme. On the other hand, Sir Neville Mott, director of the Cavendish Laboratories, said "the discovery of the Ovshinsky effect is the newest, biggest and most exciting discovery in solid state physics at the moment". Mr. Ovshinsky himself said he is delighted by all the publicity and, undeterred by all the controversy, his company is busily making some 150,000 devices a day.

At the recent Audio Engineering Society Convention (held in the Park-Sheraton Hotel, Washington, instead of the Barbizon Plaza because of the heavy demand for space in the exhibition section) Ampex were demonstrating a new high-speed cassette stereo tape duplicating unit which featured remote control operation, plug-in heads, separate recording of each instrument and up to 24 channels. Tape-Athon Corporation were showing their new tape recorder intended for station monitoring. At a tape speed of 11/32in. per second it will operate over 400 hours using a $10\frac{1}{2}$in. reel of triple-play tape! Signal to noise is given as 38dB and a response of $\pm$ 3dB from 200 to 3000Hz. Not hi-fi, of course, but adequate for its purpose. Ray Dolby was demonstrating his system (this time he was using Lansing speakers); and again I was impressed with the remarkable improvement in signal-noise. One of the most interesting items was the Model 1925 Multifilter by General Radio. This new unit contains 30 channels of parallel octave band or one-third octave band filters in the frequency range from 3.15Hz to 80kHz. There are several options of frequency range and bandwidth; it can also be supplied without attenuators. It was demonstrated as a spectrum shaper showing an indication of the curve on the scale which is calibrated at 5in per decade. Vertical range is 10dB per inch and each attenuator has a 1dB per step resolution with a control of 50dB.

America is a country of contrasts, a land of extremes where you can see great wealth next to appalling poverty and the most selfish money grabbing side by side with incredible generosity. Huge corporations can be soul destroying, yet many have a higher regard for individual freedom and civic responsibility than similar concerns almost anywhere in the world. I am used to these contradictions so I was not surprised when I read about Lockheed Project LEND. The letters stand for Lockheed Engineers for National Deployment and it is a programme which establishes a reserve of experienced engineers who are lent for specific periods to other companies who have need of their particular talents. So far the company has lent out more than 100 engineers to companies such as Philco, Chrysler, LTV and General Dynamics.

G. W. TILLETT

Answers to "Test Your Knowledge" —9

Questions on page 93

1. *(a)*.

2. *(c)*. The reference aerial is usually an isotropic radiator for which the power flux can be calculated even though it cannot physically exist. A Hertzian dipole, or a half-wave dipole, radiating in the direction giving maximum power flux, sometimes used as reference.

3. *(d)*. The effective aperture of a half-wave dipole is much greater than its physical area; that of a microwave horn aerial is less.

4. *(a)*. This follows from the Reciprocity Theorem.

5. *(b)*.

6. *(d)*. If the thickness is increased the radiation resistance falls, the resonant length becomes shorter, the bandwidth increases, but the polar diagram, and hence the gain, remains the same.

7. *(c)*. The resistive component, which accounts for radiated energy (so long as Joulean losses are small enough to be neglected) is much smaller than the radiation resistance at half-wave resonance.

8. *(d)*. The dipole produces waves with electric vectors in planes containing the dipole, the slot produces waves with electric vectors in planes perpendicular to the length of the slot.

9. *(c)*. If the elements are spaced wider than half a wavelength "end-fire" lobes occur, causing energy to be radiated along the axis of the array. For spacing less than half a wavelength mutual impedance between the elements causes undesirable effects.

10. *(a)*. Mutual impedance between the driven element and the parasitic elements reduces the input impedance of the driven element—typically to such an extent that the input impedance of a folded dipole in this application is a good match to 70 ohm coax.

11. *(c)*. The functioning of a unipole aerial involves the flow of radial currents in the earth around it. Since the unipole must be short compared to a quarter wavelength at such a frequency the radiation resistance is only two or three ohms or less. Hence dissipative resistance has a marked effect on the aerial efficiency.

12. *(a)*.

13. *(a)*. Two adjacent dipoles fed from adjacent ends in antiphase so that they radiate in phase are equivalent to a centre-fed full-wave dipole. This typically has an impedance of several thousand ohms so that a number can be conveniently fed in parallel from a twin-wire feeder of characteristic resistance in the region of 600 ohms.

14. *(c)*.

15. *(b)*.

16. *(b)*. Provided the aperture is many wavelengths across, the angle of the main lobe between half-power points is approximately λ/a radians, where λ is the wavelength and a is the aperture width in the plane concerned.

COMPONENT BRIDGE SURVEY

D.C. and A.C. Bridges

by T. D. Towers, M.B.E., M.A., M.I.E.E.*

How the electrical characteristics of components can be measured accurately by balancing them exactly against a known-value standard

Nearly one hundred and fifty years ago S. H. Christie first suggested the bridge principle of measuring component characteristics in "Experimental Determination of the Laws of Magneto-electric Induction", *Phil. Trans. Roy. Soc.*, 1833, Vol. 123, pp. 95–142. In essence the method was to insert the component being measured in a network of known components, two points in the network being connected to a current source and two others "bridged" by an instrument capable of detecting a potential difference. The values of the known network components were then adjusted until a zero reading on the detector showed the bridge points to be at the same potential. The characteristics of the one unknown component could then be calculated from the known components' values. Christie's paper is fascinating. Couched in elegant early Victorian style and with delightful illustrations, it discusses in detail the measurement of resistance for wires of different diameters, lengths and metals for nearly fifty pages without once using the word "resistance" (which had not yet been invented!)

Christie's ideas were neglected for ten years until Sir Charles Wheatstone gave them practical point in "An Account of Several New Instruments and Processes for Determining the Constants of a Voltaic Circuit", *Phil. Trans. Roy. Soc.* 1843, Vol. 133, pp. 303–327. This paper makes more comfortable reading as it uses the new term "resistance". The result was the original equal-ratio-arms "Wheatstone" bridge of Fig. 1 (a). In this, when R_V is adjusted to give zero deflection in the detector, I, (a d.c. galvanometer or what we now call a centre-reading microammeter), then the unknown resistance R_X is equal to the known R_V.

In this original Wheatstone arrangement, the calibrated variable resistance, R_V, had to be such that it could be set equal to the unknown, R_X, the ratio arms, R-R, being equal. In 1848 Siemens introduced the unequal ratio arms, P-Q, of Fig. 1 (b). The balance condition becomes $R_X = PR_VQ$. By selecting different ratios of P to Q, it was possible to use one standard variable, R_V, to cover a much wider range of unknown resistances, R_X. This is the form in which the Wheatstone bridge has been known ever since.

The next basic development took place about 1865, when Clerk Maxwell used the Wheatstone bridge principle to measure inductance values in his "Inductance Ballistic Bridge", shown in basic form in Fig. 1 (c). In this, L_X, R_X represents an unknown inductance L_X of resistance R_X. The bridge is first adjusted for d.c. balance by means of R_V. Then the switch SW is opened and the galvanometer, I, allowed to re-settle to zero. When the switch was closed again, the galvanometer needle kicked over before returning to zero. Knowing the ballistic properties of the galvanometer, you could measure the inductance value from the peak needle displacement. (Engineers who use an Avo in its resistance range for a rough estimate of a capacitance from the kick of the meter needle are using the same sort of process.)

Maxwell then followed up with the "Inductance Null Ballistic Balance" shown in Fig. 1 (d). In this the switch was first closed, and, after the detector had settled, R_V was adjusted for zero deflection. This gave R_X in terms of R_V, P and Q, all known. Next the switch was opened and closed repetitively, and the inductance L_V varied in value until no deflection could be observed on the detector. This gave L_X in terms of L_V, P and Q.

Between 1870 and 1890 many different versions of the ballistic bridge were dreamed-up both for inductance and capacitance measurements. The simple manually-operated on-off switch was soon replaced by a mechanical interruptor or commutator. The telephone (invented by Graham Bell in 1875) often replaced the galvanometer. But in 1891, Max Wien in *Ann. der Phys.*, Vol. 44, pp. 681–712 (1891) introduced the modern a.c. bridge. He abandoned the interruptor method of energising the bridge, and fed the network, as in Fig. 1 (e), with alternating current of a definite frequency produced by an induction coil in which the primary current was made and broken at a fixed rate by a vibrating wire. He also designed a more sensitive detector in his "optical telephone", This was a magnetic telephone with its diaphragm tunable to resonance with the a.c. in the bridge, and with its output displayed by reflecting a beam of light from a mirror attached to the diaphragm. Wien adapted most of the old ballistic methods to his new a.c. bridge. Since Wien, much work has gone in developing more and more refined versions of a.c. bridges.

The next big step forward was the "Wagner" earthing arrangement described in 1911 by K. W. Wagner, "Zur Messung dielektrischer Verluste mit der Wechselstrombrucke", *Elekt. Zeits.*, 1911, Vol. 32, pp. 1001–2. This was designed primarily to get rid of what was known as the "head-effect" by which the parasitic capacitances from the headphone detector could vitiate an a.c. bridge balance. Fig. 1 (f) illustrates the basic arrangement of the Wagner earth. First the bridge is balanced conventionally with the switch SW in position one by adjusting Z_V. Then the switch is changed to position two and R_E across the signal source is adjusted again for a null. By continually changing between position one and two and re-adjusting R_E and Z_V for a null, a final position is reached where both points b and d are at earth potential, so that the "head effect" is eliminated.

Over the years many different a.c. bridges have been produced as variants on the Wheatstone arrangement, all essentially working with arm elements that do not have any cross coupling between them. Then in 1928, Alan Blumlein proposed in British Patent No. 323037 a scheme for replacing the usual fixed isolated ratio arms with a pair of tightly coupled inductors as shown in basic form in Fig. 1 (g). When the bridge is balanced $Z_X = Z_V$ and equal currents flow from c to d and from c to b. Hence there is no magnetisation of the inductor core. Thus, except for a small effect from the resistance of the windings, there is no potential difference between c and d, or between c and a, and thus between b and d. This produces greater sensitivity in the bridge because the whole of the applied voltage appears across Z_V and Z_X. Also if the point c is earthed as shown in the diagram, strays from b and d to earth are innocuous, because these points are virtually at earth potential. Finally, strays from a to earth merely load the signal source and do not affect the bridge balance.

The idea of the inductively-coupled ratio arms bridge was not generally exploited

* Newmarket Transistors Ltd.

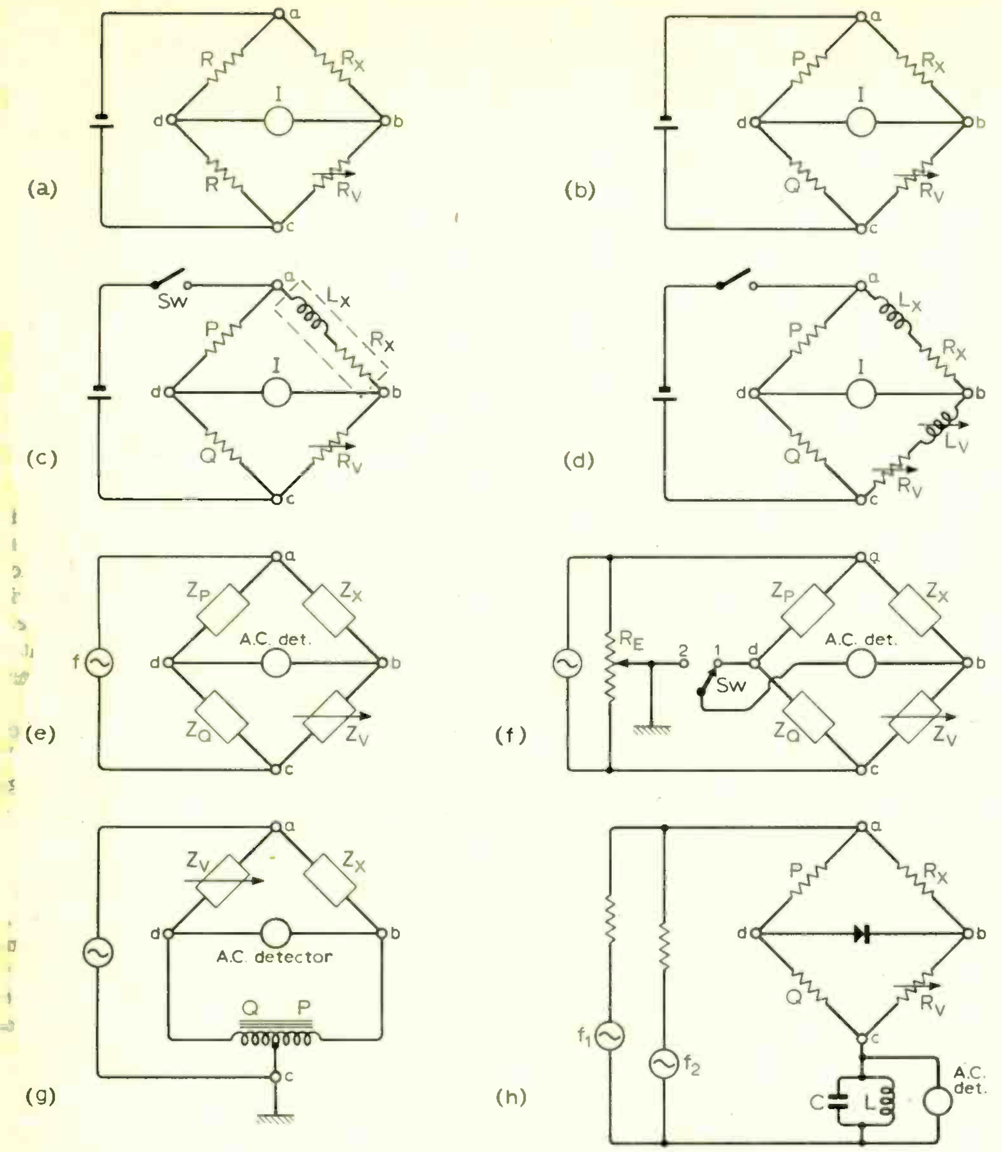


Fig. 1. The development of component bridges (a) 1843 Wheatstone: Resistance balance; equal ratio arms, R—R; adjustable standard R_V; unknown, R_X; (b) 1848 Siemens; resistance balance; unequal ratio arms, P-Q. (c) 1865 Maxwell: inductance ballistic bridge. (d) 1873 Maxwell: inductance null ballistic bridge. (e) 1891 Wien: a.c. bridge. (f) 1911 Wagner: "Wagner earth" bridge. (g) 1928 Blumlein: inductively-coupled ratio arms bridge. (h) 1960 Short: two-signal bridge.

until just before and during World War II. Then in 1946 commercial development began and in 1949 a practical design was fully described by H. A. M. Clark and P. B. Vanderlyn in "Double-ratio A.C. Bridges with Inductively-coupled Ratio Arms", *Proc. I.E.E.*, Part III, Vol. 96, 1949, pp. 189–202. Part I of that paper was taken almost verbatim from notes made by Blumlein before his death. C. G. Mayo (B.B.C.), quite independently, designed a similar bridge to Blumlein and was granted patents. Following these events, a whole family of inductively-coupled ratio arms bridges became commercially available. J. F. Golding in *Wireless World*, June 1961 gave a useful review of the practical constructional problems as well as of the principles of this kind of bridge.

All the Wheatstone-derived bridges described so far have the inconvenience that the bridge oscillator and the detector cannot have a common terminal. The connections of one diagonal of the bridge must be floating. However, an interesting development was announced in 1960 by G. W. Short in "Two-signal Bridge", *Electronic Technology*, 1960, p. 452. This used two oscillators of different frequencies in a simple modification of the usual bridge arrangement as in Fig. 1(h), and made it possible for the input signal source and the output detector to have a common terminal without shorting one arm. The two input frequencies f_1 and f_2 mix in the diode across the bridge and the bridge unbalance across the diode is sensed by the one-side-earthed detector across the *LC* circuit tuned to the sum or difference frequency. The tuned circuit offers an effective short circuit to the two separate input frequencies. I am not aware that the system has been exploited commercially.

We have seen how component impedance characteristics can be measured by balancing them against known passive components in a bridge. Voltages can also be measured with great accuracy in a special type of "bridge".

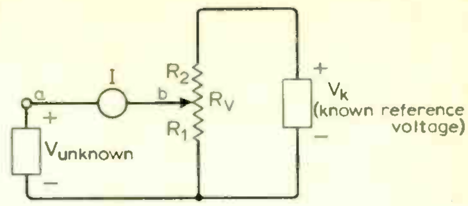


Fig. 2. Voltage measurement by potentiometer-type balanced bridge.

This is the so-called "potentiometer" circuit given in Fig. 2. Here a potential-divider network across the known reference supply voltage, V_K is adjusted until the indicator, *I*, shows zero current flow. Then points *a* and *b* are at the same potential. Since in balance no current passes through the indicator, there is no load on the potential divider and the unknown voltage at *a* is given accurately by:

$$R_1 V_K/(R_1 + R_2).$$

With R_V accurately calibrated, R_1 and R_2 are known and the unknown voltage can be computed. From Fig. 2 it can be seen that the potentiometer is really a three-arm

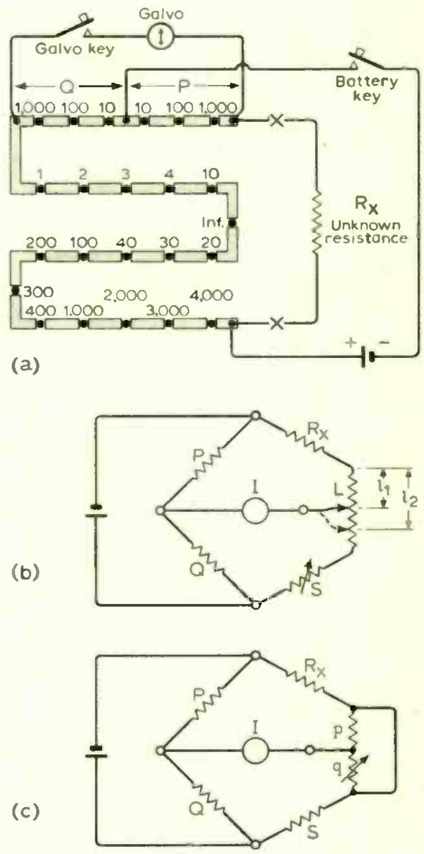


Fig. 3. Some basic arrangements used for d.c. resistance bridges (a) Wheatstone bridge for medium and high resistances as exemplified in internal connections of the P.O. box type of bridge. (b) Carey-Foster slide-wire bridge: for high accuracy mid-resistance measurements. (c) Kelvin Double-bridge: for low resistances, typically 1 Ω downwards.

bridge circuit, and like the full four-arm bridge works on null balance against a known standard.

Classification of component bridges

Component bridges can be arranged to measure resistance (or conductance), capacitance, inductance, incremental inductance (in the presence of a standing current), mutual inductance, incremental mutual inductance, quality factor, phase angle, complex impedance (or admittance). In addition, bridges have been developed to measure active device characteristics such as transistor current gain, and valve or f.e.t. transconductance.

One way of classifying these diverse bridges is into "balanced" and "unbalanced". So far we have considered only balanced bridges, but it can be shown that near balance the reading of the null meter can be correlated closely with the deviation of the component characteristic from the centre value.

Nowadays the balancing of the bridge can be manual, semi-automatic or fully automatic. In semi-automatic bridges, near-balance is achieved manually by switches or push buttons bringing in fixed standards and the final small unbalance is read on a meter. Recently there has been a trend, however, to fully automatic self-balancing bridges. Analogue versions of these incorporate a feedback servo-mechanism and display the measurement as a displacement on a scale. Digital versions, using monolithic integrated circuits, switch themselves to the correct range, display the measured values in some form of digital readout (usually a row of figures) and normally also provide digital outputs for data logging, etc.

Bridges can also be classified by the degree of accuracy to which they can be read. Instruments fall into three main categories: general purpose, semi-precision and precision. Measurements in the first category ordinarily can be made from 0·3 to 3·0% accuracy, in the second 0·03 to 0·3% and in the last better than 0·03%.

The tendency in commercial bridges is to make them capable of measuring as many different characteristics as possible, and the so-called "universal" bridge has become a lab. commonplace, able to measure at least *R*, *C* and *L*. For very refined measurement of a particular single characteristic, however you will usually find a specialist bridge devoted solely to that characteristic.

Nowadays the bridge instrument often includes the signal source and detector internally in the equipment, but there may still be facilities for attaching a separate signal source or separate high-precision standards when required. Suitable standards are readily available. These range from an inexpensive ½ to 1% decade capacitance or resistance box to expensive high-precision lab. standards supplied by specialist firms.

The student who is tempted to delve deeper into the vast literature on component bridges should find useful guidelines into the subject in standard references such as *Radio and Electronic Laboratory Handbook* by M. G. Scroggie (Iliffe Books Ltd.), *The Principles of Electrical Measurements* by H. Buckingham and E. M. Price (E.U.P.), *Alternating Current Bridge Methods* by B. Hague (Pitman), *Electrical Measurements* by F. K. Harris (Chapman and Hall), *Electrical Measurements and Measuring Instruments* by E. W. Golding and F. C. Widdis (Pitman), and *Electronic Measurements* by F. E. Terman and J. M. Pettit (McGraw-Hill). At a more popular level you can consult such references as *Bridges and Other Null Devices* by R. P. Turner (Foulsham) or *Electronic Lab. Instrument Practice* by T. D. Towers (Iliffe Books).

If you do any reading into bridges, you will immediately be shaken by the vast number of different variants produced over the years. The first classified collection of a.c. bridge networks was published by Max Wien in 1891, following a collection of old ballistic methods by W. E. Sumpner in 1888. Subsequent collections were produced by Rowland (1898), Campbell (1908), Hay (1912), Cone (1920) and others. But the definitive classification was that of J. C. Ferguson in "Classification of Bridge Methods of Measuring Impedances", *Trans. Am. I.E.E.*, 1933, Vol. 52, pp. 861–868. My own private "collection" of bridges now runs close on three hundred.

In the remainder of this article we will look only at the more common bridge circuits widely used commercially, dividing them into three main groups: d.c., l.f., and h.f.

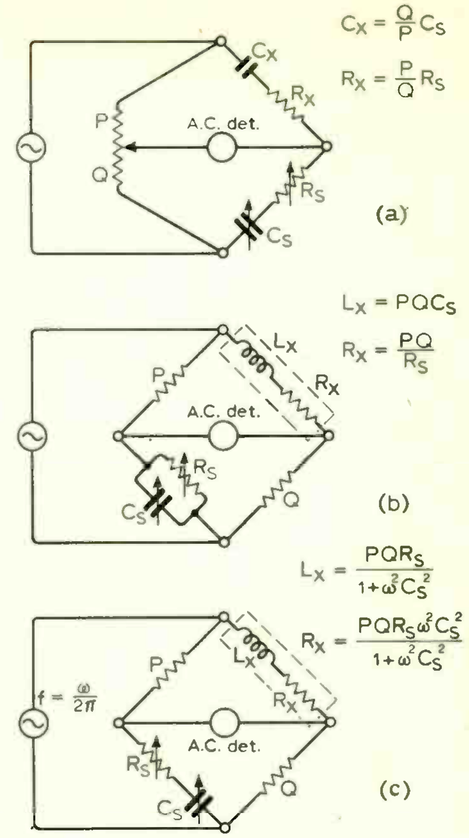


Fig. 5. Basic bridge types other than resistive-Wheatstone commonly used in l.f. bridges. (a) De Sauty: used for measuring C (in combination with a.c. resistive Wheatstone for R) in commercial C-R tester. (b) Maxwell: for low-Q inductance. (c) Hay: for high-Q inductance.

D.C. bridges

Except for very special use, you will not nowadays find in the ordinary lab. single-purpose d.c. bridges of the Wheatstone type, because so many universal bridges have adequate facilities for resistance measurements. However, where you do come across d.c. bridges, you will usually find that for medium and high resistance values the "straight" Wheatstone circuit of Fig. 1(b) given earlier is used. A venerable example of this is the old P.O. box type for which the internal connections are shown in Fig. 3(a). The resistances are non-inductively wound coils connected between brass strips on top of the instrument. Tapered brass plugs, indicated as solid dots in the diagram, are inserted between the strips to short-circuit the resistances as desired. All the s/c plugs are shown inserted in the diagram. If any one is withdrawn, it introduces into circuit a resistance of the value noted beside it in ohms. The arms *P* and *Q* are known as "ratio arms" and the plugs can be arranged to produce resistance ratios of 100:1, 10:1 1:1, 1:10 and 1:100. The variable resistance arm *R* can be adjusted by 1 Ω steps from 1 to 11,110 Ω. Thus by using the ratio arms in conjunction with *R* it is possible to balance against an unknown resistance from 0·01 to 1,111,000 Ω. A P.O. box Wheat-

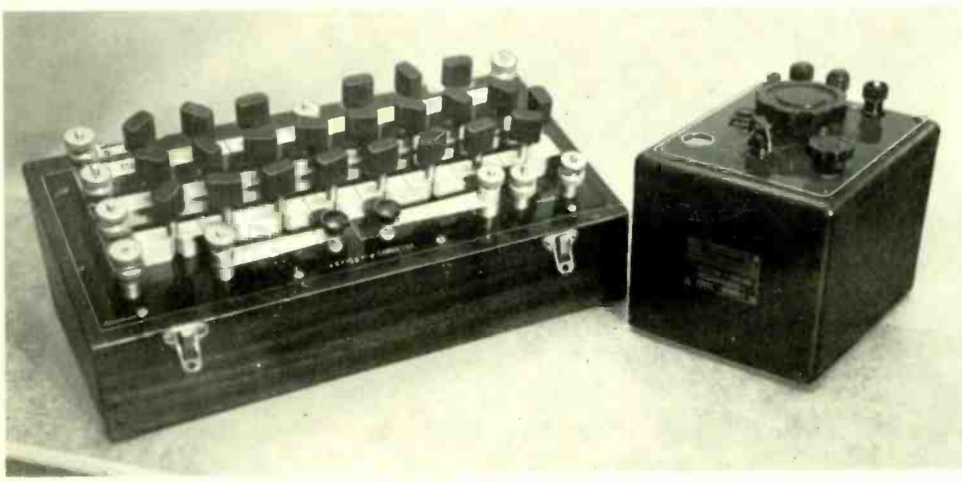


Fig. 4. Well-known bridges that used to be common around laboratories: (on left) P.O. Box d.c. Wheatstone, (on right) Mullard l.f. C-R bridge.

Whether you design, manufacture or use inductive devices, the measurement of inductance, consistently and accurately, will concern you. Measuring inductance with any certainty is difficult; and hit-or-miss methods not only waste time, but lead to expensive complications; which is why M.I. have designed the most comprehensive yet straightforward instrument available for complete inductance analysis.

The TF 2702 Inductor Analyser measures inductance at all frequencies from 20 Hz to 20 kHz, with currents up to 1,000 amps – DC, AC or mixed! And it is sensitive enough for measurements at low current levels and for low-Q inductances at high accuracy.

There is no interaction between balance controls, and operation is even further simplified by a c.r.t. detector, which rapidly indicates the direction of unbalance. A tunable voltmeter gives final balance. A full range of accessories is available.

- **Measurement range: 0·3 μH to 20,000 H**
- **Internal or external excitation frequencies**
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clear
to see . . .
. . . why our digital wheatstone bridge is so special. It is the only wheatstone bridge manufactured with illuminated digital readout.
No need to work out those tiresome ratios, the display gives four figures, decimal point and the correct unit (ohms, kilohms and megohms) thus permitting rapid checking.
so simple to use
The Doran range of precision instruments includes . . .
potentiometers
pH meters
bridges (of all types)
galvanometers
standard cells
micro cells
electrodes
power units
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stone still sometimes in use in the author's lab. to select meter shunts can be seen on the left in Fig. 4.

Where higher accuracy of resistance measurement is required, the simple Wheatstone is replaced by the Carey-Foster slide-wire modification of Fig. 3(b). This is balanced in three steps. First arms P and Q are selected for an approximate null. Then the null is sharpened by moving the slider over the length l_1 of the slide-wire, L, which has a resistance of r ohms per unit length. Next R_X and S are interchanged and the slide-wire readjusted to l_2 to give null again. Then R_X is given by:

$$R_X = S + (l_1 - l_2)r.$$

It should be noted that P and Q do not appear in the final equation. This bridge is specially suited to accurate comparison of an unknown resistance with a standard close to it in value.

When we come to measure low resistances, where contact resistances begin to make up a significant part of the total, we usually find the Kelvin Double-bridge of Fig. 3(c) used. Here R_X is the low resistance to be measured and S is a standard of the same order of magnitude. P,p,Q,q are four known ratio resistances, one pair of which (Q,q) is variable. Q and q are variable in step together so that P/p always equals Q/q. Q and q are varied until the galvanometer deflection becomes zero, when:

$$R_X = SP/Q.$$

In wide-range precision commercial d.c. bridges, accuracies around 0·03% are typical, and the internal bridge arrangement used is switched from a Wheatstone in, say, the 10 Ω to 10 MΩ range to a Kelvin for 10 μΩ to 10 Ω range. Usually neither a source nor a detector is included internally.

If you want to build your own precision d.c. resistance bridge, you will find a convenient design at p. 124 of R.P. Turner's *Basic Electronic Test Instruments* (Holt, Rinehart and Winstone).

L.F. bridges

L.F. bridges fall into three main categories: fairly simple *C-R* bridges, universal *L-C-R* bridges, and special single-characteristic bridges for inductance for example.

Many relatively cheap commercial bridges are available for measuring C and R over a wide range at medium accuracy. One "old-timer" known to many is pictured on the right side of Fig. 4. Virtually all of these use the De-Sauty bridge circuit shown in Fig. 5(a) for the capacitance measurement, switching to a simple Wheatstone for resistance. M. G. Scroggie in his *Radio and Electronic Laboratory Handbook* (Iliffe) gives a useful practical design for a simple mains-frequency 1% bridge for 10pF to 10 μF and 10 Ω to 10 MΩ, typical of these.

"Universal" l.f. bridges capable of measuring L, C and R with accuracies of 0·3% or better are widely available. Typically for R and C they use Wheatstone and De-Sauty respectively. For L they generally use a "Maxwell" bridge—Fig. 5(b)—for low values and a "Hay" bridge—Fig. 5(c)—for high values.

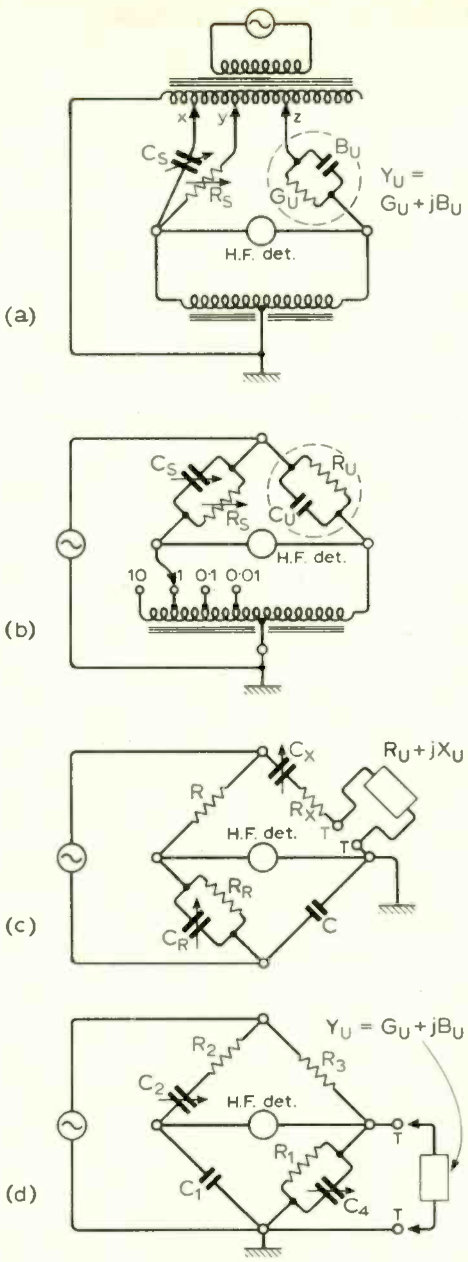


Fig. 6. Basic circuits commonly used in commercial h.f. impedance measuring bridges (a) Transformer inductive ratio arms bridge. (b) Adjustable inductively-coupled ratio arms mutual admittance bridge. (c) Schering series-substitution capacitance ratio bridge. (d) Schering parallel-substitution capacitance ratio bridge.

Inductively-coupled ratio arms techniques described earlier are used in some commercial "in situ" l.f. bridges to measure components in conditions beyond the scope of conventional universal bridges, particularly in the presence of heavy shunting or with components wired in circuit.

Over the years many designs of universal *LCR* l.f. bridges have been published. A useful complete construction was described recently by L. Nelson-Jones in "Universal Component Bridge", *Wireless World*, Dec. 1968. p. 434, covering with 1% accuracy the ranges 10 μH to 100 H, 10 pF to 100 μF, and 1 Ω to MΩ. This included a miniature c.r.t. output display.

Of single-function l.f. bridges quite a number have been on the market in the past, but they tend to be less common nowadays because freely-available wide-range multi-function universal bridges make them unnecessary. Even so, such specialised instruments as an "inductor analyser" capable of measuring inductances up to 21,000 H with standing current up to 10 A are on the market. Single-function bridges normally use one of the standard bridge circuits described earlier.

H.F. bridges

Bridges to measure component characteristics above audio frequency become progressively more difficult to design, as the measurement frequency rises. Strays ultimately become of the same order of magnitude as some characteristics being measured. Bridge layout tends to become the main design problem. The basic type of h.f. bridge used tends to be either transformer ratio arms or the "Schering" capacitance-ratio Wheatstone-derivative described below.

In practical instruments, the basic inductively-coupled ratio arms bridge illustrated earlier in Fig. 1(g) is usually the tapped-transformer driven as in Fig. 6(a), where the tappings *x*, *y* and *z*, on the input transformer enable either an inductive or capacitive unknown to be measured. For inductance, tapping *x* is moved to the right of *z*. To widen the bridge coverage with given variable standards C_S and R_S, selective tapping of the inductive ratio arms can be used as shown in Fig. 6(b), thus introducing scale factors of 10:1, 1:1, 1:10, and 1:100 into the results. The unknown admittance is usually expressed in terms of parallel conductance and capacitance, with negative capacitance corresponding to an inductive unknown.

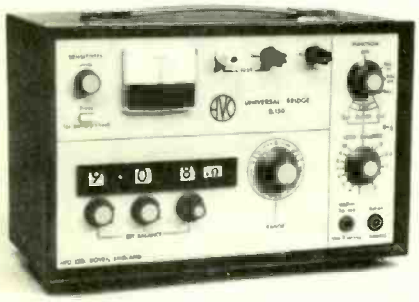
The other basic bridge common in h.f. measurements is the Schering-derived type of Fig. 6(c) and (d), whose balance equations do not involve the measurement frequency. In the series-substitution version of Fig. 6(*c*), the bridge is balanced with the test terminals, *T-T*, short circuited. The short circuit is removed and the unknown impedance, $R_U + jX_U$, connected across the terminals and the bridge rebalanced. R_U is then proportional to the change in C_R and X_U to the change in C_X (capacitive if positive and inductive if negative). In the parallel substitution version, Fig. 6(d), balance is first set with nothing connected to the test terminals, *T-T*. The unknown admittance $Y_U = G_U + jB_U$ is then connected in and the bridge re-balanced. Then G_U is inversely proportional to the change in C_2, and B_U to the change in C_4 (positive for capacitance and negative for inductance).

Transformer ratio arms and Schering bridges are available commercially for measurements up to 250MHz. Above this we move firmly into the realm of non-lumped characteristics, and generally find only very specialised admittance bridges using coaxial-line techniques measuring up to around 1500MHz.

Recent Products

Sullivan decade inductance bridge is a transformer-ratio arm instrument using a modified Maxwell circuit and it measures inductance and resistance in terms of internal capacitance and conductance. It enables one side of the unknown and one side of the standard to be earthed. Accessories include a signal generator and detector. The bridge will measure up to 11.11H with a discrimination of 0.002 μH and this range can be extended by the use of external capacitance standards. Resistance can be measured up to 100k Ω in five decades. H. W. Sullivan Ltd., Murray Road, Orpington, Kent, BR5 3QU.
WW 371 for further details

Avo universal bridge type B.150 is battery-operated and features a digital in-line display. Units of measurement and the decimal position are displayed automatically along with the relevant figures. Capacitance may be measured up to 1199μF, inductance up to 119.9H and resistance up to 11.99MΩ. An internal oscillator allows measurements to be made at 1kHz, but other audio frequencies may be supplied from an external source. A polarizing voltage of up to 500V can be applied externally in testing electrolytic capacitors.



An inductance adaptor, type A151, is available to allow iron-clad inductors to be measured directly on the bridge with varying d.c. bias current and at different a.c. signals superimposed via the bridge. Avo Ltd., Avocet House, Dover, Kent.
WW354 for further details

Startronic resistance measuring bridge type 100.2 is designed for the measurement of lower value resistors. The ranges are -0.05 to 5 Ω with an accuracy of 1.5% and 0.5 Ω to 50k Ω with an accuracy of 0.5%, in four switched ranges. Type 108.2 is designed for the measurement of resistance in the milliohm range and is powered by internally fitted dry cells. A special feature of this instrument is the ability to vary the resistance measuring current. Range is 0–160m Ω

with accuracy $\pm$ 2% above 50m Ω and $\pm$ 1m Ω below 50m Ω. The measuring current can be set at 600, 300, 200, 100 or 50 mA, as required. Both instruments are priced £39. Startronic Division, Stow Electronics Ltd., Ponswood Industrial Estate, St. Leonards on Sea, Sussex.
WW352 for further details

Bruel and Kjaer 100kHz deviation bridge type 1519, allows for measurements to be made over the following ranges:

R: 10 Ω-100k Ω
C: 12pF-1 μF
L: 5 μH-20mH

The bridge voltage is 0.35 volt for all ranges and the voltage appearing across the test component is 0.175V. The centre point of the bridge can be grounded. B. & K. Laboratories, Ltd., Cross Lances Road, Hounslow, Middx.
WW363 for further details

Advance BR1, is a bridge for the measurement of inductance, capacitance and resistance to an accuracy of at least 1%. An internal transistor oscillator of 1kHz $\pm$ 1% provides the bridge energizing source for the measurement of *L, C,* and *R* together with *Q* of an inductor and loss factor *D* of a capacitor. Alternatively, an external signal generator of frequency between 20Hz and 20kHz may be substituted. A high sensitivity, low noise, bridge amplifier detector precedes the meter circuit and facilitates an accurate and rapid balance condition. The range of measurement for *L, C* and *R* is respectively 0.2 μH to 110H, 0.5pF to 1100 μF and 10m Ω to 11M Ω, each range being covered in eight decades. Resistance measurements may be achieved using the internal d.c. supply source, a 9-V dry battery, or any externally applied potential not exceeding 500V d.c. The BR1 is fitted with an isolating transformer enabling it to be used with a wide range of signal generators for measurements at frequencies other than 1kHz. Advance Electronics Ltd., Roebuck Road, Hainault, Essex.
WW366 for further details

'Logohm' (Baldwin) wide-range resistance bridge is a direct-reading Wheatstone portable instrument. It is accurate to within 1%. A galvanometer and dry batteries are contained in the instrument. Balance is obtained by rotating a dial carrying a wire-wound logarithmic potentiometer, thus ensuring smooth and continuous adjustment. The dial carries a logarithmic scale calibrated from 5 to 500 Ω. A four-position switch marked XO.01, X1, X100, X10,000 covers an overall resistance range from 0.05 Ω to 5M Ω. Due to its logarithmic scale, the percentage accuracy is substantially uniform throughout the range of the bridge, and is, within 1%, a degree of accuracy adequate for most practical requirements. A feature of the galvanometer is that its pole-pieces are specially shaped to ensure very high sensitivity at zero for accurate balancing, and low sensitivity on maximum deflection, to prevent damage to the movement when the bridge is well out of balance. The range switch is so connected in the bridge arrangement that its contact resistance does not enter into the bridge equation for balance. P.S.B. Instruments Ltd., Palmerston Road, Wealdstone, Harrow, Middx.
WW364 for further details

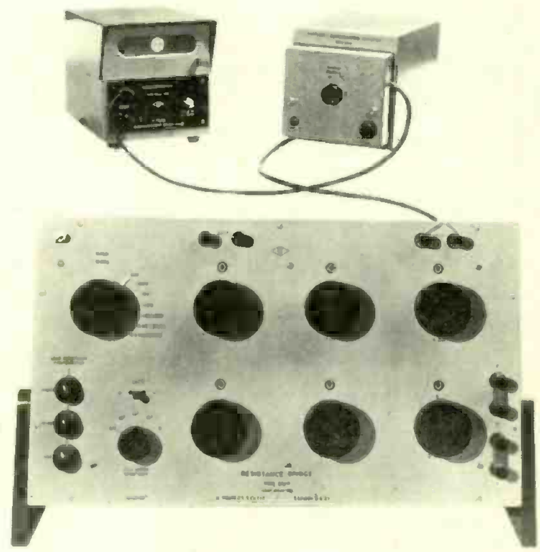
Sprague Transfarad capacitor analyser measures capacitance between 1pF and 2000 μF in five overlapping ranges. Normally, 25V d.c. is applied, but for ceramic capacitors rated below 25V, insulation resistance may be calculated from leakage current measurements at the exact rated voltage. Power factors between 0 and 50% can be measured by a Wien bridge. Leakage current can be measured between 0.6 and 600 μA in seven ranges, and is read off the meter at the exact rated d.c. voltage of the capacitor. In the a.c. bridge, only 0.5V is distributed, and less than this appears across the capacitor under test. An electronic indicator simplifies bridge balancing for capacitance and power factor measurements. In testing electrolytics, a polarizing voltage is available continuously adjustable from 0 to 150V. Sprague Electric (U.K.) Ltd., Trident House, Station Road, Hayes, Middx.
WW 350 for further details

British Physical Laboratories' 1kHz component comparator, model CZ 457 Mk. V, is capable of fast tolerance testing of *R, C* and *L* components under mass production conditions. Percentage deviation, covering tolerances from 0.1% upwards, is directly read off multi-coloured scales. Semiconductors are used throughout. The measurement ranges are:

L 10 Ω—5M Ω and 0.01 Ω—2.2M Ω
C 20pF—10 μF and 0.02pF—1.8 μF
L 2mH—100H and 2pH—18H.

The bridge voltage is less than 500mV r.m.s.

TINSLEY HIGH PRECISION RESISTANCE BRIDGES TYPE 5577



A Modern Resistance Bridge in which the variable arm consists of conductance decades, built up in binary increments covering a million steps. Six resistors per decade, lowest resistor 50 ohms therefore switch contact resistance negligible. All resistors in circuit when maximum current is flowing. Built-in lead compensator.

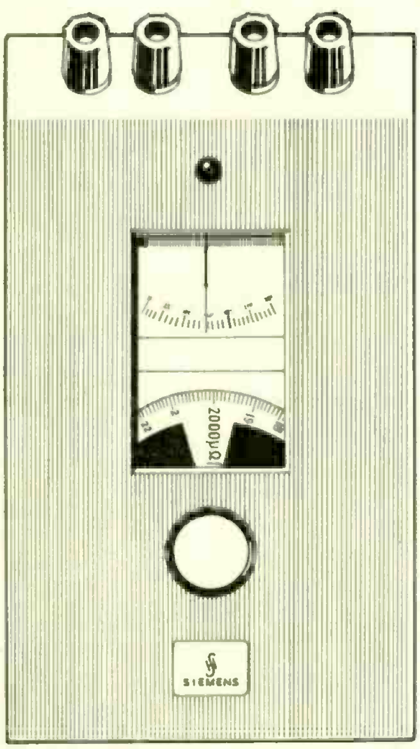
Total range 0.0001 ohms to 100M ohms in seven ranges. Limit of error at mid-range 0.001%

For full details of this and other instruments in the Tinsley range, write to:—

H.TINSLEY & CO LTD

Pacemakers in Precision Measurement
WERNDEE HALL, SOUTH NORWOOD,
LONDON, S.E.25. Tel: 01-654 6046

WW—118 FOR FURTHER DETAILS



SIEMENS SINGLE KNOB RESISTANCE BRIDGES

Three models available

M273-A1 (Illustrated)
Single Knob Kelvin
Bridge 0.2mΩ to 2.2Ω

M273-A2
Single Knob Wheatstone
Bridge 40mΩ to 50kΩ

M273-A3
Single Knob Wheatstone
Bridge 20kΩ to 220MΩ

- ☐ Rapid reliable operation
- ☐ Only one knob with built-in push button
- ☐ Resistance values directly readable from rotating scale
- ☐ High galvanometer sensitivity
- ☐ All measuring and comparison elements are built in
- ☐ No accessories required
- ☐ Bridge voltage supplied by two internal 1.5V cells
- ☐ Provision for external supplies for quantity production measurements

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CROYDON CR9 2HB
TEL: 01-686 7581 TELEX: 262346

WW—119 FOR FURTHER DETAILS

Accuracy is $\pm 2\%$ of indicated deviation or 1% of f.s.d. whichever is the greater. British Physical Laboratories, Radlett, Herts.
WW 356 for further details.

General Radio impedance bridge, type 1608-A, measures *C*, *R*, *L* and *G* with digital readout to an accuracy of $\pm 0.1\%$. Six bridge circuits cover all possible phase angles so that any network can be measured, even filters, transducers and equalizers. The ranges are as follows:
C : 0.05pF to 1100 μF in 7 decades
L : 0.05 μH to 1100H in 7 decades
R : 0.05m Ω to 1.1M Ω a.c. or d.c.
G : 0.05 nanomho to 1.1 mhos a.c. or d.c.
Also *D* and *Q*. In a.c. resistance and conductance measurements a *Q* adjustment for precise balancing gives phase information useful in predicting high-frequency behaviour. For production testing of components, a test jig is available. An internal 1kHz $\pm 1\%$ generator module is normally supplied but plug-in modules for other frequencies are available. The detector can be external or internal, flat response or selective at the frequency of the plug-in module. Three d.c. supplies are

included for maximum sensitivity over a wide range of frequencies. Operation is from mains supply and consumption is 10W. General Radio Co. (U.K.) Ltd., Bourne End, Bucks.
WW 372 for further details

Capacitance bridge B541C Mk. II by Wayne Kerr allows for rapid capacitor checks, and provides continuous readings of changing values. It has comprehensive faciltites built-in for comparative measurements, for off-setting any deflection (enabling the desired nominal value to be adjusted to mid-scale) and for backing-off the first digit of any reading to give increased meter resolution. The power unit incorporates a rechargeable battery giving long periods of operation independently of 110 or 240V supplies. Seven ranges cover 0-10pF to 0-10 μF in decade steps. Voltage and current outputs are provided for recorders, pass/reject systems or control circuits, with a response time of only 60 milliseconds. Bridge circuits of the B541 are constantly maintained in the "balance" condition by a system of feedback. A third terminal is available for screening connections when required. On all ranges accuracy is $\pm 0.25\%$ of maximum. Wayne Kerr Co. Ltd., New Malden, Surrey.
WW 367 for further details

Culton automatic component bridge, type 167, is a transformer-ratio arm bridge with an accuracy of better than 0.1% when measuring *L*, *C* or *R*. Accuracy is controlled by transformer ratios used and by an internal standardized 10nF capacitor and 10k Ω resistor which have been aged and calibrated. The instrument is suitable for checking thick film circuits which contain a number of resistors or capacitors of different values on the same substrate, and an input unit can be supplied which enables the bridge to be programmed to give "pass or fail" information. Range selection and balance is auto-

matic. Alternatively, the bridge can be connected to a unit which incorporates a detector and a circuit for driving a printer. Component values can then be logged and compared against values set into the detector; any components outside the set values can be rejected. The bridge measures inductance from 1mH to 1099.9H, capacitance from 0.01pF to 10.999 μF and resistance from 10 Ω to 10.999M Ω. The component to be measured is held in a spring-operated Y-shaped clamp. Transistors are used throughout and the bridge power source is a 1kHz oscillator which becomes 1592Hz when measuring inductance. Culton Instruments Ltd., Dorking, Surrey.
WW 370 for further details

Siemens universal bridge type M565-A1 operates over the following ranges:
R: 0.1 Ω to 110M Ω in 9 decades
L: 10 μH to 1100H in 8 decades and using a 1000Hz signal
C: 10 μF to 1100 μF in 9 decades using a 50Hz signal
A comparison circuit is provided for impedance measurements using an external standard in the range 0.1 Ω to 1M Ω. The scale division is −20% to 0 to +20%. Error is less than 1.5% of full-scale value, less than 3% of the nominal value in the ranges 10^1 to 10^7, less than 5% of the nominal value in the ranges 10 and 10^8, and less than 5% of full scale value (20%) for comparison measurements. A protection circuit is provided for the meter. An auxilliary voltage source of 9V can be employed from either dry batteries or accumulators. Distributed by Cole Electronics Ltd., Lansdowne Road, Croydon CR9 2HB.
WW 358 for further details

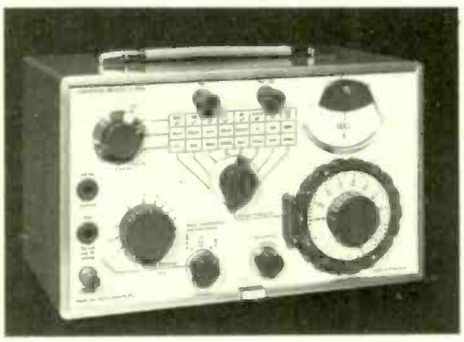
Derritron digital Wheatstone bridge, is balanced in the usual way, null balance being detected with a sensitive taut suspension galvanometer. The "unknown" resistance value is then given directly by an illuminated display. The display consists of four figures approximately 16mm high, a decimal point and the correct unit symbol, i.e. Ω, kΩ, or MΩ. The resistance value is given without ambiguity, the operator merely reads in a straight line without having to note pointer positions or to work out the ratio in use. The total range is 0-9.999 Ω in seven sub-ranges. Resistance coils are wound in Constantan and adjusted to an accuracy of better than $\pm 0.1\%$. The 2.5-volt test source is from sealed nickel-cadmium cells which are continuously trickle charged whenever the instrument is switched on. These cells require no maintenance. The 100-volt test potential is derived from a full-wave rectifier with smoothing circuit. Regulation of this supply is such that it may be short-circuited without damage. This feature also limits the power dissipated in the unknown resistor and means that the test voltage is highest for high resistance values, giving maximum sensitivity. Derritron Electronics Ltd., Instruments Division, Sedlescombe Road North, Hastings, Sussex.
WW 365 for further details

Muirhead type D-30-A is a portable, multi-purpose measuring set suitable for general resistance testing and for applications in the field, particularly in the communications industry. It embodies a Wheatstone network of resistors comprising a pair of variable ratios controlled by a single switch and a 11110 Ω four-decade resistance variable in steps of 1 Ω. An internal battery is provided and balance is detected on a pointer-type galvanometer. Multiplying powers for the ratios provided are: ×0.001, ×0.01, ×0.1, ×1, ×10, ×100, and ×1000 and accuracy between 1 Ω and 1M Ω is $\pm 0.15\%$, above 1M Ω ± 1% at 10M Ω, and below 1 Ω ± 10m Ω. Non-reactive card-wound resistors are used adjusted to within 0.1%. The galvanometer is a centre-zero moving-coil instrument calibrated 50-0-50 μA. Power is provided by two leakproof dry batteries. Muirhead & Co. Ltd., Beckenham, Kent.
WW 369 for further details

Heathkit capacitor checker, model IT28, provides complete analysis of all capacitor types, with direct reading scales. It features a low bridge voltage for safe testing of miniature electrolytics. There are 16 leakage-testing voltages. The unit measures capacitance from 10pF to 1,000 μF, and resistance from 5 Ω to 50M Ω. A comparator circuit measures *L*, *C* or *R* with an external standard. There is a calibrated power factor control and an electronic null and leakage indicator. It measures leakage in three sensitivity ranges: 2mA for electrolytics; 15 μA for miniature transistor type electrolytics and 2 μA for paper, mica, ceramic,

etc., with 18 switch-selected leakage voltages—from 3 to 600V d.c. External generator provisions are included to allow measurements at frequencies up to 10kHz. Daystrom Ltd., Bristol Road, Gloucester.
WW 351 for further details

Marconi Instruments' universal bridge model TF2700 uses the conventional bridge configurations but provision has been made for the connection of a large number of external facilities, so that a wide-range general-purpose instrument can be rapidly converted for a specialized measurement, without need of modification or special accessories. The internal battery-powered transistor oscillator provides a bridge source for measurements of *L*, *C*, and *R* at 1kHz, or an external source can be used between 20Hz and 20kHz. The internal aperiodic detector also uses battery-powered transistors, and may be used with both the internal and external bridge drive: an external detector can be used instead with either source. Resistance can also be measured with d.c. using the internal battery and galvanometer, or with either item replaced by external equivalents. Finally, mixed a.c. and d.c. can be applied to the bridge when



measuring components that require polarization, or for the determination of incremental properties. The measurement ranges are 0.1μH to 110H, and 0.5pF to 1.100μF, each in eight decades, with phase defect value, at 1kHz from internal source, or 20Hz to 20kHz from external source: 0.01Ω to 11MΩ in eight decades, at d.c. or 1kHz from internal sources, or at d.c. or 20Hz to 20kHz from external sources. Accuracy is within ± 1 or 2% depending on range. The bridge sources are 1kHz ($\pm 5\%$) from internal oscillator (or 20Hz to 20kHz from external source, for *L*, *C* or *R* measurement) and 9 volts from internal battery, or an external supply for greater discrimination. Power is supplied from an internal 9-volt battery (consumption approx. 7mA). Price £85. Marconi Instruments Ltd., Long Acre, St. Albans, Herts.
WW 349 for further details

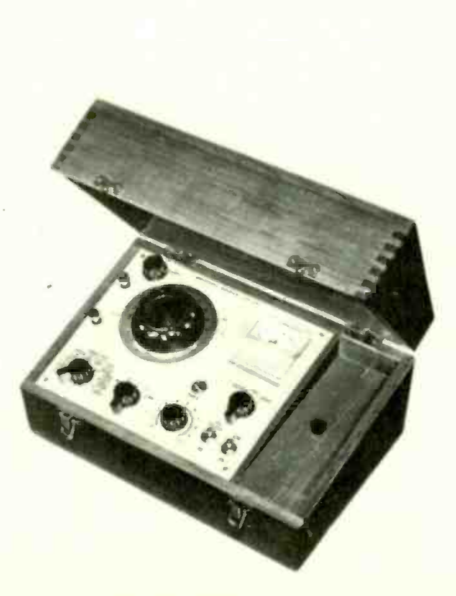
Philips type PM6300 universal measuring bridge features a large scale display, an electronic indicator, and facilities for tan δ and *Q* compensation. The bridge is balanced by means of a range selector (coarse control) and a high precision wire-wound reostat (fine control). During measurement one pole of the component being measured is at earth potential, making it possible to measure components already mounted on a chassis. For resistance measurements the measuring range is 5Ω-10.5MΩ in six sub-ranges. The error is less than 1% of the measured value $\pm 0.5\%$ of full scale. Loading is 0.05W maximum. For capacitance measurements the measuring range is 5pF-105μF in seven sub-ranges. The error here is less than 1.2% of the measured value $\pm 0.5\%$ of full scale, and the measuring frequency is 50Hz. Inductance measurements are possible over the range 0.5mH-105H in five sub-ranges. The measuring frequency is 50Hz and the error the same as that for capacitance measurements. Factor *Q* can be compensated between 1 and 65. Pye Unicam Ltd., York Street, Cambridge.
WW 361 for further details

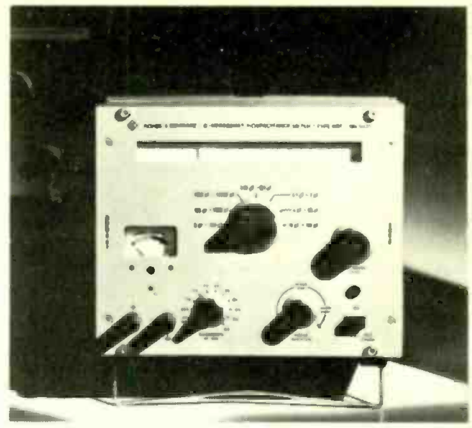
Tinsley general utility bridge, type 4551, is capable of measuring inductance, time constant *L/R*, capacitance, power factor, and effective resistance. The addition of a galvanometer and an accumulator enables it to be used as a Wheatstone bridge. The a.c. source is a battery-operated 800 Hz oscillator fixed in the case. Detection is by headphones. Accuracy is 1% over the following ranges: *L* (5mH to 10H), *C* (100pF to 11μF), a.c. resistance (0.1Ω to 100kΩ, and d.c. resistance (0.1Ω to 100kΩ. *L* and *C* measurement is also possible from 1mH to 100H and from 10pF to 10μF, but the accuracy of the measurement is reduced at the extremities of the ranges. A portable galvanometer and accumulator are available as accessories for Wheatstone bridge operation. H. Tinsley & Co. Ltd., Werndee Hall, South Norwood, London, S.E.25.
WW 373 for further details

T.I.A. model LCR20 universal bridge is designed to measure inductance, capacitance and resistance, generally to an accuracy of $\pm 1\%$. It is self-contained, and transistorized, being powered by internal batteries. Provision is made to excite the bridge from its internal oscillator at 100Hz, 1kHz and 10kHz. For the measurement of resistance of reactive components (for instance, iron cored transformers), the bridge may be excited at d.c. from internal batteries. The detector is a moving coil meter movement, preceded by a high gain amplifier. Automatic gain control is incorporated to facilitate balancing the bridge with inductors and capacitors of low power factor. At d.c. a transistor chopper is switched into the circuit to convert the amplifier to a sensitive d.c. detector. The bridge operates over the following ranges:–

R: 1.9Ω to 1.9MΩ for d.c. (to 19MΩ for 100Hz a.c.)
C: 19pF to 190μF
L: 190μH to 1900H
Q indication is: 0.01-1 at 100Hz
0.1-10 at 1kHz
1-100 at 10kHz
Tan δ indication is: 0.001-0.1 at 1kHz
0.01-1 at 10kHz

An internal 4.5 volt polarizing voltage may be applied to electrolytic capacitors during testing. Thomas Industrial Automation Ltd., Electronic Centre, Deansgate Lane, Altrincham, Cheshire.
WW 360 for further details





Inductance meter type LRT from Rohde & Schwarz measures inductances between 0.1μH and 1H in seven ranges to an accuracy of $\pm 1\%$ $\pm 0.01\mu$H. The test voltage of this transistor instrument never exceeds 80mV, not even in the case of very high-*Q* coils. Thus, the field strength is kept to within 5 and 20 mA/cm permitting measurements to be made also on highly permeable ferrite or laminated core coils without introducing an additional measuring error. Moreover, direct readings of the coil *Q* from 2 to 1000 ($L > 1\mu$H) can be obtained with the LRT. It provides also a simple means for measuring self-capacitances of coils between 0 and 200pF ($Q > 20$, $L > 42$ μH) and the resonant frequency of parallel-resonant circuits, and to make very precise *L* comparison measurements. **Capacitance meter type KRT,** is fully transistored and measures capacitance between 1pF and 100μF in seven ranges. The maximum test voltage is less than 25mV permitting accurate measurements on voltage-sensitive, high-dielectric constant, and semiconductor capacitors. With this new instrument it is possible to determine capacitances at an adjustable polarizing voltage. Moreover, a built-in bias-voltage source is provided to investigate the voltage-dependence of the capacitance of varactors. Distributed by Aveley Electric Ltd., South Ockendon, Essex.
WW 362 for further details

Nombrex transistor capacitance-resistance bridge, model 32, measures a wide range of resistance and capacitance, and has provision for indication of leakage and power factor in the larger values of capacitors. The ranges are: 5Ω—10kΩ, 100Ω—1MΩ, 10kΩ—100MΩ, 5pF—0.01μF, 100pF—1μF and 0.01μF—100μF. Accuracy at centre scale is $2\frac{1}{2}\%$, maintained to within 5% except on extreme high and low values of *R* and *C*. The instrument employs an electronic indicator to observe the measurement balance point. Separate scales are provided for resistance and capacitance, clearly marked for accurate read-off. Visual discrimination is generally within 2-4% of indicated value but as both *C* and *R* ranges overlap considerably, a read-off within $2\frac{1}{2}\%$ ($\pm$accuracy tolerance factor) can usually be achieved by choice of suitable range. Power factor measurements up to 70% can be made. A sensitivity control permits rapid initial assessment of component value, adjustable to attain optimum critical balance indications. Nominal indications of capacitor leakage are provided by a neon indicator circuit, for capacitors of any value or voltage rating. Price 10 gn. Nombrex Ltd., Instruments Division, Exmouth, Devon.
WW 357 for further details

Radiometer R,L,C component comparator, type TRB11, is a solid-state, line-operated precision measuring instrument. It is primarily intended for use at the end of production lines to provide a rapid and accurate comparison with, or a deviation from, a selected standard component. Measurements can be performed at 1kHz on resistors (10 Ω to 10M Ω), capacitors (20pF to 20 μF), and inductors (1mH to 10H) by means of two sets of terminals: one pair plus guard for the unknown, and one pair plus guard for the standard. Magnitude deviation is indicated directly in percentage within the four ranges: −1.5 to +1.5, −6 to +6, −25 to +35, and −50 to +100. The phase-angle deviation is indicated directly in radians within the four ranges: −0.015 to +0.015, −0.06 to +0.06, −0.3 to +0.3, and −0.6 to +0.6. The comparator is well suited for high-speed production testing, since one measurement can be performed every second by using an optional component jig, and since no balancing is required during operation. There are output terminals for connection to limit sensing devices such as the limit sensor, type LMS1, which can operate sorting-machines, control mechanisms, etc. Instrument marketed by Omega Laboratories Ltd., 57 Union Street, London S.E.1.

WW353 for further details

Hewlett Packard universal bridge, model 4260A, is designed for ease of operation, and measures *C, L, R, D* (dissipation of capacitors), and *Q*. The readout for *C, R* and *L* is digital with the decimal point automatically positioned. Units of measurement (e.g., pF and μF) and the equivalent circuit automatically "pop up" with a twist of the function switch. There are no multipliers and no dials that need interpolation. Operation is simple. Set the function knob for the parameter to be measured, adjust the range switch for an on-scale indication, and obtain a null with the *CRL* control. There are no interacting controls to adjust and readjust. Components with low or high *Q* are claimed to be as easy to measure as those without loss. Five bridge circuits are incorporated in the 4260A. An internal 1kHz oscillator drives the bridge for *C, L, D, Q* measurements; an internal d.c. supply is used for *R* measurements. Components may be biased by connecting a battery to the rear terminals.

The measurement range is:

C: 1pF to 1000 μF
L: 1 μA to 1000H
R: 10m Ω to 10M Ω

Error is within ±1 or 2% for these measurements. Hewlett Packard Ltd., 224 Bath Road, Slough, Bucks.

WW368 for further details

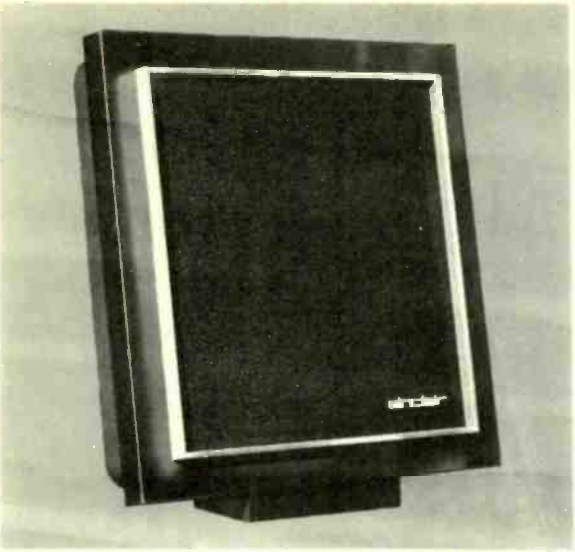
Danbridge Denmark universal bridge type UB1 may be used in conjunction with a number of accessories for most of the usual d.c. and a.c. measurements. By means of the various switches and shorting straps provided the bridge circuit may be adjusted for the measurement of resistance, capacitance and power factor, self inductance and effective resistance, mutual inductance, *Q* factor, frequency, turns ratio, resonant resistance, etc.

Measurement ranges are:—

R: 1m Ω-10M Ω
L: 1 μH-1H
C: 1pF-100 μF

The frequency range of operation is 0-20kHz. The basic error is within 1%, but the actual accuracy obtained on a.c. measurements will depend on the various earth-admittances of the generator, detector, measuring object and the bridge circuit itself. Thus it is not possible to give exact figures for the total accuracy. The ratio resistors are adjustable: 0-1-10-100-1000-1000 ohms, accuracy 0.2%. Maximum dissipation is 1 watt. The 4-decade resistor (10×0.1 − 10×100 ohms) has an accuracy of 0.2% except the 10×0.1 ohms decade with an accuracy of 3%. Maximum dissipation is 1 watt per resistor. The standard capacitor has a value of 0.1 μF, accuracy 0.2%, dissipation factor about 10^{-4}. Price £69. Distributed by Dawe Instruments Ltd., Concord Road, Western Avenue, London, W.3.

WW359 for further details



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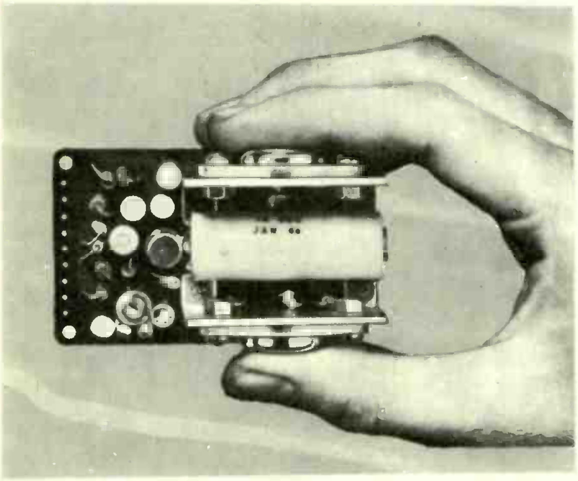
£7.19.6

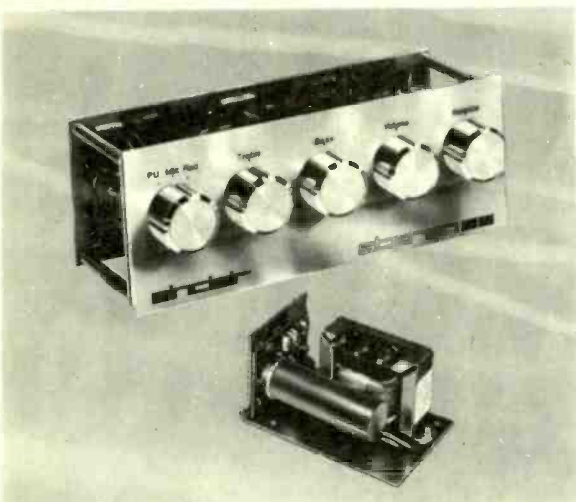


SINCLAIR Z.12

12 watt hi-fi amplifier/pre-amp

This eight transistor amplifier is the most successful of its kind ever designed and is easily adapted to a wide variety of applications. The Z.12 is supplied ready built, tested and guaranteed together with useful manual of circuits and instructions for matching the Z.12 to your precise requirements. Two may be used for stereo. Size—3in x $1\frac{3}{4}$in x $1\frac{1}{4}$in. Class B Ultralinear Output: Frequency response from 15 to 50,000Hz $\pm$1dB: Suitable for 3 to 15 ohm loudspeakers. Two 3 ohm speakers may be used in parallel: Input 2mV into 2kΩ Output 12 watts R.M.S. continuous sine wave (24 watts peak); 15 watts music power (30 watts peak). Power requirements 6—20V d.c. from battery or PZ.4 Mains Supply Unit.

89/6



SINCLAIR STEREO 25

Pre-amp/Control Unit for Z.12, IC.10 and other good Stereo assemblies. Switched inputs for P.U. (equalised to R.I.A.A. curve from 50 to 20,000Hz $\pm$1dB), Radio and auxiliary. Supplied ready built with very attractive solid brushed and polished aluminium front panel. Control knobs for Bass/Treble/Volume/Balance/Input are solid aluminium. Size—$6\frac{1}{2}$in x $2\frac{1}{2}$in x $2\frac{1}{2}$in plus knobs. Built, tested and guaranteed.

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Heavy duty transistorised power supply unit to deliver 18V d.c. at 1.5A. Designed specially for use with two Z.12 or IC.10 Amplifiers together with Stereo 25. Built, tested and guaranteed.

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WW—121 FOR FURTHER DETAILS

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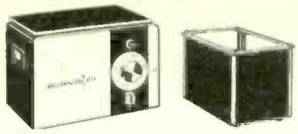

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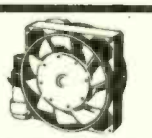

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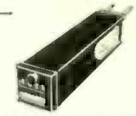

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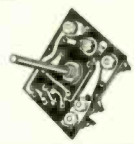

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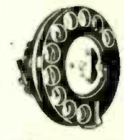

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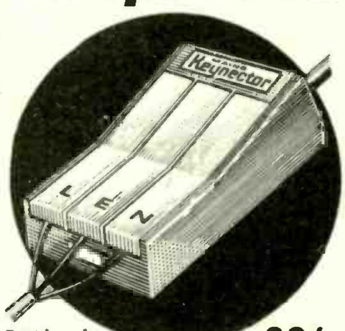

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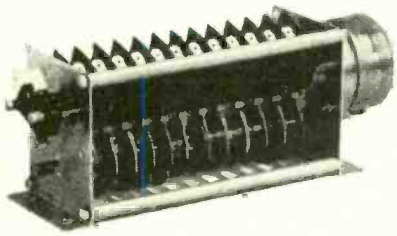
20 Amp. £37. 0.0	**C. & P. Extra**



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Capacity: 2 models available; 150 watts or 225 watts
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Output: Adjustable up to **20** AMPS. **CONTINUOUS** at 12/24 volts. **FULLY FUSED,** Neon indicator, 0-20 amp. meter. Size 16 × 12 × 20in. high, in heavy gauge steel cabinet. Grey Hammer finish—Weight 50 lb. Input: 220/230/240 v. A.C. 50 cycles.
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UP TO 24 v. D.C. WITH SMOOTH STEPLESS VARIATION
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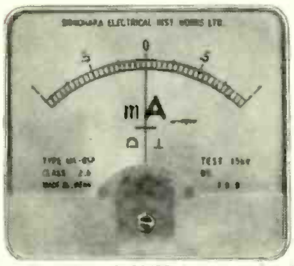


Type MR.38P. 1 21/32in. square fronts.

50µA	37/6	750mA	25/-
50-0-50µA	35/-	1 amp	25/-
100µA	35/-	2 amp	25/-
100-0-100µA	32/6	5 amp	25/-
200µA	32/6	3V. D.C.	25/-
500µA	27/6	10V. D.C.	25/-
500-0-500µA	25/-	20V. D.C.	25/-
1mA	25/-	100V. D.C.	25/-
1-0-1mA	25/-	150V. D.C.	25/-
2mA	25/-	300V. D.C.	25/-
5mA	25/-	500V. D.C.	25/-
10mA	25/-	750V. D.C.	25/-
20mA	25/-	15V. A.C.	25/-
50mA	25/-	50V. A.C.	25/-
100mA	25/-	150V. A.C.	25/-
150mA	25/-	300V. A.C.	25/-
200mA	25/-	500V. A.C.	25/-
300mA	25/-	8 meter 1mA	29/6
500mA	25/-	VU meter	39/6

Type MR.45P. 2in. square fronts.

50µA	42/6	10V. D.C.	27/6
50-0-50µA	39/6	20V. D.C.	27/6
100µA	39/6	50V. D.C.	27/6
100-0-100µA	35/-	300V. D.C.	27/6
500µA	29/6	15V. A.C.	27/6
1mA	27/6	300V. A.C.	27/6
5mA	27/6	8 meter 1mA	35/-
10mA	27/6	VU meter	42/6
50mA	27/6	1 amp. A.C.*	27/6
100 mA	27/6	5 amp. A.C.*	27/6
500mA	27/6	10 amp. A.C.*	27/6
1 amp	27/6	20 amp. A.C.*	27/6
5 amp	27/6	30 amp. A.C.*	27/6

Type MR.52P. 2½in. square fronts.

50µA	59/6	10V. D.C.	37/6
50-0-50µA	49/6	20V. D.C.	37/6
100µA	49/6	50V. D.C.	37/6
100-0-100µA	45/-	300V. D.C.	37/6
500µA	42/6	15V. A.C.	37/6
1mA	37/6	300V. A.C.	37/6
5mA	37/6	8 Meter 1mA	39/6
10mA	37/6	VU Meter	59/6
50mA	37/6	1 amp. A.C.*	37/6
100mA	37/6	5 amp. A.C.*	37/6
500mA	37/6	10 amp. A.C.*	37/6
1 amp	37/6	20 amp. A.C.*	37/6
5 amp	37/6	30 amp. A.C.*	37/6

Type M.R.85P. 4¼in. × 4¼in. fronts.

50µA	69/6	15 amp.	49/6
50-0-50µA	59/6	30 amp.	49/6
100µA	59/6	20V. D.C.	49/6
100-0-100µA	59/6	50V. D.C.	49/6
200µA	55/-	150V. D.C.	49/6
500µA	52/6	300V. D.C.	49/6
500-0-500µA	49/6	15V. A.C.	49/6
1mA	49/6	300V. A.C.	49/6
1-0-1mA	49/6	8 Meter 1mA	55/-
5mA	49/6	VU meter	69/6
10mA	49/6	1 amp. A.C.*	49/6
50mA	49/6	5 amp. A.C.*	49/6
100mA	49/6	10 amp. A.C.*	49/6
500mA	49/6	20 amp. A.C.*	49/6
1 amp.	49/6	30 amp. A.C.*	49/6
5 amp.	49/6		

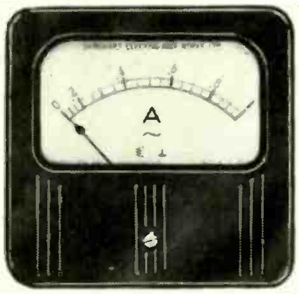
Type MR.65P. 3½in. × 3½in. fronts.

50µA	65/-	20V. D.C.	39/6
50-0-50µA	52/6	50V. D.C.	39/6
100µA	52/6	150V. D.C.	39/6
100-0-100µA	49/6	300V. D.C.	39/6
500µA	45/-	15V. A.C.	39/6
1mA	39/6	50V. A.C.	39/6
5mA	39/6	150V. A.C.	39/6
10mA	39/6	300V. A.C.	39/6
50mA	39/6	500V. A.C.	39/6
100mA	39/6	8 meter 1 mA	45/-
500mA	39/6	VU meter	65/-
1 amp	39/6	50mA A.C.*	39/6
5 amp	39/6	100mA A.C.*	39/6
10 amp	39/6	200mA A.C.*	39/6
15 amp	39/6	500mA A.C.*	39/6
20 amp	39/6	1 amp. A.C.*	39/6
30 amp	39/6	5 amp. A.C.*	39/6
50 amp	39/6	10 amp. A.C.*	39/6
10V. D.C.	39/6	20 amp. A.C.*	39/6
		30 amp. A.C.*	39/6

BAKELITE PANEL METERS

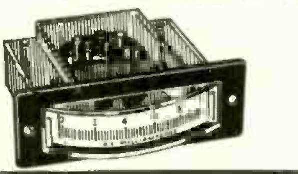
Type MR.65 3½in. square fronts.

25µA	67/6	5V. D.C.	32/6
50µA	45/-	10V. D.C.	32/6
50-0-50µA	42/6	20V. D.C.	32/6
100µA	42/6	50V. D.C.	32/6
100-0-100µA	42/6	150V. D.C.	32/6
500µA	39/6	300V. D.C.	32/6
1mA	32/6	30V. A.C.*	32/6
1.0 1mA	32/6	50V. A.C.*	32/6
5mA	32/6	150V. A.C.*	32/6
10mA	32/6	300V. A.C.*	32/6
50mA	32/6	1 amp. A.C.*	32/6
100mA	32/6	5 amp. A.C.*	32/6
500mA	32/6	10 amp. A.C.*	32/6
1 amp.	32/6	20 amp. A.C.*	32/6
5 amp	32/6	30 amp. A.C.*	32/6
15 amp	32/6	50 amp. A.C.*	32/6
30 amp.	32/6	VU meter	59/6
50 amp	32/6		



* Moving iron, all other moving coil

NEW RANGE OF "SEW" EDGEWISE METERS



MODEL PE70. Dimensions 3 17/32 × 1 11/32 × 2⅞in. deep. overall. Available as follows:

50 microamp	57/6	200 microamp	52/6
50-0-50 microamp	55/–	500 microamp	49/6
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100-0-100 microamp	52/6	300 volt A.C.	45/-
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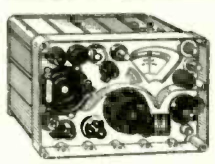
Model 7 £13/10/0

P. & P. 7/6.

R209 Mk. II COMMUNICATION RECEIVER



11 valve high grade communication receiver suitable for tropical use. 1-20 Mc/s. on 4 bands. AM/CW/FM operation. Incorporates precision vernier drive. B.F.O. Aerial trimmer, internal speaker and 12v. D.C. internal power supply. Supplied in excellent condition, fully tested and checked, £15 Carr. 20/-.

SINCLAIR EQUIPMENT

Z12. 12 watt amplifier	89/6
PZ4. Power supply Unit	89/6
STEREO 25. Pre-amplifier	£9/19/6
Q.14 Speakers	£7/19/6
Micromatic Radio Kit	49/6
Built	59/6

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2 Z12 amps. PZ4 Power Supply, Stereo 25, Preamplifier £22
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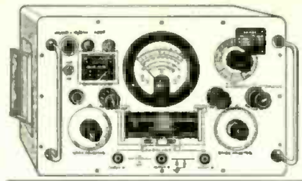
NEW SINCLAIR 2000 SYSTEM

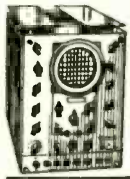
35 watt Integrated Amplifier, £29. Carr. 5/-
Self-powered FM Tuner, £25. Carr. 5/-

AVO CT.38 ELECTRONIC MULTIMETERS



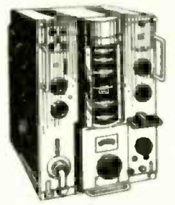
High quality 97 range instrument which measures A.C. and D.C. Voltage. Current, Resistance and Power output. Ranges D.C. volts 250mV-10,000 v. (10 megΩ-110megΩ input). D.C. current 10µA 25 amps. Ohms: 0-1,000 megΩ. A.C. volt 100 mV-250 v. (with R.F. measuring head up to 250 Mc/s). A.C. current 10µA-25 amps. Power output 50 microwatts-5 watts. Operation 0/110/200/250 v. A.C Supplied in perfect condition, complete with circuit lead and R.F. probe, £25. Carr. 15/-.

TYPE 13A DOUBLE BEAM OSCILLOSCOPES BARGAIN



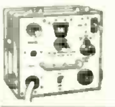
An excellent general purpose D/B oscilloscope. T.B. 2 cps-750 Kc/s. Bandwidth 5.5 Mc/s Sensitivity 33 Mv/cm. Operating voltage 0/110/200/250 v. A.C. Supplied in excellent working condition. £22/10/-. Or complete with all accessories, probe, leads, lid, etc. £25. Carriage 30/-.

ADMIRALTY B.40 RECEIVERS



Just released by the Ministry. High quality 10 valve receiver manufactured by Murphy. Coverage in 5 bands 650 Kc/s-30 Mc/s. I.F. 500/Kc/s. Incorporates 2 R.F. and 3 I.F. stages, bandpass filter, noise limiter, crystal controlled B.F.O. calibrator I.F. output, etc. Built-in speaker, output for phones. Operation 150/230 volt A.C. Size 19½ × 13½ × 16in. Weight 114lb. Offered in good working condition. £22/10/0. carr. 30/-. A few brand new, £35. Carr. 30/-. With circuit diagrams. Also available B41 L.F. version of above. 15 Kc/s-700 Kc/s. £17/10/-. Carr. 30/-.

CLASS D. WAVEMETERS



A crystal controlled heterodyne frequency meter covering 1.7-8 Mc/s. Operation on 6 v. D.C. Ideal for amateur use. Available in good used condition £5-19-6 Carr. 7/6. Or brand new with accessories £7-19-6 Carr. 7/6.

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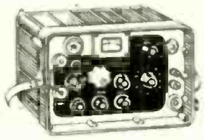

Oscillator Test No. 2. A high quality precision instrument made for the Ministry by Airmec. Frequency coverage 20-80 Mc/s. AM/CW/FM. Incorporates precision dial, level meter, precision attenuator 1µV-100Mv. Operation from 12 volt D.C. or 0/110/200/250 v. A.C. Size 12 x 8½ x 9in. Supplied in brand new condition complete with all connectors. fully tested, £45. Carr. 20/-.

MARCONI CT44 TF956 AF ABSORPTION WATTMETER

1 u/watt to 6 watts. £20. Carr. 20/-.

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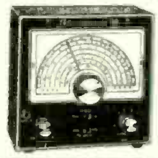

5 Ranges 400 KHZ-30 MHZ. An inexpensive instrument for the handyman. Operates on 9v. battery. Wide easy to read scale. 800 KHZ modulation. 5¼: × 5¼: × 3½:. Complete with instructions and leads. £7/19/6. P/P 4/-.

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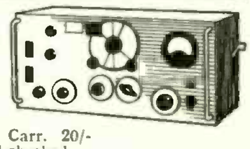
MARCONI TEST EQUIPMENT



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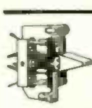

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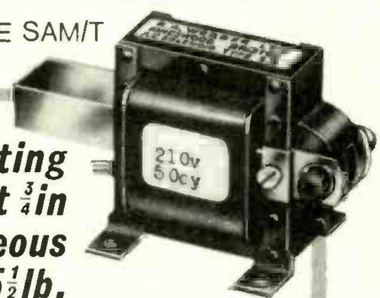

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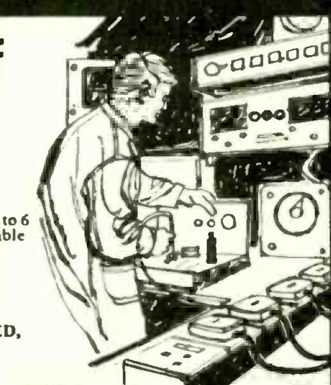

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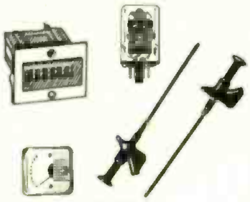
WW—131 FOR FURTHER DETAILS

CONTIL AND PIDAM SYSTEMS



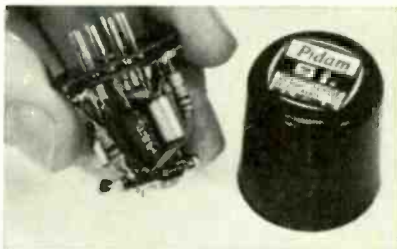
ACCESSORIES
A full range of accessories are available for PIDAM. Shown are the meter, scaled 0-9, at 35/6. Test prods insulated and flexible with fine steel clips at the tip, red or black at 13/–. High speed resetting counter including bezel and socket, with speed of over 40 operations per sec. 165/-. Plug-in Octal relay 24v. with two changeover at **17/6**. Not shown, 15 range test meter, **45/–**.

PIDAM (Plug-in Digital and Analogue Modules) perform all the usual logic functions, but, unlike other units, can be plugged in, using their B9A bases and can be quickly connected to the required configuration. To help learning, the module covers are easily removable for circuit examination and sets of components are available.
The 22 modules have an enormous range of use, from a single MONO for a tachometer, to over 300 units in a computer interface; nevertheless, their greatest asset is extreme simplicity. Design time is cut and elaborate breadboards superseded and any reader of "Wireless World" could with **PIDAM**, build up a low cost system for his own needs.
6 NEW modules—send for free information.

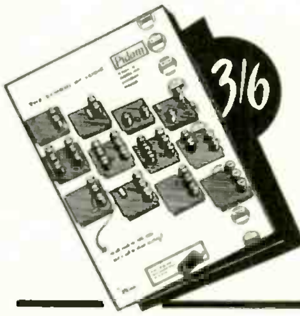
NEW

PIDAM PLUG-IN MODULES, PRICES

per module range from 8/– to 28/– and all necessary accessories are supplied. A complete starting kit is only **£20/19/0** (normally £23/12/6).

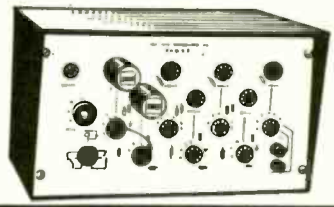


B1 (Bistable) module shows B9A base for ease of connection. Pins 7, 8, 9 are always power connections.



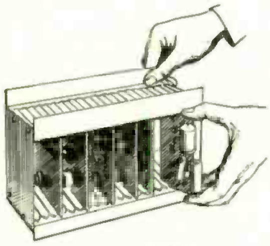
PIDAM BROCHURE

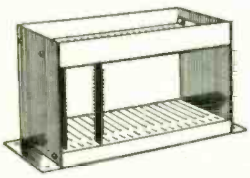
Send for this complete explanatory booklet showing detailed examples of use and circuit diagrams of all modules. Examples and circuits given include voice-operated switch alarms, flashers, tachometer, timers, batch counters, etc. 3/6 post free.



PIDEC

(Plug-in Digital Educational Circuit). This Pidec unit allows seven modules to be interconnected for demonstration or mock-up without soldering. Including internal power supplies, **380/-**.





PRINTED CIRCUIT CHASSIS

Printed circuit chassis type "P" which fits into 1277 or 16127 case, or type "Q" which can be mounted on an aluminium chassis. Both types take up to 20 boards and connectors on ¼in. centres. Prices from **42/6** down to 37/- for quantities.

CONTIL CASES

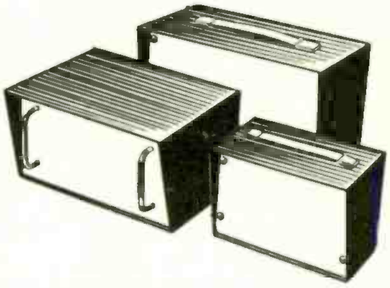
now available with aluminium and NEW "Contilcote" panels.

Contil cases are mass-produced to give the lowest prices yet. In 21-gauge steel. Finished hammer blue, with 18-gauge front panel supplied with easy-to-strip protective covering for easy marking out. For ease of ordering Contil cases are described by their dimensions, i.e. 755 is 7×5×5in. Individually packed, inc. feet and screws.

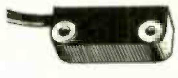
Range of chromium-plated and Delrin handles available with matching chassis, spare panels, etc.

	ONE	FIVE
755	45/6	44/–
867 or 975	47/6	46/–
1277	53/–	51/–
16127	98/6	96/6
191010	133/–	130/–

Kit **£11/19/–** (normally £14/12/-).



TRANSFORMERS
Two West Hyde transformers are available for transistorised equipment, one at 2 amps giving 6, 10, 15, 18 and 30v i.e., 3, 4, 5, 6, 8, 9, 10, 12, 15, 18, 24 and 30 with 12-0-12 and 15-0-15. The second at 1 amp. 6, 10, 18v. taps. Price **37/6** and **26/–**. Additional type available, providing 2 amps as above and in addition supplies 100mA at 150, 80, 0, 80, 150 volts to supply indicator tubes, etc. Price **50/-**.



REED SWITCH
The West Hyde Reed Switch works at up to 2,000 times a second for more than fifty thousand million operations. Ideal for: over and under speed monitors, counting, timing, switching, rev counting, etc. Hermetically sealed and moulded. Prices from 14/- each to 8/- each per thousand.

We now supply Q-Max sheet metal punches in ⅛in. sizes up to 1½in. and ¼in. sizes up to 1¾in.

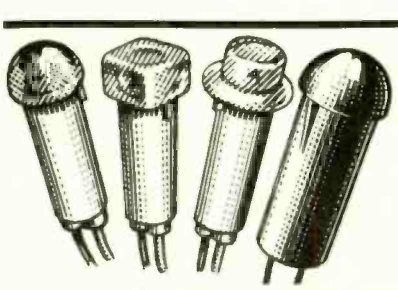
NEW
Neon Oscillator
Operates from 6v. to 24v. D.C. down to 50mW. Prices from 25/– down to 18/–. Powers neons or number tubes from low voltage D.C.

"A" board shows plugged into "M" 20-way connector with "S" board supports. Note: Power supply rails at right angles to signal rails "S" supports 3/- pair. Less for quantities.

CONTIL LOW COST PRINTED CIRCUIT BOARDS

	ONE	TEN	FIFTY
Standard transistor board	9/9	9/3	9/–
Half board	7/6	7/–	6/6
Connectors, 20-way	9/6	9/–	8/–
,, 10-way	6/–	5/6	5/–
"P" chassis to fit 1277 Contil case	39/6	37/6	37/–

Printed circuit kit: including case, normally £14/4/6 for only **£11/19/6**.



NEW BRIGHTLIFE NEONS

now available with alphanumeric caps.

25,000 hr. average life with high intensity and resistor in housing; either ⅜in. or ½in. dia. Standard units 160-250v. with 6in. lead variants. 10 off at 2/6 each with 10 different caps. In quantity down to **1/8** each. Neon only, down to 5½d. each.

We supply our standard neons in 110 volt nominal at the same prices.

We now supply Brightlife Fluorescent Starter Switches direct in minimum quantities of 50 off for **50/–** C.W.O. only. As supplied to leading manufacturers in large quantities.

SUB-MINIATURE NEON

The smallest yet. Type "Q" overall dia. $\frac{3}{16}$in., body length $\frac{7}{16}$in. with resistor for mains, **3/6** each. Minimum quantity 10. Down to **2/9** each.

PLEASE NOTE
All products ex-stock for normal quantities. Return of post service. No S.A.E. Minimum order £1. Fully detailed leaflets available. All prices include postage and packing.

WEST HYDE

WEST HYDE DEVELOPMENTS LTD.
30 HIGH STREET, NORTHWOOD, MIDDLESEX
Tel: Northwood 24941

PARMEKO TRANSFORMERS AND CHOKES

SPECIAL OFFER

Neptune Potted Type Transformers

Pri. 230 v. Sec. 70 v. 5 amps. 85/-. Carr. 8/6.
Pri. Tapped 200-250 v. Sec. 200 v. 50 m/amps. 20 kv. D.C. Wkg. 95/-. Carr. 10/6.
Pri. Tapped 200-250 v. Sec. 450-400-0-400-450 v. 180 m/amps. 6.3 v. 4 amps. 6.3 v. 4 amps. 6.3 v. 3 amps. 5 v. 3 amps. 75/-. Carr. 8/6.
Pri. Tapped 200-250 v. Sec. 500-0-500 v. 180 m/amps. 6.3 v. 6 amps. 6.3 v. 3 amps. 5 v. 3 amps. 85/-. Carr. 10/6.
Pri. Tapped 200-250 v. Sec. 500-0-500 v. 120 m/amps. 6.3 v. 5 amps. 6.3 v. 3 amps. 5 v. 3 amps. 55/-. Carr. 7/6.
Pri. Tapped 200-250 v. Sec. 250-0-250 v. 60 m/amps. 6.3 v. 3 amps. 6.3 v. 3 amps. 5 v. 3 amps. 45/-. Carr. 6/6.
Pri. Tapped 200-240 v. Sec. 12.9 v. 3 amps. 6.5 v. 5 amps. 6.5 v. 4.5 amps. 49/6. Carr. 6/-.
Pri. Tapped 200-240 v. Sec. Tapped 250-260-270 v. 150 m/amps. 35/-. Carr. 6/-.
All transformers very conservatively rated and supplied new and guaranteed.

Jupiter Series Swinging Chokes, Potted

34 H. 60 m/amps. 70 H. 35 m/amps. 2.8 Kv. D.C. Wkg. 29/6. Carr. 6/6.

Neptune Series

50 H. 25 m/a. 10/6. Carr. 4/6. 10 H. 120 m/a. 12/6. Carr. 4/6. 10 H. 75 m/a. 10/6. Carr. 3/6. 5 H. 150 m/a. 12/6. Carr. 4/6. 5 H. 60 m/a. 8/6. Carr. 3/6. .7 H. 450 m/a. 12/6. Carr. 5/6. .2 H. 150 m/a. 10/6. Carr. 4/6.

GARDNERS POTTED CHOKES

30 H. 50 m/a. 15/-. Carr. 4/6. 20 H. 40 m/a. 8/6. Carr. 3/6. 12 H. 200 m/a. 29/6. Carr. 6/6. 10 H. 150 m/a. 12/6. Carr. 4/6.

PARTRIDGE CHOKES

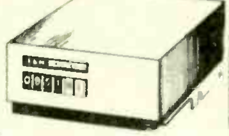
5 H. 250 m/a. 22/6. Carr. 6/6.

CONSTANT VOLTAGE TRANSFORMERS

By Advance. Input 190-260 v. 50 cycles. Output 230 v. at 60 watts. Type M.T. 161A. £4/15/-. P.P. 7/6.

DIGITAL HOUR METERS

6 figs inc. 1/10ths, 1/100ths 40v. A.C. but complete with transformer for 240v. A.C. operation. All in plastic case. Size 6½ × 6½ × 3in. Condition as new 45/-. P&P 5/-.



Samson's

(ELECTRONICS) LTD.

9 & 10 CHAPEL ST., LONDON, N.W.1

01-723-7851 01-262-5125

SEND 6D. STAMP FOR LATEST PRICE LIST OF TRANSFORMERS, CHOKES RECTIFIERS, CAPACITORS AND ELECTRONIC COMPONENTS.

AMERICAN OIL FILLED CAPACITORS

10 MFD	1500V DC Wkg	17/6	3/6 carr.
10 ,,	600V ,, ,,	12/6	3/- ,,
8 ,,	1000V ,, ,,	15/-	3/6 ,,
8 ,,	750V ,, ,,	12/6	3/6 ,,
8 ,,	600V ,, ,,	10/6	3/- ,,
5.25 ,,	1000V ,, ,,	8/6	3/6 ,,
3 ,,	1000V ,, ,,	5/-	2/- ,,

BRITISH TYPES

T.C.C. 25 MFD	300V AC Wkg	25/-	5/-
,, 10 ,,	350V DC Wkg	7/6	2/6
,, 8 ,,	500V ,, ,,	6/6	2/6
,, 4 ,,	600V ,, ,, Sub chassis mtg.	5/-	2/-
,, 1 ,,	600V ,, ,,	2/-	1/-
,, 0.5 ,,	600V ,, ,,	1/6	9d.
,, 8 ,,	250V ,, ,,	3/6	1/6
,, 4 ,,	800V ,, ,,	8/6	3/-
,, 2 ,,	4000V ,, ,,	35/-	5/-
,, 1 ,,	5000V ,, ,,	35/-	5/6
,, 0.25 ,,	7500V ,, ,,	17/6	4/6
,, 0.1 ,,	7500V ,, ,,	15/-	3/-
,, 0.1 ,,	5000V ,, ,,	8/6	2/-
Philips 60 MFD	275V AC Wkg	45/-	7/6

SPECIAL OFFER

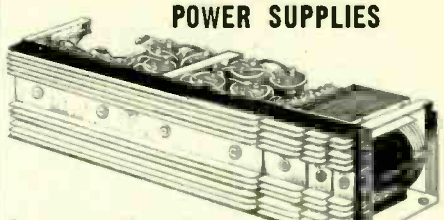
G.E.C. 8 MFD 600V DC Wkg. 6 FOR 29/6 CARR. 7/6.
DUBILIER 1 MFD 600V Wkg. 6 FOR 9/- P.P. 3/6. STC 5 MFD 400V AC Wkg. 3 FOR 15/- CARR. 7/6.

REDCLIFFE & GARDNER TRANSFORMERS

Redcliffe 'C' Core PRI 200-240 SEC 26-27-28-28-27 26V 0.3A DC and 27-0-27V 0.3 ADC. 35/- P.P. 5/-.
Redcliffe PRI 200-240 SEC 2000V 7 M/A sealed type. 6.3V 0.5A 3KV DC Wkg. 35/- P.P. 5/-.
Gardners totally enclosed. PRI 230V SEC 70-75-80V 4 AMPS. Very conservatively rated, 85/- CARR. 10/-.

SCOTCH MAGNETIC TAPE. Type 3M 459. ¼in. 3,600 feet. Suitable for video. Brand new in maker's sealed cartons. List Price £18/10/-. Our Price £3/19/6. P.P. 5/-.

ex COMPUTER LOW VOLTAGE STABILISED POWER SUPPLIES



Open chassis. Re-conditioned and guaranteed perfect. Choke/capacity transistorised smoothing. Ripple better than 3000:1. Incorporates printed circuit S.C.R. Board for overload protection and overload switch with manual re-set button. Insulation of high standard. Designed for 120/130 volts. A.C. operation, but transformer for 200/240 volts. A.C. mains supply included in list price.

DIMENSIONS: 6in. × 6in. square and between 10 in. and 20 in. long according to type.

6v—8A	£10	30v—4A	£14
12v—20A	£26	30v—7A	£18
20v—15A	£26	56v—6A	£26

All 12/6 carriage.

Few other values available

BRAND NEW L.T. TRANSFORMERS

All by Famous Makers

Twickenham. Pri. Tapped 110-220-235-255V. Sec. 55V 24 amps, 14V 10 amps, 60V 2 amps. All windings very conservatively rated. Tropically finished. Terminal connections £9/19/6. carr. 15/-.

Woden' Pri. 240V. Sec. 50V 5 amps, 18-0-18V 1 amp. E.S. Tropically finished. 65/- carr. 7/6.

Others. Pri. 230V Sec. Tapped 70-75-80V 4 amps. Sealed type. 89/6 carr. 10/-.

Pri. 200-240V. Sec. 12.8V 12 amps. 50/- carr. 7/6.

Pri. 240V. Sec. 45V 25 m/amps, 1V ½ amp. "C" core. 17/6 carr. 4/-.

Pri. 230V. Sec. Tapped 130-65V 85 m/amps, 6.3V 5 amps, 6 v. 1 amp. 17/6. carr. 5/-.

Pri. 6.3V. Sec. 2-0-2V 4 amps. 5 kv. Wkg. Potted. 17/6 carr. 3/6.

Pri. 220-240V. Sec. 12V 90 amps. Flying lead connections. Size 7 × 6½ × 6 ins. £13/19/6 carr. 17/6.

BECKASTAT

This is an instant thermostat, simply plug your appliance into it and its lead into wall plug. Adjustable setting for normal air temperatures. 13A loading. Will save its cost in a season. 19/6 P. & In. 2/9.

DRY JOINT TESTER

The most reliable way of testing for a dry joint is to measure the resistance between the component lead and the printed circuit board. Our kit for doing this comprises a large-scale (3in.) moving-coil meter, a variable resistance for adjusting zero setting, and a wiring diagram with instructions. The only additional items you will need are a battery, some wire, a pair of test rods. Price 19/6. Postage and Insurance 2/6.

REED-SWITCH

Suitable for dozens of different applications, such as burglar alarms, conveyor-belt switching. These are simply glass-encased switches which can be operated by a passing permanent magnet coil. A special buy enables us to offer these at 2/6 each, or 24/- a dozen. Suitable magnets are 1/- each.

BLANKET SIMMERSTAT

Although looking like, and fitted as an ordinary blanket switch, this is in fact a device for switching the blanket on for varying time periods, thus giving a complete control from off to full heat. Also suitable for controlling the temperature of any other appliances using up to 1 amp. Listed at 27/6 each, we offer these while our stock lasts at only 12/6 each.

16 R.P.M. GEARED MOTOR

Made by Smiths Electrics, these are almost silent running, but are very powerful. They operate from normal 240 V. mains and the final-shaft speeds 16 R.P.M. 15/-. P. & In. 2/9.

THERMOSTATS

Type "A" 15 amp. for controlling room heaters, greenhouse, airing cupboard. Has spindle for pointer knob. Quickly adjustable from 30-80 deg. F. 9/6 plus 1/- post. Suitable box for wall mounting 5/-. P. & P. 1/-.

Type "B" 15 amp. This is a 17in. long rod type made by the famous Sunvic Co. Spindle adjusts this from 50 to 550 deg. F. Internal screw alters the setting so this could be adjustable over 30 deg. to 1000 deg. F. Suitable for controlling furnace, oven kiln, immersion heater or to make flame-start or fire alarm. 8/6 plus 2/6 post and insurance.

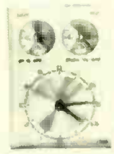
Type "D". We call this the Ice-stat as it cuts in and out at around freezing point. 2/3 amps. Has many uses, one of which would be to keep the loft pipes from freezing, if a length of our blanket wire (16 yds., 10/-) is wound round the pipes. 7/6. P. & P. 1/1.

Type "E". This is standard refrigerator thermostat. Spindle adjustments cover normal refrigerator temperatures. 7/6. plus 1/- post.

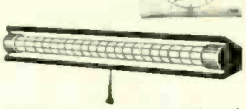
Type "F". Glass encased for controlling the temp. of liquid—particularly those in glass tanks, vats or sinks—thermostat is held (half submerged) by rubber sucker or wire clip—ideal for fish tanks—developers and chemical baths of all types. Adjustable over range 50 deg. to 150 deg. F. Price 18/-, plus 2/- post and insurance.

ELECTRIC CLOCK WITH 25 AMP. SWITCH

Made by Smith's these units are as fitted to many top quality cookers to control the oven. The clock is mains driven and frequency controlled so it is extremely accurate. The two small dials enable switch on and off times to be accurately set. Ideal for switching on tape recorders. Offered at only a fraction of the regular price—new and unused only 39/6, less than the value of the clock alone—post and insurance 2/9.



INFRA-RED HEATERS



Make up one of these latest type heaters. Ideal for bathroom, etc. They are simple to make from our easy-to-follow instructions uses silica enclosed elements designed for the correct infra-red wave length (3 microns). Price for 750 watts element, all parts metal casing as illustrated. 19/6. plus 4/6 post and ins. Pull switch 3/- extra.

THIS MONTH'S SNIP

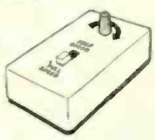
DEAC RECHARGEABLE BATTERIES

6v, 500 mA/hr. size 2½" × 1½" dia. Really powerful, will deliver 1 amp for ½ hour. Regular price 65/-—our price 29/6. New and unissued.

DRILL CONTROLLER

CONTROL DRILL SPEEDS

Electronically changes speed from approximately 10 revs. to maximum. Full power at all speeds by finger-tip control. Kit includes all parts, case, everything and full instructions 19/6, plus 2/6 post and insurance. Or available made up 29/6. Plus 2/6 post.



ELECTRIC CLOCK with 3 amp switch

made by Smiths for Dreamland. These are mains driven and frequency controlled so are extremely accurate. The dial enables "switch-on" time to be accurately set. Switch off is 3 hours later or by manual control. Intended for switching electric blankets this needs only one setting for the season. Suitable also to control tape recorder, radio and lamp etc. In neat plastic case with mains lead and two outlet plugs. New and unused, 39/6, post and insurance 3/6.

VARYLITE

Will dim fluorescent or incandescent lighting up to 600 W. from full brilliance to out. Fitted on M.K. Flush plate, same size and fixing as standard wall switch so may be fitted in place of this, or mount on surface. Price complete in heavy plastic box with control knob. £3.19.6.

Where postage is not stated then orders over £3 are post free. Below £3 add 2/9. Semi-conductors add 1/- post. Over £1 post free. S.A.E. with enquiries please.

See in the Dark INFRA-RED BINOCULARS

These infra-red binoculars when fed from a high voltage source will enable objects to be seen in the dark, provided the objects are in the rays of an infra-red beam. Each eye tube contains a complete optical lens system as well as the infra-red cell. These optical systems can be used as lenses for TV cameras—light cells, etc. (details supplied). The binoculars form part of the Army night driving (Tabby equipment). They are unused and believed to be in good working order but sold without a guarantee. Price £3/17/6, plus 10/- carr. and ins. Handbook 2/6.

MINIATURE WAFER SWITCHES

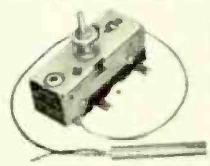
4 pole, 2 way—3 pole, 3 way—4 pole, 3 way—2 pole, 4 way—3 pole, 4 way—2 pole, 6 way—1 pole, 12 way. All at 3/6 each, 36/- dozen, your assortment.

WATERPROOF HEATING ELEMENT
26 yards length 70W. Self-regulating temperature control. 10/- post free.

BLANKET SWITCH

Double pole with neon let into side so luminous in dark, ideal for dark room light or for use with waterproof element—new plastic case. 5/6 each. 3 heat model 7/6.

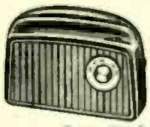
THERMOSTAT WITH PROBE



This has a sensor attached to a 15A switch by a 14in. length of flexible capillary tubing—control range is 20deg.F. to 150deg.F. so it is suitable to control soil heating and liquid heating especially when in buckets or portable vessels as the sensor can be raised out and lowered into the vessel. This thermostat could also be used to sound a bell or other alarm when critical temp. is reached in stack or heap subject to spontaneous combustion or if liquid is being heated by gas or other means not controllable by the switch. Made by the famous Teddington Co., we offer these at 12/6 each.

ELECTRONICS (CROYDON) LTD

Dept. WW, 266 London Road, Croydon CRO-2TH



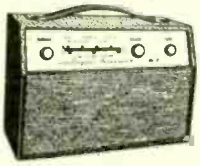
The DORSET (600mW Output)

7-transistor fully tunable M.W.-L.W. superhet portable—with baby alarm facility. Set of parts. The latest modulized and pre-alignment techniques makes this simple to build. Sizes: 12" x 8" x 3".
MAINS POWER PACK KIT: 9/6 extra.

Price **£5.5.0** plus 7/6 p. & p. Circuit 2/6. FREE WITH PARTS

The ELEGANT SEVEN MK. III (350mW Output)

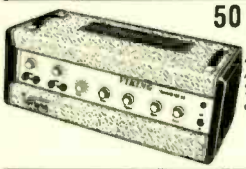
7-transistor fully tunable M.W.-L.W. portable. Set of parts. Complete with all components, including ready etched and drilled printed circuit board—back printed for foolproof construction.
MAINS POWER PACK KIT: 9/6 extra.



Price **£4.9.6** plus 7/6 p. & p.

Circuit 2/6. FREE WITH PARTS

50 WATT AMPLIFIER AC MAINS 200-250V

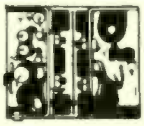


An extremely reliable general purpose valve Amplifier—with six electronically mixed inputs. Suitable for use with: mics, guitars, gram, tuner, organs etc. Separate bass and treble controls.

Price **27 gns.** plus 20/- p. & p.

X101 10w. SOLID-STATE HI-FI AMP WITH INTEGRAL PRE-AMP.

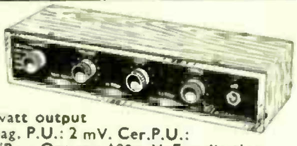
Specifications: RMS Power Output (into 3 ohms speaker) 10 watts.
Sensitivity (for rated output): 1mV into 3 Kohms (0.33 microamp). Total Distortion (at 1 KHz): At 5 watts 0.35%; At rated output 1.5%. Frequency Response: Minus 3 db points 20 Hz and 40 Khz. Speaker: 3-4 ohms. (3-15 ohms may be used). Supply voltage: 24v D.C. at 800 mA. (6-24V. may be used).



Price **49/6** plus 2/6 p. & p.

CONTROL ASSEMBLY: (including resistors and capacitors). 1. Volume: **Price 5/-**. 2. Treble: **Price 5/-**. 3. Comprehensive bass and treble: **Price 10/-**. The above 3 items can be purchased for use with the X101. **POWER SUPPLIES FOR THE X101:** P101 M (for mono) 35/- p. & p. 4/6: P101 S (for stereo) 42/6 p. & p. 4/6.

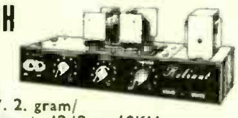
The CLASSIC



CONTROLS: Selector Switch. Tape Speed Equalisation Switch (3¾ and 7½ i.p.s.). Volume. Treble. Bass. 2 position scratch filter and 2 position rumble filter.

SPECIFICATION: Sensitivities for 10 watt output at 1 KHz. Tape Head: 3mV (at 3¾ i.p.s.). Mag. P.U.: 2 mV. Cer.P.U.: 80 mV. Radio: 100mV. Aux. 100 mV. Tape/Rec. Output: 100 mV. Equalisation for each input is correct to within ± 2dB (R.I.A.A.) from 20 Hz to 20KHz. Tone Control Range: Bass ± 13 dB at 60 Hz. Treble ± 14 dB at 15 KHz. Total Distortion: (for 10 watt output) < 1.5%. Signal Noise: < −60dB. AC Mains 200-250v. Size 12½" long, 4¾" deep, 2¾" high.
Teak finished case. Price **8 gns.** plus 7/6 p. & p.

The RELIANT 10W SOLID-STATE HIGH QUALITY AMPLIFIER



Specifications: Output: 10 watts. Output Impedance: 3 to 4 ohms. Inputs: 1. xtal mic 10mV. 2. gram/radio 250mV. Tone Controls: Treble control range ± 12dB at 10KHz; Bass control range ± 13dB at 100Hz. Frequency response: Minus 3dB points are 20Hz and 40KHz. Signal to Noise Ratio: better than —60dB. Transistors: 4 silicon Planar type and 3 Germanium type. Mains input: 220-250V. A.C. Size of chassis: 10" × 3¾" × 2". A.C. Mains, 200-250V. For use with Std. or L.P. records, musical instruments, all makes of pick-ups and mikes. Two inputs with control for gram. and mike. Built and tested. 8" × 5" speaker to suit. Price 14/6 plus 1/6 p. & p. Crystal mike to suit 12/6 plus 1/6 p. & p.
Price **£5.5.0** plus 5/- p. & p.

THE VISCOUNT

Integrated High Fidelity Transistor Stereo Amplifier

SPECIFICATIONS: Output: 10 watts per channel into 3 to 4 ohms speakers (20 watts monoral). Input: 6 position rotary selector switch (3 pos. mono and 3 pos. stereo), P.U., Tuner, Tape and Tape Rec. Sensitivities: All inputs 100mV. into 1.8M ohm. Frequency response: 40Hz—20KHz + 2db. Tone controls: Separate bass and treble controls. Treble 13db lift and cut at 15KHz. Bass 15db lift and 25db cut at 60Hz. Volume controls: Separate for each channel. AC Mains input: 200-240v. 50-60Hz.
Size 12⅛" × 6" × 2¾" in teak-finished case. Built and tested.
PRICE 13½ gns. *POSTAGE & PACKING 7/6d. EXTRA.*

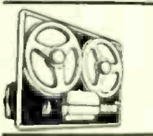
CYLDON U.H.F. TUNER

Complete with PC88 and PC86 Valves. Fullvariabletuning. New and unused. Size 4½" x 5½" x 1½". Complete with circuit diagram.

35/- p. & p. 3/6

THREE-IN-ONE HI-FI 10 WATT SPEAKER

A complete Loud Speaker system on one frame, combining three matched ceramic magnet speakers with a low loss cross-over network. Peak handling power 10 watts. Impedance 15 ohms. Flux density 11,000 gauss. Resonance 40-60 c/s. Frequency range 50 c/s to 20 kc/s. Size 13½ x 8 1/16 x 4½ inches. By famous manufacturer. List price £7. Our price 69/6 plus 5/- p. & p. Similar speaker to the above without tweeters in 3 and 15 ohms.
Price **39/6** plus 5/- p. & p.



MOTEK

3 Speed 2 track Tape Deck complete with heads, takes 7in spool. Incorporating 3 motors. A.C. mains, 240 volts, listed at £21.0.0.
Our Price **£9.19.6** plus 10/- p. & p.

Goods not despatched outside U.K. Terms C.W.O. All enquiries SAE.

RADIO & TV COMPONENTS (ACTON) LTD.
21A High Street, Acton, London, W.3
Orders by post to our Acton address please.
Also at 323 Edgware Road, London, W.2
Personal callers only at our Edgware address.

SILICON N.P.N. TRANSISTORS. Similar to 2N2926. All individually tested. Gold plated leads for easy soldering. Unbeatable value at **1/6** each or £5 per 100.

***TRANSISTORISED FLUORESCENT LIGHT. 8 WATT 12in. TUBE.** Current drain only 700mA! Complete and tested **£2/19/6** only! Or in kit form:

*Case		10/-
Transistor		10/-
Lamp holders	pair	5/-
Condensers, etc.		3/-
Transformer		13/6
Tube		8/-

**Post and packing 5/-*

TRANSISTORS
OC200, OC203, OC204, all at 2/- each.
ASY22, 2N753, BSY28, BSY65, 2G344A, 2G345A, 2G345B, 2G371A, 2G378A, all at 1/6 each.
Transistors similar to OC44, OC71 and OC72, all 1/- each.
Unmarked, untested transistors, 7/6 for 50.

LIGHT SENSITIVE TRANSISTORS (similar OCP 71), **2/-** each.
30 watt transistors (ASZ17), **10/-** each.

ORP 12 Cadmium sulphide light sensitive resistors **9/-**.

RECTIFIERS
BY100, 800 p.i.v., **2/6** each, **24/-** per doz., **£7/10/-** per 100, **£50** per 1,000.
BYZ13, 6-amp, 400 p.i.v., available on same terms.

MULLARD POLYESTER CAPACITORS
FAR BELOW COST PRICE!

0·001μF	400 volts	3d	0·02μ	200 volts	3d
0·0015μF	400 volts	3d	0·15μF	160 volts	6d
0·0018μF	400 volts	3d	0·22μF	160 volts	6d
0·0022μF	400 volts	3d	0·27μF	160 volts	6d
0·01μF	400 volts	3d	1μF	125 volts	1/-

VERY SPECIAL VALUE! Small Silver-mica, Ceramic, Polystyrene Condensers. Well assorted. Mixed types and values. **10/-** per 100.
PAPER CONDENSERS, MIXED BAGS, 0·0001 to 0·5μF. **12/6** per 100.

RESISTORS! Give-away offer! Mixed types and values, ¼ to ½ watt. **6/6** per 100, **55/-** per 1,000. Individual resistors 3d each. Also ½ to 3 watt close tolerance. Mixed values. **7/6** 100, **55/-** 1,000.
WIRE-WOUND RESISTORS. 1 watt to 10 watts. Mixed bags only. 16 for **10/-**.

RECORD PLAYER CARTRIDGES
ACOS

GP	67/2	Mono.	15/- complete with needles.
GP	91/3	Stereo Compatible	£1/-/- „
GP	93/1	Stereo Ceramic	£1/5/- „
GP	94/1	Stereo Ceramic	£1/5/- „

Small pick-up arms complete with cartridge and needle, **10/-** only.

UNREPEATABLE OFFER!
GIANT SELENIUM PHOTO-CELLS. OUTPUT UPWARDS OF 5ma AT ·6V
FEW ONLY 10/- EACH

TRANSISTORISED SIGNAL INJECTOR KIT R.F./I.F./A.F. **10/-** only
TRANSISTORISED SIGNAL TRACER KIT 10/- only.
TRANSISTORISED REV. COUNTER KIT 10/-.

VEROBOARD

2½in. × 1in 0·15in matrix	1/1	17in × 2½in. 0·15in. matrix	11/-
3¾in × 2½in 0·15in. matrix	3/3	17in × 3¾in 0·15in. matrix	14/8
3¾in × 3¾in 0·15in. matrix	3/11	3¾in × 2½in 0·1in matrix	4/2
5in × 2½in 0·15in matrix	3/11	3¾in × 3¾in 0·1in matrix	4/9
5in × 3¾in 0·15in matrix	5/6	5in × 2½in 0·1In matrix	4/7
		5in × 3¾in 0·1in matrix	5/6

Spot Face Cutter **7/6** Pin Insert Tool **9/6**. Terminal Pins **3/6** for 36.
SPECIAL OFFER!
Five 2½in × 1in. Boards and a cutter **9/9**.

MULTIMETERS. 20,000 ohms per volt.
Ranges: a.c. 1,000V, 500V, 100V, 50V, 10V.
d.c. 250mA, 2·5mA, 50μA.
d.c. 2,500V, 500V, 250V, 50V, 25V, 5V.
Resistance: 0/60kΩ and 0/6MΩ.
Special price £4/-/- only.

ELECTROLYTIC CONDENSERS

0·25μF	3 volt	4μF	12 volt	25μF	6 volt	320μF	10 volt
1μF	6 volt	4μF	25 volt	25μF	12 volt	400μF	6·4 volt
1μF	20 volt	5μF	6 volt	25μF	25 volt		
1·25μF	16 volt	6μF	6 volt	30μF	6 volt		
2μF	3 volt	8μF	3 volt	30μF	10 volt		
2μF	350 volt	8μF	12 volt	50μF	6 volt	All at 1/- each.	
2·5μF	16 volt	8μF	50 volt	64μF	2·5 volt		
3μF	25 volt	10μF	6 volt	64μF	9 volt	20 assorted	
3·2μF	64 volt	10μF	25 volt	100μF	9 volt	(our selection)	
4μF	4 volt	20μF	6 volt	320μF	4 volt	10/-	

SKELETON PRE-SET POTENTIOMETERS 100Ω, 100KΩ, 200KΩ, 500KΩ, 680K 6d. each.
PRE-SET SLIDERS
SMALL TRANSISTOR OUTPUT TRANSFORMERS 2/6 each.
SMALL TRANSISTOR DRIVER TRANSFORMERS 2/6 each.
CRYSTAL OR MAGNETIC LAPEL MIKES. 10/- each.
CRYSTAL TAPE RECORDER MIKES. 12/- each.

Orders by post to:

G. F. MILLWARD
DRAYTON BASSETT, NEAR TAMWORTH, STAFFS.

Please include suitable amount to cover post and packing. Minimum 2/-. Stamped addressed envelope must accompany any enquiries.
For customers in Birmingham area goods may be obtained from Rock Exchanges, 231 Alum Rock Road, Birmingham 8.

SENSATIONAL R.S.C. HIGH FIDELITY STEREO PACKAGE OFFERS

Matched for optimum performance. Compare prices with equipment and cabinets purchased individually.

'Package 3' 30 Watt System

- ★ Goldring Transcription Turntable on Plinth.
- ★ Shure Magnetic Pick-up Cartridge.
- ★ Super 30 Amplifier in cabinet.
- ★ Pair of Stanton Loudspeaker Units.

Special inclusive price. Fully wired units ready to "plug-in". **85 Gns.** Really superb performance Carr. 25/-
Send S.A.E. for leaflet.

Illustrated with TFM1 Tuner fitted.

'Package 2' 30 Watt System

- ★ Garrard SP25 Mk. II Turntable on Plinth.
- ★ Goldring CS90 Ceramic P.U. Cartridge.
- ★ Super 30 Amplifier in cabinet.
- ★ Pair of Stanton Loudspeaker Units.

Special inclusive price. Fully wired units ready to "plug-in."
75 Gns. Carr. 25/-
EXTREMELY ATTRACTIVE AND VERSATILE PLINTHS finished in Teak or Afrormosia veneer. Tinted Perspex "hinged" cover with satin chrome handle.

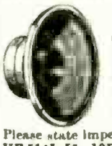
'Package 1' 13 Watt System

- ★ Garrard SP25 Mk. II 4-speed Player Unit, on plinth.
- ★ Goldring CS90 Ceramic P.U. Cartridge.
- ★ TA12 Amplifier in cabinet.
- ★ Pair of Dorset Loudspeaker Units.

Special inclusive price. **49½ Gns.**
Perspex cover 3 gns extra. Or Dep. £10. and 9 mthly. pmts. £5.4.0. Carr. 25/- (Total £56.16.0.)

BLACKPOOL AGENT APPOINTED See addresses

AUDIOTRINE HIGH FIDELITY LOUDSPEAKERS



Heavy construction. Latest high efficiency ceramic magnets. Treated Cone surround giving low fundamental resonance. "D" indicates Tweeter Cone providing extended frequency range 40-15,000 c.p.s. Impedance 3 or 15 ohms. Exceptional performance at low cost.

Please state impedance. Prices include carriage.

HF 510L 5"	10W	57/9	HF 120	12"	15W	69/9
HF 801D 8"	8W	57/9	HF 120D	12"	15W	79/9
HF 811D 8"	10W	£4/4/0	HF 126	12"	15W	89/9
HF 102D 10"	8W	59/9				
HF 100D 10"	15W	£5/15/0	HF 126D	12"	15W	5 Gns.

AUDIOTRINE HI-FI SPEAKER SYSTEMS

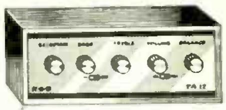
Consisting of matched 12in. 12,000 line 10 watt 15 ohm high quality speaker, cross-over unit and tweeter. Smooth response and extended frequency range ensure surprisingly realistic reproduction. **5 Gns.**
Or Senior 15 watt inc. HF 126 15,000 line Speaker 6 Gns. Carr. 6/6. Carr. 5/9

HI-FI 'SPEAKER ENCLOSURES

Teak or Afrormosia veneer finish. Modern design. Acoustically lined and ported. Prices inc. carr.
JE8 Size 16 × 11 × 9in. Pressurised. Gives pleasing results with any 8in. Hi-Fi speaker. **4 Gns.**
SE8 For optimum performance with any 8in. Hi-Fi 'speaker. Size 22 × 15 × 9in. **5 Gns.**
SE10 For outstanding results with 10in. Hi-Fi speaker. Size 24 × 15 × 10in. **£5.10**
SE12 For high performance with 12in. Hi-Fi speaker and Tweeter. Size 25 × 16 × 10½in. pressurised. **6 Gns.**

R.S.C. TA12 13 WATT STEREO AMPLIFIER

FULLY TRANSISTORISED, SOLID STATE CONSTRUCTION HIGH FIDELITY OUTPUT OF 6.5 WATTS PER CHANNEL



Designed for optimum performance with any crystal or ceramic Gram P.U. cartridge, Radio tuner, Tape recorder, 'Mike' etc. ★ 3 separate switched input sockets on each channel ★ Separate Bass and Treble controls ★ Slide Switch for mono use ★ Speaker Output 3-15 ohms ★ For 200-250 v. A.C. mains ★ Frequency Response 30-20,000 c.p.s. —2dB ★ Harmonic Distortion 0.3% at 1000 c.p.s. Hum and Noise —70dB ★ Sensitivities (1) 300 mV (2) 50 mV (3) 100 mV (4) 2 mV ★ Handsome brushed silver finish Facia and Knobs. Output rating I.H.F.M. Complete kit of parts with full wiring diagrams and instructions. 12½ GNS. Carr. 7/9. Factory built with 12 mth. gntee. 15 GNS. Or Dep. £4/16/- and 9 mthly. pymts. 29/- (Total 17 Gns.) Or in Teak or Afrormosia veneer housing 19 GNS. or Dep. £4/19/- and 9 mthly. pymts. 39/- (Total £22/10/-.)

HIGH FIDELITY LOUDSPEAKER UNITS

Cabinets of latest styling Satin Teak or Afrormosia veneer. Acoustically lined or filled with woollen damping material. Ported where appropriate. Credit terms available.

DORSET Size 16 × 11 × 9in. Range 45-15,000 c.p.s. Rating 8-10 watts. Fitted High flux 8" Dual cone speaker. Impedance 3 or 15 ohms. **£8.19.9** inc. carr.

STANTON IIIS Size 18 × 11 × 10in. Rating 10 watts. Incorporating Fane 803b speaker with roll rubber cone surround and 15,000 line magnet. High flux tweeter. Handsome Scandinavian design cabinet. Range 30-20,000 c.p.s. Impdnce. 3 or 15 ohms. Gives smooth realistic sound o/pt. **16 Gns.**

GLOUCESTER Size 25 × 16 × 10in. 12in. High flux 12,000 line speaker. Cross-over unit and Tweeter. Rating 10 watts. Frequency range 40-20,000 c.p.s. Impedance 15 ohms. **12½ Gns.**

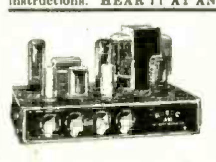
THE 'YORK' HIGH FIDELITY 3 'SPEAKER SYSTEM

•Moderate size approx. 25 × 14 × 10 in. •Range 30-20,000 Complete kit. c.p.s. Impedance 15 ohms. • Performance comparable with units costing considerably more. Consists of (1) 12 in. 20 watt Bass unit with cast chassis. Roll rubber cone surround for ultra low resonance, and ceramic magnet. (2) 3-way quarter section series cross-over system. (3) 8 × 5in. high flux middle range speaker (4) High efficiency tweeter. (5) Measured weight of woollen acoustic damping material. (6) Teak veneered cabinet. (7) Circuit and full instructions. HEAR IT AT ANY BRANCH. **18 Gns.**

R.S.C. BATTERY/MAINS CONVERSION UNITS

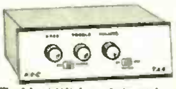
Type BM1. An all-dry battery eliminator. Size 5½ × 4½ × 2in. approx. Completely replaces batteries supplying 1.5 v. and 90 v. where A.C. mains 200/250 v. 50 c/s. is available. Complete kit with diagram 49/11 or Ready for use 59/11.

R.S.C. A10 30 WATT ULTRA LINEAR HI-FI AMPLIFIER



Highly sensitive. Push-Pull high output, with Pre-amp./Tone Control Stages. Performance figures: Hum level —70dB. Frequency response ±3dB 30-20,000c/s. Sectionally wound output transformer. All high grade components. Valves EF86, EF86, ECC83, 807, 807, GZ34. Separate Bass and Treble Controls. Sensitivity 36 millivolts so that any kind of Microphone or Pick-up is suitable. Designed for Clubs, Schools, Theatres, Dance Halls or Outdoor Functions, etc. For use with Electronic Organ, Guitar, String Bass, etc. Gram, Radio or Tape. Reserve L.T. and H.T. for Radio Tuner. Two inputs with associated volume controls so that two separate inputs such as Gram and "Mike" can be mixed. 200-250 v., 50 c/s. A.C. mains. For 3 and 15 ohm speakers. Complete Kit parts wiring diags., instructions. Twin-handled perforated cover 27/6. Supplied factory built with EL34 output valves. **14 Gns.** 12 months' guarantee for 17 gns. Tech. figs. apply to factory built units. Carr. 12/6
TERMS: Deposit £5/14/- and 9 monthly payments of 31/3 (Total £19/15/3). Send S.A.E. for leaflet.

R.S.C. TA6 6 Watt HIGH FIDELITY SOLID STATE AMPLIFIER



200-250v. A.C. mains operated Frequency Response 30-20,000 c.p.s. —2dB. Harmonic Distortion 0.3% at 1,000 c.p.s. Separate Bass and Treble 'lift' and 'cut' controls. 3 input sockets for Mike, Gram, Radio or Tape. Input selector switch. Output for 3-15 ohm speakers. Max. sensitivity 5mV. In fully enclosed enamelled case, 9¼ × 2¼ × 5¼in. Attractive brushed silver finish facia plate 10¼ × 3¼in. and matching knobs. Complete kit of parts with full wiring diagrams and instructions. **6 Gns.** Or factory built with 12 months' guarantee. 8 Gns. Carr. 7/6.

INTEREST CHARGES REFUNDED

On Credit Sales settled in 3 months.

R.S.C. COLUMN SPEAKERS

Covered in two-tone Rexine/Vynair. Ideal for vocalists and Public Address. 15 ohm matching. Type C57 15 watts inc. 5 7 × 4in. spkrs. £7/19/11. Type C48S, 30 watts. Fitted four 8in. high flux 8 watt speakers. Overall size approx. 42 × 10 × 5in. 16 Gns. Or deposit 65/- and 9 mthly pmts. 34/9 (Total £18/17/9). Carr. 10/-
Type C412s, 50 watts. Fitted four 12in. 11,000 lines 15 watt speakers. Overall size 56 × 14 × 9in. approx. 24Gns. Or Deposit £4/13/6 and 9 monthly payments Carr. 15/- of 52/6 (Total £28/5/-).

R.S.C. A11T 15 WATT HIGH FIDELITY AMPLIFIER

DUAL PURPOSE P.A. or HI-FI SOLID STATE CIRCUITRY. ★ 3 input sockets. ★ 2 vol. controls for mixing purposes. ★ Input Selector. ★ Output for speakers between 3 and 15 ohms. ★ Separate Bass and Treble Controls. Suitable for Gram, Radio, Tape, Microphone, or Guitar P.U. For Vocal and Instrumental groups. Frequency Response 20-40,000 c.p.s.—3dB. Harmonic Distortion 0.2% at 10 watts R.M.S. Operation on 200-250v. A.C. mains. Size 9¼ × 2¼ × 5¼in. Complete Kit of parts with comprehensive wiring diagrams and instructions. **9 Gns.** Carr. 9/6
Or Factory built with 12 mths. guarantee 13 gns. Carr. 9/6. Terms: Deposit £4 and 9 monthly payments 25/6 (Total £15/9/6).

R.S.C. MAINS TRANSFORMERS

FULLY GUARANTEED. Interleaved and Impregnated. Primaries 200-250 v. 50 c/s. Screened

MIDGET CLAMPED TYPE 2½ × 2¼ × 2¼in.

250 v., 60 mA, 6.3 v. 2 a.	15/11
250-0-250v., 60mA, 6.3v. 2a.	16/11

FULLY SHROUDED UPRIGHT MOUNTING

250-0-250v. 60mA., 6.3v. 2a., 0-5-6.3v. 2a.	21/9
250-0-250v. 100mA, 6.3v. 4a., 0-5-6.3v. 3a.	35/9
300-0-300v. 100mA, 6.3v. 4a., 0-5-6.3v. 3a.	35/9
300-0-300v. 130mA, 6.3v. 4a., c.t., 6.3v. 1a. For Mullard 510 Amplifier	43/9
350-0-350v. 100mA., 6.3v. 4a., 0-5-6.3v. 3a.	35/9
350-0-350v. 150mA., 6.3v. 4a., 0-5-6.3v. 3a.	45/9
425-0-425v. 200mA, 6.3v. 4a. c.t., 5v. 3a.	69/9
425-0-425v. 200mA, 6.3v. 4a., 6.3v. 3a. 5v. 3a	75/-
450-0-450v. 250mA, 6.3v. 4a., ct., 5v. 3a.	85/9

TOP SHROUDED DROP-THROUGH TYPE

250-0-250v. 70mA, 6.3v. 2a., 0-5-6.3v. 2a.	21/9
250-0-250v. 100mA, 6.3v. 3.5a.	23/9
250-0-250v. 100mA, 6.3v. 2a., 6.3v. 1a.	24/9
350-0-350v. 80mA, 6.3v. 2a., 0-5-6.3v. 2a.	25/9
250-0-250v. 100mA, 6.3v. 4a., 0-5-6.3v. 3a.	35/9
300-0-300v. 100mA, 6.3v. 4a., 0-5-6.3v. 3a.	35/9
300-0-300v. 130mA, 6.3v. 4a., 0-5-6.3v. 1a. Suitable for Mullard 510 Amplifier	42/9
350-0-350v. 100mA., 6.3v. 4a., 0-5-6.3v. 3a.	35/9
350-0-350v. 150mA., 6.3v. 4a., 0-5-6.3v. 3a.	43/11

FILAMENT or TRANSISTOR POWER PACK Types 6.3 v.1.5a. 7/9; 6.3v. 2a. 8/9; 6.3v. 3a. 10/9; 6.3v. 6a. 21/9; 12v. 1a. 8/9; 12v. 3a. or 24v. 1.5a. 21/9; 0-9-18v. 1½a. 17/9; 0-12-25-42v. 2a. 29/9.
CHARGER TRANSFORMERS 0-9-15v. 1½a. 14/11; 2½a. 17/9; 3a. 19/11; 5a. 23/9; 6a. 27/9; 8a. 33/9.
AUTO (Step UP/Step DOWN) TRANSFORMERS

0-110/120v.-200-230-250v. 50-80 watts	15/9
150 watts 29/11; 250 watts 49/9; 500 watts	99/9

OUTPUT TRANSFORMERS

Standard Pentode 5,000Ω or 7,000Ω to 3Ω	8/9
Push-Pull 8 watts EL84 to 3Ω or 15Ω	12/9
Push-Pull 10 watts 6V6 ECL86 to 3, 5, 8 or 15Ω	22/9
Push-Pull EL84 to 3 or 15Ω 10-12 watts	21/9
Push-Pull Ultra Linear for Mullard 510, etc.	38/9
Push-Pull 15-18 watts, sectionally wound 6L6 KT66, etc., for 3 or 15Ω	33/9
Push-Pull 20 watt high quality sectionally wound EL34, 6L6, KT66, etc. to 3 or 15Ω	59/9

SMOOTHING CHOKES 150mA, 7-10H, 250Ω 12/9; 100mA, 10H, 200Ω 10/9; 80mA, 10H, 350Ω, 8/9; 60mA, 10H, 400Ω 4/11.

R.S.C. TFM1 SOLID STATE VHF/FM RADIO TUNER

Total cost of parts with detailed wiring diagrams & instructions. Inc. Carr. **14 Gns.** Or factory built 16½ gns. Or in Teak finished cabinet as illustrated 19½ gns. Terms: Deposit £5 and 9 monthly payments £2. Total £23.

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150-0-1500 mA. 3½in. round panel	25/-
1.5 KV with res. 2in. round panel	27/6

MOVING IRON METERS

15 VAC 2½in. round panel	27/6
500 VAC 2½in. round clip fix	25/-

MINIATURE METERS. General Electric 1½in. round flush, clip mounted:
1 mA D.C., 22/6
25 mA D.C., 20/-. P. & P.
65 mA. D.C., 18/-. 3/-.
150 mA. D.C., 15/-.

"S" METER FOR H.R.O. RECEIVERS. Brand new, £2/10/-. Carriage paid U.K.

SUB - MINIATURE "PENNY SIZE" METERS. 1in. round, flush ring nut mounted 500µA FSD, calibrated 0-1 mA. 20/-. P. & P. 3/-.

NULL METER (unscaled 25-0-25 micro-amps) 3½in. square panel. 45/-.

NAGARD OSCILLOSCOPE TYPE DE 103, £85. Carriage 10/-.

PORTABLE SONTRANIC OSCILLOSCOPE 2½in. tube 220/250v. A.C., £22 10s. Carriage 30/-.

HEWLETT-PACKARD VTVM MODEL 410B. A compact instrument for A.C., D.C. and resistance measurements with A.C. meas. in excess of 100 mc/s; D.C. polarity reverse facility and 7 resistance ranges. Large easily readable meter. A.C. range 1-300V in 6 ranges. D.C. range 1-1,000V in 7 ranges. Resistant 0-50 Mohms. £22/10/-. Carriage 15/-.

RF WATT METER PM16. Frequency 0.2-500 mc/s, 3 ranges 0-150, 0-600, 0-1,500w. Impedance 51.5 ohms. "N" type connector. £75. Carriage 40/-.

PHASE MONITOR ME-63/U. Manufactured recently by Control Electronics Inc. Measures directly and displays on a panel meter the phase angle between two applied audio frequency signals within the range from 20-20,000 c.p.s. to an accuracy of ±1.0°. Input signals can be sinusoidal or non-sinusoidal between 2 and 30 v. peak. In excellent condition together with handbook and necessary connector. £45. Carriage 30/-.

SPARES FOR AR.88D. RECEIVERS. Ask for your needs from our huge selection.

INSET MICROPHONE for telephone handset, 2/6. P. & P. 2/-.

FIELD TELEPHONES TYPE "F" Housed in portable wooden cases. Excellent for communication in- and out-doors for up to 10 miles. For pair including batteries and 1/6th mile field cable on drum. Completely new, £6/10/-. Slightly used, £5/10/-. Carriage 10/-.

FIELD TELEPHONES TYPE "L" As above but in portable metal cases. Per pair including batteries and 1/6th mile field cable on drum. £5/10/-. Carriage 10/-.

HARNESS "A" & "B" control units, junction boxes, headphones, microphones, etc.

29/41FT. AERIALS each consisting of ten 3ft., ⅜in. dia. tubular screw-in sections. 11ft. (6-section) whip aerial with adaptor to fit the 7in. rod, insulated base, stay plate and stay assemblies, pegs, reamer, hammer, etc. Absolutely brand new and complete ready to erect, in canvas bag, £3/9/6. P. & P. 10/6.

300W 15V JAP Petrol Generator (Charging set). £35. Carriage 15/-.

1260W 35V CHARGING SET. Complete with switchboard. New £45. Carriage 40/-.

L.T. SUPPLY UNIT RECTIFIER No. 19. Consists of two separate 12V DC circuits each rated at 3 amp, which may be used independently, giving two separate outputs of 12V at 3 amps, connected in parallel giving 12V 6 amps or connected in series giving 24V at 3 amps. Ideal for battery charging, DC power supply, etc. 100/250V AC input. Brand new, complete with connectors. £6/19/-. Carriage 9/-.

SMALL 28V MOTORS. 150/200mA approx. 4,000 r.p.m. Ideal for small fans, running models, miniature drills, grinders, etc. 12/-. P. & P. 2/-.

MECHANICAL TIMED DELAY RELAYS. Coil resistance 150 ohms, working from 12-40v D.C. Adjustable delay within range of few seconds. 17/-. P. & P. 3/-.

HIGH SPEED ULTRA SENSITIVE PLUG IN RELAYS with two separate windings each of 1685 ohms. 12/-. P. & P. 2/-.

LOW INERTIA 24V D.C. MOTOR, complete with gears. 15/-. P. & P. 3/-.

UNIVERSAL GALVANOMETER SHUNTS. 25/-. P. &. P. 3/-.

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Installation Kits for C11/R210 Sets

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COLLINS TCS. Complete Installations and spare parts.

POWER SUPPLY UNITS FOR C42 & C45. 12v and 24v.

RECEIVERS R 210.

R.C.A. TRANSMITTER TYPE ET 4336. 2-20 Mc/s., complete with M.O., Cryst. mult. and speech ampl. Fully tested and guaranteed. All spares available.

BC 610E & BC 610I TRANSMITTERS. Complete with speech amplifier BC 614E. Aerial tuning unit BC 939A, exciter units, tank coils, ect. Fully tested and guaranteed. All spares available.

No. 19 HIGH POWER SETS. By introducing RF Amplifier the output increased to 25 watts. Complete installations supplied.

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LIGHT SENSITIVE SWITCHES

Kit and parts including ORP.12 Cadmium Sulphide Photocell. Relay Transistor and Circuit. Now supplied with new Siemens High Speed Relay for 6 or 12 volt operations. Price 25/-, plus 2/6 P. & P. **ORP 12 and Circuit 10/- post paid.**

220/240 A.C. MAINS MODEL incorporates mains transformer rectifier and special relay with 3 × 5 amp. mains c/o contacts. Price inc. circuit 47/6, plus 2/6 P. & P.

PHOTO ELECTRONIC COUNTER

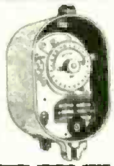
Can be set for counts of up to 500 per minute. 210-250 v. A.C. powered. Kit of Components, including photo cell, high speed non-resettable counter, transformer, relay, etc., together with clear circuit diagram, £3/2/6, plus 3/6 P. & P. With resettable counter, £4/2/6, P. & P. 3/6.

LIGHT SOURCE AND PHOTO CELL MOUNTING

Precision engineered light source with adjustable lens assembly and ventilated lamp housing to take MBC bulb. Separate photo cell mounting assembly for ORP.12 or similar cell with optic window. Both units are single hole fixing. Price per pair £2/15/0 plus 3/6 P. & P.

VAN DE GRAAF ELECTROSTATIC GENERATOR, fitted with motor drive for 230 v. A.C. giving a potential of approx. 50,000 volts. Supplied absolutely complete including accessories for carrying out a number of interesting experiments, and full instructions. This instrument is completely safe, and ideally suited for School demonstrations. Price **£7/7/-**, plus 4/- P. & P. L't. on req.

200/250 v. AC HORSTMAN 20AMP TIME SWITCH

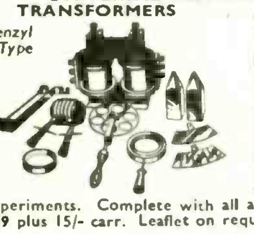


2 on/off every 24 hrs. at any pre-set time. Fitted in metal case 36 hr. spring reserve. Used but fully tested. Fraction of maker's price. **£3.19.6** plus 4/6d. post and pack. Available with solar dial on request.

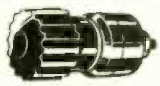
COPPER LAMINATE PRINTED CIRCUIT BOARD. Large sheet 15½ × 5½in. Price 3/9, 3 for 10/- post paid.

UNIVERSAL DEMONSTRATION TRANSFORMERS

Stenzyl Type



A complete composite apparatus, comprising a robustly built Transformer and electro-magnet with removable coils and pole pieces, coil tapped for 230 v., 220 v., 110 v., 115 v., 6, 12, 36, 110 v. A.C. These coils are also used for D.C. experiments. Complete with all accessories as shown. **£19** plus 15/- carr. Leaflet on request.

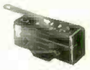


INSULATED TERMINALS

Available in black, red, white, yellow, blue and green. New 17/- per doz. P. & P. 2/-.

AUTO TRANSFORMERS. Step up, step down. 110-200-220-240 v. Fully shrouded. New. 300 watt type, **£3** each. P. & P. 4/6. 500 watt type, £4/2/6 each. P. & P. 6/6. 1,000 watt type, £5/5/- each. P. & P. 7/6.

LEVER MICRO SWITCH



Brand new lever operated micro switch. 20 amp. A.C. Price 4/6 each plus 1/6 P. & P. 5 for £1 post paid.

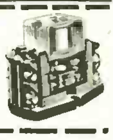
DRY REED SWITCHES

New special offer of Dry Reed Switches, ¼ amp. contact, 1¼ × 1¼in., 4 for 10/-, post paid.

SEMI-AUTOMATIC "BUG" SUPER SPEED MORSE KEY

7 adjustments, precision tooled, speed adjustable 10 w.p.m. to as high as desired. Weight 2¼lb. £4/12/6 post paid.

A.C. CONTACTOR



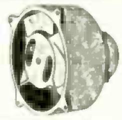
2 make and 2 break (or 2 c/o) 15 amp. contacts. 230/240 v. A.C. operation. Brand new. 22/6 plus 1/- P. & P.

CONDENSERS

New at a fraction of maker's price.

2,500 mfd. 100 v.	12/6	4,000 mfd. 25 v.	10/-
10,000 mfd. 35 v.	15/-	4,000 mfd. 50 v.	15/-

220/240v. A.C. COOLING UNIT



2,300 r.p.m. 6in. blade size. Smooth powerful motor. All metal construction. Continuously rated. Individually tested. Offered at fraction of maker's price, £2/15/-. P. & P. 7/6.

100 WATT POWER RHEOSTATS

(NEW) Ceramic construction, winding embedded in Vitreous Enamel, heavy duty brush assembly designed for continuous duty.

AVAILABLE FROM STOCK IN THE FOLLOWING 11 VALUES: 1 ohm 10a., 5 ohm 4.7a., 10 ohm 3a., 25 ohm 2a., 50 ohm 1.4a., 100 ohm 1a., 250 ohm 7a., 500 ohm 45a., 1,000 ohm 280mA., 1,500 ohm 230mA., 2,500 ohm .2a. Diameter 3½in. Shaft length ⅝in. dia. ⅜in., 27/6. P. & P. 1/6.

50 WATT 1/5/10/25/50/100/250/500/1,000/1,500/2,500 ohm, 21/-, P. & P. 1/6.

25 WATT 10/25/50/100/250/500/1,000/1,500/2,500 ohm, 14/6, P. & P. 1/6.

Black Silver Skirted knob calibrated in Nos. 1-9. 1½ in. dia. brass bush. Ideal for above Rheostats, 3/6 each.

STROBE! STROBE! STROBE!

TWO EASY TO BUILD KITS USING XENON WHITE LIGHT FLASH TUBES. SOLID STATE TIMING + TRIGGERING CIRCUITS. PROVISION FOR EXTERNAL TRIGGERING. 230-250v. A.C. OPERATION.

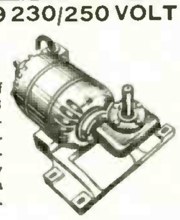
The Strobe is one of the most useful and interesting instruments in the laboratory or workshop. It is invaluable for the study of movement and checking of speeds. Many uses can be found in the psychiatric and photographic fields, also in the entertainment business. It is used a great deal in the motor industry and is a real tool as well as an interesting scientific device.

EXPERIMENTERS "ECONOMY" KIT. 1 to 36 Flash per sec. All electronic components including Veroboard S.C.R. Unijunction Xenon Tube + instructions £5.5.0 plus 5/- P. & P.

INDUSTRIAL "ADVANCED" KIT. 1 to 80 Flash per sec. IDEAL FOR LABORATORY OR SCHOOL USE. Fully isolated from the mains supply by specially wound transformer. 500v. FLASH CIRCUIT and stabilised timing circuit. Higher output flash tube. Price £8.8.0 plus 7/6 P. & P.

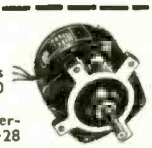
6½ INCH POLISHED REFLECTOR. Ideally suited for above Strobe Kits. Price 8/6 post paid. Regret not sold separately.

PARVALUX TYPE SD19 230/250 VOLT AC REVERSIBLE GEARED MOTORS



30 r.p.m. 40 lb. ins. Position of drive spindle adjustable to 3 different angles. Mounted on substantial cast aluminium base. Ex-equipment. Tested and in first-class running order. A really powerful motor offered at a fraction of maker's price. **6 gns.** P. & P. 10/-.

BODINE TYPE N.C.1 GEARED MOTOR



Type 1. 71 r.p.m. torque 10 lb. inches Reversible 1/70th h.p. 50 cycle ·38 amp.

Type 2. 28 r.p.m. torque 20 lb. In reversible 1/80th h.p. 50 cycle ·28 amp.

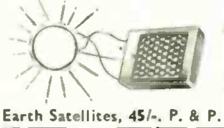
The above two precision made U.S.A. motors are offered in 'as new' condition. Input voltage of motor 115v A.C. Supplied complete with transformer for **230/240v A.C. input**

Price, either type **£2.17.6** plus 6/6 P. & P. or less transformer **£2.2.6** plus 4/6d. P. & P.

230/250 v. A.C. SOLENOID Heavy duty type. Approx. 3lb. pull. **17/6** plus 2/6 P. & P.

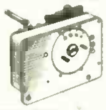
12/24 v. D.C. SOLENOID Approx. 8 oz. push, 8/6 plus 1/6 P. & P.

34R SILICON SOLAR CELL



4 × .5 volt unit series connected, output up to 2 v. at 20 mA. in sunlight, 30 times the efficiency of selenium. As used in power Earth Satellites, 45/-. P. & P. 1/6d.

PRECISION INTERVAL TIMER



From 0-30 seconds (repetitive). Jewelled balanced movement. Lever re-set. Operates 230 v. A.C. 5 amp. c/o micro-switch. Brand New 17/6 plus 2/6 P. & P.

Latest American. New. Plastic THYRISTOR 400 P.I.V. 8 amp. Data sheet. 19/6 post paid.

LATEST TYPE SELENIUM BRIDGE RECTIFIERS

30 volt 3 amp., 11/-, plus 2/6 P. & P.
30 volt 5 amp., 16/-, plus 2/6 P. & P.

NICKEL CADMIUM BATTERY

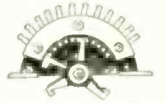
Sintered Cadmium Type 1.2 v. 7AH. Size: height 3½in., width 2¼in. × 1⅛in. Weight: approx. 13 ozs. Ex-R.A.F. Tested 12/6. P. & P. 2/6.

A.C. AMMETERS 0-1, 0-5, 0-10, 0-15, 0-20 amp. F.R. 2¼in. dia. All at 21/- each.

A.C. VOLTMETERS 0-25 v., 0-50 v., 0-150 v. M.I 2½in. Flush round all at 21/- each. P. & P. extra.

0-300 v. A.C. Rect. M-Coil 2½in. 29/-
0-300 v. A.C. Rect. M-Coil 3½in. Type W23 ...... 55/-

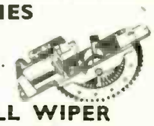
MINIATURE UNISELECTOR



3 banks of 11 positions, plus homing bank. 40 ohm coil. 24-36 v. D.C. operation. Carefully removed from equipment and tested. 22/6, plus 2/6 P. & P.

UNISELECTOR SWITCHES

***NEW* 4 BANK 25 WAY**

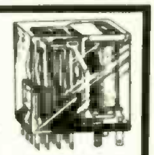


25 ohm coil, 24 v. D.C. operation. £5/17/6, plus 2/6. P. & P.

8-BANK 25-WAY FULL WIPER

24 v. D.C. operation, £7/12/6, Plus 4/- P. & P.

RELAYS



BULK PURCHASE ENABLES US TO OFFER THE FOLLOWING *NEW* **SIEMENS PLESSEY**, etc. MINIATURE PLUG IN RELAYS COMPLETE WITH BASE, AT A FRACTION OF MAKER'S PRICE

COIL Ω	WORKING VOLTAGE	CONTACTS	PRICE
280	6—12	2 c/o	14/6
280	9—18	4 c/o	15/6
700	12—24	2 c/o	12/6
700	16—24	4 c/o	15/6
700	16—24	4M 2B	12/6
1250	20—40	2 c/o Heavy Duty	12/6
2500	30—50	2 c/o Heavy Duty	12/6
5800	50—70	4 c/o	10/-
9000	40—70	2 c/o	10/-

POST PAID

SEALED RELAY

230 VOLT AC COIL

Two c/o 5 amp contacts. Plug-in I.O. Base. Price 14/6d. incl. base. Post Paid. Three c/o 5 amp contacts. 17/6. incl. base. Post Paid.

SANGAMO WESTON

Dual range voltmeter. 0-5 and 0-100 v. D.C. FSD 1 mA. In carrying case with tests prods and leads. 32/6. P. & P. 3/6.

GALVANOMETER

300-0-300 microamp. Calibrated 30-0-30. Mounted in sloping front case £2/10/-. P. & P. 3/6 **D.C. Voltmeter** 0-3 V and 0-15. V £2 plus 3/6 P. & P. **D.C. Ammeter.** 0-6 amp. and 0-3 amp. £2, 3/6 P. & P. The set of 3 matching instruments £6, P. & P. 6/6.

SANWA MULTI RANGE METERS

Acknowledged throughout the world as the ultimate in test motors.

NEW MODEL U-50D MULTI TESTER, 20,000 O.P.V. MIRROR SCALED WITH OVERLOAD PROTECTION. Ranges: D.C. volts: 100mV., 0.5 v., 5 v., 250 v., 1,000 v. A.C. volts. 2.5 v., 10 v., 50 v., 250 v., 1,000 v. D.C. current: 5μA. 0.5mA., 5 mA., 50 mA., 250mA. Size: 5¼ × 3½ × 1⅞in. **Complete with batteries and test prods. £7.5.0** Post paid. Three other models available from stock. Descriptive leaflet on request.

"AVO" 25,000 VOLT D.C. MULTIPLIER

For E.T.M. Complete with leads. New and boxed, 21/- P. & P. 6/6.

L.T. TRANSFORMERS

All primaries 220-240 volts.

Type No.	Sec. Taps	Price	Carr.
1	30, 32, 34, 36 v. at 5 amps.	£4 5 0	6/-
2	30, 40, 50 v. at 5 amps.	£6 5 0	6/6
3	10, 17, 18 v. at 10 amps.	£4 10 0	4/6
4	6, 12 v. at 20 amps.	£5 17 6	6/6
5	17, 18, 20 v. at 20 amps.	£6 12 6	6/6
6	6, 12, 20 v. at 20 amps.	£6 5 0	7/6
7	24 v. at 10 amps.	£4 15 0	5/6
8	4, 6, 24, 32 v. at 12 amps.	£6 10 0	6/6

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KITS • COMPONENTS • ACCESSORIES • EQUIPMENT

A SUPERB NEW TRS MONO-STEREO F.M TUNER

- A.F.C & A.G.C
- NOISE LIMITER
- PRE-TUNED
- CHASSIS READY BUILT
- TUNES 81-101 MHz

This advanced design hi-fi mono/stereo FM tuner comes in easy-to-assemble prefabricated units engineered to the highest standards of efficiency and performance. Valuable refinements include switchable A.F.C., automatic noise suppression, flywheel tuning, excellent audio response. Sensitivity better than 5 microvolts. Stereo can be added on to chassis as required. Gorler I.F. amplifier. Styled to match the TRS Stereo 4-4. S.A.E. brings full details.

Kit to make MONO tuner inc. chassis and tuning assembly. **15 gns.** (p. & p. 3/6)
Add-in Stereo Unit and Indicator light 10 gns. (p./p. 2/6)
Power Unit £2.5.0 (p./p. 2/6).
Simplex Cabinet £1.17.6 (p./p. 2/6)
Total price (for mains operation) **£29.10.0 post free.**

PLAYING UNITS BY GARRARD AND E.M.I.

GARRARD LM 3000 Record Player with 9T.A. Stereo Cartridge. £10.15.0.
GARRARD AT.60 Mk. II De-Luxe Auto-changer, diecast turntable. Less cartridge. £13.17.6.
SP.25 De-luxe single record player, die-cast turntable. Less cartridge. £12.10.0. Brand new in maker's cartons. Packing and carriage on any one of above 7/6.
GARRARD PLINTH WB.1. In fine Teak for any of above units. (Packing and carriage 5/-). 67/6.

GARRARD clear-view rigid perspex cover (carriage 4/6), 65/-.

CARTRIDGE OFFER TO PURCHASERS OF PLAYER UNITS—STEREO Sonotone 9TA/HC Ceramic with diamond 52/6; Decca Deram with diamond 95/-; **MONO** Acos GP91-1 22/6; Goldring MX2M 27/6.

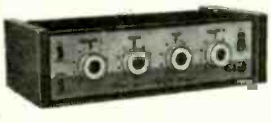
EMI 4 speed single player, 10½in. T/table with separate arm and T/O cartridge 69/6 (p. & p. 5/-).

TO MAKE A BOOKSHELF SPEAKER

A real bargain this—Matched speaker assembly comprising 5in. bass unit with special cone suspension and powerful magnet system, cross-over and 2¾in. tweeter. Loads easily up to 6 watts. Response 80-20,000 Hz. Ideal for today's small "bookshelf" cabinets or installation where maximum quality is required from a small space. **£3 19 6** Complete (p. & p. 5/-)

TRS HEAVY DUTY MAINS SUPPLY UNIT

A heavy duty unit for A.C. mains operation supplied ready built. Very compact, measuring only 3¼ × 2 × 2in. Available in two models—**PU.12** giving 12V. D.C. at 1.5A. **PU.24** giving 24V. D.C. at 0.75A. Recommended for latest TRS 4-4 and F.M. described in this advt. as well as other equipment. **PU/VFM** to give 200V/25mA and 6.3V/1.5A, any model **45/-** (p. & p. 2/6)



TRS STEREO 4-4 INTEGRATED AMPLIFIER

A T.R.S. design based on newly developed Mullard 4 watt modules with BC108 pre-amp. Suitable for speakers from 3 to 15 ohms. Bass and treble cut/boost. Response—60 to 14kHz ±3dB. This excellently engineered layout requires only wiring between controls and modules. Complete with metal chassis and T.R.S. simplex teak-ended cabinet for instant assembly. Stereo/Mono and Radio/PU switches.

Amplifier Kit £7.19.6 (p/p 3/6)
T.R.S. Power Unit £2.5.0 (p/p 2/6)
T.R.S. Simplex Cabinet £1.17.6 (p/p 2/6)
4 prs. DIN plugs and sockets if purchased separately, 15/-

Complete kit inc. cabinet/power pack/DIN plugs and sockets **£12.10.0** Carr. 7/6

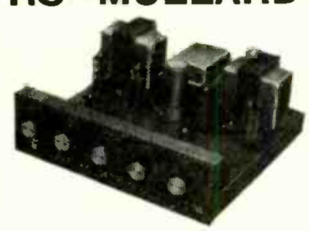
TRS FM DECODER

This is a very efficient FM stereo decoder based on Mullard design and produced by T.R.S. It is quite easily added to existing tuners. Built-in indicator. 6-transistor model, readily adaptable for use with valve tuners as well. For 9-15 v. operation. Complete kit with Mullard specified inductors already aligned. **£5 5 0** (p. & p. 2/6).

TRS LISTS

If you have not had one of our lists since September, please send 6d. for latest copy. 8 printed, foolscap pages full of bargains and hard to get lines.

TRS—MULLARD AMPLIFIERS & PRE-AMPS



The finest materials are used by TRS in this famous range of valve-powered stereo and mono amplifiers. Well-styled knobs and escutcheon plates are provided as well as plugs and sockets as necessary. S.A.E. brings full technical details.

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A top-flight valve instrument with ultralinear RMS output of 10W. per channel. Kit with valves and passive control system. KIT **£18 10 0**
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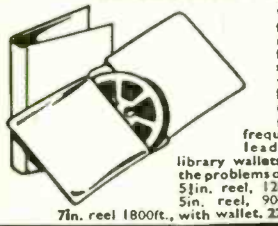

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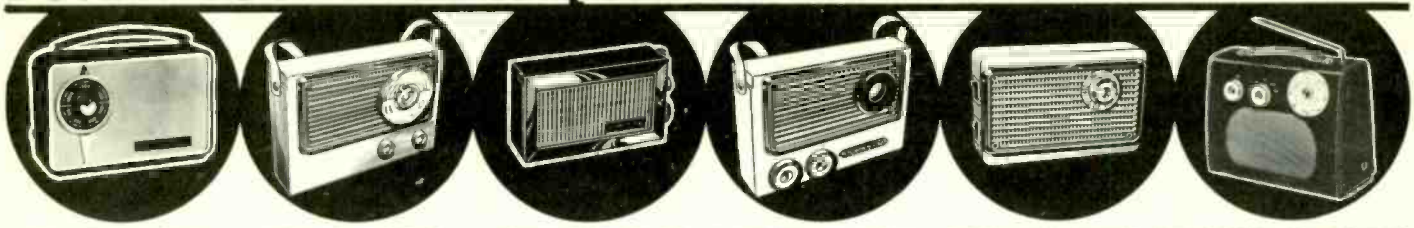

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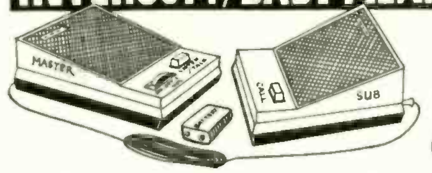

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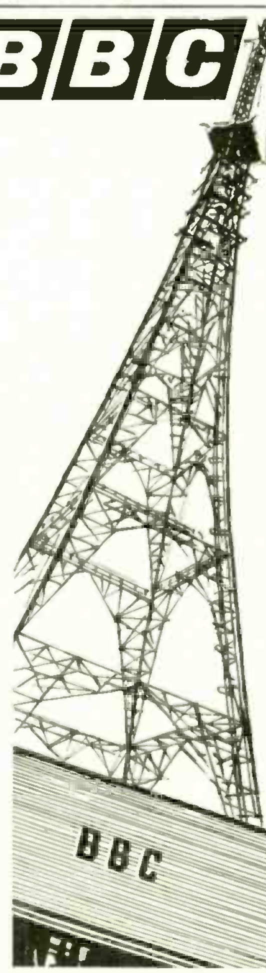

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RWW 8

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With knowledge of Circuitry and able to undertake testing and fault finding of a wide range of communications transmitters and receivers, data-handling equipment, radar, and a variety of electronic aids. Should have previous production test experience or similar experience as ex-regular Forces' Technicians.

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Please apply by letter quoting REF/WW/2, giving age, education, experience and present salary to:

D. M. McPhail, Personnel Officer
The Marconi Company Limited
Lancelot Road, Wembley, Middx.

UNIVERSITY INSTITUTE OF TECHNOLOGY
CARDIFF
A constituent college of the University of Wales
DEPARTMENT OF APPLIED PHYSICS

M.Sc./DIPLOMA COURSE IN ELECTRONICS

Applications are invited for places in the full-time one-year M.Sc./Diploma course in Electronics, commencing 29th September, 1969.

Application forms (together with further details) can be obtained from, and must be returned to the Registrar, University Institute of Technology, Cardiff, CF1 3NU as soon as possible.

ENTHUSIASTS Have you considered a career in Technical Authorship? If you have sound experience in electronics or communications and ability to write clear concise English we would train applicants as Technical Authors. The commencing salaries range from £1,450 to £1,800 depending on experience with the prospects of high future rewards and earnings. Box No. 5052.

TECHNICIANS

The Margaret McMillan College of Education require the following:

Audio Visual Aids Technician—Grade 2—to be responsible for the maintainance and repair of audio visual aids equipment. An interest in general craftwork and model making would be an advantage.

Junior Technician—Grade 1—to assist in the maintainance of equipment and making of teaching aids. An interest in craft, e.g. woodwork, would be an advantage and candidates should preferably have 3 G.C.E. ('O' level) passes in appropriate subjects.

Salaries are in accordance with the N.J.C. Technicians Grades namely:

Grade 2—£765 to £895
Grade 1—£330 to £765

Plus a qualification allowance of either £30 or £50 per annum where appropriate.

Application forms and further details of the posts may be obtained from the Principal, Margaret McMillan College of Education, Trinity Road, Bradford 5, and should be returned within 14 days of the appearance of the advertisement.

KODE LTD.
Data Processing Equipment

KODE LTD. require

ELECTRONIC SERVICE ENGINEERS

for the Greater London Area.

The applicants with semiconductor and/or valve experience, capable of organising and fulfilling service loading independently, will secure excellent salaries, company vehicles (for business and private use), together with very real opportunities for advancement.

Apply with summary of career to:—

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Tel. Calne 3771

We have vacancies for

FOUR EXPERIENCED TEST ENGINEERS

in our Production Test Department. Applicants are preferred who have experience of Fault Finding and Testing of VHF and UHF Mobile Equipment. Excellent opportunities for promotion due to expansion programme.

Please apply to Personnel Manager

PYE TELECOMMUNICATIONS LTD., Cambridge Works, Haig Rd., Cambridge. Tel: Cambridge 51351, ext. 355

IRELAND
RADIO TELEFÍS ÉIREANN
ENGINEERS

Opportunities exist in Ireland's national broadcasting service for Engineers with initiative and imagination.

Experience in broadcasting, telecommunications or related fields is desirable but not essential. Of equal importance is the ability to relate specific technologies to the wide range of problems that occur in radio and television.

Applicants should have a Degree or equivalent qualification in Electrical Engineering or Experimental Physics.

The salary scale extends to £2,070 per annum and excellent promotional opportunities exist. The commencing salary will depend on experience.

Age limit—35 years.

Applications, giving particulars of age, qualifications and experience should reach the **Personnel Administration Manager, Radio Telefís Éireann, Donnybrook, Dublin, 4. IRELAND,** not later than 7th February, 1969.

Envelopes should be marked "ENGINEER (W.W.)."

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Racal Communications is now producing new sophisticated systems which embrace Radar and Communications techniques. It requires a man possessing sound knowledge of basic communications biased towards U.H.F. and Radar applications.

He will establish, control and guide a team of Test Engineers performing comprehensive Test and Inspection duties to rigid engineering specifications.

Opportunities in the Test Engineering field are excellent throughout the RACAL Group and the successful candidate will join a dynamic team.

Salary will be attractive and location at Bracknell, possessing plenty of private building plus facilities for rented accommodation in the New Town, which is adjacent to open country.

Please submit details of experience and present salary to

Mr. P. Cousins,
Group Personnel Manager,
Racal Electronics Limited,
Western Road, Bracknell,
Berks. Tel: Bracknell 3244

RACAL THE RACAL GROUP

ELECTRONIC ENGINEERS

Are you interested in applying your knowledge? Our high powered electronic flash units and light sources with associated measuring accessories are being used in many fields ranging from photography to heavy industry. If you are qualified to construct and service such equipment, we can offer you interesting opportunities. Send details of experience and qualifications to Strobe Equipment Limited, 56 Turnmill Street, London E.C.1. CLERKENWELL 9268.

THE GENERAL POST OFFICE
has vacancies for

RADIO OPERATORS II
at its
COAST RADIO STATIONS

Applications are invited from men between 21 and 35 years of age who must hold either the Postmaster General's First or Second Class Certificate of Competence in Radiotelegraphy or an equivalent certificate issued by a Commonwealth Administration or the Irish Republic.

The posts which will be temporary in the first instance, carry a salary scale of £765-£1,129, depending on age at entry, but successful applicants will be eligible to enter the open competitive selection for permanent appointment to be held in the spring and autumn of 1969.

Applicants should write to: The Inspector of Wireless Telegraphy, Union House, St. Martin's-le-Grand, London E.C.1, or telephone 01-432 5628 for further information.

THE UNIVERSITY OF ASTON IN BIRMINGHAM
ELECTRICAL ENGINEERING DEPT.
M.Sc. COURSES
October 1969 to September 1970

Graduate courses, of one year duration, leading to a Master's Degree are offered in Electrical Engineering and in Precision Measurement and Instrumentation.

M.Sc. in ELECTRICAL ENGINEERING (Ref. M.Sc.8)

One-third of the lecture work will cover mathematics and electrical engineering materials. The remaining time will be devoted to one specialist option selected from the following:

(a) Control and Systems
(b) Power Systems
(c) Communication Systems
(d) Design and Pulse and Digital Circuits and Systems
(e) Electrical Machines.

The Science Research Council has accepted this course as suitable for tenure of its advanced course studentships.

M.Sc. in PRECISION MEASUREMENT AND INSTRUMENTATION (Ref. M.Sc.27)

This course is un by an interdepartmental group comprising Electrical Engineering, Mathematics, Mechanical Engineering, Physics and Production Engineering departments.

Both courses are open to applicants who have graduated in science or engineering or who hold equivalent professional qualifications.

Suitably qualified persons who wish to attend for part of either course (without examination) may do so by arrangement.

Application forms and further particulars (quoting ref. no.) may be obtained from:

THE HEAD OF THE DEPARTMENT OF ELECTRICAL ENGINEERING,
THE UNIVERSITY OF ASTON IN BIRMINGHAM,
GOSTA GREEN,
BIRMINGHAM 4.

RACAL Communications

Applications are invited for the following positions:

TEST EQUIPMENT REPAIR & CALIBRATION ENGINEERS

To carry out repair and calibration of high quality proprietary test equipment including spectrum analysers, oscilloscopes, signal generators, etc. Previous experience essential and it is expected that the successful applicants will be qualified to at least ONC level. Attractive salaries will be discussed at interviews.

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Progressive position for electronic Test Engineers and Testers engaged on a wide range of communications equipment, including transmitters and receivers. Applicants should have technical knowledge equivalent to City & Guilds with previous experience of testing commercial equipment. Attractive salaries plus productivity payment.

Applications in writing, please, to:

**Mr. P. Cousins, Group Personnel Manager,
Racal Electronics Ltd.,
Western Road, Bracknell, Berkshire.**

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OPPORTUNITIES exist for Radio Technicians to undertake interesting work involved with the maintenance and installation of equipment at airfields, Inland and marine mobile networks and on North Sea Drilling Rigs.

APPLICANTS should have experience in one or more of the following classes of equipment. VHF and UHF base station and mobile equipment employing both AM and FM techniques. HF Receivers and Transmitters up to 1kw with SSB, ISB and FSK techniques.

Remote control systems for Transmitters and Receivers operating over GPO landlines.

Teleprinters and Telegraph error correction equipment.

City and Guilds Certificate or equivalent level qualification is desirable.

Applicants must have a valid U.K. driving licence and be willing to work outside normal working hours on a call-out roster basis.

THE POSTS offer starting salaries in the range £1,200–£1,500 commensurate with experience and excellent career prospects and will be based at the Company's Head Office between Hayes and Heston which is situated in close access to the M4 Motorway. Benefits include membership of an excellent Contributory Pension and Life Assurance Scheme and concessions on holiday air fares. IAL are a fast expanding company engaged in the field of communications, aviation services and engineering.

Please write stating brief details of age and career to date to:

Personnel Officer (R)

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Government of ZAMBIA

REQUIRES

Assistant Superintendent of Police

(Radio Specialist)

for the Police Department, Ministry of Home Affairs, on contract for one tour of 36 months in the first instance. Commencing basic salary Kwacha 3408 (£STG.1988) a year, plus an Inducement Allowance of £STG.585. Gratuity 25% of total salary drawn. A direct payment of £STG.291 is also payable direct to an officers home bank account. Both gratuity and direct payment are normally TAX FREE. Free passages. Quarters at low rental. Children's education allowances. Liberal leave on full salary or terminal payment in lieu. Pension scheme available in certain circumstances.

Candidates must have completed an appropriate apprenticeship of five years or be in the possession of either a Service Trade Certificate or some other equivalent qualification, *and* have had not less than six years experience since qualifying in the installation and maintenance of modern low and medium power HF equipment, single and independent side band equipment, and of VHF equipment including multiplex links. A knowledge of the maintenance of teleprinters and diesel and petrol generators up to 10 K.V.A. The officer will be required to install and maintain police radio equipment throughout Zambia *and* train Zambian Officers to qualify for City and Guilds examinations.

Apply to CROWN AGENTS, M. Dept., 4 Millbank, London, S.W.1. for application form and further particulars, stating name, age, brief details of qualifications and experience and quoting reference M2K/681113/WF.

FIELD SALES

MAINTENANCE

CALIBRATION

TEKTRONIX need more ENGINEERS

Work with State-of-the-art oscilloscopes in first-class working conditions, with top pay, profit sharing, non-contributory Life Assurance and Pension Scheme.

Write or telephone Bob Garrett, out-of-hours interviews can be arranged where necessary.

TEKTRONIX U.K. LIMITED
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Become part of a professional audio success story

In only two and a half years the Dolby Audio Noise Reduction System has become internationally recognised as providing a new premium quality master recording standard. Moreover, domestic versions of this revolutionary new system are already being licensed abroad. But this is only the beginning of the story; much more needs to be done in applying the system to a host of exciting new applications.

In our new spacious quarters in south London (about two miles south of Chelsea), we are embarking upon a phased programme of expansion. London staff, now numbering 20, will soon be considerably increased in all respects – engineering, production, marketing, and administration. At the moment, however, the focus is on an electronics engineer and a good audio sales engineer. If you measure up to our present requirements write or telephone our Chief Engineer, Mr. D. P. Robinson.

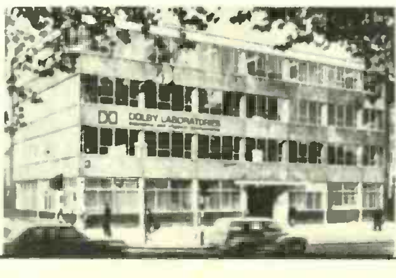
AUDIO ENGINEER–ELECTRONICS c.£2,300

The job: To design a variety of new audio products, both professional and consumer, based on Dolby noise reduction techniques.
The qualifications: An absorbing interest in audio, a degree in electrical engineering or physics, electronic circuit design talent, familiarity with latest solid-state circuit techniques (including IC's), age about 25–30.

AUDIO SALES ENGINEER c.£2,500

The job: To demonstrate and sell the Dolby A301 professional noise reduction system to recording studios, motion picture studios, radio and television authorities, and other users.
The qualifications: Experience as recording engineer or A & R man, a thorough understanding of studio procedures and techniques, a reasonable understanding of electronics, a desire and ability to sell, age about 25–30.

If your qualifications do not meet our immediate requirements but you feel you would like to become a member of our growing team, write to us giving full details; we will consider your application in relation to our future plans.



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LEC

This private College provides efficient theoretical and practical training in the above subjects. One-year day courses are available for beginners and shortened courses for men who have had previous training.

Write for details to: The Secretary, London Electronics College, 20 Penywern Road, Earls Court, London, S.W.5. Tel.: 01-373 8721.

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Large book publishing company based in London requires an experienced EDITOR to head a section producing books on electronics subjects, including radio and television servicing. Applicants (age 28-40) should have a recognised technical qualification in this field and experience in technical publishing. Industrial experience also will be an advantage.

Apply in writing giving full details of experience and qualifications to:
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If so, we offer

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★ Good prospects of promotion (top posts in excess of £2000 pa).
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Vacancies exist at:

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Write to: MINISTRY OF DEFENCE, CE 3(H) (AIR), SENTINEL HOUSE SOUTHAMPTON ROW, LONDON, W.C.1
or call at No. 30 MU, RAF SEALAND, between the following times:
Monday-Friday 8.30-4, Saturday 8.30-12.30

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COLOUR TELEVISION FAULTFINDERS & TESTERS

We have a number of vacancies in our Production Test Departments for experienced faultfinders and testers.

Knowledge of transistor circuitry and experience with Colour Receivers together with R.T.E.B. Final Certificate or equivalent qualifications required.

These will be staff appointments with all the expected benefits.

Applications to:

**Works Manager,
Rediffusion Vision Service Ltd.,
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Chessington, Surrey (near Ace of Spades).
Phone: 01-397 5411**

SITUATIONS VACANT

A FULL-TIME technical experienced salesman required for retail sales; write giving details of age, previous experience, salary required to—The Manager, Henry's Radio, Ltd., 303 Edgware Rd., London, W.2. [67

DESIGN DEVELOPMENT ENGINEER for laboratory work in the design of audio amplifiers, V.H.F. tuners and quality tape recorders. Only persons holding a similar position need apply. Salary according to experience. Apply to Elizabethan Electronics Ltd., Ref: W.W.1. Crow Lane, Romford, Essex. Tel. Romford 64101. [2108

ELECTRONIC ENGINEER required for development/maintenance on electronic/mechanical servo systems and professional recording equipment. Qualifications ONC/HNC Electronics or C. & G. Salary £1,000—£1,500, according to age, qualifications and experience. —Apply with details of qualifications and experience to Box W.W.315 Wireless World.

EXPERIENCED TV Engineer required. Permanent position, good salary. Transport available if required. This is an addition to staff to cope with expanding TV service. REM RADIO, 79 Church Road, Ashford. Tel. Ashford 5336 (Middlesex). [79

GUATEMALA: Small radio station requires volunteer radio technician to assist in establishing relay stations and radio schools. Interesting post concerning the development of remote areas. Volunteer terms: board, lodging, pocket-money, fares, allowances.—Write: CIIR/OV, 38 King St., London, W.C.2. [74

PRODUCTION TEST ENGINEER wanted to join our senior staff with experience of valve and transistor audio equipments. 40-hour week. Salary £1,200 per annum. North West London area. Box W.W. 2124 Wireless World.

RADIO AND TAPE RECORDER TESTERS AND TROUBLE-SHOOTERS required. Excellent rates of pay; 8 a.m. to 5 p.m. Five-day week. Elizabethan Electronics Ltd., Crow Lane, Romford, Essex. Tel.: Romford 64101. [78

REDIFON LTD. require fully experienced TELECOMMUNICATIONS TEST ENGINEERS. Good commencing salaries. We would particularly welcome enquiries from ex-Service personnel or personnel about to leave the Services. Please write giving full details to—The Personnel Manager, Redifon Ltd., Broomhill Rd., Wandsworth, S.W.18. [26

TESTERS and Trouble-Shooters required by manufacturers of car radios, tape recorders, record players, etc. Good rates of pay. Apply to Elizabethan Electronics Ltd. Ref: W.W.2, Crow Lane, Romford, Essex. Tel. Romford 64101. [2109

THE Liverpool Clinic, 1 Myrtle Street, Liverpool, 7. Applications are invited for the post of MEDICAL PHYSICS TECHNICIAN in the Department of Nuclear Medicine. Persons appointed will be required to maintain nucleonic and electronic equipment and would be expected to assist in the design and building of new equipment and modification of existing apparatus. Duties are principally in the Liverpool Clinic, but at times extend to other hospitals in the region. Grade III, IV, or V according to qualifications and experience. Salary according to grade within the scale £747 per annum Grade V to £1,365 Grade III.—Application forms from the Hospital Secretary to be returned not later than 10 days (3452). [2123

UNIVERSITY College of London. Chemistry Department. Electronics Engineer required to lead group responsible for design, development, construction and maintenance of wide variety of electronic instrumentation. Post provides opportunity for well-qualified man to take part in expanding application of electronics to chemical research. Salary at present under review. Generous leave allowance. Application forms from Establishment Officer (Chem/9), University College London, Gower Street, W.C.1. [2122

URGENTLY REQUIRED. Messenger Boy for sound department of recording studio.—Write to Peter Gilpin, World Wide Pictures Ltd., 34 Cursitor Street, London, E.C.4, stating age, interests and experience. [314

WE HAVE VACANCIES for Four Experienced Test Engineers in our Production Test Department. Applicants are preferred who have Experience of Fault Finding and Testing of Mobile VHF and UHF Mobil Equipment. Excellent Opportunities for promotion due to Expansion Programme. Please apply to Personnel Manager, Pye Telecommunications Ltd., Cambridge Works, Haig Road, Cambridge. Tel. Cambridge 51351, Extn. 327 [77

WEST London Aero Club invite "A" and "B" licensed engineers with capital and/or necessary equipment to commence Radio Workshop. Alternative propositions may be considered. Write full details to—White Waltham Airfield, near Maidenhead, Berks. [68

SITUATIONS WANTED

MAN 60. Long experience industrial electronics, instruments, etc. Good radio-TV repairs. Seeks work, Huddersfield-Holme Valley area.—Box WW321 Wireless World.

WANTED. A Young Man seeks semi-permanent Maintenance Employment outside of Europe. Trained HF. SSB/AM, VHF. AM/FM Tx and Rx. Marker beacons. intercom systems, mobile equipment, radio-TV repair.—Box WW319 Wireless World.

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BACK COPIES of "Wireless World" 1950-1968 complete. Offers? Some earlier copies.—Cave, 16 Gordon Road, Newport, Isle of Wight. [317

BBC2 KITS and T.V. SERVICE SPARES. Suitable for Colour:—Leading British makers dual 405/625 six position push button transistorised tuners £5.5.0, 405/625 transistorised sound & vision IF panels £2.15.0, incl. circuits and data, P/P 4/6. Basic dual purpose 405/625 transistorised tuners incl. circuit £2.10.0, P/P 4/6. New UHF tuners incl. valves, slow motion drive assy, knobs, leads, fittings £5.12.6 P/P 4/6. Sobell/GEC 405/625 IF & output chassis incl circuit 45/- P/P 4/6. Ferguson 625 IF amplifier chassis incl. circuit 19/6. Ultra 625 IF amplifier plus 405/625 switch assy incl circuit 25/- P/P 4/6. New VHF turret tuners:—Cyldon C 20/-, Pye CTM 13 ch. incremental 27/6. P/P 4/6. Many others available incl. large selection

channel coils. New fireball tuners 58/6, used good condition 30/-, salvaged 15/-. P/P 4/6. LOPTs, Scan coils, Frame output transformers, Mains droppers etc. available for most popular makes. TV signal boosters transistorised Pye/Labgear B1/B3, or UHF battery operated 75/-, UHF mains operated 97/6, UHF mast-head 95/- post free. Enquiries invited, COD despatch available.
MANOR SUPPLIES, 64 GOLDERS MANOR DRIVE, LONDON N.W.11. CALLERS 589B HIGH RD., N. FINCHLEY N.12. (near GRANVILLE RD.) TEL. 01-445 9118. [60

BUILD IT in a DEWBOX quality plastics cabinet. 2 in. x 2½ in. x any length. D.E.W. Ltd. (W), Ringwood Rd., FERNDOWN, Dorset. S.A.E. for leaflet. Write now—Right now. [76

CAPACITORS, oil filled, new, Westinghouse. 0.25mfd., 32.5 KV DC working. Price £8 each, plus carriage. Box WW 2125 Wireless World.

D.I.Y. All materials and components for construction of high fidelity loudspeaker systems (empty enclosures, BAF wadding, Tygan, Vynair fabric, cross-overs, etc). Many other audio accessories and speaker kits.—S.a.e. for lists: P. R. & A. F. Helme, Dept. WW, Summerbridge, Harrogate, Yorks. [318

FOR SALE. New American Equipment. Qty. LORAIN Sub-Cycle Frequency Converters Input 125v 50/60 cycle; Output 86-110v 16 2/3-20 cycle. Rectifiers. Power Supplies, etc.—For details write Box WW 2126 Wireless World.

HEATHKIT 5" general-purpose Oscilloscope with double-beam generator. New model. Excellent value. Cost £67, £35 o.n.o.—Tippet, 4 Norfolk Street, Barrow-in-Furness. Tel. 3005. [313

LARGE QUANTITIES and huge range of RF connectors by transradio, available for immediate delivery at huge discounts, or will consider bids for entire stock —approximately 60,000 items. Large quantity ½"×3,600 ft. tape and ½"×2,400 ft. tape on N.A.B. centre reels and in plastic containers. 9 Edwardes high vacuum T.I. H.F. Insulation Flashover Testers. 60 Power Supplies 115 v. a.c. input 50-60 cycles. Output 7-15 v. d.c. at 20 amps. Variac controlled fully transistorised and stabilised. Of American origin, 19" rack mounting. We also buy redundant stocks in bulk.—All enquiries to Connectors & Electronics, Ltd., 20 College Drive, Ruislip, Middx. (Ruislip 35953). Ask for Mr. G. Drake. [320

ONE 12-channel Oscillograph Type 1200A, manufactured by Southern Instruments Ltd. Price £250. (Suitable for vibration investigation.) J. Black. 44 Green Lane, Hendon, N.W.4. Tel. 203 1855 or 203 3033. [2114

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THE IDEAL PANEL Mounting Meter Movement for any Sensitive Test Meter. etc. 200 Micro Amp F.S.D. 4⅜"×4⅜" in clear plastic case. Our special price only 39/6. P. & P. Free. Limited number only. Walton's Wireless Stores, 55A Worcester Street, Wolverhampton, Staffs. [71

500-VOLT Bridge Megger, Signal Generators and other equipment. S.a.e. for List.—A. C. Mansell, 46 Headley Road, Woodley, Reading, RG5 4JE. [316

VORTEXION full track (7½, 15) series 5 recorder used for play-back only, superb condition, £92 (London). Box W.W. 2128.

TEST EQUIPMENT — SURPLUS AND SECONDHAND

SIGNAL generators, oscilloscopes, output meters, wave voltmeters, frequency meters, multi-range meters, etc., etc., in stock.—R. T. & I. Electronics, Ltd., Ashville Old Hall, Ashville Rd., London. E.11. Ley. 4986. [64

RECEIVERS AND AMPLIFIERS—SURPLUS AND SECONDHAND

CLOSED CIRCUIT TELEVISION equipment at very special prices. Llittle used bargains surplus to requirements all in first-class working order. Video Tape Recorders: ½" Shibaden SV 700E £298. Video Monitors: 12" Shibaden TU 12U £40; 19" Shibaden TU 19E £55; 19" Thorn type VM 857 six channel £46; 23" Thorn type VM 859 six channel £50. All Monitors have audio facilities.—Full specifications on request from RADIO RENTALS WIRED SYSTEMS LTD., Shrivenham Road, Swindon, Wilts. [2127

HRO Rx5s, etc., AR88, CR100, BRT400, G209, S640, etc., etc., in stock.—R. T. & I. Electronics, Ltd., Ashville Old Hall, Ashville Rd., London, E.11. Ley. 4986. [65

NEW GRAM AND SOUND EQUIPMENT

CONSULT first our 70-page illustrated equipment catalogue on Hi-Fi (5/6). Advisory service, generous terms to members. Membership 7/6 p.a.—Audio Supply Association. 18 Blenheim Road, London, W.4. 01-995 1661. [27

GLASGOW.—Recorders bought, sold, exchanged; cameras, etc., exchanged for recorders or vice-versa.—Victor Morris, 343 Argyle St., Glasgow, C.2. [11

TAPE RECORDING ETC.

IF quality, durability matter, consult Britain's oldest transfer service. Quality records from your suitable tapes. (Excellent tax-free fund raisers for schools, churches.) Modern studio facilities with Steinway Grand.—Sound News, 18 Blenheim Road, London, W.4. 01-995 1661. [28

TAPE to disc transfer, using latest feedback disc cutters; EPs from 22/-; s.a.e. leaflet.—Deroy, High Bank, Hawk St., Carnforth, Lancs. [70

VALVES

VALVE cartons by return at keen prices; send 1/- for all samples and list.—J. & A. Boxmakers, 75a Godwin St., Bradford, 1. [10

PRODUCTION UNIT ENGINEER

Miniature electro-acoustic products

Engineer with mechanical production training required to manage production of high quality hearing aids. Some electronic experience desirable, successful applicant will be responsible for production methods, co-ordinating all departments including inspection, tests, services and for quality of final product.
Previous experience on hearing aids not essential.
Position could be of great interest; working conditions are excellent.

Please apply: Personnel Officer, Amplivox Ltd., Beresford Avenue, Wembley, Middx.

THE CIVIL SERVICE

RADIO AND ELECTRONIC ENGINEERS

Board of Trade (Civil Aviation)

Qualified engineers required as Assistant Signals Officers in the field of Civil Aviation for the provision and installation of advanced electronic equipment—including the latest type of radar, telecommunications, navigational aids, etc.

Qualifications: Degree with 1st or 2nd class honours in Electrical Engineering or Physics, or have passed all examinations for M.I.E.E., A.M.I.E.R.E. or A.F.R.Ae.S.

Age: 23 and normally under 35 on 31st December, 1969 (extension for Forces or Overseas Civil Service).

Salary (Inner London): On the scale £1,212-£2,190 depending on age and qualifications. Pensionable appointments. Good prospects of promotion.

Application Forms are obtainable by writing to the Secretary, Civil Service Commission, 23 Savile Row, London, W1X 2AA, or by telephoning 01-734 6010 Ext. 229 (after 4.30 p.m. 01-734 6464 "Ansafone" Service). Please quote S/85/ASO.

ELECTRONIC SERVICE ENGINEERS

The Installation and Maintenance Division of E.M.I. Electronics Ltd. urgently requires engineers with drive and ability to assist with the division's rapidly expanding work programme.

The successful candidates will be engaged on work in one of the following areas:–

***Servicing and calibration of a wide range of electronic instruments.**

***Installation and Maintenance of automation, numerical, digital and multiplex systems.**

Applicants should have had several years' experience of the maintenance of electronic equipment. These vacancies would appeal to engineers with industrial experience or a services background. Some travelling will be necessary for certain positions.

Excellent commencing salaries and staff benefits.

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E.M.I. LTD BLYTH ROAD · HAYES · MIDDX

WW/2/69

SOUTHERN
INDEPENDENT TELEVISION

require a

SENIOR ENGINEER
(ELECTRONIC MAINTENANCE SECTION)

The successful applicant will be based at the Southampton studios and will be required to work shift duties.

Applicants must have had considerable experience in the Electronic Maintenance Section of a broadcasting organisation and be conversant with modern solid state circuitry and the PAL system of colour television.

Technical qualifications of at least Higher National Certificate are required and candidate must be in good health and have normal colour vision. The post commands a salary of £2,166 per annum (A.C.T.T. Grade B) and the Company operates a first-class contributory pension scheme.

Applications in writing to:

The Personnel Officer,
Southern Independent Television,
Northam,
Southampton, SO9 4YQ

EAST SUFFOLK EDUCATION COMMITTEE

LOWESTOFT COLLEGE OF FURTHER EDUCATION

St. Peter's Street, Lowestoft, Suffolk
Principal: A. E. Body, B.Sc. (Econ), F.R.G.S.

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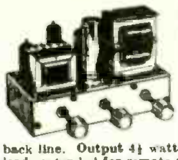

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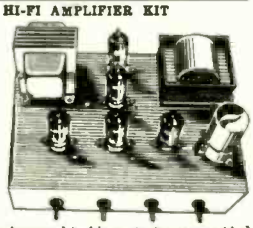

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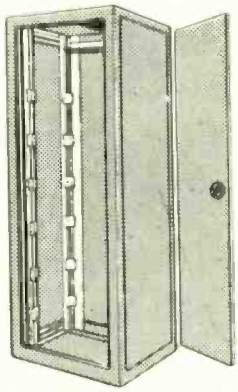

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2N685	200	16	19/6
2N687	300	16	25/6
2N688	400	16	32/6
2N689	500	16	47/6
2N690	600	16	50/-
2N691	700	16	56/-
2N692	800	16	62/-

TO-46 CASE (STUD)

Type No.	PIV	Amp	Each
2N1771	50	4·7	9/-
2N1772	100	4·7	9/6
2N1774	200	4·7	12/6
2N1776	300	4·7	16/6
2N1777	400	4·7	19/-
2N1778	500	4·7	25/6
2N2619	600	4·7	30/-
BTY79-150	150	4·7	12/-
BTY79-250	250	4·7	14/-
BTY79-400	400	4·7	20/-

1/- each TESTED TRANSISTORS 1/- each

ONE PRICE ONLY PNP. NPN. SILICON PLANAR 1/- EACH

BC108	2N696	2N1132	2N2220	2S733
BC109	2N697	2N1613	2N3707	2N3391
BFY50	2N706	2N1711	2N3711	TIS44
BFY51	2N708	2N2904	2S102	2N2906
BFX84	2N929	2N2905	2S103	2N2907
BFX86	2N930	2N2924	2S104	2N2696
BFX88	2N1131	2N2926	2S732	2N3702
				2N3703

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AC126	ACY27	NKT141	NKT713	OC82
AC127	ACY28	NKT142	NKT773	2G301
AC128	ACY29	NKT212	OC44	2G302
AC130	ACY30	NKT213	OC45	2G303
ACY19	ACY31	NKT214	OC71	2G308
ACY20	ACY34	NKT215	OC72	2G371
ACY21	ACY35	NKT271	OC75	2G374

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ORP12 Cadmium Sulphide Cell. 1-24 **9/-** each; 25-99 **7/-** each; 100-999 **6/-** each; 1,000 up **5/6** each. Made in Holland.
BY100 SIL. RECT'S 800 PIV 550 mA. 1-49 **2/6** each; 50-99 **2/3** each; 100-999 **2/-** each; 1,000 up **1/10** each. Fully Coded. 1st Qlty.

Sub-Min. Plastic 1 Amp Sil. Rect.

Type No.	PIV	Each
1N4001	50	1/3
1N4002	100	1/6
1N4003	200	2/-
1N4004	400	2/9
1N4005	600	3/3
1N4006	800	3/9
1N4007	1,000	4/9

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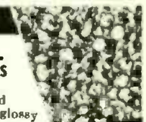

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