ELECTRONIC & RADIO ENGINEER

Incorporating **WIRELESS ENGINEER**

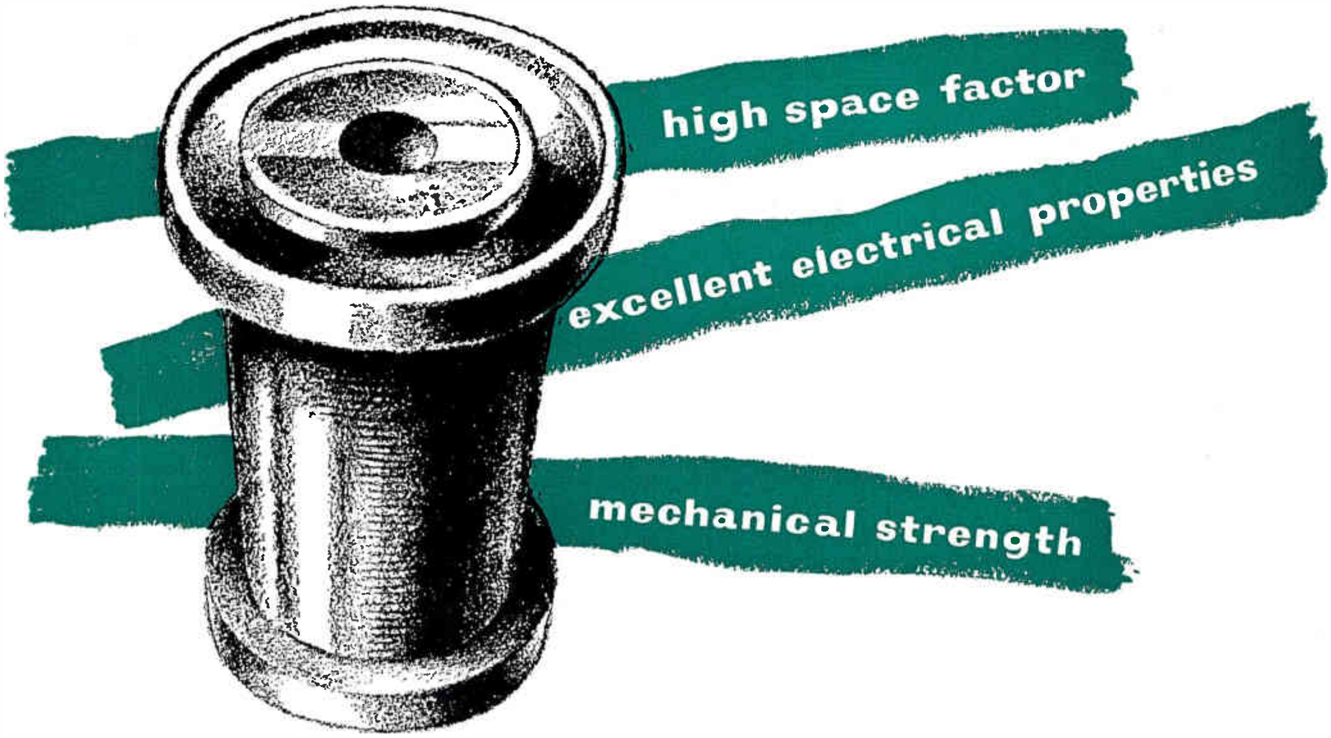
In this issue

Three shillings and sixpence

OCTOBER 1958 Vol 35 *new series* **No 10**

3 BIG FACTORS

where small windings are concerned



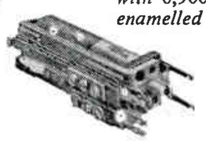
These are three good reasons why BICC Enamelled Winding Wires are ideal for small windings. In addition, coverings are flexible, strongly adhesive to conductors and resistant to heat and damp.

For full details, write for BICC Publication No. 303. We will be glad to send you a copy.

Experienced engineers of the BICC Technical Advisory Service are always ready to assist you in the selection of the right winding wire for your purpose.

1 *Coil for Amplivox miniature magnetic earphone wound with* ·001 *inch enamelled wire.*

2 *Telephone Relay Coil wound with* 6,900 *turns of* ·0036 *inch enamelled wire.*



3 *Field Coil for motor car dynamo wound with* 280 *turns of* ·030 *inch enamelled wire.*

BICC

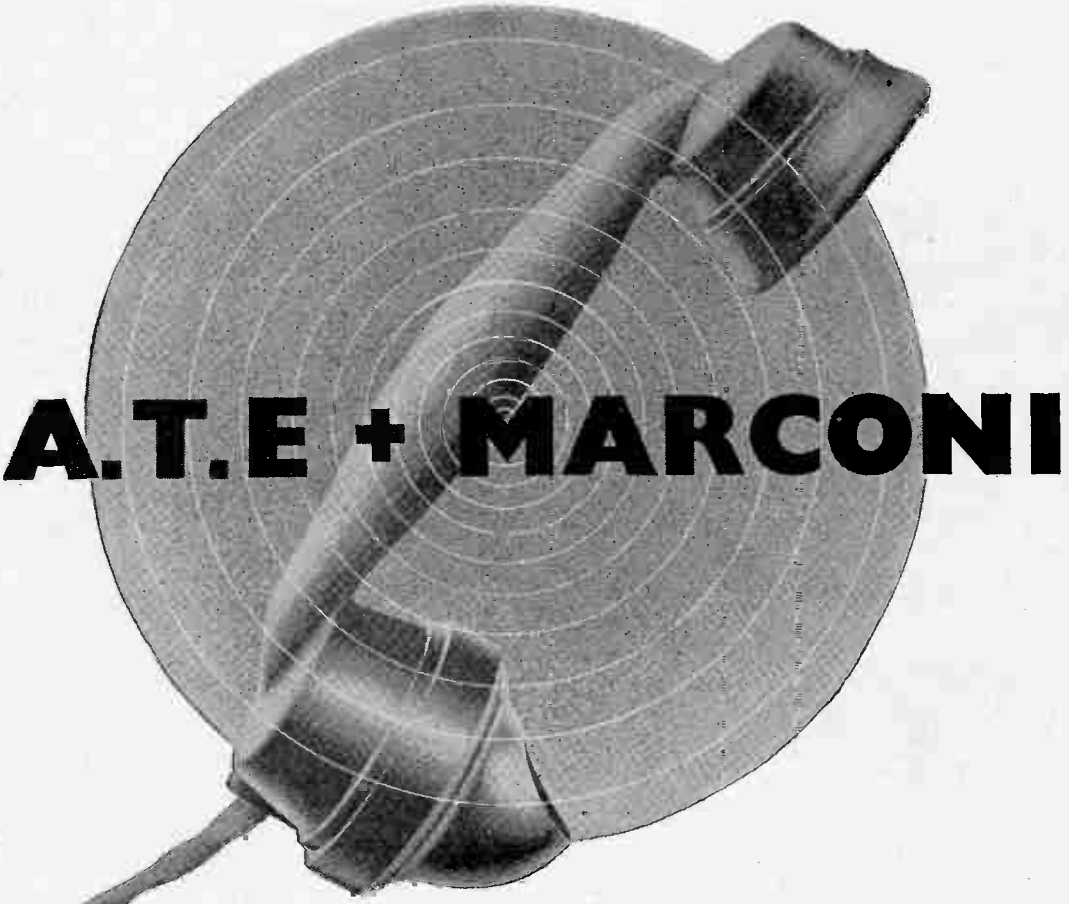
(OIL-BASE) ENAMELLED

Winding Wires

BRITISH INSULATED CALLENDER'S CABLES LIMITED

21 Bloomsbury Street, London, W.C.1

A.T.E + MARCONI



Combined Operations

The complexity of modern radio-multichannel systems involving hundreds of telephone channels has brought about a collaboration between the two leading specialist organizations in the field—Marconi's in radio, and A.T.E. in carrier transmission.

This completely unified approach to development, systems planning, supply, installation, maintenance of equipment and training of personnel covers radio-multichannel systems in the V.H.F., U.H.F. and S.H.F. frequency bands all over the world.

Marconi

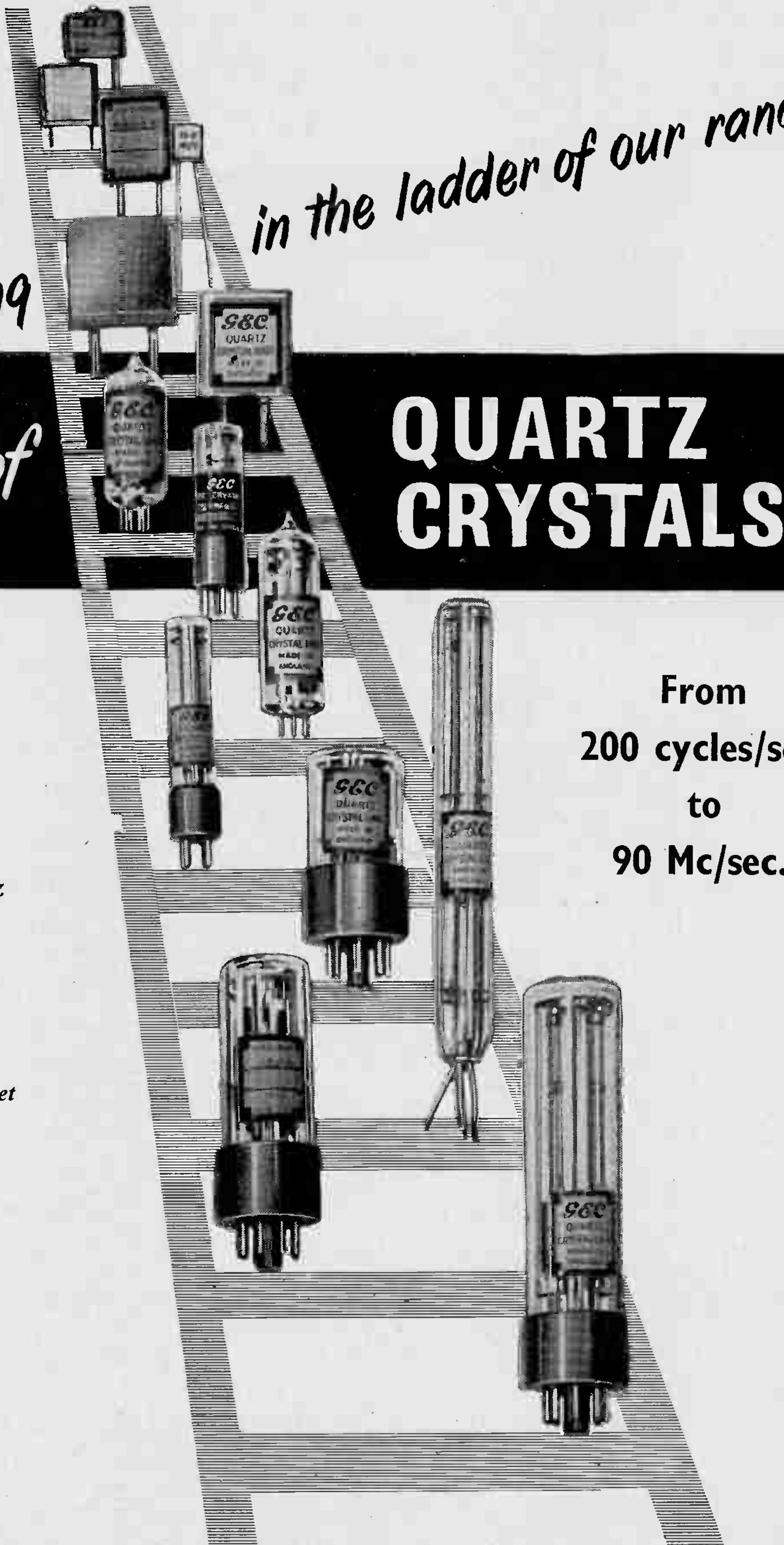
ATM

Full information may be obtained from either:
MARCONI'S WIRELESS TELEGRAPH COMPANY LIMITED, CHELMSFORD, ESSEX, ENGLAND.

or AUTOMATIC TELEPHONE & ELECTRIC CO. LTD., STROWGER HOUSE, ARUNDEL STREET, LONDON, W.C.2

no rungs missing in the ladder of our range of

QUARTZ CRYSTALS



G.E.C.

For long term stability and unfailing activity, G.E.C. Quartz Crystal Units provide the basis for reliable communications systems.

A complete range of units to meet D.E.F. 5271 and R.C.L.271 Inter-Services styles can be supplied.

From 200 cycles/sec. to 90 Mc/sec.

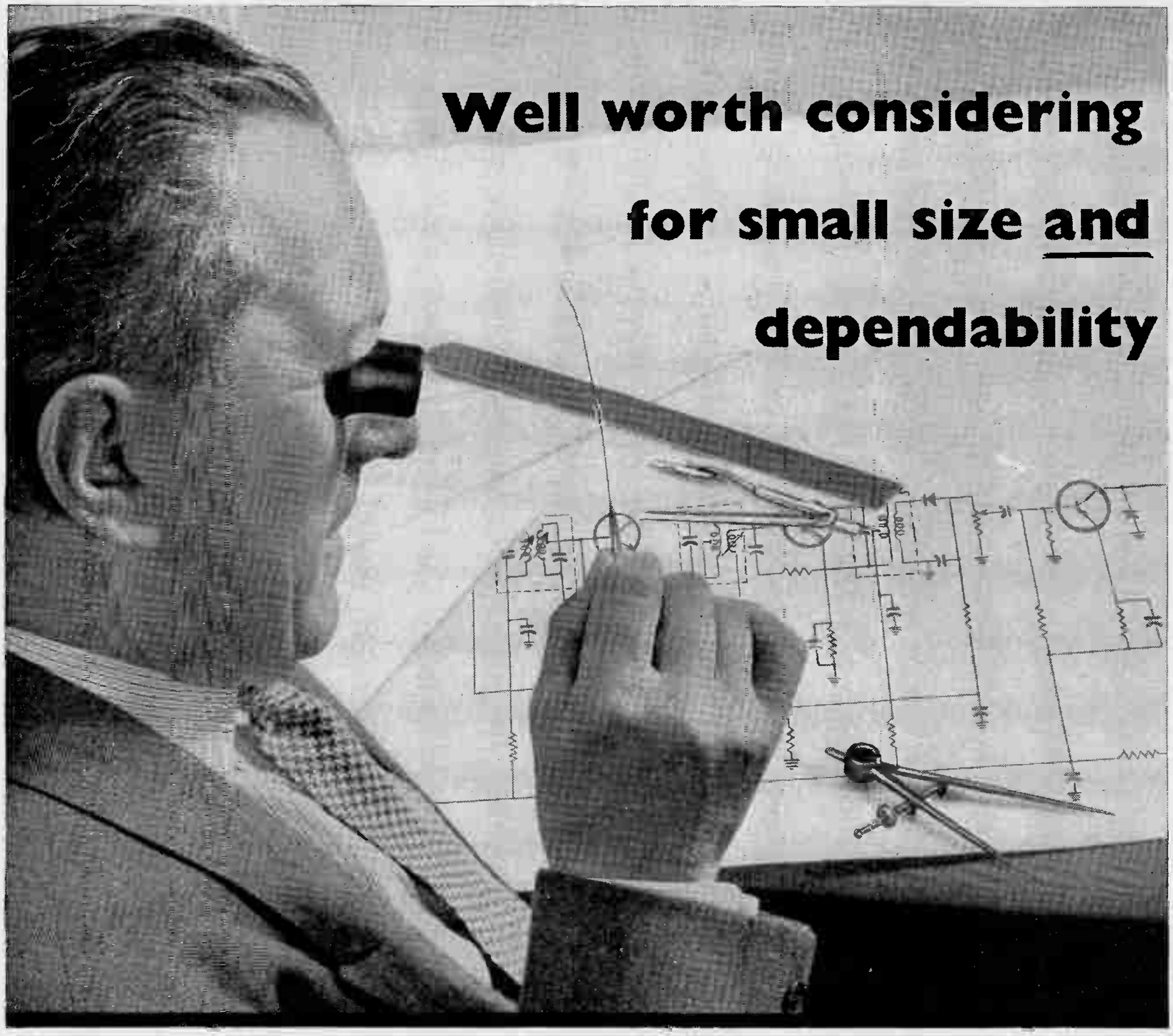
SALFORD ELECTRICAL INSTRUMENTS LIMITED

(COMPONENTS GROUP)

TIMES MILL · HEYWOOD · LANCASHIRE Tel: Heywood 6868

London Sales Office Tel: Temple Bar 4669

A SUBSIDIARY OF THE GENERAL ELECTRIC CO. LTD. OF ENGLAND



The new type BTH Germanium Point Contact Rectifiers—

Only ¼ in. long, yet their miniature size is combined with high performance and complete dependability! They offer the following outstanding characteristics:

- HIGH TEMPERATURE STABILITY
- ABILITY TO WITHSTAND TROPICAL CONDITIONS
- SMALLER DIMENSIONS
- VERY LONG LIFE

RATINGS: CONTINUOUS OPERATION AT 25°C. (77°F.)

TYPE	PEAK INVERSE VOLTAGE† V	MAX. INPUT CURRENT mA	MAX. RESISTANCE at + 1 volt ohms	MIN. RESISTANCE at — 50 volts kilohms
CV 448*	80	30	333	500
CG41-H	65	30	250	50
CG42-H	100	30	500	1,000
CG44-H	80	30	333	500
CG50-H	100	30	500	200

*Type CV 448 has been granted 'type approval'. †Corresponds to 1·2 mA inverse current.

B T-H

BRITISH THOMSON-HOUSTON

THE BRITISH THOMSON-HOUSTON CO·LTD·LINCOLN·ENGLAND

an A.E.I. Company

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NICKEL METALLISING

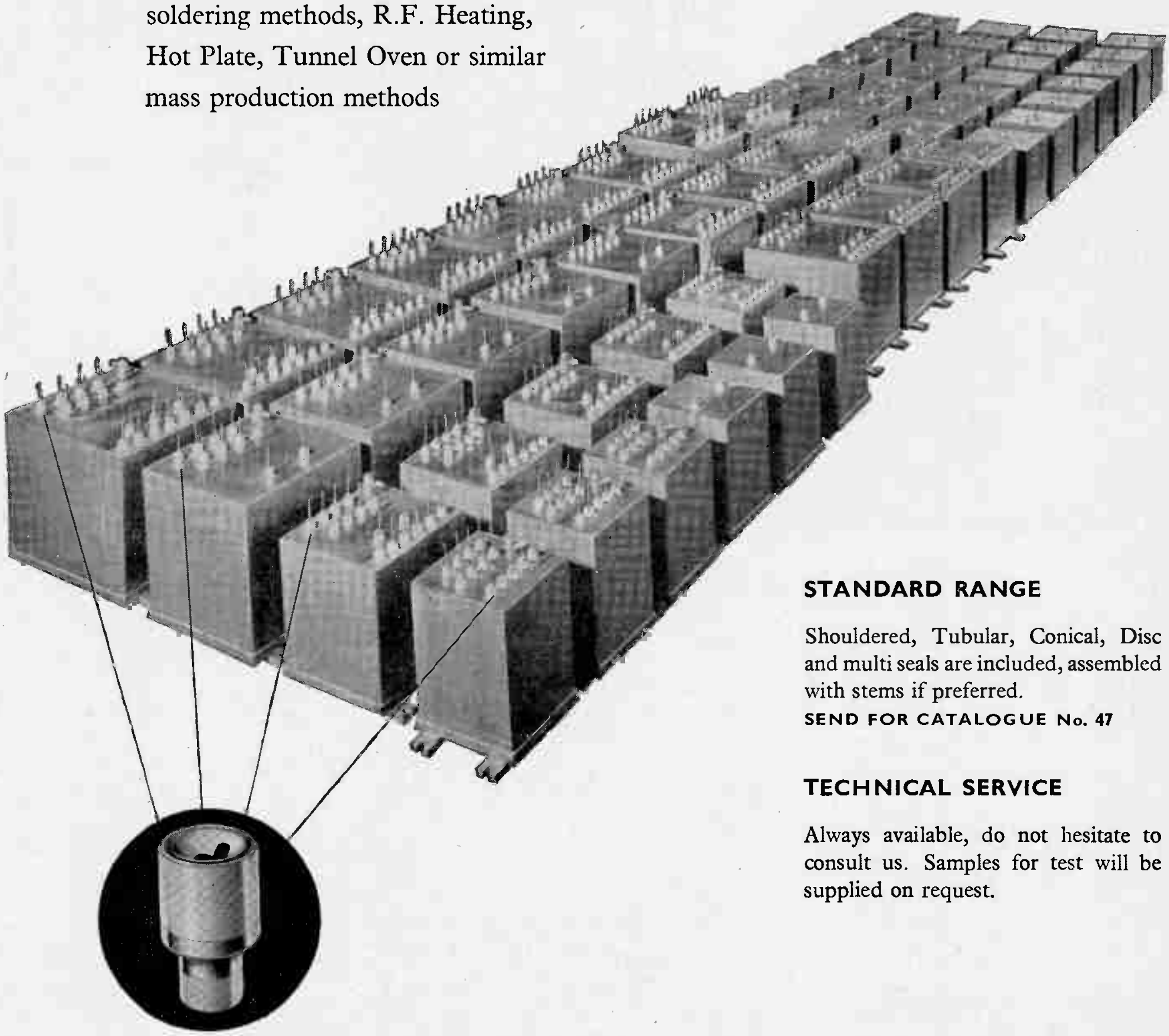
Quality Approved (Joint Service R.C.S.C.)

WILL MEET THE MOST EXACTING REQUIREMENTS

METALLISED BUSHES

Perfect Terminations

—made readily without special precautions by semi-skilled labour, employing simple hand soldering methods, R.F. Heating, Hot Plate, Tunnel Oven or similar mass production methods



STANDARD RANGE

Shouldered, Tubular, Conical, Disc and multi seals are included, assembled with stems if preferred.

SEND FOR CATALOGUE No. 47

TECHNICAL SERVICE

Always available, do not hesitate to consult us. Samples for test will be supplied on request.

STEATITE & PORCELAIN PRODUCTS LTD.

STOURPORT ON SEVERN, WORCS. **Telephone: Stourport 2271.** **Telegrams: Steatain, Stourport**

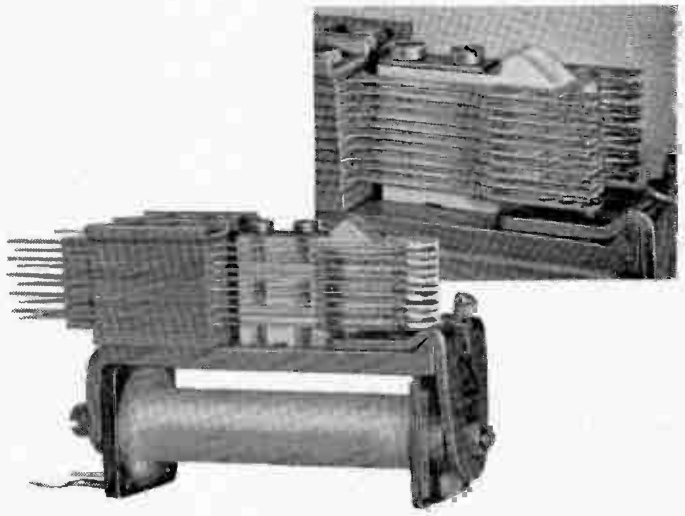
SP100

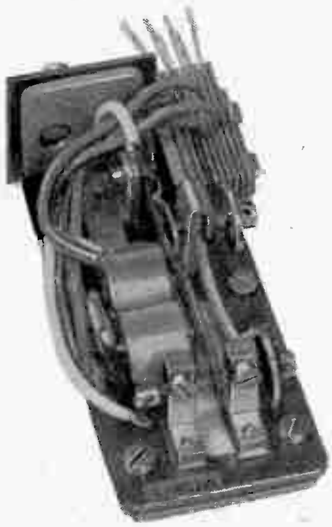
3 outstanding RELAYS

These relays are available
for early delivery;
your enquiries are welcomed

Comb Relay

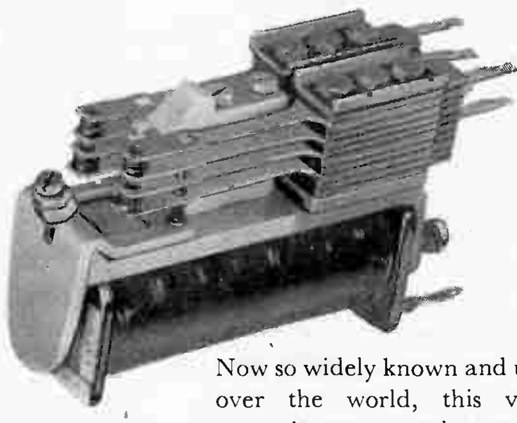
This is our latest development in relays and will give 100 million operations without the need for readjustments. Long life and reliability have led to its adoption by the British Post Office for use where continuous pulsing is required. A wide range of contact combinations is available with a maximum of 10 make or 10 break actions. It is suitable for switching light currents at 250 v.





High Speed Relay

Originally developed for use in fast telephone switching circuits, this high speed relay is of great value in automation systems. It can effect a single changeover action in as little as 1.5 milliseconds. A high speed relay is also available with two changeover actions.



B.P.O.
3000
Type

Now so widely known and used all over the world, this versatile general-purpose relay was designed by us in the early 'thirties for the British Post Office. Many millions are now in use in both telephone and industrial applications. It is available in an extremely wide range of coil resistances and spring set combinations for practically all normal voltages and frequencies.

SIEMENS EDISWAN

SIEMENS EDISON SWAN LTD.
An A.E.I. Company
Woolwich, London, S.E.18
Telephone Woolwich 2020 Extn. 621

Although many of the ratings are increased, the price of these diodes has been reduced. As a result of the outstanding thermal properties the same increased rating is possible with capacitive or resistive load. The diodes are suitable for high temperature operation and have extremely high ratios of forward to reverse resistance.

Fast recovery time computer diodes are in development. The first of the range to become available is the EW78 which is suitable for use up to 100Mc/s.

LOW VOLTAGE TYPES

SX641 SX642

Suitable for use as Second Detectors at frequencies of up to 10 Mc/s and for the majority of other low power circuit functions. The rectified current rating at 25°C is 300 mA.

HIGH VOLTAGE TYPES

SX643 SX644 SX645

Suitable for use as H.T. rectifiers in telecommunication type power supplies, and for Blocking and Gating functions. Typical ratings for resistive or capacitive input circuits at 25°C are given below:—

Circuit Arrangements	Max rectified current (mA)			RMS input voltage (V)			DC output voltage (V)		
	SX643	SX644	SX645	SX643	SX644	SX645	SX643	SX644	SX645
Half-wave	280	210	210	64	106	140	90	150	200
Bi-phase	560	420	420	64–0–64	106–0–106	140–0–140	90	150	200
Bridge	560	420	420	128	212	280	180	300	400

For further information, please write to the G.E.C. Valve & Electronics Department

THE GENERAL ELECTRIC CO LTD MAGNET HOUSE KINGSWAY LONDON WC2


OPERATIONAL RELIABILITY
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EDDYSTONE
TRADE MARK
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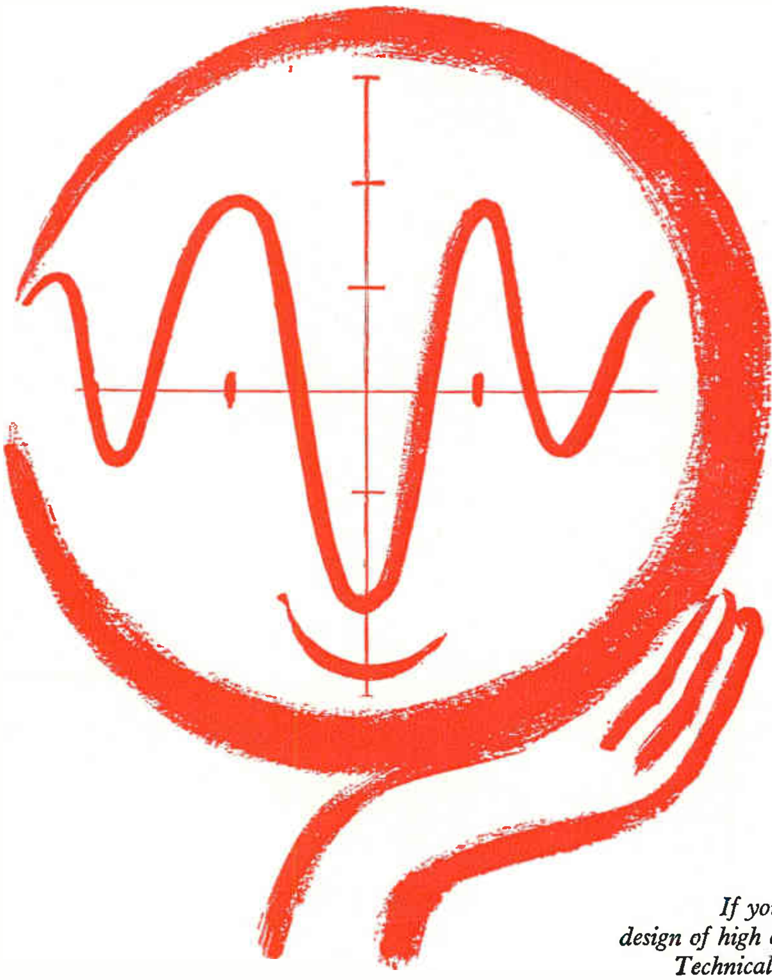
VHF & UHF
(AM & FM)
Communications Receivers
Model 770R.
19-165 Mc/s.
Model 770U.
150-500 Mc/s.
Agents in all parts of the world
Please write for full Technical Specifications to the Manufacturers
STRATTON & CO. LTD., BIRMINGHAM, 31



EVEN IF THEY HAVE TO BE SPECIALLY MADE

We've always said that Unbrako screws cost less than trouble.

But it happens that once in a while a customer needs a screw that cannot be found even in the vast Unbrako range.

So we make them to the customer's own specification, or design specially for him.

And even when we have to make specially, Unbrako still costs less than trouble.

So, rest assured, standard or not, you can always safely specify Unbrako screws and make sure of getting the finest fasteners that are made anywhere in the world. Details of sizes and threads will gladly be sent on request.

UNBRAKO SOCKET SCREW COMPANY LIMITED · COVENTRY

UNBRAKO SCREWS *still* COST LESS THAN TROUBLE

UNBRAKO

PARMEKO
ATLANTIC SERIES

STANDARD SMOOTHING CHOKES

Catalogue Number	D.C. Current Milliamps	Inductance Henries	Approx. D.C. Resis. Ohms.	Model Size
P-2772	10	50	2000	9000/39
P-2773	25	10	520	9000/39
P-2774	25	25	1500	9000/39
P-2775	25	50	1200	9000/41
P-2776	50	10	700	9000/39
P-2777	50	20	850	9000/40
P-2778	50	50	1200	9000/49
P-2779	75	10	230	9000/41
P-2780	75	15	450	9000/41
P-2781	75	20	500	9000/49
P-2782	100	10	290	9000/41
P-2783	120	10	240	9000/49
P-2784	120	15	280	9000/49
P-2785	120	20	300	9000/57
P-2786	150	1·5	115	9000/41
P-2787	180	5	140	9000/49
P-2788	180	10	190	9000/57
P-2789	180	15	260	9000/57
P-2790	180	20	280	9000/65
P-2791	250	1·5	45	9000/41
P-2792	250	2·5	70	9000/49
P-2793	250	5	120	9000/49
P-2794	250	10	140	9000/65
P-2795	250	20	180	9000/73
P-2796	350	10	100	9000/73
P-2797	500	2·5	32	9000/65
P-2798	500	5	50	9000/73

The inductance quoted is measured at 10 volts, 50 c.p.s. with rated D.C. current

Standard Mains and Filament Transformers (see tables below) have all primaries wound 10-0-200-220-240V. 50 cps; an electrostatic shield is fitted between primary and secondary windings on all models; the DC rectified current is quoted for full wave rectifier windings with condenser input filter.

STANDARD MAINS TRANSFORMERS

Ref. No.	ELECTRICAL SPECIFICATION						Model Size
	Secondary 1		Sec. 2	Sec. 3	Sec. 4	Sec. 5	
P-2749	150–0–150 V.	25 mA	6·3 V. 0·6 A.	6·3 V. 0·6 A.	—	—	9000/41
P-2750	150–0–150 V	50 mA	6·3 V. 0·6 A.	6·3 V. 1 A.	—	—	9000/49
P-2751	150–0–150 V.	75 mA	6·3 V. 1 A.	6·3 V. 2 A.	6·3 V. 1 A.	—	9000/57
P-2752	200–0–200 V.	75 mA	6·3 V. 1 A.	6·3 V. 2 A.	6·3 V. 1 A.	—	9000/57
P-2753	250–0–250 V.	75 mA	0/5/6·3 V. 2·5 A.	6·3 V. 3 A.	6·3 V. 2 A.	—	9000/65
P-2754	250–0–250 V.	100 mA	0/5/6·3 V. 2·5 A.	6·3 V. 3 A.	6·3 V. 2 A.	—	9000/65
P-2755	250–200–0–200–250	50 mA	6·3 V. 1 A.	6·3 V. 1·5 A.	—	—	9000/49
P-2756	300–250–0–250–300 V.	180 mA	0/5/6·3 V. 3 A.	6·3 V. 3 A.	6·3 V. 3 A.	—	9000/73
P-2757	350–300–0–300–350 V.	75 mA	0/5/6·3 V. 3 A.	6·3 V. 3 A.	6·3 V. 3 A.	—	9000/73
P-2758	350–300–0–300–350 V.	100 mA	0/5/6·3 V. 2 A.	6·3 V. 3 A.	6·3 V. 1 A.	—	9000/65
P-2759	350–300–0–300–350 V.	120 mA	0/5/6·3 V. 3 A.	6·3 V. 3 A.	6·3 V. 4 A.	—	9000/73
P-2760	350–300–0–300–350 V.	180 mA	0/5/6·3 V. 3 A.	6·3 V. 3 A.	6·3 V. 4 A.	—	9000/73
P-2761	350–300–0–300–350 V.	250 mA	0/5/6·3 V. 3 A.	6·3 V. 3 A.	6·3 V. 4 A.	6·3 V. 4 A.	9000/81
P-2762	450–400–0–400–450 V.	120 mA	0/5/6·3 V. 3 A.	6·3 V. 3 A.	6·3 V. 5 A.	—	9000/73
P-2763	450–400–0–400–450 V.	180 mA	0/5/6·3 V. 3 A.	6·3 V. 3 A.	6·3 V. 3 A.	6·3 V. 4 A.	9000/81
P-2764	450–400–0–400–450 V.	250 mA	0/5/6·3 V. 3 A.	6·3 V. 3 A.	6·3 V. 4 A.	6·3 V. 4 A.	9000/81
P-2765	550–500–0–500–550 V.	120 mA	0/5/6·3 V. 3 A.	6·3 V. 3 A.	6·3 V. 5 A.	—	9000/81
P-2766	550–500–0–500–550 V.	200 mA	0/5/6·3 V. 3 A.	6·3 V. 3 A.	6·3 V. 5 A.	—	9000/81

- ✳ **DESIGN**: Complies with BSS2214
- ✳ **CONSTRUCTION**: Steel encased, compound filled
- ✳ **DIMENSIONS**: Plan and fixing to RCL215
- ✳ **HUMIDITY**: Category H2 or better
- ✳ **TERMINALS**: Patented design insulators, layout to RCL215
- ✳ **MOUNTING**: Upright or inverted all models
- ✳ **FINISH**: Grey hammer, stoved enamel

STANDARD FILAMENT TRANSFORMERS

Ref. No.	ELECTRICAL SPECIFICATION						Model Size
	Secondary 1		Sec. 2	Sec. 3	Sec. 4	Sec. 5	
P-2767	6·3 V.	1 A.	—	—	—	—	9000/39
P-2768	0–4–5–6·3 V.	2 A.	—	—	—	—	9000/40
P-2769	0–4–5–6·3 V.	3 A.	—	—	—	—	9000/41
P-2770	0–4–5–6·3 V.	2 A.	0/4/5/6·3 V. 2 A.	—	—	—	9000/41
P-2771	0–4–5–6·3 V.	3 A.	0/4/5/6·3 V. 3 A.	6·3 V. 3 A.	6·3 V. 3 A.	—	9000/65

PARMEKO LIMITED
PERCY ROAD . LEICESTER
England

to satisfy the most discriminating...

ESSENTIAL DATA

NOMINAL SIZE	15"
PEAK POWER HANDLING CAPACITY	25 watts.
VOICE COIL DIAMETER	3"
TOTAL FLUX	290,000 Maxwells
FREQUENCY RESPONSE	30–15,000 C/S
BASS RESONANCE	35 C/S
IMPEDANCE AT 400 C/S	15 ohms.

The Celestion "Colaudio" Loudspeaker, with a substantially level response from 30–15,000 c.p.s., embodies two distinct techniques in order to provide a satisfactory answer to the ever widening demand for truer reproduction.

Utilising a 15-in. direct radiator loudspeaker specially designed to produce the lower frequencies, particular features of this bass unit are the 3-in. Voice Coil and dustproof suspension of the anular type, permitting free cone excursion whilst reducing lateral movement to a minimum.

The high frequency reproducer incorporates two direct radiator pressure type units, mounted in column form within the cone of the bass radiator. This arrangement enables the higher frequencies to be dispersed over a wide area in the horizontal plane with a narrow vertical lobe, minimising unwanted reflections and improving efficiency.

The vertical position of this column can be adjusted to suit the position in which the loudspeaker is mounted in the cabinet.

The main housing is cast, finished in black crackle with silver trim.

CELESTION

COLAUDIO

Full technical details available direct from:

Rola Celestion Ltd. THAMES DITTON, SURREY, ENGLAND. Phone: Emberbrook 3402/6

A new Plessey range of Plugs and Sockets

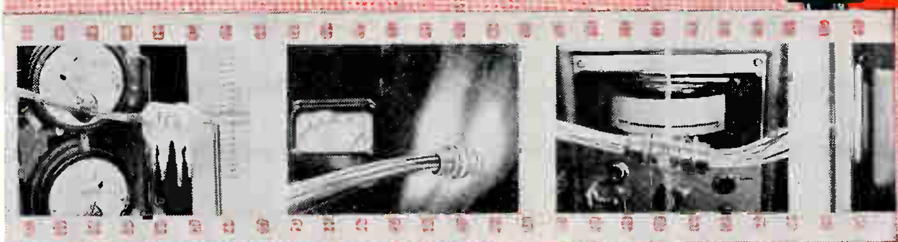
COVERING THE ENTIRE 'AN' RANGE

The Plessey UK–AN series of electrical connectors is now available and, for the first time from a non-dollar source, manufacturers will be able to obtain a full range of plugs and sockets completely interchangeable with the existing AN range.*

The Plessey UK–AN range has been designed and developed to M.O.S. Specification EL 1884 and RCS 321, and every UK–AN connector is fireproof, pressure sealed and environmental resisting. No separate wiring accessories are needed.

Write for test reports and full technical details.

Thawing out after low-temperature test at -60° C. *Fireproofness test (15 mins. at 1,100° C.)* *Testing insulation resistance under direct water jet.*



* There are many thousands of separate items in the AN range as it exists at present, whereas the ingenious Plessey UK–AN list comprises only 880 separate items, yet achieves the same service requirements.

ELECTRICAL CONNECTORS DIVISION

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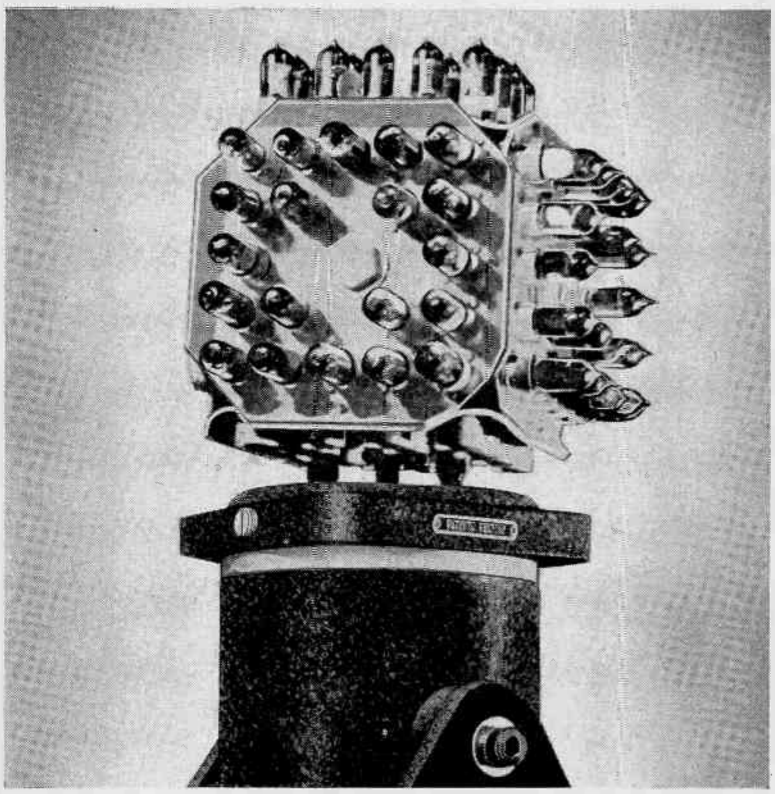
GOODMANS

VIBRATION EQUIPMENT

in Electronics



MODEL 790 VIBRATION GENERATOR provides a peak thrust of 50 lb. and can be used at frequencies up to 500 c/s.

The complexity of modern techniques, the ever increasing use of electronics in technological, military and domestic applications, and the gradually intensifying stringency of acceptance tests for many products on the home or export market—these dictate a more fundamental approach to many design problems and test procedures than we have been accustomed to. Illustrated is a vibration test being performed on a batch of valves—just one of many techniques necessary to maintain the high standard of consistency and reliability sought by today's Electronics Industry. In this instance, testing is carried out on valves oriented in three mutually perpendicular planes, a requirement of several modern test specifications.

It requires only elementary insight into the problems associated with intricate mechanical assemblies (ranging from valves to the navigating systems of modern high-speed airliners or to automatically controlled machine tools) to realise that this test procedure is of very wide applicability, and affords excellent opportunities.

Consult our Technical Advice Bureau if you have a problem concerning Vibration.

The full range of GOODMANS Vibration Equipment caters for peak thrusts from 2 lb to 10,000 lb, and for frequency ranges up to 10,000 c/s. It comprises Vibration Generators, Oscillator-Power Amplifiers, and a Control Amplifier.

ENQUIRY FORM

TO GOODMANS INDUSTRIES, LIMITED
AXIOM WORKS · LANCELOT RD. · WEMBLEY · MIDDX. ENGLAND

We are interested in the following:—

- [ ] General Catalogue
- [ ] Equipment to vibrate load of ....lb at ....g(........in) ....c/s to........c/s
- [ ] Suitable driving equipment
- [ ] Other items........
- [ ] A vibration system for the duty of ....

Name ....

Company ....

Address ....

Please mark details required. R23

GOODMANS *Vibration Equipment*

GOODMANS INDUSTRIES, LIMITED

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GD 23

ANOTHER

NEW

NASHTON

INSTRUMENT

Sensitive Valve Voltmeter

Voltage ranges — 10 mV to 300 volts in nine ranges · Accuracy better than 3% on all ranges High Input Impedance · Good frequency response between 40 c/s and 100 Kc/s · Exceptional stability against mains fluctuations and negligible zero drift · Top quality moving coil meter to B.S. 89 : 54 · Fully guaranteed for one year from date of purchase.

This new addition to the 'Nashton' range of miniaturised electronic test equipment is a compact Valve Voltmeter of wide range and good accuracy which will prove extremely useful in Laboratories where the measurement of A.C. voltages at high impedance is required. It forms an ideal companion to the D.C. Valve-Voltmeter Micro-ammeter and the R.C.C. Bridge which are already available.

For further information on the 'Nashton' range of miniaturised electronic test gear write to:

Nash and Thompson
LIMITED

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WHG/NT66

VALVE DATA BOOKS

English Electric Valve Co., Ltd., announce a new service for all valve users. These new Data Books give full information on all E.E.V. products in two handsomely bound volumes. Each book opens flat to ensure easy access to characteristic curves without complete release of pages, whilst a simple lever gives full opening for the ready insertion of new pages. Each subscriber will receive a regular service of new data sheets.

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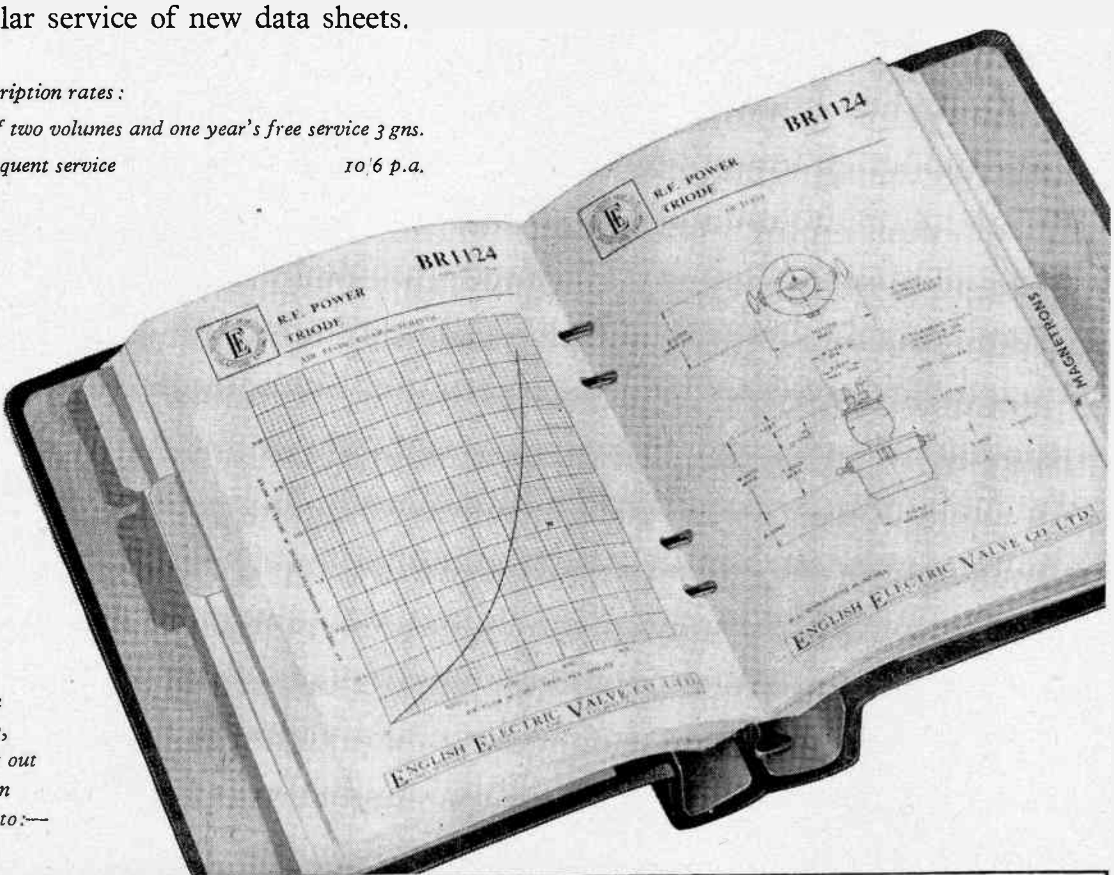

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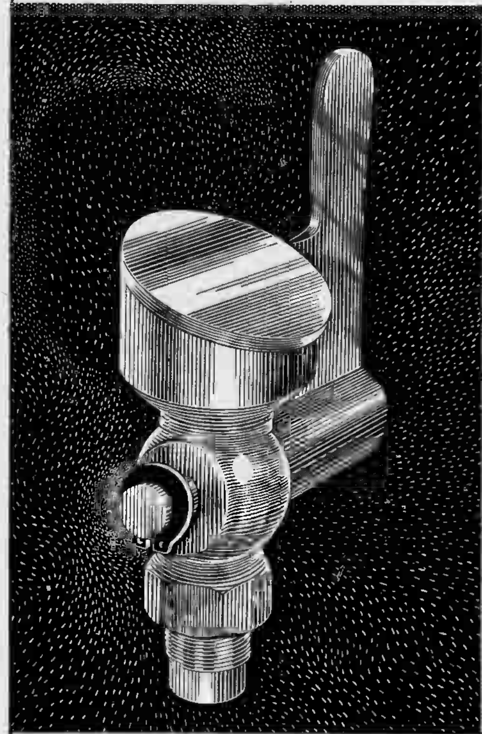
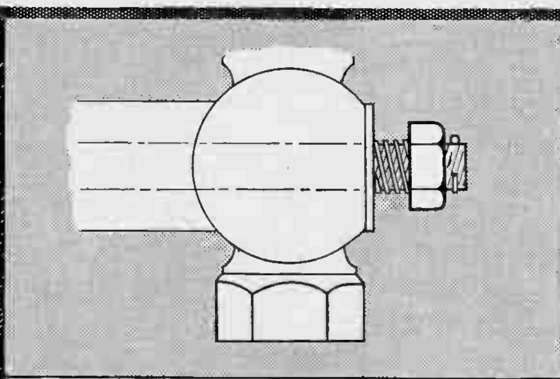
AP 92

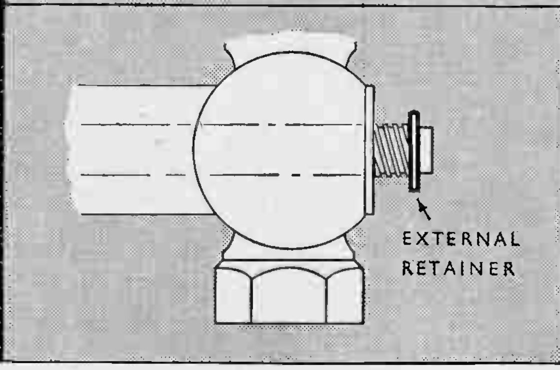
The logical advance in Retaining





OLD WAY

To provide a shoulder for the tensioning spring on this filler cup entailed an extra long, threaded shaft, a nut, a hole drilled to take a cotter pin and an altogether tedious assembly.



THE SALTER WAY

The spring is quickly positioned on a shorter, **PLAIN SHAFT** by a ***Grip Ring*** which is snapped into position for secure, frictional grip. No groove required.

save material–reduce assembly time–cut costs

When it's a question of assembling components in any engineering field, Salter Retainers are the answer. They replace nuts and bolts, screws, cotter pins, and eliminate expensive threading and machining operations. A large standard range is at your immediate disposal, and we should welcome the opportunity to assist in developing special retainers to solve your problems.

Send for the Salter Retainer catalogue — no designer is complete without it.

NEATER – MORE POSITIVE – PERMANENT RETAINING

SALTER "TRUARC" Regd. Trade Mark

Circlips *Fasteners* *Retainers* *Fixes*

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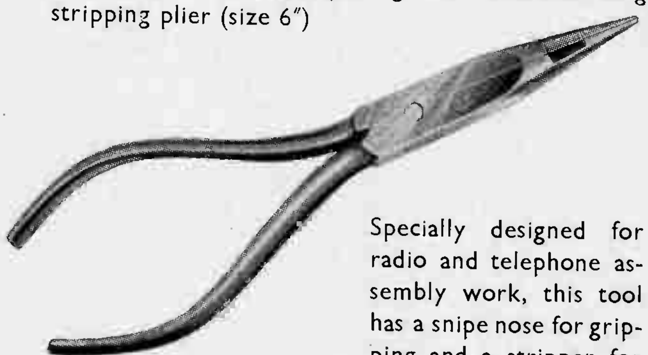

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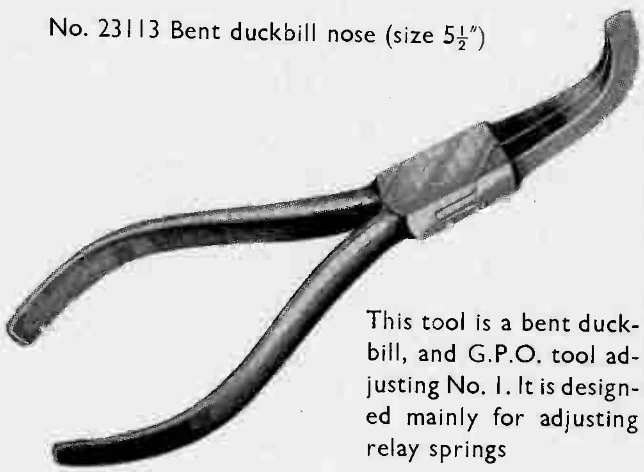

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# ELECTRONIC & RADIO ENGINEER

incorporating *WIRELESS ENGINEER*

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Permanent Magnets

Design Advisory Service

No.7

Stability

Advertisements in this series deal with general design considerations. If you require more specific information on the use of permanent magnets, please send your enquiry to the address below, mentioning the Design Advisory Service.

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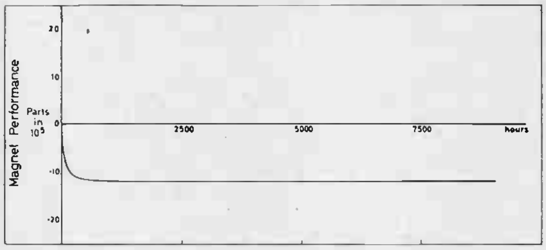

This graph indicates the extreme stability of a "Ticonal" "G" magnet working at approximately $(BH)_{max}$, after being stabilised by a 2% reduction from initial magnetic saturation.

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VOLUME 35 NUMBER 10 **ELECTRONIC & RADIO ENGINEER**

OCTOBER 1958 *incorporating WIRELESS ENGINEER*

Earls Court in Retrospect

THIS year's Radio Show is now over. One feature marked it out definitely from its predecessors. It was no longer mainly a television exhibition. This year, the stress was almost equally divided between television and sound reproduction. In the sound field, the stereophonic reproduction of disc recordings held pride of place, although quite a lot of high-quality single-channel apparatus was shown.

The sound demonstration rooms, too, were a welcome innovation, even if some demonstrators did, in true 'hi-fi' style, operate their apparatus at excessive volume. In doing so, they harm only themselves, for the public inevitably attributes the unpleasant effects of overloaded ears to the apparatus!

It is still too early to say what the public reaction to stereophony will be. Compared with single-channel apparatus it has the grave disadvantage of requiring one or more extra loudspeakers and it is not easy to dispose of these and their wiring tastefully in the average living-room. One or two makers did manage to arrange for self-contained equipment, but only by making the cabinet abnormally wide and this also raises accommodation problems.

Stereophony is, of course, claimed to provide much greater realism than single-channel apparatus. Its advantage lies in this. Here, however, we leave the hard facts of science and enter the realm of subjective impressions, which is the realm of the arts. We shall not, therefore, comment on the performance obtained. For one thing, we have not yet heard enough of it under proper conditions; for another, it is a sphere in which our opinion is no more valuable than anyone else's.

We noted with some amusement, however, that the advent of stereophony has made it necessary to find a name for apparatus which is not stereophonic. The name that most people have chosen is 'monaural'! This is singularly inappropriate, for all loudspeaker listening is binaural if the listener has two ears. We avoided the use of 'monaural' above by referring to single-channel apparatus. This is, perhaps, a little clumsy and it may not convey much to non-technical people.

We rather fear that 'monaural' has come to stay. It is the right-sounding sort of word, even if it is the wrong one. But we shall avoid it for the present!

Latching Counters

PART 1—DEVELOPMENT OF FOUR-PHASE CIRCUIT

By W. P. Anderson, B.Sc., A.M.I.E.E.,* and N. A. Godel, B.Sc., Grad. I.E.E.†

SUMMARY. *Maintenance difficulties encountered with conventional scaling circuits during the development, between the years* 1951 *and* 1956, *of a large digital data transmission system led to a reconsideration of the basic principles of operation of these circuits. A new type of scaling circuit was evolved which, although being inherently more complex than the familiar Eccles-Jordan type, compensates for the additional complexity by offering increased reliability and an independence of rise time, the circuit being capable of operating at any frequency between about* 500 *kc/s and d.c. No serious attempt was made to raise the upper limit, since the application did not require operation above* 200 *kc/s. The multi-phase output feature of the circuit was found to be of considerable advantage in the elimination of spurious pulses, which were a source of trouble in the formation of gates and were produced when mutually-opposing transitions occurred in the controlling waveforms.*

Hard-valve counting chains or scaling circuits, originally developed to count the randomly-occurring pulses met with in experimental investigations in the field of atomic physics, have since been extensively employed in digital computing and data-handling equipments. They may form adders, as in the serial computer, or analogue-digital converters as in Reeves' Pulse Code Modulation system, but in any high-speed digital-computing or data-handling system, excepting the most elementary, they must be provided to generate the signals required to direct the information being handled to the appropriate part of the system at the proper time, to operate devices which store or translate it and to insert such additional signals as might be required; for example, to synchronize the two ends of a data transmission link.

The essential features of a typical counting circuit, from which conventional counting chains are constructed, are shown in Fig. 1. The circuit has two stable states, the first with V_1 cut-off and V_2 conducting and the second with V_1 conducting and V_2 cut-off. The application to the input terminal of a negative-going voltage step having an amplitude of a few volts and a rise time not greater than a few microseconds causes the circuit to change state. A similar positive-going step produces no effect. When driven by a pulse train or square-wave of the proper amplitude and rise time the circuit thus behaves as a frequency divider, the square-wave outputs from the valve anodes having a frequency half that of the driving waveform.

A complete counter may consist of twenty or more of such circuits cascade-connected, each being termed a 'stage'. An output from each stage drives the succeeding one, the first in the counter chain being driven by the train of pulses to be counted. Alternatively, in other applications, such as data-handling systems, the first stage might be driven by a square-wave obtained by amplitude-limiting the sine-wave output of an oscillator, crystal-controlled where stability of frequency is important.

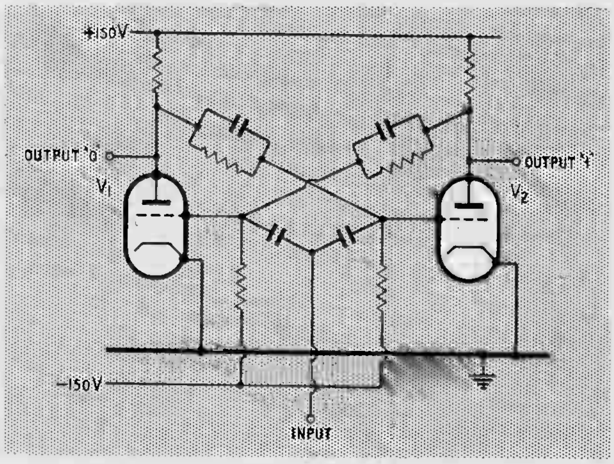
* *Admiralty Compass Observatory.*
† *Admiralty Signal and Radar Establishment.*

Limitations of Single-Pulse Counters

Experience of the behaviour of counting chains of the type described in the previous section was obtained during the development of a large digital data transmission system and the design was elaborated with the object of improving both performance and reliability. The circuit shown in Fig. 2 was adopted and in this, as in other digital units used in the equipment, anode-voltage limiting diodes D_1–D_5 were fitted, restricting the voltage excursions in both positive-going and negative-going directions. It was found, however, that the counting chains remained the most unsatisfactory feature of the equipment, for the following reasons:

(a) The reliability of the counter circuits was much

Fig. 1. *Simple single-pulse counter*



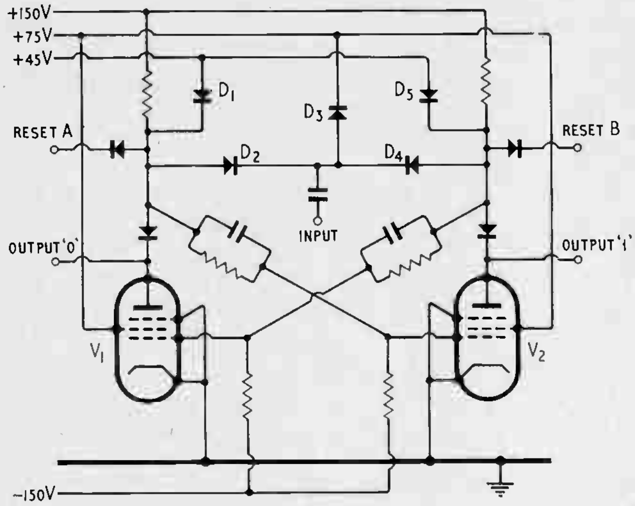


Fig. 2. *Negative-resetting single-pulse counter*

lower than that of other digital circuits used in the construction of gates.

(b) It was very difficult to trace a fault in a counting chain.

(c) The performance of the counting circuits when used in the production of gating waveforms was not satisfactory, as the finite rise and decay times of the square-wave outputs led to the generation of spurious pulses, which caused a great deal of trouble when the gating waveforms were used for the operation of registers, this being a common requirement.

(d) The counters could not be relied upon to drive any of the other units in the equipment efficiently without the use of buffer amplifiers.

(e) The provision of non-binary counts, which were essential, introduced difficulties. Although a number of simple schemes had been described at that time, it was found in practice that the only method which was reasonably reliable involved the use of a monostable trigger circuit, which reset a number of binary stages when the required count was reached. This, unfortunately, meant the provision of a special unit which was used only in small numbers and the acceptance of a spurious pulse which arose from the fact that the undesired counter transition had to take place before the reset pulse could be generated.

The low reliability of the counting chains was the feature which caused most concern, as it appeared at that time that the attainment of a reasonable standard of reliability, with the maintenance facilities to be expected on board ship, was the main difficulty which remained to be overcome in the development of the equipment. A very high proportion of the total faults occurred in the counting chains and these faults were, on the average, considerably more difficult to trace than faults in the other digital units.

On consideration, it appeared that the low reliability of the counter stages was due simply to the fact that they were more complex in construction and operation than the other digital units shown in Fig. 3. The counter stage requires for its proper operation the correct relation between the time-constants of the grid and cross-coupling circuits. If the cross-coupling capacitors are too small, the counter may fail by behaving as a multivibrator and possibly perform a number of oscillations each time it receives a pulse; if too large, it will not count at high frequencies. The input square-wave must have, in addition to the correct amplitude, a sufficient rate of rise and the grid bias must be adjusted fairly accurately; otherwise the counter may fail to count or fail to divide.

Using components of the closest tolerances available, it did not appear to be possible to construct a counter stage which would operate reliably in any position in the counting chain. It was not considered to be practicable to provide preset adjustments owing to limitations of space, quite apart from the undesirable complications which extensive use of such controls in a complex equipment would introduce into lining-up and subsequent maintenance procedures. Attention was therefore turned to the possibility of improving the reliability by more radical changes in design.

Some consideration was given to a possible four-valve counter stage which was, in effect, an elaboration of the existing design in which the grid and cross-coupling

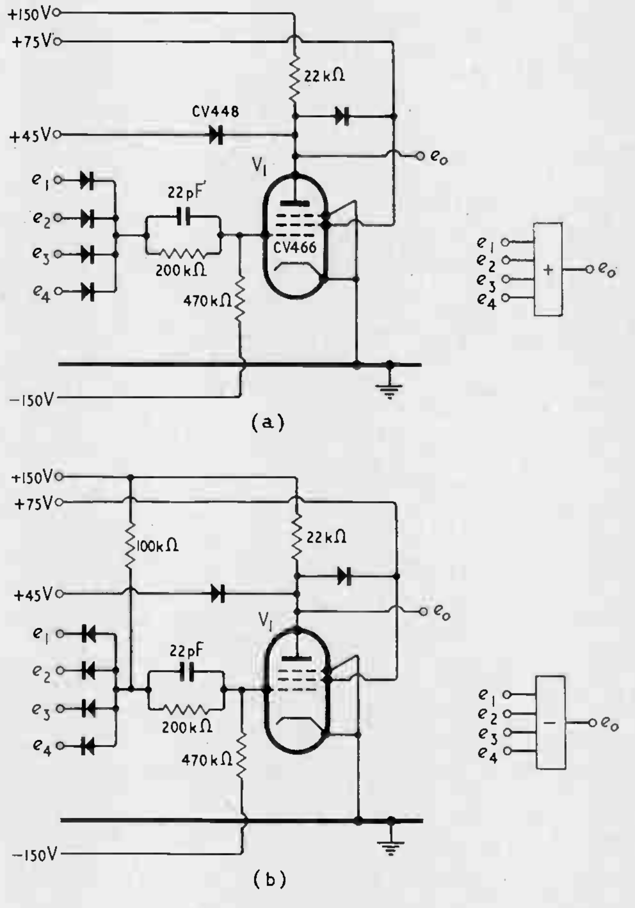


Fig. 3. *Gating amplifier circuits: (a) positive gating amplifier and symbolic form.* $e_0 = (1 - e_1), (1 - e_2), (1 - e_3), (1 - e_4)$ *where* e_0, e_1, e_2, e_3, e_4 *have the binary values* '0' $(+45V)$ or '1' $(+75V)$. *All four inputs need not be used. (b) Negative gating amplifier and symbolic form.* $e_0 = 1 - e_1, e_2, e_3, e_4$

time-constant circuits were separated by a valve. Before this was constructed, however, it was realized that, if four valves per stage were accepted, it was possible to design a counter which did not require any time-constant circuits, but consisted only of diode gates and d.c. amplifiers of the kind used in the remainder of the digital equipment.

The Double-Pulse Binary Counting Stage or 'Latching Counter'

In a counting stage not dependent on internal time-constants to perform the switching between pulses which ensures that successive input pulses produce opposite effects, switching must be determined by external means. A push-pull output such as exists at the two anodes of a conventional counter stage provides, in principle, such a means. A counter stage may be imagined in which there are two input terminals, to each of which is connected an anode output of a conventional counter stage. When the first input goes positive, the stage makes a transition, say, from condition '0' to condition '1'. The second input then goes positive and the first negative. This has no effect on the stage output but changes over internal conditions so that when the first input becomes positive again the stage changes back to condition '0'.

It so happened that the units required to make up a counting stage of this type were already available, being employed in small numbers as 'disconnecting registers' (Fig. 4). The signal it is desired to register is applied in push-pull to terminals b and c. As long as terminal a is in condition '1' (+ 75 V), the outputs from terminals d and e are controlled by the inputs, but when the input to terminal a changes to '0' (+ 45 V) they cease to be so controlled and remain in the condition existing at the time of the change.

Two of these units, connected as in Fig. 5, operate as a binary counter when supplied with a push-pull square-wave input, limited in amplitude to the range + 75 V to + 45 V. The cycle of operations is set out in the accompanying input–output table. If the two output terminals on one unit are regarded as the output terminals of the stage, the arrangement is exactly as envisaged in the first paragraph but, in fact, the four output terminals may equally well be regarded as the terminals of a 4-phase square-wave supply, the numbering [0], [1], [2], [3] indicating the phase sequence as shown in Fig. 5.

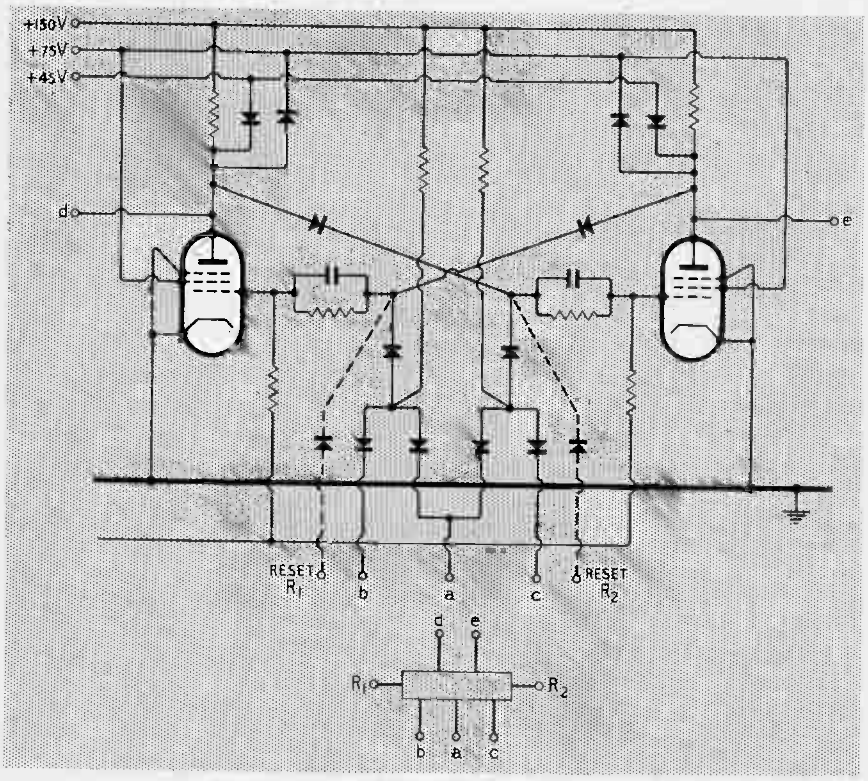
A counter stage was constructed and driven by one of the high-frequency counting stages in the experimental equipment. As was anticipated, it operated without difficulty and without adjustment, so that it was decided to introduce the new type of counter into the main counting chain in place of some of the existing stages. The new counters were named 'latching counters' as a result of a somewhat fanciful comparison with electro-mechanical relays designed for impulse operation, many of which embody a latching mechanism.

The highest frequency stages of the main counter were chosen for the initial experiment, partly because they were binary stages which had given most trouble and partly because they did not need to be reset. The latching counters constructed from two disconnecting registers possessed no means for resetting.

Before making the substitution, it had to be decided if buffer amplifiers were to be used with the latching counters; this decision was of considerable and immediate practical importance for, if buffer amplifiers were dispensed with, the removal of the old-type counter stage and its amplifiers would leave sufficient space for the installation of a latching counter stage, thus reducing very greatly the disturbance caused by the changeover, the equipment having been constructed on a plug-in unit basis. It was reasoned that, as the digital units used as registers operated satisfactorily without buffer amplifiers and, since there was little difference between their operation thus and as latching counters, it should be possible to dispense with buffer amplifiers and still obtain a very marked advantage from the introduction of the latching-counter stages.

The highest frequency counter stages were therefore replaced by latching-counter stages and the wiring from the output terminals of the original counter stages transferred to the [0] and [2] output terminals of the latching counters. These being exactly equivalent to the original push-pull outputs, no

Fig. 4. *Disconnecting register and symbolic form*



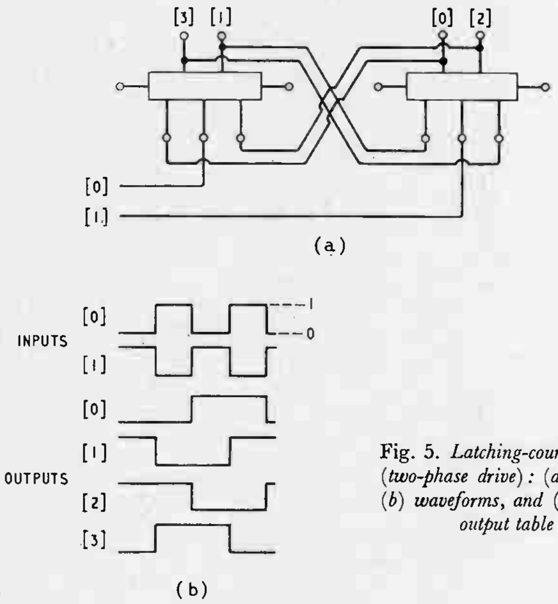


Fig. 5. *Latching-counter stage (two-phase drive): (a) circuit, (b) waveforms, and (c) input-output table*

(c)

Inputs		Outputs			
[0]	[1]	[0]	[1]	[2]	[3]
0	1	0	1	1	0
1	0	0	0	1	1
0	1	1	0	0	1
1	0	1	1	0	0
0	1	0	1	1	0
1	0	0	0	1	1
0	1	1	0	0	1

changes in the rest of the equipment were required. The expected improvement in reliability was obtained and, as was hoped, the early stages became as reliable as the rest of the ordinary digital units in the equipment.

It was accordingly decided to proceed with the replacement of the remaining stages of the main counter, starting with the binary stages as it was not at that time clear what would be the best type of non-binary latching counter. Since all the remaining binary stages required resetting as part of the synchronizing procedure, it was necessary either to modify the disconnecting registers so that they could be assembled into latching counters with reset facilities, or to alter the synchronizing circuits so as to eliminate the need for resetting. This second alternative could have been adopted for the main counter at the expense of some increase in circuit complexity and some increase in the synchronizing time. This might possibly have been accepted, but it appeared that considerable difficulties were likely to arise in the case of some of the other counter chains in the equipment, owing to the very short time available for the resetting operation and, as it was intended to replace these with latching counters in due course, it was decided that the best solution was to provide the latching counters with reset facilities.

The required modification consisted simply of the addition of two diodes to each disconnecting register unit, as shown dotted in Fig. 4, so that there are four possible reset inputs to a complete latching-counter stage. The resetting procedure with a latching-counter stage is more complicated than that with a normal binary counter, as the reset pulse applied must be consistent with the input condition. The four resetting terminals are normally in the '0' condition. To reset the counter stage, the register which has the '0' input from the previous stage has a '1' applied to one or the other of its reset terminals, depending on whether it is desired to reset it to the '0' or '1' condition. If it changes condition as the result of the application of the reset pulse, the other register changes condition automatically. The reset feature is discussed in more detail in Part 2.

It had at first been intended to make use of only the [0] and [2] output phases of each binary stage, as these provided waveforms identical with those provided previously by the old counter stages, making the change-over of the gating circuits very simple. Before the modifications were made, however, it was realized that by taking advantage of the 4-phase outputs obtainable from the latching-counter stages, one of the serious limitations of the single-pulse counter could be overcome, because a gate pulse of any required width could be produced without any possibility of spurious pulses being produced at the same time. How this is accomplished is illustrated in Figs. 6 and 7. The spurious pulse shown in Fig. 6 arises because two nominally simultaneous transitions are involved so that a small delay in one of them will leave a gap. In Fig. 7, which shows the same gate pulse produced by latching counters, no simultaneous transitions are involved. In the particular case illustrated, the pulse is produced by combining two of the outputs of a single counter stage, but the same principle applies to pulses less than a quarter of a cycle long, which will require the combination of the outputs of more than one counter stage. Although it is possible to eliminate spurious pips, where single-pulse counters are used, by deliberately introducing phase shifts with extra capacitors, this was considered undesirable in the system being developed in view of the need to keep the number of different types of plug-in unit down to a minimum and

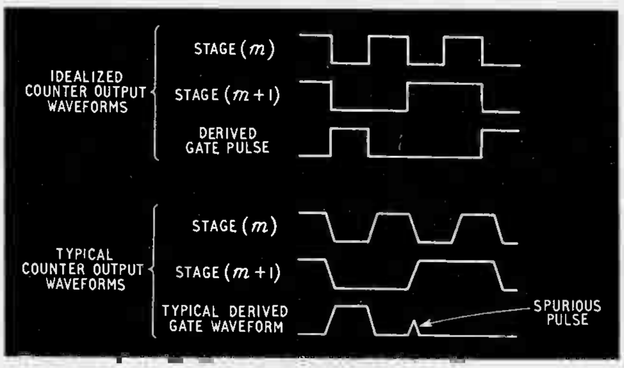


Fig. 6. *Production of spurious pulses. The 'typical' waveforms are for counter circuits employing anode-voltage-limiting diodes and in which overshoots are negligible*

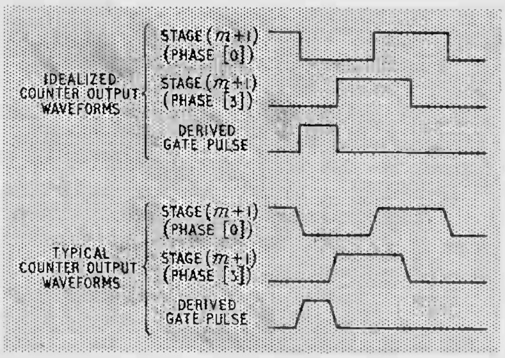


Fig. 7. *Elimination of spurious pulses*

the desire to avoid including components in the rack wiring.

In view of the unsatisfactory nature of the methods available for the suppression of the spurious pulses resulting from the use of counter stage output phases [0] and [2], it was decided to accept the additional work involved in the redesign of the gating circuits and convert all those fed from the binary stages of the main counter for 4-phase operation. No unforeseen difficulties arose as a result of this conversion and there was again a corresponding improvement in the reliability of the equipment.

The whole of the binary stages of the main counter had now been converted and the question of the conversion of the non-binary stages naturally arose. On consideration, it appeared that there were a number of possible methods of constructing non-binary latching counters and it was by no means clear which was the best. The problem involved in this conversion was postponed until more thought had been given to it and, in the meantime, the conversion of the coding counters and other short binary counting chains was proceeded with instead. This conversion produced no difficulties apart from one incident which focused attention on to a weakness of the design of latching counter then in use.

It so happened that there was only a single-ended drive available for one of the new counting chains, this being all that was necessary for the original single-pulse counter. The push-pull drive for the latching counter was therefore produced by adding a single-stage amplifier. It was found that the counter did not operate reliably and the trouble was traced to the delay in the amplifier which permitted the two inputs of the first latching-counter stage to be in the '1' condition simultaneously for a period long enough for incorrect operation to occur. The immediate difficulty was overcome by rearranging the circuit so that the two inputs to the counter were obtained from opposite anodes of a register. In this case, the feedback connection ensures that the transitions at the two anodes occur more nearly together. It was appreciated, however, that it would be safer and would also ease fault detection if there were a definite clearance between the end of the operating pulse applied to one input terminal of the counter stage and the beginning of the operating pulse applied to the other.

The possibility of producing this clearance by the use of capacitor coupling at the input to the counter and between successive stages was considered, but it was decided that it would be difficult to maintain such a system because, assuming that the same capacitance were used in all cases, the clearance would be so short that it would be very difficult to detect on a monitoring oscilloscope set to display the output from one of the lower frequency stages. The use of capacitors of larger capacitance for the lower frequency stages would overcome this difficulty but the resulting increase in the number of different types of units was considered unacceptable for the same reasons as before.

The solution finally arrived at is illustrated in Fig. 8. The required clearance is obtained by feeding each stage with all four outputs from the previous stage and providing extra diodes which combine two of the quadrature inputs to form a single pulse a quarter of a cycle wide, as in Fig. 7, and the other two into a similar pulse displaced by half a cycle. Input and output waveforms are shown together with a table in Fig. 9. One pulse is, in effect, applied to one half-section of a stage and the second pulse to the other half-section so that there is a clearance of a quarter of a cycle between the

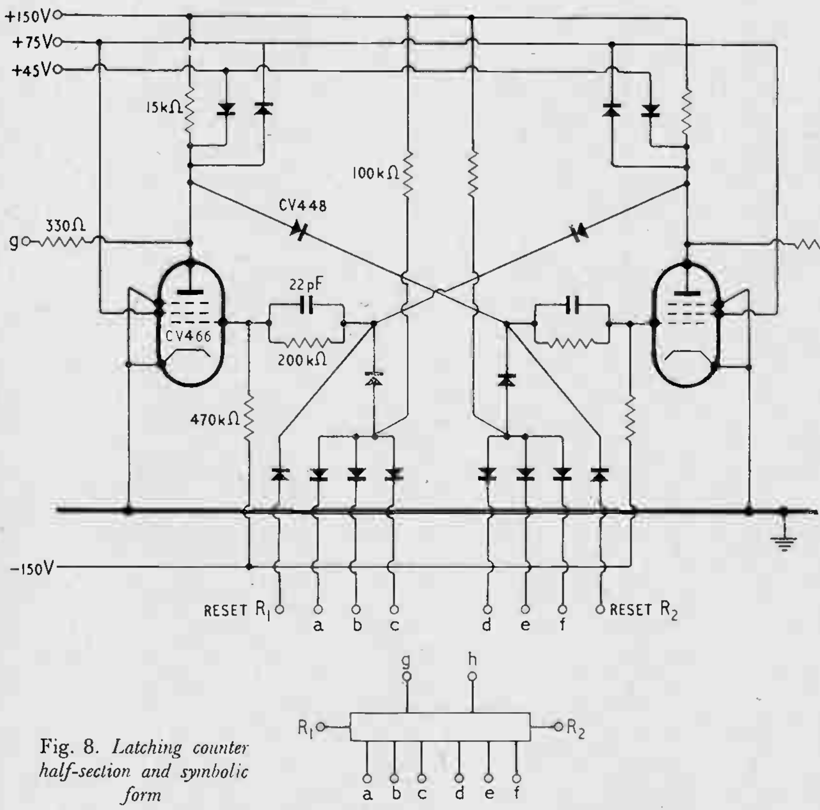
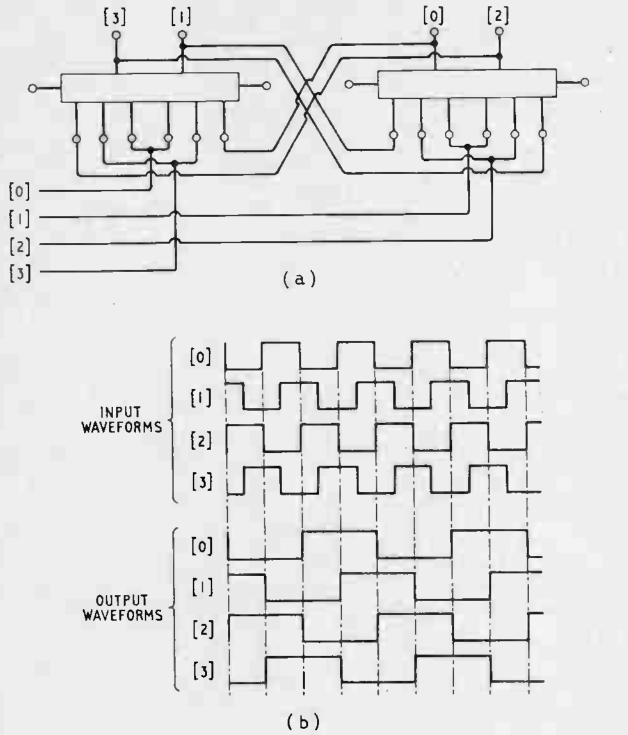


Fig. 8. *Latching counter half-section and symbolic form*



(c)

Inputs				Outputs			
[0]	[1]	[2]	[3]	[0]	[1]	[2]	[3]
0	1	1	0	0	1	1	0
0	0	1	1	0	1	1	0
1	0	0	1	0	0	1	1
1	1	0	0	0	0	1	1
0	1	1	0	1	0	0	1
0	0	1	1	1	0	0	1
1	0	0	1	1	1	0	0
1	1	0	0	1	1	0	0

Fig. 9. *Binary latching-counter stage (4-phase drive): (a) block schematic, (b) waveforms, and (c) input-output table*

pulses. Although the modified binary stages of the main counter had so far given little trouble it was decided that the principle of 4-phase drive would be introduced therein also, in order to provide a greater margin of safety, particularly as the equipment had not then reached a state of completion and it was not known what effects the final increased loading might have on the counter stage output waveforms. It was not possible to incorporate this modification into the equipment at the time in question for various constructional reasons, but it was intended that it should be incorporated in the final equipment in which the constructional difficulties did not arise.

(To be concluded)

The Fringe of the Field — *by Quantum*

"THINK OF A NUMBER . . . . ."

Alertly poised for the next instruction, the loyal reader has doubtless fixed on a Quantum Number, the choosy type a Preferred Number, the really calculating person a number expressed in the binary scale, and the one who wants to play the hard way something like the product of the first five primes. You can now relax. For this month I simply want to think of a Number, or rather of a particular type of Number—the 'dimensionless product', of which Reynolds' Number and the Mach Number are probably the best-known examples.

In the last article I mentioned something about scale factors, and the way in which observations made in one system can be applied to another system on a different scale of linear size if similarity is preserved by keeping the values of the appropriate dimensionless products the same. I did not really explain what a dimensionless product is, or what is meant by similarity; nor did I attempt to show why the transference from one system to another is possible. These points are usually overlooked in elementary discussions of dimensions, such as you will find in the early chapters of any physics textbook. I do not think they are made with outstanding clarity in the more advanced works on dimensions either, since these concentrate chiefly on justifying the processes of dimensional analysis and showing that it is really a respectable subject after all. And I am not sure that people accept that they are really important, or are at all interested; believe it or not, when I borrowed a copy of Campbell's "Elements" to refresh my memory the other week, I found that the pages of the chapters on dimensions were still uncut after some forty years of sojourning on various scientific shelves.

I am not saying much this time about dimensional analysis itself; it is a fascinating topic, but well covered in at least three excellent books. I shall probably have to come back to it later, though. But it will take me all my time to get through what there is to say about Reynolds' Number and its congeners.

It will be best to start by trying to remove some possible sources of confusion, since you will probably find quite enough of it without them anyhow. In the first place, the quite arbitrary choice of fundamental units will not come into the story. Such a choice has to be made, of course, and the usual mass (M), length (L) and time (T) system is assumed. In particular, the dimensions of electrical quantities are outside the syllabus; these quantities may be mentioned, but only with reference to *any* consistent unit system. Next, we shall not argue as to how many fundamental units there ought to be. N. R. Campbell would include volume, and probably shape (if a unit shape can be imagined); the real criterion here is that however many there are they must be independent, for the purpose of the kind of measurement proposed. For example, in purely thermal calculations, quantity of heat, or temperature, can be taken as fundamental; but you do get complications over this if there is conversion of heat to other forms of energy. Fishenden and Saunders' "Introduction to Heat Transfer" (Clarendon Press, 1950) is a useful source of information on the application of dimensions to heat problems, and in this field there are several more dimensionless products that you never normally hear of—the Prandtl Number, the Nusselt Number, and the Grashof Number; with the indispensable Reynolds' Number there all the time. Lastly, we shall not get too involved with what might be called the metaphysics (or is it merely the semantics?) of dimensions. If you come along with questions like "If mass is a form of energy, it has the dimensions of energy—so what about $E = mc^2$?" I am afraid that I can only echo "So what?", and recommend you to C. M. Focken's "Dimensional Methods and their Applications" (Arnold, 1953), a scholarly and critical work that I hope to use fully in a later article. (I am sure that Focken would say that it is slipshod to speak of the dimensions of fundamental *units* rather than of fundamental *quantities*, but he sets a standard of precision that only people like Campbell and Dingle and Bridgman have ever lived up to consistently.)

Dimensionless Products

First, consider a fluid possessing density ρ, viscosity η, and bulk modulus of elasticity κ, the symbols standing for the measures of these properties in a consistent MLT system. The force per unit mass f, used throughout this discussion, has dimensions $M^0L^1T^{-2}$, the same as acceleration. The dimensions of η, which is defined as tangential stress per unit velocity gradient, are $M^1L^{-1}T^{-1}$; those of density ρ are $M^1L^{-3}T^0$; the quantity η/ρ, given the symbol ν and called the kinematic viscosity, has dimensions $M^0L^2T^{-1}$; and the bulk modulus κ dimensions $M^1L^{-1}T^{-2}$. The velocity of sound, U, in the fluid is $\sqrt{\kappa/\rho}$.

It remains to define the other symbols used; this is rather harder, since we are concerned with their measures in a variety of possible contexts. Here V stands for 'a velocity', which is *proportional* to the velocity of, or relative to, some part of the fluid; and l stands for 'a length', or 'a characteristic length', which is *proportional* to some linear measurement of the system which

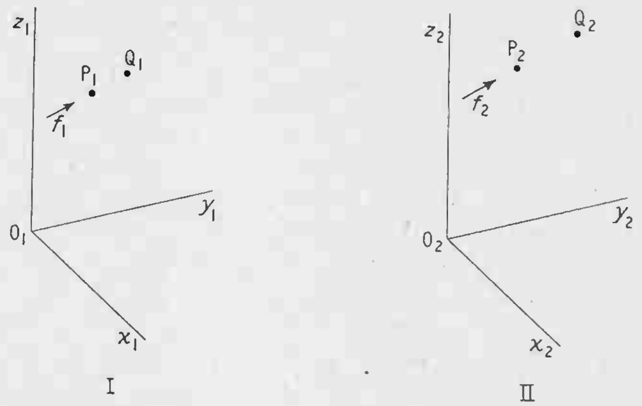


Fig. 1. *Motions of corresponding particles in two dynamically-similar systems. The scale factors for length, force-per-unit mass, and velocity are α, β and γ respectively. Thus, $O_2P_2/O_1P_1 = O_2Q_2/O_1Q_1 = P_2Q_2/P_1Q_1 = \alpha$, where P_1, P_2 and Q_1, Q_2 are similar successive positions of the particles; $f_2/f_1 = \beta$; and V_2/V_1 = increment of V_2/increment of $V_1 = \gamma$*

may be anything from the beam of a ship or the diameter of a tube to the mean free path of a molecule. The constant of proportionality can of course be 1. You can see the difficulty about defining V and l precisely; a fluid can have only one η or ρ, but V and l differ from problem to problem.

The next thing is to pause for a moment to consider why η, ρ and κ are going to be involved with forces and velocities and lengths at all. The density ρ is the Second-Law-of-Motion inertia coefficient (the mass, if you can forget its mc^2 context) for unit volume; ρV^2 is proportional to the kinetic energy of unit volume. The viscosity η is a measure of the lateral dissipation of energy by internal friction. The bulk modulus κ is proportional to the energy stored in unit volume of fluid when it is under a given stress. Each of them is, in fact, a sort of delegate appointed to represent an energy interest at a dimensional conference; ρ speaks for kinetic energy, κ for potential energy, and η for dissipation. What all this leads up to is the idea that additional, or perhaps substitute, representatives will be needed for energy and dissipation when a fluid is subjected to electromagnetic forces; different properties of the fluid, its magnetic permeability and electrical conductivity, may be elected—but they are there to do the same kind of job.

By substituting the dimensions of the quantities in each expression it is seen that each of the following is of dimensions $M^0L^0T^0$:—

The Froude Number, F: $F = V^2/lf$

The Reynolds' Number, R: $R = Vl\rho/\eta$, or $R = Vl/\nu$.

The Mach Number, M: $M = V/U$.

Before going more fully into the real meaning and use of these expressions, it might be well to try and sort out their mathematical status. In N. R. Campbell's "Physics —The Elements" the point is made that the whole of the dimensional-analysis procedure is analogous to the setting up of a differential equation in the orthodox way, and involves the same assumptions and also the same understanding of the physical processes that are occurring. A dimensional equation thus obtained has an undetermined proportionality factor. A differential equation has a latent 'constant of integration' which is only determinable when the boundary conditions are given. I must not cite Campbell as authority for the next step in the argument, though I feel sure that it is implied in what he says. If you are to relate an undetermined *factor* to an undetermined *additive constant*, the only way of doing it is to take logarithms. Dimensional equations must then always be expressible in terms of quantities which possess logarithms; that is, dimensionless quantities like F, R, and M. What determines the size of the unknown factor is the base to which the logarithms are taken.

Just as a differential equation is a generally applicable statement which does not depend for its validity on the boundary conditions of a particular problem, so a dimensional equation expressed in terms of dimensionless products is true whatever base we like to choose for taking logarithms; that is, whatever the scale of measurement may be. Of course, nobody does go taking logarithms, and we always forgo the luxury of being able to say 'equals' in a dimensional argument, preferring to say 'is proportional to'; this is analogous to working all the time with differential equations which are rarely integrated. Have you ever integrated Maxwell's equations, or sorted out the eigenvalues of a wave-function? Very well, then—don't look down on a dimensional equation as a rough sort of job. There is a sort of mathematical parallel in the use of expressions like $Z = R + jX$, or the general employment of j. Behind this simple-looking ruse lurk the differential equations that form so decorative a pattern in the pages of, say, Jeans. This is so obvious that it would not be worth remarking on, except to emphasize that you have to know enough about the physics of the problem to be able to write down the differential equations if you wanted to—otherwise the j-operator won't do you much good. In this case, it is true, the form of the equations happens to be well known, and we can therefore use an "equals" sign throughout.

Similarity and Dimensionless Products

Similarity of plane figures in geometry means that corresponding angles are equal, and corresponding sides proportional. The idea of physical similarity is an extension of this, involving proportionality of physical properties as well. Thus, two spheres with radii in the ratio $x : 1$, densities in the ratio $y : 1$, and masses in the ratio $z : 1$ are physically similar; and there turns out to be a relation between x, y and z which is $x^3y/z = 1$.

Campbell defines *physically similar* systems as those in which similar propositions are true, not only for lengths characteristic of the systems, but also for the magnitudes of all terms characteristic of them. If the propositions are those of Newtonian mechanics, the systems are called *dynamically similar*. The details of this situation are worked out fully in Chapter IV of W. J. Duncan's "Dynamical Similarity and Dimensional Analysis" (Arnold, 1950), which I quote below, with some simplification and change of symbols.

Consider two spatial frames of reference, I and II (Fig. 1), each with particles subject to Newton's laws of motion. The scale factor for length, l, is α, so that

$$O_2P_2 = \alpha O_1P_1 \quad \ldots \quad (1)$$

The path traced out by a particle in space II is geometrically similar to that of space I, so that for successive positions $O_2Q_2 = \alpha O_1Q_1$ . . . etc. The scale factor for force per unit mass, f, is β, so

$$f_2 = \beta f_1 \quad \ldots \quad (2)$$

and that for velocity, V, is γ, whence

$$V_2 = \gamma V_1 \quad \ldots \quad (3)$$

The ratio *time for distance* P_2Q_2/*time for distance* P_1Q_1 is α/γ; and that for the velocity increments in space II and space I is the time ratio multiplied by the acceleration ratio β, which is $\alpha\beta/\gamma$. Now, acceleration must be governed by the condition that the velocity ratio is unaltered by it, if the similarity of (3) is to be preserved; hence these velocity increments are in the same ratio as the original velocities, so $\alpha\beta/\gamma = \gamma$, and $\gamma^2/\alpha\beta = 1$. From this relation between the scale factors, it is easily seen that $V_1^2/l_1f_1 = V_2^2/l_2f_2$; that is, the dimensionless product V^2/lf always has the same value in the two systems. This is the Froude Number, F. Thus *the condition for dynamical similarity of two systems is that the value of the Froude Number shall be the same for both.*

The system so far discussed has not necessarily to be a fluid; we shall come to fluids in a moment, when we consider how f arises. But first it is as well to see what, if anything, has been deduced from this argument. Since the acceleration is proportional to V^2/l, the constancy of F simply means that the ratio *acceleration/force per unit mass* is the same in both systems, which we assumed all the time. However, what we have done is to write down a dimensionless product, or an equation $V^2/lf = F$ which is common to both, instead of having a couple of equations of motion, one for each. The next step is to apply this to a fluid which has one or more of the physical properties ρ, η, and κ.

Consider first a fluid which possesses density ρ but no other physical property, a sort of macroscopic ideal gas. An externally-applied force P will accelerate a portion of the fluid in the direction of P, and will do work upon it, giving it kinetic energy. The force per unit mass, f, is proportional to $P/\rho l^3$, where l is an appropriate characteristic length. The value of the Froude Number F then becomes $V^2\rho l^2/P$, which when written as $V^2\rho l^3/Pl$ is recognizable as representing *the ratio of the kinetic energy gained by the fluid to the work done on it by the external force.*

It does not matter really whether we put things in the form of a ratio between quantities of energy, or of a ratio between forces; and for the rest of this section we will stick to the force-ratio.

Now for the Reynolds' Number. The systems this time are fluids which are viscous (so that energy is dissipated) and incompressible (so that no potential energy is stored). Here the symbol l stands for each and every length, the 'characteristic length', whether measured in the direction of the flow-velocity V or at right angles to it. This is perfectly fair, since all lengths are in the same ratio, $1 : \alpha$, in the two systems. The velocity-gradient perpendicular to V is proportional to V/l, and the tangential stress on a moving lamina of fluid is proportional to $\eta V/l$. The force, which is *stress* $\times$ *area*, is proportional to $(\eta V/l) \times l^2$, that is, to ηVl. Now, for physically similar systems, masses are proportional to ρl^3 and accelerations proportional to V/l, so the Second-

Law or inertia force, *mass* $\times$ *acceleration*, is proportional to $\rho l^3 V/l$, that is, to $\rho l^2 V^2$.

The ratio of the inertia force to the viscous force on an element of fluid is thus proportional to $\rho l^2 V^2/\eta V l$, that is, to $\rho V l/\eta$, which is Reynolds' Number, R.

We agreed that constancy of the Froude Number V^2/lf was the criterion for dynamical similarity. In this case f is the viscous drag per unit mass, which is proportional to $\eta V l/\rho l^3$ and thus to $\eta V/\rho l^2$. Substituting this for f in the expression $F = V^2/lf$, and forgetting the constant of proportionality,

$$F = \frac{V^2}{l} \div \frac{\eta V}{\rho l^2} = \frac{\rho V l}{\eta} = R.$$

So, *if Reynolds' Number is constant for two viscous-fluid systems they are dynamically similar.* In other words, Reynolds' Number is really the appropriate Froude Number for a viscous incompressible fluid.

For a compressible but non-viscous fluid, in which there is energy-storage but no dissipation, a similar argument shows that the Mach Number (or really its square) is the appropriate Froude Number. For, under any distortion, the elastic stress is proportional to the bulk modulus κ, the elastic force to κl^2, and the elastic force per unit mass to $\kappa l^2/\rho l^3$, or to $\kappa/\rho l$. Substituting this value for f in the expression V^2/lf, we get $(V^2/l) \times (\rho l/\kappa)$, which is $\rho V^2/\kappa$. This represents the ratio *inertial force/elastic force*, and two fluids which have the same value of $\rho V^2/\kappa$ are dynamically similar. Now, Newton's formula for the velocity of sound, U, in any medium is $U = \sqrt{\kappa/\rho}$; so $\rho V^2/\kappa = (V/U)^2 = M^2$.

The condition for dynamical similarity of two fluids of this kind is thus that the value of the Mach Number M is the same for both.

The general case is harder to visualize, because a fluid cannot be both viscous and non-viscous, both compressible and incompressible. But, in practice, over wide ranges of the values of the Numbers, a fluid just never tries very effectively to do two things at once. Full dynamical similarity is unattainable, but almost constant-F, constant-R, and constant-M conditions are separately possible, and there is a sharp boundary between the ranges for each.

The Values of the Numbers

The size of any one of the Numbers, for a given system under given conditions, is independent of the units of measurement, provided that they are consistent. If R is below a certain value, viscous resistance is important; if F departs very much from its value for low V, then Newtonian mechanics cannot be applied; while if M is greater than unity, ordinary compression waves cannot be propagated. Usually we think of V as the variable which determines the change from one set of conditions to another, for the simple reason that we deal mostly with apparatus of given size. But the same sort of change can be obtained by variation of the size of the characteristic length; and indeed, any one of the Numbers can, since it is dimensionless, be regarded as a ratio between two lengths—or for that matter, two times, or any two quantities of the same dimensions.

What is really being done in a dimensional argument is to use Newtonian mechanics and the law of conservation of energy in an unusual way; and if the right characteristic length is chosen for a particular system—it may be anything from the radius of an electron to that of the observable universe—the argument should be just as helpful as it is in problems on pipes and orifices and notches and weirs.

A Circuit Counterpart

Can you possibly have been using a dimensionless product daily for years without realizing it? I said that I would keep off the dimensions of electrical quantities, for this is a topic which leads very quickly to wrangles over systems of units. But I don't need to put in any, for the quantity Q is dimensionless and so independent of the units chosen. Taking your pick of absolute electrostatic, absolute electromagnetic, MLTμ_0, Giorgi, or Kalantaroff, you can verify that the expression

$$Q = \frac{1}{R}\sqrt{\frac{L}{C}}$$

is of zero dimensions. The constancy of Q is, in fact, the condition for *electrical similarity* between two circuits.

The reason for straying so far from the Fringe into the Field is that Q itself, from the very multiplicity of its definitions, illustrates the versatility of the dimensionless product so well. It can be expressed as a ratio between two frequencies; as a ratio between two capacitances; as a ratio between two powers; and in the most useful general form is actually *defined* as the ratio

$$\frac{\text{energy stored in the circuit per half-cycle}}{\text{energy dissipated in the circuit per half-cycle}}$$

multiplied by the factor 2π.

The numerical size of Q determines the *kind* of behaviour that a circuit exhibits—whether free oscillations can occur or not. It is, in fact, an electrical Reynolds' Number. Or, if you like, R is simply the hydrodynamical version of Q. This thought should reconcile you to what has been said in the present article, and perhaps even condition you for what may appear in a later one.

Conclusion

This veiled threat about the future should perhaps be made explicit. There are three papers dealing with various applications of dimensions that I'm doing my homework on at the moment. These are: (1) G. J. Lehmann and A. R. Vallarino, *Proc. Inst. Radio Engrs*, Vol. 33, 10 (1945), (2) W. M. Elsasser, *Phys. Rev.*, Vol. 95, 1 (1954), and (3) R. J. Bickerton and H. London, *Proc. Phys. Soc.*, Vol. 72, 463 (1958). The first, dealing with ultra-high-frequency vacuum tubes, is expounded fully in Focken; the second, on cosmic phenomena, is an exercise on the magnetic Reynolds' Number, and so important that it seemed worth while to re-learn all that I had forgotten about dimensions in order to read it; the third, on the stabilized pinch discharge, compares the behaviour of Zeta with that of similarly designed machines. If you have previously thought of dimensions merely as a means of eliciting Stokes' Formula, of gratuitously calculating magnetic moments in electrostatic units, or of arguing for (or against) the distinction between B and H, which is about as far as the textbooks go, then you may find these papers as interesting as I have done. This will be in December; next month I shall be back on to something more like orthodox physics.

Miniature Delay Lines

FOR MILLIMICROSECOND PULSES

By Reinhold Gerharz*

SUMMARY. *Wire-wound delay lines are used as frequency-determining elements for recycling v.h.f. pulse generators. Characteristic features of the delays are the enclosure of a thin wire by metallic foils and their arrangement as a coil to save weight and space. Measurements on the devices led to the necessity of making the physical properties of the lines similar to those of coaxial cables, rather than using lumped inductive and capacitive elements, in order to keep the line losses tolerable.*

One of the important disadvantages of delay lines in millimicrosecond pulse circuitry is the bulkiness of the commonly-utilized coaxial-cable lines. For a time delay $t = 100 \times 10^{-9}$ sec, the required length s in centimetres of a coaxial cable is of the order of $s = c_{cable} \times t = 2 \times 10^{10} \times 10^{-7} = 20$ metres, the weight of which can exceed several pounds. The volume of such a cable line also becomes intolerable.

In experiments with high-frequency pulse generators and in instrumentational applications as memory components, portable standard-frequency devices, and in clocks, these disadvantages are particularly evident, and it becomes necessary to reduce the weight and the bulk volume of the delay line.

In millimicrosecond pulse circuitry, lumped delay lines increase the losses and signal dispersion considerably and the ultimate conception of a coaxial line therefore should not be abandoned. Thus, the total delay value still remains based upon the propagation time of electromagnetic signals travelling along the straight surface of a metallic conductor. Sommerfeld[1] (1899) has shown that the group velocity of such a signal does not deviate much from the velocity of light. This velocity also depends essentially on the dielectric constant of the medium surrounding the conductor and on material which might serve as spacers in the interior of a coaxial system. The attenuation of the signal is in many delay lines of secondary importance, as long as the signal amplitude is large enough effectively to control a suitable amplifier which is generally connected to the end of the delay line.

Applied to high-frequency pulse generators (Gerharz[2], 1956) this would mean that after travelling over the required length of the delay line, the incoming pulse should still be of sufficient amplitude to trigger a new signal upon arrival at the valve control section. In employing the delay line for such feedback purposes, the pulse repetition frequency of the device will only be determined by the signal propagation times along the line and through its amplifying components.

Constructional Details

Since the aim of the new feedback or delay line is the reduction of weight and bulk, the only dimension that can tolerate essential changes appears to be the radius of the line. In several laboratory tests, this has been successfully accomplished by the following simple methods.

A thin insulated copper wire was carefully wound on a sheet of aluminium foil, which has been previously wrapped around a symmetrical body (a glass tube) of about 3 cm diameter, adjacent turns of foil overlapping. After finishing one layer, another sheet of foil was put on it to serve simultaneously as the base for a second layer and as cover for the first layer. After winding on the required length of wire, all aluminium-foil layers were electrically interconnected and earthed. A cross-section through such a line reveals that the wire along each turn of the coil is well-shielded by the surrounding and covering foil. The electric field distribution of the travelling signal on the line (i.e., between conductor and foil) resembles very closely that of microstrip-lines, which have been investigated theoretically by Oberhettinger[3] (1943) and various other authors[4] (1955).

As Fig. 1 demonstrates, this construction represents a sort of transition between a coaxial cable and a

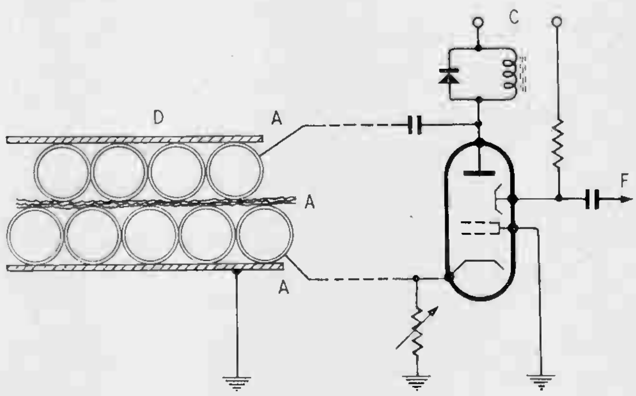


Fig. 1. *Complete diagram of a high-frequency pulse generator with wire-wound delay line; A, metallic shields at earth potential; C, inductive voltage-dropping element; D, cross-section of the magnified wire pack with aluminium foil between layers; F, output connector for a frequency meter. This cut is part of a rotational structure around a distant axis of symmetry*

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Lecher-wire system with little interspace between the conductors. Such a delay line requires a relatively small volume and appears compact and suitable for the originally desired properties. The total cylindrical volume demand of such a structure is hardly more than 80 cm³ and its weight can be kept below 50 grams.

In operation, the pulse repetition frequency f_r of the system is determined by the reciprocal of the total time delay t_d:

$$f_r = \frac{1}{t_d} = \frac{1}{t_{valve} + t_{delay\ line}} \text{ c/s}$$

For a type EFP60 secondary-emission amplifier, t_v amounts to $3 \cdot 41 \times 10^{-9}$ sec, which has been obtained by measurements and computation. This time includes the electron time-of-flight and the delay, caused by the signal propagation along the leads and electrodes of the valve.

From these values the propagation velocity of the delay line c_d will be found according to

$$c_d = \frac{s_d}{\frac{1}{f_r} - t_{valve}}$$ cm/sec, where s_d is the physical length of the embedded centre conductor.

Performance

In a series of tests, the characteristics of several delay units have been investigated. Some of these have the values shown in Table 1.

Table 1

Delay Number	Wire Diameter (mm)	Length (metres)	Insulation	Pulse Frequency (Mc/s)	Propagation Constant ($\gamma = c_d/c_0$)
1	0·1	9·30	lacquer	19·2	0·641
2	0·1	14·30	enamel	15·7	0·795
3	0·05*	10·00	lacquer	18·0	0·639
4	0·2	10·00	'Neoprene'	21·0	0·755
5	0·3	5·00	rubber	39·4	0·760
6	0·5	34·00	'Neoprene'	5·53	0·772
7	0·9	8·55	air and spacers	26·5	0·843

* Thin 3-strand h.f. litz wire.

In each case, the same valve and circuit was used. The inductive voltage-dropping element in the anode circuit of the valve consisted of a 4-μH choke and a crystal diode. The emitted pulses at the anode had a duration t_p of about 9×10^{-9} sec. This would correspond to a wave-packet of about $c_{cable} \times t_p = 2 \cdot 2 \times 10^{10} \times 9 \times 10^{-9} = 200 \cdot 0$ cm length while travelling along the delay line. The fundamental frequency of each pulse is about $1/(2 \times 9 \times 10^{-9}) = 55 \cdot 5 \times 10^6$ c/s.

Signal attenuation and losses in the insulation material of the delay are quite large at this frequency. In a survey test on a delay unit with a 'Neoprene'-insulated centre conductor (No. 6), the pulse dispersion was found to amount to 30% and the attenuation was about 2·5 dB per 10 m total length.

Both attenuation and dispersion also depend on the amount of shielding. One of the experimental 10-metre delay lines consisted of a single layer of turns on a metallic base. This layer could be covered by a tightly fitting but sliding metallic cylinder. An increasing

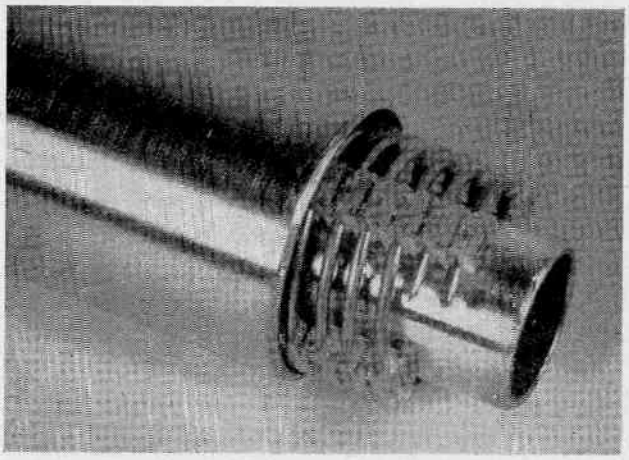

Fig. 2. *Photograph of the end of a delay line of the type 7 (in Table 1). This line was made from a balun transformer coil, one conductor of which is earthed; the other wire is the centre conductor of the approximated coaxial system, consisting of a pair of aluminium shielding tubes and the earthed wire of the balun coil. The three components will telescope into each other*

amount of shielding caused a decrease of the pulse repetition frequency of about 2%. With the shield covering completely the delay line, the pulses were shorter than without the covering shield. This can be due to the reduced attenuation of the line. Upon observation with a fast oscilloscope (Tektronix 541, the signals were directly fed into the deflection plates at the cathode end of the delay line) the pulses appeared to be almost free from overshoot.

Nearly perfect pulse shapes have been achieved with a double wire line, wound bifilarly on a metallic base which, like the previous examples, was covered with the sliding shield. The ends of one of the two wires were connected to common earth and to the shield. In this example, the inner conductor was embedded in a tight and circumferencially shielding and conducting cover at earth potential, so that the arrangement closely resembled a coaxial system.

The pulse repetition frequency obtained with all the delay lines tested was found to be very sensitive to temperature and valve voltage fluctuations. Experiments to overcome this dependence are in process. One of the methods of eliminating temperature effects is the insertion of the delay line into a temperature-stabilized crystal oven. Electrolytic deposition of the outer conductor increases the mechanical rigidity and a more careful selection of the insulation material for the inner conductor should provide a successful approach to the development of this type of pulse generator into a lightweight secondary frequency standard for airborne applications. The estimated stability of such a device with temperature and voltage stabilization should approach 1 part in 10^7 for a designed basic pulse-repetition frequency of $2 \cdot 5 \times 10^7$ c/s.

It is of interest to mention that in the course of the experiments, the delay times of single wires which were suspended in air and which formed part of a closed loop for recirculating pulses have also been tested. These investigations were carried out with wire lengths up to 40 m under various conditions (like straight or looped arrangements, insulated or bare wires). The measured pulse-width at the anode circuit was about 13 × 10^{-9} sec. The attachment of reflecting cones, facing each other at both ends of the out-stretched wire resulted into a 25% improvement of the pulse attenuation measured at the cathode end of the delay wire.

By employing beat-frequency methods, the change of the pulse repetition frequency of the generator in consequence of electric field distortions could be accurately determined for any approaching object less than 2 m away from the repetition loop. The same method permitted a sensitive detection of building vibrations with a suitably supported single-wire loop.

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Temperature Compensating Networks

DESIGN OF THERMISTOR BIAS NETWORKS FOR TRANSISTOR AMPLIFIERS

By Haim D. Polishuk, M.Sc.*

SUMMARY. *A generalized analytical design procedure is proposed for the realization of two typical temperature-compensating bias networks, employing thermistors, for class-B push-pull transistor amplifiers. A set of simple relations is derived for evaluating the network component values, and restrictions are indicated on the choice of appropriate thermistors.*

Practically all transistor parameters are more or less considerably sensitive to temperature changes, and thereby cause marked variations in the performance of an amplifier. This fact constitutes perhaps the most unfortunate phenomenon in transistor operation. When the behaviour of the junction-transistor amplifier in the large-signal domain and the overall problem of operating-point stability as a function of temperature are considered, a limiting high-temperature barrier is found to exist where the cumulative action of the interdependent parameters comes into play, rendering the transistor unstable ; the junction ceases to behave as a junction and a destructive thermal runaway condition sets in.

The variation of collector current with temperature is essentially a result of two basic mechanisms, one of which appears throughout the temperature range and another whose magnitude becomes appreciable only at the higher temperatures. In Fig. 1 is shown the transistor transfer characteristics, exhibiting the variation of collector current with base-to-emitter voltage as the temperature increases. The first effect, which at the lower temperatures exists nearly alone, accounts for the apparent crowding of the transfer curves towards the left which, for any particular operating point, may be regarded as an equivalent shift of the bias scale to the right. This shift is an inherent characteristic, being predominantly a function of the semiconductor energy-gap and is brought about by the variation of the d.c. input conductance of the p-n emitter junction with temperature. Both theory and experiment indicate that for practically all germanium transistors the average rate of this shift is approximately −2·5 mV/°C. It therefore appears that, for stability, one definite way of maintaining the collector current constant (in the lower temperature range) would be to force the base-to-emitter voltage to follow this −2·5 mV/°C variation.

The second temperature effect, which at higher temperatures emerges at a rapidly increasing rate on top of the first continuous effect, is due to thermally-generated carriers in the base region and contains a surface-leakage current component, ohmic in character, that varies with the applied reverse voltage. It is a function of the semiconductor material, geometry and energy-gap, and is approximately equal in magnitude to the open-emitter collector current. Being an uncontrollable part of the collector current, it saturates with respect to the collector voltage when the latter is greater than a few tenths of a volt. This so-called saturation current causes the transistor transfer curves to shift upwards by an amount equal to its value at the corresponding temperature and is known to vary at an approximate average rate of 10% per degree Centrigrade Except at very small currents, the lower temperature transfer curves are affected only to a minor extent. However, this added current component may, for certain amplifier configurations, become very pronounced because of the current gain involved, and particularly so where the transistor base circuit contains appreciable resistance.

The maintenance of a low collector junction temperature is of prime importance in the design of a reliable transistor power stage. The ability to remove heat by

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conduction constitutes a major factor in determining the maximum power-dissipation capability of the transistor. It is measured by the thermal rise per unit dissipated power. Other factors are: saturation current, circuit stability factor, maximum ambient temperature, and collector voltage. A low junction temperature with signal-power output may be achieved through properly applied heat sinks and dissipators; however, there will still exist the temperature-controlled variations in collector current which at high enough ambient temperatures may tend to produce a positive thermal feedback loop with cumulative regeneration and eventual runaway.

Employing transistors in a class-B push-pull power output stage of a common-emitter configuration offers the important advantages of high power sensitivity, high collector-circuit efficiency, and low battery power drain. When such a circuit, for which Fig. 1 indicates also the change in the operating point with variations in temperature, is operated with a constant bias voltage, an increase in temperature would lower the output resistance, cause an appreciable increase in quiescent output current with the operating point moving into the class-A region and consequently a decrease in the maximum power output and efficiency, since less of the load line would then be available for signal swing. On the other hand, a decrease in temperature would lower the quiescent collector current appreciably, slightly increase power output, and introduce cross-over distortion, since the operating point would be shifted into the non-linear part of the transfer characteristic. Hence, for optimum performance, some method of temperature compensation should be applied for the purpose of restricting the variation of zero-signal collector current over a wide range of ambient temperature changes, stabilizing the operating point. The techniques commonly employed utilize temperature-sensitive elements such as thermistors, semiconductor diodes, or the temperature features of the transistor itself. These

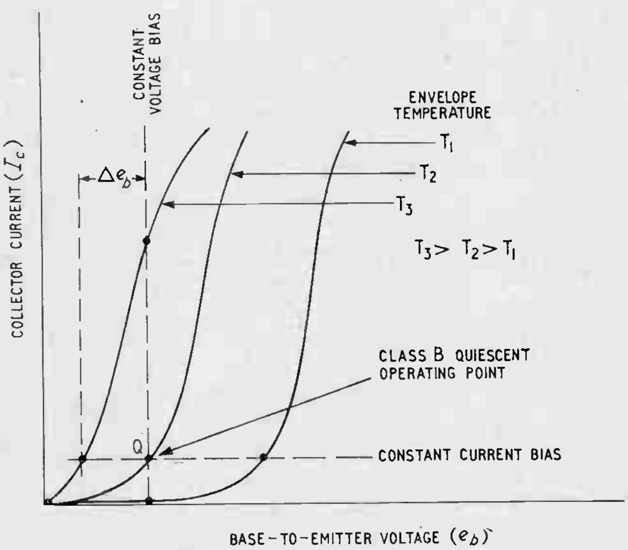


Fig. 1. *The effect of variations in temperature on the operating point*

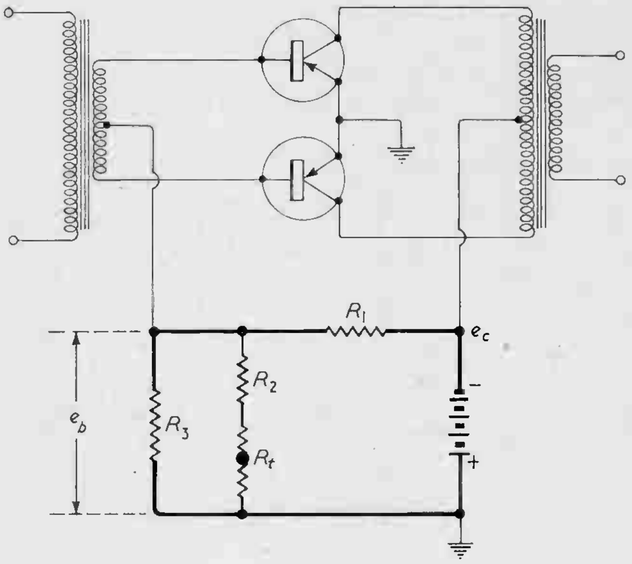


Fig. 2. *Class B push-pull transistor amplifier with temperature compensating bias network*

elements, in conjunction with linear resistors, make up the transistor bias circuit as well as a proper curve-shaping network for deriving a compensating bias that varies in the desired manner. The following treatment presents a generalized analytical design technique* for the realization of a temperature-compensating bias network, incorporating a thermistor, for the class-B germanium transistor amplifier in the common-emitter configuration. In the course of discussing the pertinent aspects of such a network, a short step-by-step design procedure based upon a set of simple relations, is evolved.

Conditions for Three Point Tracking

In Fig. 2 is shown a typical shaping network composed of linear (zero temperature-coefficient) resistors R_1, R_2 and R_3 and a directly-heated thermistor R_t in series with R_2. With $-e_c$ as the applied voltage (for the p-n-p transistor stage considered), the bias voltage e_b, appearing across R_3 will decrease with increasing temperature owing to the approximately exponential decrease of the thermistor resistance. A bias curve may thus be produced, depending upon an appropriate relationship among the network elements, that provides a close approximation to the desired temperature function by tracking at three selected temperature points.

The small size, robustness, stability, and versatility of the thermistor make it an extremely useful circuit element. The one considered here (such as the disk type) is regarded as being primarily very sensitive to ambient-temperature variations (and of a composition having practically a negligible voltage coefficient) whereas the power generated by any small current flowing in it is easily dissipated and is too small to produce sufficient self-heating to raise its temperature noticeably above that of its surroundings. Under these conditions the thermistor resistance R_t decreases with

* A somewhat similar graphical procedure has been proposed by A. J. Wheeler.

increasing temperature according to the approximate expression

$$R_t = Ae^{B/T} \quad \ldots \quad (1)$$

where R_t is the resistance in ohms at the temperature of T degrees K. The quantities A and B are fundamental parameters of the thermistor depending upon material composition.

Let e_{b1}, e_{b2} and e_{b3} be the respective forward bias voltages at temperatures T_1, T_2 and T_3, where $T_3 > T_2 > T_1$, all in °K; then if α represents the linear rate of change of bias voltage per °C,

$$\frac{e_{b3}}{e_{b2}} = \frac{e_{b2} - \alpha\,(T_3 - T_2)}{e_{b2}} = 1 - \frac{\alpha\Delta T}{e_{b2}} = 1 - k \quad (2)$$

and similarly

$$\frac{e_{b1}}{e_{b2}} = \frac{e_{b2} + \alpha\,(T_2 - T_1)}{e_{b2}} = 1 + k \quad \ldots \quad (3)$$

where, for simplicity, let $T_3 - T_2 = T_2 - T_1 = \Delta T$ and introducing

$$|k| = \frac{\alpha\Delta T}{e_{b2}}, \quad \ldots \quad (4)$$

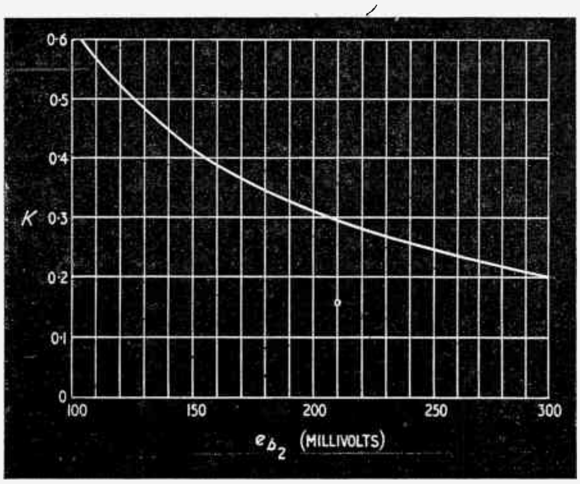
the relative expected voltage-deviation within the temperature range considered, with respect to the reference design bias voltage at the central temperature point T_2. It is readily evident in this case, that e_{b2} is an arithmetic mean between e_{b1} and e_{b3}. Fig. 3 illustrates the hyperbolic variation of k as a function of e_{b2} for $\alpha = 2{\cdot}5$ mV/°C and $\Delta T = 25$°C, taking $T_1 = 0$°C, $T_2 = 25$°C and $T_3 = 50$°C.

For the network of Fig. 2 the bias voltage at any temperature T may be given by

$$e_b = \frac{e_c R_3}{R_1 + R_3} \cdot \frac{R_2 + R_t}{\dfrac{R_1 R_3}{R_1 + R_3} + R_2 + R_t} = \frac{e_c H}{R_1} \cdot \frac{R_x}{H + R_x} \quad (5)$$

where $R_x = R_2 + R_t$ and $H = R_1R_3/(R_1 + R_3)$. If R_{x1}, R_{x2} and R_{x3} equal respectively $R_2 + R_{t1}$, $R_2 + R_{t2}$ and $R_2 + R_{t3}$ at the corresponding temperatures T_1, T_2 and T_3, then, the ratio of the bias voltages at either T_1 or T_3 to that at T_2 may also be expressed in terms of the network element values or

Fig. 3. *Fractional bias-voltage deviation versus forward bias (for $\Delta T = 25$°C and $\alpha = -2{\cdot}5$ m/V°C.)*



$$\frac{e_{b3}}{e_{b2}} = \frac{R_{x3}}{R_{x2}} \cdot \frac{H + R_{x2}}{H + R_{x3}} \quad \ldots \quad (6)$$

and

$$\frac{e_{b1}}{e_{b2}} = \frac{R_{x1}}{R_{x2}} \cdot \frac{H + R_{x2}}{H + R_{x1}} \quad \ldots \quad (7)$$

Eliminating H from (6) and (7) and substituting (2) and (3), yields the following expression:

$$\frac{1 + k}{R_{x1}/R_{x2}} + \frac{1 - k}{R_{x3}/R_{x2}} = 2 \quad \ldots \quad (8)$$

This non-linear relationship determines the tracking conditions at the selected temperatures for the three values of bias voltages. The curves shown in Fig. 4 exhibit, in view of the fact that $R_{x1}/R_{x2} > 1 > R_{x3}/R_{x2}$, the distribution of possible values of these resistance ratios, which satisfy condition (8), for three different values of k (hence, of e_b).

Choice of Thermistors. Evaluation of R_2

It is further noted that

$$\frac{R_{x1}}{R_{x2}} = \frac{R_2/R_{t2} + R_{t1}/R_{t2}}{R_2/R_{t2} + 1} = \frac{S + m}{S + 1} \quad \ldots \quad (9)$$

and

$$\frac{R_{x3}}{R_{x2}} = \frac{R_2/R_{t2} + R_{t3}/R_{t2}}{R_2/R_{t2} + 1} = \frac{S + n}{S + 1} \quad \ldots \quad (10)$$

where $S = R_2/R_{t2}$, $m = R_{t1}/R_{t2}$ and $n = R_{t3}/R_{t2}$. S represents the ratio of R_2 to the thermistor resistance at the reference temperature T_2, while m and n constitute definite values selected out of the particular thermistor characteristic resistance curves, depending upon the available rate of change of resistance with temperature. A point (m, n) can be located within the co-ordinate plane of R_{x1}/R_{x2} and R_{x3}/R_{x2} to mark a position at which $S = 0$ (or $R_2 = 0$). For any such chosen point, relationships (9) and (10) describe the variation of R_{x1}/R_{x2} and R_{x3}/R_{x2} as R_2 increases from zero to any higher value. Eliminating S from (9) and (10) leads to the following function

$$\frac{R_{x1}}{R_{x2}} = -\frac{m - 1}{1 - n} \cdot \frac{R_{x3}}{R_{x2}} + \frac{m - n}{1 - n} = -\lambda \frac{R_{x3}}{R_{x2}} + (1 + \lambda) \quad \ldots \quad (11)$$

letting

$$\lambda = \frac{m - 1}{1 - n}. \quad \ldots \quad (12)$$

Thus it appears that R_{x1}/R_{x2} and R_{x3}/R_{x2} are also linearly related, for common values of R_2, along a slope which is equal to $-\lambda$. The intersection of (11) with (8) fixes the proper value of S, as determined by (9) and (10), and therefore the required value of R_2. Substituting (11) into (8), the following quadratic equation is obtained:

$$\left(\frac{R_{x1}}{R_{x2}}\right)^2 - \left[\frac{(1 + k)(1 + \lambda)}{2} + 1\right]\left(\frac{R_{x1}}{R_{x2}}\right) + \frac{(1 + k)(1 + \lambda)}{2} = 0 \quad \ldots \quad (13)$$

Hence, solving (13) one easily arrives at the points of intersection given by

$$\left(\frac{R_{x1}}{R_{x2}}\right)_0 = \frac{(1 + k)(1 + \lambda)}{2} \quad \ldots \quad (14)$$

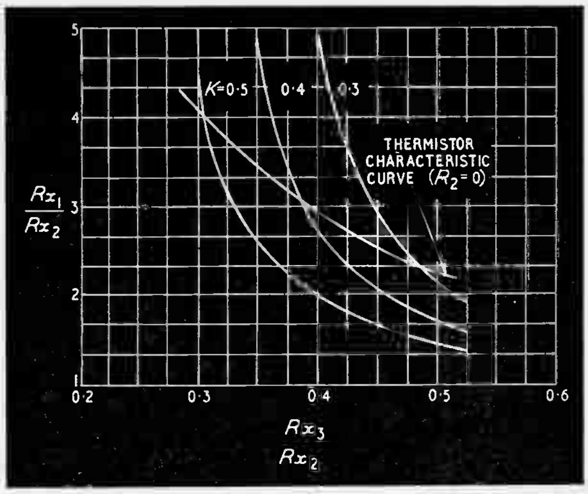


Fig. 4. *General conditions for three-point tracking at 0°C, 25°C and 50°C*

and, when introducing (14) in (8)

$$\left(\frac{R_{x3}}{R_{x2}}\right)_0 = \frac{(1-k)(1+\lambda)}{2\lambda} \quad \ldots \quad (15)$$

Now, substituting either (14) or (15) into (9) or (10) establishes the dependence of S upon k, m and n. For (9) we have

$$S = \frac{m-(R_{x1}/R_{x2})_0}{\left(\frac{R_{x1}}{R_{x2}}\right)_0 - 1} = \frac{2}{\frac{1+k}{1-n} - \frac{1-k}{m-1}} - 1 \quad (16)$$

which determines immediately R_2, since $R_2 = SR_{t2}$. It is obvious, therefore, that for a non-negative value of S, the following conditions must be met:

$$m \geqslant (R_{x1}/R_{x2})_0 \text{ and } n \leqslant (R_{x3}/R_{x2})_0 \quad \ldots \quad (17)$$

Hence, realization condition (17) restricts the choice of thermistor composition by suggesting that the point (m, n) picked must lie to the left of, or be coincident with, the desired bias curve, to yield a realizable value of R_2.

In this connection, it may be worth noting that if within the required temperature range $T_1 - T_3$ the thermistors considered follow closely the conduct of function (1), then generally

$$R_{t1}/R_{t2} = e^{B\left(\frac{1}{T_1}-\frac{1}{T_2}\right)} = e^{B\frac{\Delta T}{T_1 T_2}}$$

$$= e^{-B\frac{\Delta T}{T_2 T_3}\left(-\frac{T_3}{T_1}\right)} = (R_{t3}/R_{t2})^{\left(-\frac{T_3}{T_1}\right)}$$

i.e., $m = n^{(-T_3/T_1)}$ .. .. (18)

Thus, for $T_1 = 273$°K and $T_3 = 323$°K, $m = n^{-1.183}$ (19)

which is plotted in Fig. 4 as a universal thermistor characteristic curve for the 0°C to 50°C temperature range, describing the approximate location of all different (m, n) points, as dependent upon the temperature coefficient of the particular type of thermistor material selected, which will not be the same for different thermistor compositions. It is further observed that for m-values ranging from 2·2 to 4·2, for instance, the corresponding approximate thermistor B-values of the resistance–temperature constant will range from 2,500°K to 4,500°K, whereas the exact reference value of R_{t2} involves also parameter A.

Determination of R_3 and R_1

Apart from the desired magnitude of the bias voltage at the reference temperature T_2 and restrictions based on relations (8), (14) and (15) that together affect the choice of a suitable thermistor, it is also necessary to maintain a low-resistance d.c. path between base and emitter in order to prevent excessive power loss of input signal; however, the resistance of R_3 and R_x in parallel should not be so low that battery drain is excessive. In the final circuit, moreover, the current through the thermistor is to be kept low enough so as not to produce self-heating, and consequently a lower than calculated bias-voltage, which would result in the tracking points assuming different positions.

In order to arrive at a convenient set of expressions for the evaluation of R_3 and R_1, it will be necessary to perform a few more simple algebraic manipulations. From (6) and substituting (2) we have

$$H = \frac{\left(1-\frac{e_{b3}}{e_{b2}}\right)R_{x3}}{\frac{e_{b3}}{e_{b2}} - \frac{R_{x3}}{R_{x2}}} = \frac{k\,R_{x3}}{\left(1-k\right) - \frac{R_{x3}}{R_{x2}}} \quad \ldots \quad (20)$$

At the reference temperature T_2, (5) may be given as

$$e_{b2} = e_c \frac{R_3 - H}{R_3} \frac{R_{x2}}{H + R_{x2}} \quad \ldots \quad (21)$$

from which, after substituting (20) and rearranging, the following ratio is extracted

$$\frac{R_3}{R_{x2}} = \frac{k\frac{e_c}{e_{b2}}}{\left(\frac{e_c}{e_{b2}} - 1\right)\left(\frac{1-k}{R_{x3}/R_{x2}} - 1\right) - k} \quad \ldots \quad (22)$$

As the working point is $[(R_{x1}/R_{x2})_0\,;\,(R_{x3}/R_{x2})_0]$, inserting (15) and setting $\rho = e_c/e_{b2}$, (22) reduces finally to

$$R_3 = \frac{\rho\,R_{x2}}{\left(\frac{\rho-1}{k}\right)\frac{\lambda-1}{\lambda+1} - 1} \quad \ldots \quad (23)$$

However, since $k < 1$ and, as is quite usually the case, $\rho \gg 1$ Equ. (23) may be simplified to yield

$$R_3 \approx \frac{k\,R_{x2}}{(\lambda-1)(\lambda+1)} \quad \ldots \quad (24)$$

It should be noted that R_3 may be determined as soon as the appropriate thermistor has been chosen and R_2 evaluated.

Denoting by Z_2 the bias circuit impedance between base and emitter, we have, at the reference temperature T_2,

$$Z_2 = \frac{R_3\,R_{x2}}{R_3 + R_{x2}} \quad \ldots \quad (25)$$

for $R_1 \gg Z_2$. Substituting (24) into this equation provides an expression for the approximate estimation of R_{t2}, the thermistor resistance required at T_2, when the bias impedance is known. Hence,

$$R_{t2} \approx R_{x2} \approx \left(1 + \frac{1}{k}\frac{\lambda-1}{\lambda+1}\right) Z_2 \quad \ldots \quad (26)$$

since $R_{x2} = (1 + S) R_{t2}$, and $S \ll 1$. Now, from Fig. 2 it is immediately evident that

$$R_1 = (\rho - 1) Z_2 = (\rho - 1) \frac{R_3 Rx_2}{R_3 + Rx_2} \quad .. \quad (27)$$

which, when introducing (23) and simplifying, can be put in the form

$$R_1 = \frac{\rho Rx_2}{1 + \frac{1}{k} \frac{\lambda - 1}{\lambda + 1}} \quad .. \quad .. \quad .. \quad .. \quad .. \quad (28)$$

This is the final step in the realization of the required bias-shaping network.

Alternative Bias Network Configuration

Fig. 5 illustrates an alternative bias-shaping network which is particularly attractive for applications requiring a very low bias impedance between base and emitter, when the transistors used have a low input impedance. In place of R_3, a voltage divider is introduced, made up of two linear resistors R_{31} and R_{32} in series. The required bias voltage is taken across R_{32}. Hence, if $R_{31} + R_{32} = R_3$, we have

$$e_{b2} = \frac{e_c R_{32}}{R_1 + R_3} \frac{R_{x2}}{\frac{R_1 R_3}{R_1 + R_3} + R_{x2}}$$

$$= \frac{e_c R_{32}}{R_3} \frac{R_3 - H}{R_3} \frac{R_{x2}}{H + R_{x2}} \quad .. \quad .. \quad (29)$$

which can be arranged and put in the form of the following quadratic equation

$$R_3^2 - MR_3 + MH = 0 \quad .. \quad .. \quad .. \quad (30)$$

where

$$M = \frac{\rho R_{32}}{1 + H/R_{x2}} = \frac{\rho R_{32}}{1 + k \frac{\lambda + 1}{\lambda - 1}} ; \quad .. \quad .. \quad (31)$$

since, by substituting (15) into (20) it may readily be shown that

$$H = k \frac{\lambda + 1}{\lambda - 1} R_{x2} . \quad .. \quad .. \quad .. \quad .. \quad (32)$$

Solving (30), a relation for determining R_{31} is obtained; i.e.,

$$R_{31} = \tfrac{1}{2} [(M - 2 R_{32}) + \sqrt{M^2 - 4MH}]. \quad .. \quad (33)$$

Resistor R_{32} can be taken as very approximately equal to the actual required resistance between base and emitter terminals, provided $R_{31} \gg R_{32}$. For R_{31} to be realizable, however, the following condition must be satisfied

$$M \geqslant 4 H \quad .. \quad .. \quad .. \quad .. \quad .. \quad (34)$$

or, substituting (31), (32) and (16) and noting that $R_{x2} = (1 + S) R_{t2}$, inequality (34), after regrouping and simplifying, reduces to

$$R_{t2} \leqslant \frac{\rho R_{32} \frac{\lambda - 1}{m - 1}}{8 k \frac{\lambda + 1}{\lambda - 1}} . \quad .. \quad .. \quad .. \quad .. \quad .. \quad (35)$$

This relationship represents an additional restriction upon the selection of a proper thermistor resistance value. R_1 may now immediately be extracted from Equ. (29); i.e.,

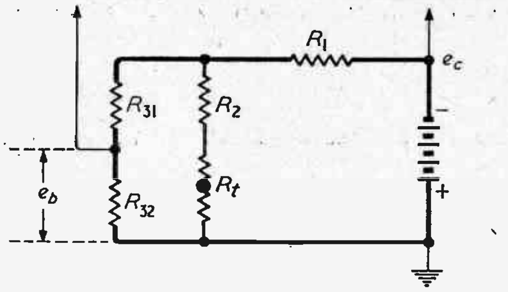


Fig. 5. *An alternative temperature-compensating bias network*

$$R_1 = \frac{R_3 \ R_{x2}}{R_3 + R_{x2}} \left(\rho \frac{R_{32}}{R_3} - 1 \right) \quad .. \quad .. \quad (36)$$

The values for k, ρ, λ and S, are readily calculated using the expressions previously derived.

Example. Applying the proposed method to the design of a temperature-compensating bias circuit, let a class-B output stage operate with a supply voltage of 7·5 volts. To minimize cross-over distortion, let a forward bias voltage of 200 mV be required, with the base-to-emitter bias resistance of approximately 10 Ω.

Selecting the tracking points at 0°C, 25°C and 50°C, and taking $\alpha = 2 \cdot 5$ mv/°C, the value of k is calculated from Equ. (4) and is 0·3125. Also $\rho = 7 \cdot 5/0 \cdot 2 = 37 \cdot 5$. Consulting the manufacturers' resistance–temperature thermistor characteristics and guided by the curves of Fig. 4, an available point (m, n) is sought (preferably a low point, so that lower resistance values may result) to accommodate requirement (17). If the chosen point be $m = 2 \cdot 8$ and $n = 0 \cdot 41$, then λ calculated from Equ. (12) equals 3·05; and from Equ. (16), $1 + s = 1 \cdot 0854$. Using the value of 10 Ω for R_{32}, the nearest available value of the required thermistor resistance R_{t2} can now be selected to satisfy inequality (35) which, when evaluated, indicates that $R_{t2} \leqslant 84 \cdot 4$ Ω. If a thermistor value of 72 Ω at 25°C is available, then $R_{x2} = (1+s) R_{t2} = 78$ Ω and $R_2 = 78 - 72 = 6$ Ω

The value of M given by Equ. (31) is 231·8 and the value of H given by Equ. (32) is 48·2, hence from Equ. (33) $R_{31} = 153$ Ω. A value of 150 Ω may be chosen as the closest value. Now, $R_3 = 153 + 10 = 163$ Ω and, finally, the value of R_1 is calculated from Equ. (36) and is 71 Ω. A value of 68 Ω may be selected for R_1.

Acknowledgement

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SEMICONDUCTOR CONVENTION

An international convention on Transistors and Associated Semiconductor Devices, by the Radio and Telecommunication Section of the Institution of Electrical Engineers, will be held at Earls Court, London, from 25th to 29th May 1959. The convention will be accompanied by an international exhibition (from 20th to 28th May) covering all aspects of transistors and semiconductor devices.

The exhibition, promoted by the Institution, is being arranged by Industrial and Trade Fairs Ltd., Drury House, Russell Street, London, W.C.2, to whom exhibiting inquiries should be addressed.

Conditions for Minimum Variation in a Function—3

In last month's article, we obtained an expression for the group delay τ_4 associated with the network of Fig. 1 (the same as Fig. 2 last month), namely

$$\tau_4 = \frac{2x_0}{\omega_0}\left[\frac{(1 - Kx_0^2X^2 + Mx_0^4X^4)\ (1 - 3Lx_0^2X^2) + x_0^2X^2\ (1 - Lx_0^2X^2)\ (2K - 4Mx_0^2X^2)}{(1 - Kx_0^2X^2 + Mx_0^4X^4)^2 + x_0^2X^2\ (1 - Lx_0^2X^2)^2}\right] \quad \ldots \ldots \quad (1)$$

where x_0, K, L, M are closely related to the elements of the network [Equs. (30), (19) and (20) of last month's article], so that if we know the elements we can find x_0, K, L, and M and, conversely, if we know x_0, K, L, M and the frequency range $\omega/2\pi$ over which we wish to minimize group-delay variations, we can determine the required network elements. Here, we wish to choose the algebraically-significant parameters K, L, M so that the variation shall either be 'maximally flat', or the total variation in the range $0 < X < 1$ shall be as small as possible; x_0 is virtually a mere scale factor.

First, let us suppose that we wish the group delay τ_4 to be 'maximally flat', that is to say, to have no term in X^2, X^4 or X^6 if expressed as a series of ascending powers of X^2. Last month it was noted that such a series could be obtained by dividing the denominator of τ_4 in Equ. (1) into the numerator, and cancelling the lowest power of X^2 at each stage of the division. If we want the coefficients of X^2, X^4 and X^6 to be absent from the series thus obtained, however, it is easier to make the coefficients of X^2, X^4 and X^6 equal in the numerator and denominator of Equ. (1), which can be rearranged in the form

$$\tau_4 = \frac{2x_0}{\omega_0}\left[\frac{1 + (K - 3L)x_0^2X^2 + (KL - 3M)x_0^4X^4 + LMx_0^6X^6}{1 + (1 - 2K)x_0^2X^2 + (2M - 2L + K^2)x_0^4X^4 + (L^2 - 2KM)x_0^6X^6 + M^2x_0^8X^8}\right] \ldots \ldots \ldots \quad (2)$$

so that the conditions required are

$$K - 3L = 1 - 2K \quad \ldots \ldots \ldots \quad (3)$$

$$KL - 3M = 2M - 2L + K^2 \quad \ldots \ldots \ldots \quad (4)$$

$$LM = L^2 - 2KM \quad \ldots \ldots \ldots \quad (5)$$

Equ. (3) simplifies to

$$L = K - \frac{1}{3} \quad \ldots \ldots \ldots \ldots \quad (6)$$

Substituting for L from Equ. (6) into Equ. (4), we have

$$M = \frac{1}{3}(K - 0{\cdot}4) \quad \ldots \ldots \ldots \ldots \quad (7)$$

and substituting from Equs. (6) and (7) into Equ. (5) to eliminate L, M we obtain

$$K = \frac{3}{7},\ \text{whence}\ L = \frac{2}{21},\ M = \frac{1}{105} \quad \ldots \ldots \quad (8)$$

Thus Equ. (8) gives the conditions for maximal flatness, but if K is arbitrary and L and M are given by Equs. (6) and (7), the group delay will be 'quartically flat' and, if expanded in ascending powers of X^2, will have no term in X^2 or X^4; this last result was found by Gouriet[1] who has studied the general behaviour of τ_4 for varying K when Equs. (6) and (7) apply. If we substitute from Equ. (8) into Equ. (2), the result can be written

$$2x_0 - \omega_0\tau_4 = \frac{2x_0^9X^8}{11025 + 1575\,x_0^2X^2 + 135\,x_0^4X^4 + 10\,x_0^6X^6 + x_0^8X^8} \quad (9)$$

and the expression on the right-hand side of Equ. (9) continually increases with X whatever the value of x_0 may be; for sufficiently large values of x_0X it differs from $2x_0$ by a small quantity. It is evaluated in Table 1 for certain values of x_0, for comparison with the other type of group-delay characteristic discussed below, in which we seek to minimize the total variation for $0 < X < 1$.

In last month's article, we considered the difference between the group delay (τ_2) and its initial value $2a$ [Equ. (13) last month] and our best hope of minimizing the total variation seemed to be that this difference should be zero when $\omega = 1$; it was only because the right-hand side of Equ. (13) (last month) had a denominator as well as a numerator that this hope was not a certainty. In the present case, therefore, let us also examine the behaviour of the difference

$$2x_0 - \omega_0\tau_4 = \frac{2x_0}{D_4^2}\left[(3L - 3K + 1)\,x_0^2X^2 + (5M - 2L - KL + K^2)\,x_0^4X^4 + (L^2 - ML - 2MK)\,x_0^6X^6 + M^2x_0^8X^8\right] \quad (10)$$

where D_4 has the same meaning as in last month's article [Equ. (25) last month] and D_4^2 is the denominator of the right-hand sides of Equs. (1) and (2) above, namely

$$D_4^2 = 1+(1-2K)x_0^2X^2+(2M-2L+K^2)x_0^4X^4 + (L^2-2KM)x_0^6X^6+M^2x_0^8X^8 \quad .. \quad (11)$$

If there were no denominator D_4^2, the numerator on the right-hand side of Equ. (10) would be a polynomial whose variations we would wish to minimize for X varying between 0 and 1. As this numerator only contains even powers of X, it is effectively variations of X between -1 and $+1$ that matter; Equs. (10) and (11) are unaltered when X is changed into $-X$. From the August "Mathematical Tool", therefore, it follows that the numerator of the right-hand side of Equ. (10) ought to be a multiple of $(1 - \cos 8\theta)$ if X is put equal to $\cos\theta$*. But

$$1 - \cos 8\theta = 2\sin^2 4\theta = 8\sin^2 2\theta\cos 2\theta$$
$$= 32\sin^2\theta\cos^2\theta\cos^2 2\theta = 32(1-X^2)X^2(2X^2-1)^2$$
$$= 128X^2(X^2-\tfrac{1}{2})^2(1-X^2) \quad .. \quad .. \quad .. \quad (12)$$

Now the expression $(1 - \cos 8\theta)$ in Equ. (12) is always positive; it has a minimum value zero when θ is a multiple of $\pi/4$ and a maximum value 2 when θ is an odd multiple of $\pi/8$. Translated into terms of X, this means that the expression

$$U = X^2(X^2-\tfrac{1}{2})^2(1-X^2) \quad .. \quad .. \quad .. \quad (13)$$

not only has the obvious minimum values of zero when $X = 0$ and when $X = 1/\sqrt{2}$, and an ordinary zero when $X = 1$, but it also has equal maximum values of 1/64 when $X = \cos\pi/8 = 0{\cdot}92388$ and when $X = \cos 3\pi/8 = 0{\cdot}38268$. In Equ. (10), the coefficient of X^8 is $M^2x_0^8$ so, if we are to make $D_4^2(2x_0 - \omega_0\tau_4)/2x_0$ a multiple of U at all, it will have to be $-M^2x_0^8U$. For

*In the August article, the variation of x was between 0 and 1 with symmetry about $x = \frac{1}{2}$, so $(\frac{1}{2} - x)$ was equated to $\frac{1}{2}\cos\theta$. Here the effective variation of X is from -1 to $+1$ with symmetry about $X = 0$, so the corresponding procedure is to put $X = \cos\theta$.

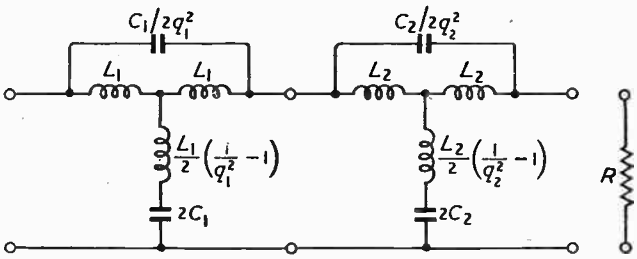


Fig. 1. *Two bridged-T all-pass filters in cascade*

TABLE 1

Parameters for various Group-Delay Characteristics [Equ. (13)]

Set. No.	x_0	x_0^2	α	M	K	L	First: Max. $(\omega_0\tau-2x_0)$	First: Value of X	Second: Max. $\omega_0\tau-2x_0$	Second: Value of X	Remarks
1	1·95	3·80	1	0·012	0·4361	0·1001			0	1	
2	2·36	5·575	$1/\sqrt{2}$	0·012	0·4357	0·1003					
3	2·63	6·90	0·5	0·012	0·4351	0·1008	0·003	0·3	0·033	0·8	All maximum values, and values of X at which they occur, are very roughly estimated.
4	2·83	8·02	0	0·012	0·4360	0·1027	0	0			
5	2·43	5·90	1	0·014	0·4494	0·1027			0	1	
6	2·96	8·77	$1/\sqrt{2}$	0·014	0·4469	0·1025	0·1	0·4	0·04	0·9	
7	3·26	10·60	0·5	0·014	0·4417	0·1035					
8	3·27	10·66	0	0·014	0·4420	0·1087	0	0			
9	2·67	7·14	1	0·016	0·4706	0·1062			0	1	
10	3·28	10·76	$1/\sqrt{2}$	0·016	0·4651	0·1052	0·34	0·5	0·11	0·9	
11	3·58	12·79	0·5	0·016	0·4503	0·1058					
12	3·44	11·81	0	0·016	0·4480	0·1147	0	0			
13	2·79	7·785	1	0·018	0·4949	0·1106			0	1	
14	3·44	11·85	$1/\sqrt{2}$	0·018	0·4869	0·1087					
15	3·76	14·14	0·5	0·018	0·4603	0·1079	0·2	0·3	1·3	0·85	
16	3·49	12·21	0	0·018	0·4540	0·1207	0	0			
17	2·85	8·10	1	0·02	0·5199	0·1157			0	1	
18	3·54	12·50	$1/\sqrt{2}$	0·02	0·5112	0·1128					
19	3·87	15·00	0·5	0·02	0·4713	0·1099					
20	3·77	14·20	0·6	0·02	0·4929	0·1101	0·7	0·3	0·8	0·9	
21	3·50	12·22	0	0·02	0·4600	0·1267	0	0	3·2	0·8	
22	2	4·00	—	↑	↑	↑	↑	↑	−0·05	↑	Nos. 22-27 are all maximally flat. $\omega_0\tau$ decreases for $X>1$.
23	2·4	5·76	—						−0·19		
24	2·8	7·84	—	1/105	3/7	2/21	0	0	−0·525	1	
25	3·2	10·24	—						−1·025		
26	3·6	12·96	—						−1·95		
27	4·0	16·00	—	↓	↓	↓	↓	↓	−2·96	↓	

the moment, let us not worry about how this is to be done, but only assume that it can and should be done. Equ. (10) becomes

$$\omega_0\tau_4 = 2x_0\left[1+\frac{M^2x_0^8U}{D_4^2}\right] \quad .. \quad .. \quad .. \ (14)$$

and τ_4 therefore has a minimum value of $2x_0$ when $X = 0$ and when $X = 1/\sqrt{2}$, and returns to the value $2x_0$ when $X = 1$. τ_4 exceeds $2x_0$ for all X between 0 and 1, since U and D_4^2 are always positive for this range of X. Hence τ_4 must have one maximum for $0 < X < 1/\sqrt{2}$ and another for $1/\sqrt{2} < X < 1$; in the absence of the denominator D_4^2 in Equ. (14), these two maxima would be equal, and the total variation of τ_4 could be satisfactorily controlled. But the denominator D_4^2 may grossly upset the balance by having a value d_{41} when X is near cos $3\pi/8$ (so that U is near its first maximum) very different from its value d_{42} when X is near cos $\pi/8$ (so that U is near its second maximum). In this case the two maxima of τ_4 will differ greatly, and an adjustment of the available parameters which reduced the higher maximum relative to the lower one would appear to be required in order that the total variation of τ_4 in the range $0 < X < 1$ might be reduced. In order to have a parameter that could be used at a late stage for this kind of adjustment, we shall not in fact carry out the procedure for making $D_4^2\,(2x_0 - \omega_0\tau_4)$ a multiple of U (which we have so far only assumed possible); we shall instead make $D_4^2\,(2x_0 - \omega_0\tau_4)$ a multiple of

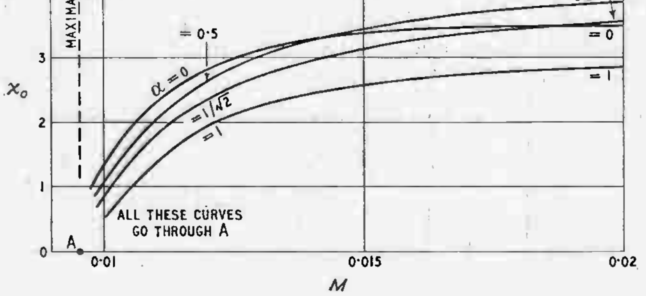
$$V = X^2\,(X^2 - \alpha^2)^2\,(1 - X^2) \quad .. \quad .. \quad .. \ (15)$$

$V = U$ if $\alpha = 1/\sqrt{2}$, but we intend to keep α general as long as possible, so that it can be adjusted as late as possible. V, like U, has the minimum value zero when $X = 0$ and also is zero for $X = 1$; it also has the minimum value zero for $X = \alpha$. If therefore we now choose K, L, M, x_0 so that

$$\omega_0\,\tau_4 = 2x_0\left[1+\frac{M^2x_0^8\,V}{D_4^2}\right] \quad .. \quad .. \quad .. \ (16)$$

instead of Equ. (14), it will still be true that τ_4 must have one maximum for $0 < X < \alpha$ and one for $\alpha < X < 1$, and minimum value $2x_0$ for $X = 0$ and $X = \alpha$; τ_4 will also be $2x_0$ when $X = 1$. Clearly if α is sufficiently near zero, the maximum in the range $0 < X < \alpha$ will be below that in the range $\alpha < X < 1$, whereas if α is sufficiently near 1, the reverse will be true. Thus it must be possible to find a value of α for which the two maxima are equal (assuming that one of the variables K, L, M, x_0, say M, is given, since, as we shall see, Equ. (16) leads to three relations between these variables).

Fig. 2. (Mx_0) *curves for constant* α [*see Equs.* (18)–(20)]



In order that Equ. (16) may be consistent with Equ. (10), we must have

$$\begin{aligned} & M^2x_0^8\,V \\ & = -[(3L-3K+1)\,x_0^2X^2+(5M-2L-KL+K^2)\,x_0^4X^4 \\ & \quad +(L^2-ML-2MK)\,x_0^6X^6+M^2x_0^8X^8] \quad .. \ (17) \end{aligned}$$

for *all* values of X, and therefore the coefficients of X^6, X^4 and X^2 on the two sides of Equ. (17) must be equal. This gives

$$3L - 3K + 1 = -x_0^6\,M^2\,\alpha^4 \quad .. \ (18)$$

$$5M - 2L - KL + K^2 = x_0^4\,M^2\,(2\alpha^2 + \alpha^4) \quad .. \ (19)$$

$$M\,(L + 2K) - L^2 = x_0^2\,M^2\,(2\alpha^2 + 1) \quad .. \ (20)$$

Equs. (18)–(20) are much easier to handle than at first appears. Multiply Equ. (18) by $K/3$ and add to Equ. (19), and only terms linear in K and L remain. The resulting equation, together with Equ. (18), forms a pair of linear simultaneous equations for K and L in terms of M, x_0 and α; the value of K is

$$K = \frac{(2+15\,M)-6\,\alpha^2x_0^4\,M^2+\alpha^4x_0^4\,M^2\,(2\,x_0^2-3)}{5-\alpha^4\,x_0^6\,M^2} \quad .. \ (21)$$

and L is then deduced from Equ. (18).

We now require a number of sets of values of K, L, M, x_0 and α satisfying Equs. (18)–(20). Twenty-one such sets are listed in Table 1 (Nos. 1–21). The procedure for obtaining them is as follows. To begin with, choose values for M and α. Then choose arbitrarily a value ξ_1 of x_0 [or rather, of x_0^2: it is convenient to have x_0^2 rounded off since only even powers of x_0 occur in Equs. (18)–(21)]. Obtain a first approximation to K from Equ. (21), and a first approximation to L from Equ. (18). Check that the values of M, α, x_0^2, K, and L obtained at this stage satisfy Equ. (19). Now evaluate separately the two sides of Equ. (20), and it will be indeed fortunate if they turn out to be equal! Usually, therefore, it will be necessary to repeat the whole process with a different value ξ_2^2 of x_0^2 (and the same values of M, α). Now the right-hand side of Equ. (20) is directly proportional to x_0^2 for given M, α, and it turns out that the left-hand side is nearly so. We can therefore obtain a good approximation ξ_3^2 to x_0^2 by assuming that both sides of Equ. (20) vary linearly with x_0^2. If we restart with the same value of M and α and replace x_0^2 by ξ_3^2, the two sides of Equ. (20) may still not be quite equal, so this time we obtain a fourth and sufficient approximation ξ_4^2 by again assuming that the two sides of Equ. (20) vary linearly with x_0^2, and use the changes in the two sides when x_0^2 varies from ξ_1^2 to ξ_3^2 (or ξ_1^2 to ξ_2^2) to determine the rate of this variation. If x_0^2 is now replaced by ξ_4^2, M and α are as before, and K is now obtained from Equ. (21), L from Equ. (18), the set of values M, α, ξ_4^2, K, L will satisfy all of Equs. (18)–(20) as required.

All the sets of values in Table 1 are worth considering for small total variation of τ_4 in the range $0 < X < 1$. Sets 1–21 were obtained in the way just described; Sets 22–27 are for maximally-flat characteristics, and are included for comparison. When M is $0{\cdot}012$, the variation of τ_4 is very small, and it is not worth taking great trouble to obtain the best possible value of α. We have calculated τ_4 for $X = 0{\cdot}1, 0{\cdot}2 \ldots 1{\cdot}0$ for Set No. 3 only, and from this we have roughly estimated the two maxima of $(\omega_0\tau_4 - 2x_0)$. The first of these maxima is about one-tenth of the second, so a higher value of α than $0{\cdot}5$ would be needed to equalize the maxima, but we have not sought this. For Sets 5–8, M has been made $0{\cdot}014$; this time τ_4 has been similarly calculated for Set 6 alone, and the first maximum of $(\omega_0\tau_4 - 2x_0)$ is now about $2{\cdot}5$ times the second, so that to equalize the maxima, α should be reduced. The variation in $\omega_0\tau_4$, however, is again so small that it is not worth determining the best possible value of α more accurately. Similar considerations apply to Sets 9–12, for which $M = 0{\cdot}016$, and Sets 13–16 for which $M = 0{\cdot}018$. The variation in $\omega_0\tau_4$ increases with M, but is not sufficiently serious to require the best possible value of α to be accurately determined. For Sets 17–21, M is $0{\cdot}02$, and here the variation in $\omega_0\tau_4$ is likely to be excessive unless α is chosen with care (we have assumed that a variation of $\omega_0\tau_4$ of the order of 1 is tolerable), so that the extra value $0{\cdot}6$ of α has been included here in Set 20. The remaining sets of values are principally useful in enabling us to determine the way in which x_0 varies with M for constant α; this is shown in Fig. 2, from which further sets of values of x_0, M, α could be obtained approximately by interpolation. The approximation could be improved by the procedure already described.

Given any set of x_0, α, L, M and N for which the associated group-delay characteristic is regarded as satisfactory, the network elements required to produce that characteristic are found by first evaluating c_1, c_2, c_3 and c_4 from Equ. (30) of last month's article. Thus we have the quartic $\phi_4(p)$ [Equ. (21) of last month] and can factorize this [Equ. (22) of last month] as indicated in earlier "Mathematical Tools" (February and March 1957; May 1958). Knowing a_1, a_2, b_1 and b_2 from the factors, Equ. (19) of last month gives the required network elements. This is done in Table 2 for Set No. 20 of Table 1, and for the "maximally-flat" sets (Nos. 22–27).

TABLE 2

Determination of Network Parameters for obtaining Certain Group-Delay Characteristics specified in Table 1

Set No. 20. $K = 0{\cdot}4929$, $L = 0{\cdot}1101$, $M = 0{\cdot}02$, $x_0^2 = 14{\cdot}20$

$\omega_0 c_1 = 3{\cdot}7683$; $\omega_0^2 c_2 = 6{\cdot}9992$; $\omega_0^3 c_3 = 5{\cdot}8914$; $\omega_0^4 c_4 = 4{\cdot}0328$

$$\phi_4(p) = 1 + 3{\cdot}7683\, p/\omega_0 + 6{\cdot}9992\, p^2/\omega_0^2 + 5{\cdot}8914\, p^3/\omega_0^3 + 4{\cdot}0328\, p^4/\omega_0^4$$
$$= (1 + 0{\cdot}6917\, p/\omega_0 + 1{\cdot}0575\, p^2/\omega_0^2)(1 + 3{\cdot}0766\, p/\omega_0 + 3{\cdot}8136\, p^2/\omega_0^2)$$

$\omega_0 L_1 = 0{\cdot}6917R$; $\omega_0 C_1 = 0{\cdot}6917/R$; $q_1 = 0{\cdot}6726$;
$\omega_0 L_2 = 3{\cdot}0766R$; $\omega_0 C_2 = 3{\cdot}0766/R$; $q_2 = 1{\cdot}5755$.

Maximally-Flat Sets. $K = 3/7$, $L = 2/21$, $M = 1/105$, x_0 arbitrary

$$\omega_0 c_1 = x_0;\quad \omega_0^2 c_2 = \frac{3}{7}x_0^2;\quad \omega_0^3 c_3 = \frac{2}{21}x_0^3;\quad \omega_0^4 c_4 = \frac{1}{105}x_0^4$$

$$\phi_4(p) = 1 + \frac{px_0}{\omega_0} + \frac{3}{7}\left(\frac{px_0}{\omega_0}\right)^2 + \frac{2}{21}\left(\frac{px_0}{\omega_0}\right)^3 + \frac{1}{105}\left(\frac{px_0}{\omega_0}\right)^4$$
$$= \left\{1 + 0{\cdot}6337\frac{px_0}{\omega_0} + 0{\cdot}1094\left(\frac{px_0}{\omega_0}\right)^2\right\}\left\{1 + 0{\cdot}3663\frac{px_0}{\omega_0} + 0{\cdot}08705\left(\frac{px_0}{\omega_0}\right)^2\right\}$$

$\omega_0 L_1 = 0{\cdot}6337\, x_0 R$; $\omega_0 C_1 = 0{\cdot}6337/x_0 R$; $q_1 = 1{\cdot}916$;
$\omega_0 L_2 = 0{\cdot}3663\, x_0 R$; $\omega_0 C_2 = 0{\cdot}3663/x_0 R$; $q_2 = 1{\cdot}241$.

REFERENCE

[1] G. G. Gouriet, "Two Theorems Concerning Group Delay with Practical Application to Delay Correction". I.E.E. Monograph No. 275R, December 1957.

MANUFACTURERS' LITERATURE

Texas Instruments Ltd. have announced that a series of Semiconductor Application Reports will be published at approximately monthly intervals, thus providing a continuous service of information relating to the use of the firm's silicon semiconductor devices.

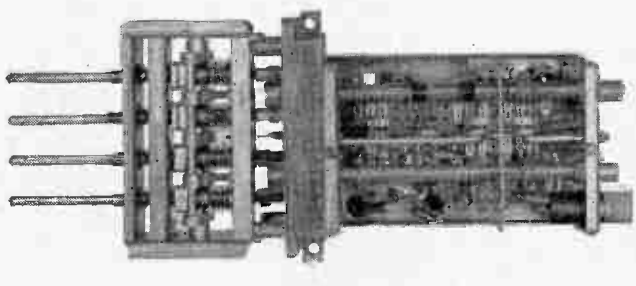
Reports already published include "An Introduction to Silicon Semiconductor Devices" and "The Design of A.C. Servo Amplifiers using Silicon Transistors: Part 1, Output stages."
Texas Instruments Ltd., Dallas Road, Bedford.

Ferranti Ltd. have published a 48-page booklet describing their Mercury Computer with its ancillary equipment.
Ferranti Ltd., 21 *Portland Place, London, W.*1.

Ferranti Panel Instruments. Pp. 16. Moving-coil, thermocouple, moving-iron and electrostatic meters, 2–3· inch. Electrostatic voltmeters with f.s.d. down to 150 V are listed.
Ferranti Ltd., Hollinwood, Lancs.

Short Form Catalogue 1958. Pp. 8. Waveguide components, coaxial equipment, waveguide instruments, bolometers and thermistors, microwave ferrite components.
Aveley Electric Ltd., Ayron Road, Aveley Industrial Estate, South Ockendon, Essex.

PUSH-BUTTON STATION SELECTOR



Interior of Bush television tuner with push-button station selection. Two sets of coils are used each with ganged permeability tuning, one for Band I and one for Band III. Two push-buttons operate on one band and two on the other. On pressing a button, an extension rod pushes the core against a return spring to a predetermined position and, if the previously-operated button was for the other band, at the same time operates a switch.

A feature of the design is the ease with which the tuner can be set up to any channel. After operating a button, its front end is lifted with the finger. It then becomes loose and on pulling out slightly it engages with a pin and can be turned to adjust the cores to any frequency in the band. Releasing the button and pressing it down disengages the adjusting mechanism.

Phase-Shift at Microwave Frequencies

MEASUREMENTS ON WAVEGUIDE COMPONENTS

By M. H. N. Potok, M.A., B.Sc., Ph.D., A.M.I.E.E., A.M.Brit.I.R.E.*

SUMMARY. *Phase-shift through waveguide arbitrary lossless networks can be measured by the application of the nodal shift method. Measurements on filters in the 4-kMc/s range agree well with calculations.*

The application of microwaves to communication and, in particular, the development of microwave links often demands the knowledge of phase-shift or, more accurately, of group delay (i.e., rate of change of phase-shift with frequency) caused by the waveguide components used. Several methods have been described of measuring the group delay directly by modulating the microwave signal and observing the shift in the envelope. Invariably these methods involve mixing in crystals which introduce a large and indefinite error. It may not be generally realized that it is possible to measure phase-shift directly at microwave frequencies by the application of the nodal shift method attributed to Weissfloch[1]. In the following discussion a uniform lossless waveguide is assumed as the basis of all networks and all impedances are normalized to it. The network is assumed terminated by a matched load.

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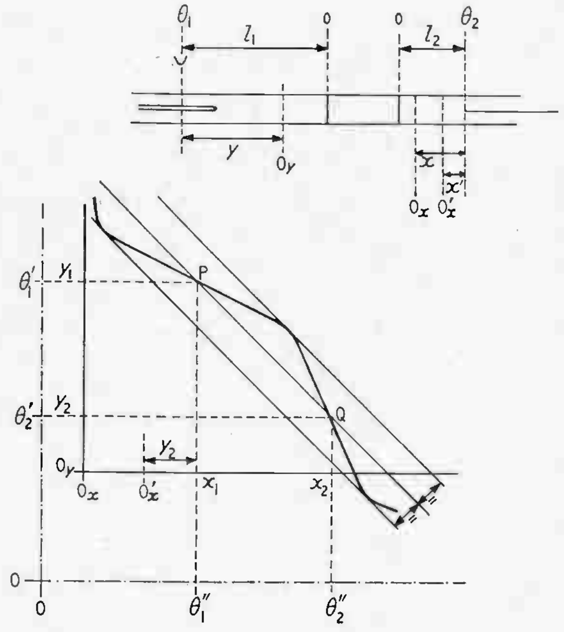


Fig. 1. *Method of locating axes of reference for phase-shift measurement*

Phase-Shift Through Symmetrical Networks

The input and output currents and voltages of a four-terminal lossless network are related by the equations

$$\left.\begin{aligned} V_{in} &= A \,.\, V_{out} + jB \,.\, I_{out} \\ I_{in} &= jC \,.\, V_{out} + D \,.\, I_{out} \end{aligned}\right\}$$

or in matrix form

$$\begin{vmatrix} V_{in} \\ I_{in} \end{vmatrix} = \begin{vmatrix} A & jB \\ jC & D \end{vmatrix} . \begin{vmatrix} V_{out} \\ I_{out} \end{vmatrix}$$

where A, B, C and D are real.

The insertion phase-shift ψ between the output and the incident wave of such a network is given by the relation

$$\tan \psi = \frac{B + C}{A + D} \qquad \ldots \quad (1)$$

In a symmetrical network $D = A$, hence

$$\tan \psi = \frac{B + C}{2A} \qquad \ldots \quad (2)$$

If the output were short-circuited, then $V_{out} = 0$ hence the input impedance

$$Z_{in\ s.c.} = \frac{V_{in}}{I_{in}} = \frac{jB}{A} \qquad \ldots \quad (3)$$

On the other hand, with open-circuited output $I_{out} = 0$ hence

$$Z_{in\ o.c.} = \frac{A}{jC}$$

Thus

$$Z_{in\ s.c.} + \frac{1}{Z_{in\ o.c.}} = \frac{jB}{A} + \frac{jC}{A} = j\frac{B + C}{A} = j2 \tan \psi \qquad \ldots \quad (4)$$

This relation has been derived by Döring and Klein[5], who do not make it clear, however, that the network must be strictly symmetrical. Thus although apparently only two simple measurements are called for, in fact the

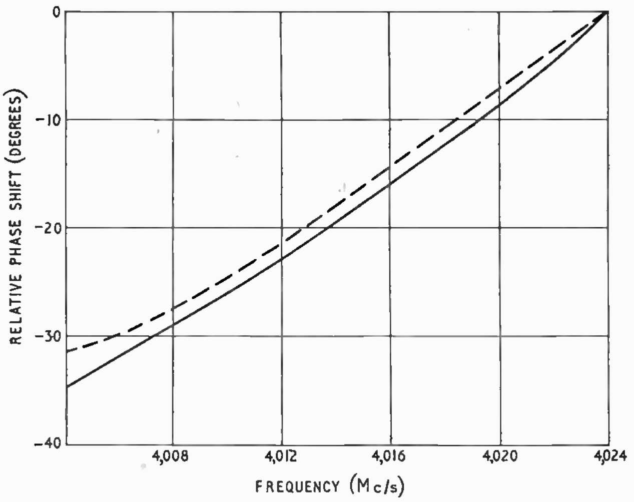


Fig. 2. *Phase shift through a single-cavity filter, 3-dB bandwidth 50 Mc/s centred on 4024 Mc/s. Solid line—measured phase shift; dashed line—computed phase shift*

situation is not so simple. Even assuming a physically strictly symmetrical network the very nature of its being built into a waveguide makes it difficult to find physically two planes of reference equidistant from the axis of symmetry of the network. This can, however, be done electrically by the application of the nodal shift method, as will be seen from the following argument.

Assume that the network is placed within two arbitrary lengths of guide l_1 and l_2 of electrical lengths θ_1 and θ_2, then by repeated matrix multiplication it can be shown that the final matrix is of the form

$$\begin{vmatrix} \alpha & \beta \\ \gamma & \delta \end{vmatrix}$$

where
$$\alpha = A\cos(\theta_1+\theta_2) - B\cos\theta_1\sin\theta_2 - C\sin\theta_1\cos\theta_2$$
$$\beta = j\{A\sin(\theta_1+\theta_2) + B\cos\theta_1\cos\theta_2 - C\sin\theta_1\sin\theta_2\}$$
$$\gamma = j\{A\sin(\theta_1+\theta_2) - B\sin\theta_1\sin\theta_2 + C\cos\theta_1\cos\theta_2\}$$
$$\delta = A\cos(\theta_1+\theta_2) - B\sin\theta_1\cos\theta_2 - C\cos\theta_1\sin\theta_2$$

hence if the output is short-circuited, the input impedance is, by reference to expression (3),

$$Z_{in\ s.c.} = j\frac{A\sin(\theta_1+\theta_2) + B\cos\theta_1\cos\theta_2 - C\sin\theta_1\sin\theta_2}{A\cos(\theta_1+\theta_2) - B\sin\theta_1\cos\theta_2 - C\cos\theta_1\sin\theta_2} \quad \ldots \quad \ldots (5)$$

Since the circuit is lossless $Z_{in\ s.c.}$ must be zero at some values of θ_1 and θ_2, and these are given by

$$A\sin(\theta_1+\theta_2) + B\cos\theta_1\cos\theta_2 - C\sin\theta_1\sin\theta_2 = 0 \quad \ldots \quad \ldots (6)$$

If one now plots θ_1 against θ_2 (i.e., the distance from input reference plane to a voltage minimum on the generator side of the network against the distance from output reference plane to the short-circuit at the other side of the network) then one obtains a curve of the type shown in Fig. 1. This is a typical nodal shift curve discussed by Weissfloch and others[1,2,3,4].

Two important points emerge from this: The first is that if points P and Q in Fig. 1 denote respectively the minimum and maximum slope of the curve, then θ'_1 and θ''_2 and also θ''_1 and θ'_2 are equidistant from the axis of symmetry. Secondly, the slope and scale of the curve remains unchanged if the reference planes are shifted. The points P and Q lie on the intersection of the curve with a line inclined 45° to both axes and set midway between the two tangents to the curve.

In practice it is rarely possible to have access to planes such as OO and instead one has to work with arbitrary planes of reference such as O_x and O_y which may not be equidistant (electrically) from OO. Nevertheless, due to the characteristics of the nodal shift curve the respective co-ordinates of the points P and Q [i.e., y_1 and x_2 as well as y_2 and x_1 (referred to O_x and O_y)] must be equidistant from the axis of symmetry of the network. Hence by shifting the reference plane O_x through a distance $(x_1 - y_2)$ to O'_x one ends up with two planes of reference O'_x and O_y within which the network is symmetrical, and one can now proceed to find the phase-shift by the method given by Döring and Klein. It is clear that the phase-shift thus found, apart from the inherent uncertainty of an integral number of 180°, is not strictly that through the network alone, since the waveguide between OO and O'_x O_y adds to it, but in practice one is concerned with relative phase-shift only, and primarily with the change in phase-shift due to change in frequency, and this is very small for a short length of waveguide and relatively small frequency change:

$$\delta\theta = \theta\left(\frac{\lambda_g}{\lambda_0}\right)^2\frac{\delta f}{f}$$

so that a negligibly small error is introduced in computing the group delay.

However, once the planes O'_x and O_y have been established it is no longer necessary to follow the method of Döring and Klein, since the point P is now at a distance y_2 from O'_x and it follows from the characteristics of the nodal shift curve that y_1 and y_2 are separated by 90°, hence the co-ordinates of P are

$$y = y_1 = \theta_a$$
$$x' = y_2 = \theta_b = \theta_a + 90$$

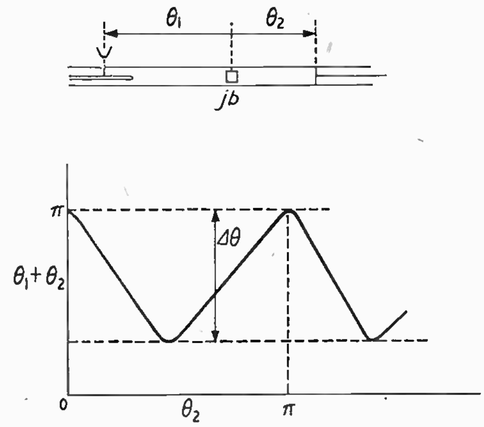


Fig. 3. *Nodal shift curve after Meinke*

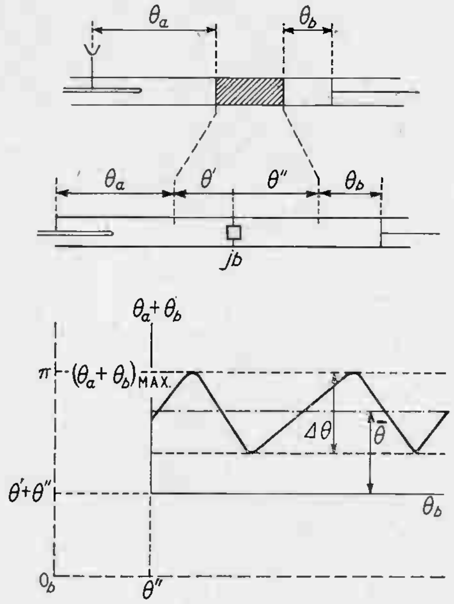


Fig. 4. *Nodal shift relations in the equivalent circuit*

$\theta'' + \theta' = \pi - (\theta_a + \theta_b)$

$\tan \frac{\Delta\theta}{2} = \frac{b}{2}$

Now these co-ordinates refer to a symmetrical network, hence they must satisfy expression (6) thus

$$A' \sin(\theta_a + \theta_b) + B' \cos\theta_a \cos\theta_b - C' \sin\theta_a \sin\theta_b = 0$$

where the matrix of the network between O'_x and O_y is given by

$$M' = \begin{vmatrix} A' & jB' \\ jC' & jA' \end{vmatrix}$$

Hence

$$-A' \cos 2\theta_a + \frac{B'}{2} \sin 2\theta_a + \frac{C'}{2} \sin 2\theta_a = 0$$

or $$\frac{B' + C'}{2A'} = \frac{1}{\tan 2\theta_a}$$

but by expression (4) the phase-shift between the planes O'_x and O_y is

$$\psi' = \left(\tan^{-1} \frac{B' + C'}{2A'}\right) \pm n\pi$$

hence

$$\psi' = \left(\tan^{-1} \frac{1}{\tan 2\theta_a}\right) \pm n\pi$$

thus one can determine ψ' as soon as the nodal shift curve has been plotted without any further analysis beyond finding the electrical distance from the plane of reference to the voltage minimum corresponding to the minimum slope of the curve; i.e., $y_1 = \theta_a$. Of course, if the plot of the nodal shift curve does not extend to include the point P but only point Q, then one can still determine y_1 since $y_1 = y_2 \pm 90°$.

Using this method the relative phase-shift has been measured through a single-cavity post filter having Q of 80°, centre frequency 4,024 Mc/s. The result is plotted in Fig. 2, which also shows the relative phase-shift computed on the basis of measured susceptance of the posts making up the cavity.

Phase-Shift Through Arbitrary Lossless Wave-guide Networks

The limitation of the above-described method to symmetrical networks is a serious one and demands further analysis.

Consider a shunt susceptance jb placed within two sections of waveguide of electrical lengths θ_1 and θ_2 where b is positive.

The matrix of the equivalent circuit is

$$\begin{vmatrix} p & q \\ r & s \end{vmatrix}$$

where $p = \cos(\theta_1 + \theta_2) - b \sin\theta_1 \cos\theta_2$,

$$q = j[\sin(\theta_1 + \theta_2) - b \sin\theta_1 \sin\theta_2]$$

$$r = j[\sin(\theta_1 + \theta_2) + b \cos\theta_1 \cos\theta_2]$$

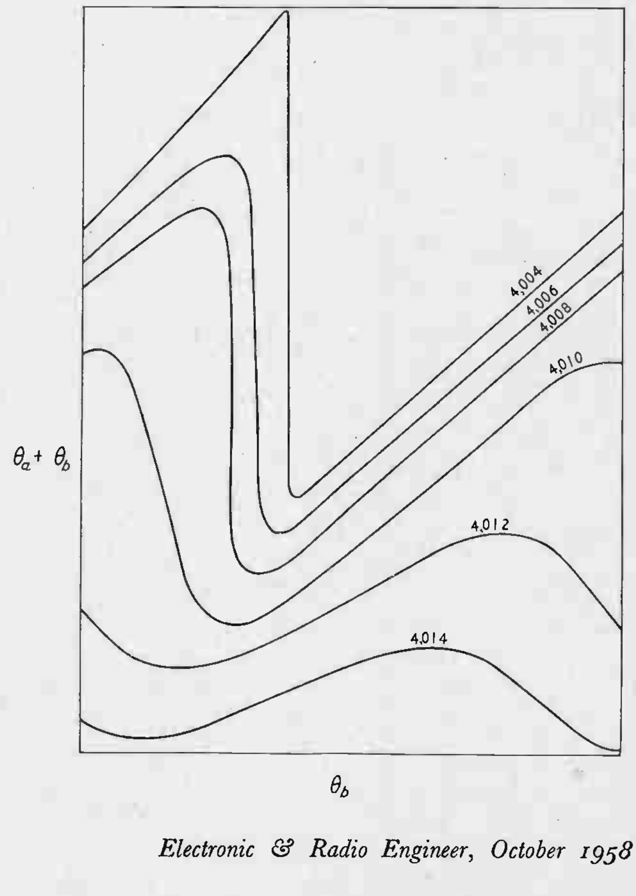
$$s = \cos(\theta_1 + \theta_2) - b \cos\theta_1 \sin\theta_2$$

Let a short-circuit be placed at the right-hand end of the guide, then, by reference to expression (3), the input impedance

$$Z_{in\ s.c.} = j \frac{\sin(\theta_1 + \theta_2) - b \sin\theta_1 \sin\theta_2}{\cos(\theta_1 + \theta_2) - b \cos\theta_1 \sin\theta_2}$$

Let θ_1 and θ_2 be such that as a result of the short-circuit at the output end θ_2 degrees from the shunt susceptance a minimum occurs at the input end θ_1 degrees from the susceptance (i.e., $Z_{in\ s.c.} = 0$) hence

Fig. 5. *Nodal shift curves obtained with a 5-cavity filter*



$$\sin(\theta_1 + \theta_2) - b \sin\theta_1 \sin\theta_2 = 0$$

or
$$\frac{\sin\theta_1 \cos\theta_2 + \cos\theta_1 \sin\theta_2}{\sin\theta_1 \sin\theta_2} = b$$

i.e.,
$$\cot\theta_1 + \cot\theta_2 = b$$

or
$$\cot\theta_1 = b - \cot\theta_2$$

Now

$$\tan(\theta_1 + \theta_2) = \frac{\tan\theta_1 + \tan\theta_2}{1 - \tan\theta_1 \tan\theta_2} = \frac{\cot\theta_1 + \cot\theta_2}{\cot\theta_1 \cot\theta_2 - 1}$$

Substituting for $\cot\theta_1$, we get eventually

$$\tan(\theta_1 + \theta_2) = \frac{b \sin^2\theta_2}{b \sin\theta_2 \cos\theta_2 - 1}$$

$$= \frac{b(1 - \cos 2\theta_2)}{b \sin 2\theta_2 - 2}$$

This has been fully treated by Meinke[6], who, having arrived at these results by a different approach, has shown that remembering that a half wavelength of guide can be arbitrarily added or subtracted without change of performance the graph of $\theta_1 + \theta_2$ against θ_2 is as shown in Fig. 3 (for $b > 0$), also the difference between minimum and maximum of the curve is given by $\tan \Delta\theta/2 = b/2$

Now the total phase-shift through the circuit of Fig. 3 is by expression (1)

$$\tan\psi = \frac{2\sin(\theta_1 + \theta_2) + b\cos(\theta_1 + \theta_2)}{2\cos(\theta_1 + \theta_2) - b\sin(\theta_1 + \theta_2)}$$

or
$$\psi = \theta_1 + \theta_2 + \tan^{-1}\frac{b}{2}$$

$$= \theta_1 + \theta_2 + \frac{\Delta\theta}{2}$$

which is the basis of the measurement of phase-shift. Any two-port waveguide component can be represented at one frequency by an equivalent shunt susceptance within two lengths of waveguide. If a short-circuit were placed in the waveguide following the component and the position of a minimum observed in the guide preceding the component then by looking at Fig. 4 it is obvious not only that the graph of $\theta_a + \theta_b$ against θ_b will be of the same form as that given in Fig. 3, but also the total phase-shift through the equivalent network between the minimum and the short-circuit must be given by $\psi' = \theta_a + \theta' + \theta_b + \theta'' + \Delta\theta/2$ which must be true everywhere hence also at $(\theta_a + \theta_b)_{max}$ whereas the total phase-shift through the network itself is

$$\psi = \theta' + \theta'' + \frac{\Delta\theta}{2}$$

Now since the maximum of the curve in the co-ordinate system referred to a plane through jb $(b > 0)$ must be π which in the actual case corresponds to $(\theta_a + \theta_b)_{max}$ it follows that

$$\theta' + \theta'' + (\theta_a + \theta_b)_{max} = \pi$$

hence

$$\psi = \pi - (\theta_a + \theta_b)_{max} + \frac{\Delta\theta}{2}$$

$$= \pi - \left[(\theta_a + \theta_b)_{max} - \frac{\Delta\theta}{2}\right] = \pi - \overline{\theta}$$

The meaning of $\overline{\theta}$ is explained in Fig. 4 as the median of the curve. Thus to measure the phase-shift between any arbitrary terminals at either end of a network one has to measure the position of a short-circuit and the corresponding minimum with respect to these terminals at any frequency at which phase-shift is to be found. Those two distances are then added to the median of the sum estimated by calculation or graph and, after converting it to degrees, subtracted from 180°, giving the desired phase-shift but for an inherent uncertainty of an integral number of 180°. Fig. 5 gives the results of measurement on a five-cavity $3\lambda_g/4$ coupled filter and Fig. 6 gives the relative phase-shifts of three- and five-cavity filters as measured and also in case of the three-cavity filter as computed from measured values of filter susceptances and coupling sections.

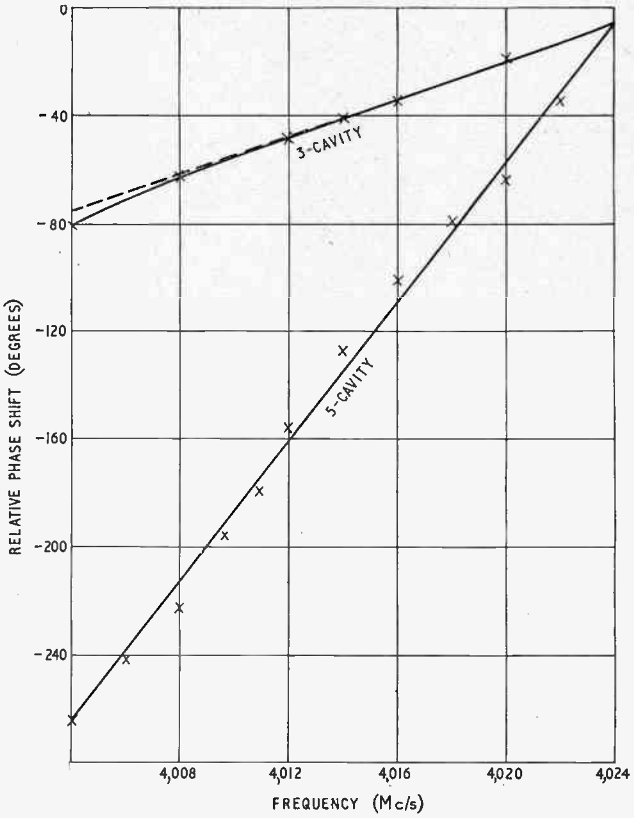


Fig. 6. Phase-shift through 3 and 5-cavity filters designed for 20-Mc/s bandwidth centred on 4024 Mc/s. Solid line—measured phase-shift; dashed line—computed phase-shift

It will be noted that the accuracy of the measurement is primarily dependent on the stability of the signal source which has not only to be kept constant within 100 kc/s or so for the duration of one test taking some fifteen to thirty minutes, but if one should want to derive from the phase-shift the group delay accurately the frequency must be known to within better than 100 kc/s. Of course, one must also be able to measure accurately the position of the short-circuit and the minimum on the slotted section, but here surprisingly accurate and repeatable results can be obtained with commonly used laboratory gear.

The fact that the network need not be symmetrical makes this method superior to that described previously. It will be noted that the three- and five-cavity filters measured have been designed as symmetrical, but because of manufacturing tolerances and need to tune the cavities by auxiliary screws while the signal is swept through the frequency range of interest the filters are not in fact symmetrical, as is soon found by reversing them and repeating the measurements. Thus the measurement based on the earlier method may lead to a serious error.

Conclusions

The above analysis shows that it is possible to measure accurately if laboriously the phase-shift through any lossless waveguide networks by the nodal shift method. From the knowledge of phase-shift one can compute the group delay, which is of great interest in the application of microwaves to communication.

The author wishes to thank Mr. J. J. Rudolf, Chief Microwave Engineer of Messrs. Pye Telecommunications, for many helpful discussions, and in particular for drawing attention to the work of Meinke.

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Recording Techniques for H.F. Direction Finding

By C. W. McLeish*

SUMMARY. *The need for a means of recording direction-finding waves propagated by the ionosphere is discussed. Graphical recording systems are described which have been used on a twin-channel direction-finder for producing 'bearing indication versus time' and 'bearing indication versus signal-amplitude' records.*

In general, the display or output of a high-frequency direction-finder does not directly indicate the true directions of arrival of received signals. Some interpretation of the display by the observer is usually required before an estimate can be given. The reason for this is, of course, the varying nature of a rough ionosphere, which supports the propagation of long-distance transmission[1,2]. Each primary mode of transmission supports a bunch of rays distributed in azimuth, phase, and amplitude, so that a complex interference pattern results at the ground. The direction of arrival of this bunch of rays can be determined to a given accuracy, either by a short observation over a wide aperture, or by a long observation with a narrow-aperture aerial. The actual times involved depend on the rates of fading which, in turn, are proportional to the rates of physical motion in the ionosphere and the frequency of transmission. The conditions of wave interference have, of course, a much more severe effect on the display when multi-mode propagation is possible.

The Requirement for Recording

An adequate recording system for high-frequency direction-finding is desirable if one is to study in detail the rapid variations in bearing indication of the d.f. display, and to provide an interpretation of them for the benefit of the operator. Slow variations of bearing with time are usually associated with ionospheric layer tilts[3]. In the study of these with a narrow-aperture aerial, in which the rapid variations due to wave interference mask the slow changes due to lateral deviation, a recording system is obviously desirable. Furthermore, if different aerial systems are to be compared under actual receiving conditions, some form of recording must be used to eliminate operator bias.

Fig. 1. *(a) D.f. Display, and (b) scanner output waveform*

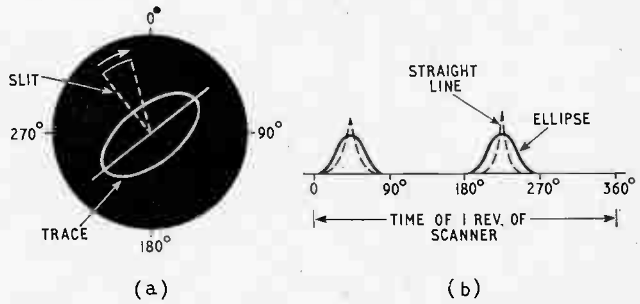

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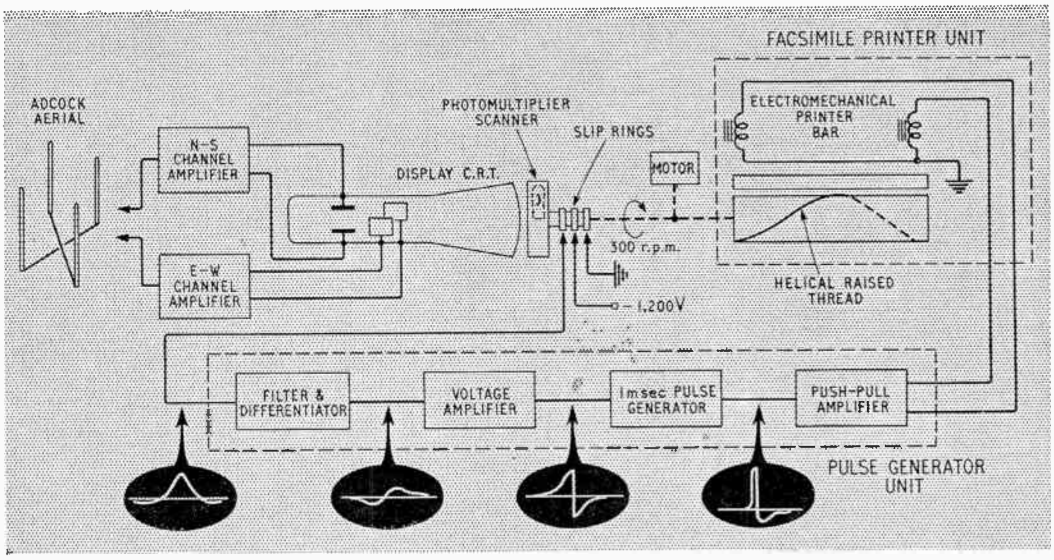
Fig. 2. *Bearing-time paper recording system*



Parameters which may be recorded simply are signal amplitude and indicated bearing. Certain forms of recording are desirable for certain studies, and perhaps a form which would be universally acceptable would be that which supplied the data in a form readily digested by a computer. The present paper, however, describes only some simple forms of graphical recording of the output of a twin-channel direction-finder, which are not particularly well suited to quantitative analysis, but which perhaps may be useful for drawing qualitative conclusions.

Forms of Recording

(*a*) *Bearing versus Time*

The method used is very similar to that described by J. D. Peat[4], who recorded the output of a spinning-goniometer direction-finder, using a facsimile printer. The following system was devised to record similarly the display of a twin-channel cathode-ray direction-finder, which is, in general, an ellipse in the simple case of reception of a single unmodulated carrier. For the sake of simplicity, no attempt has been made to record bearing information which is contained in the complex pattern produced by the combination of several signals of different azimuths and slightly different frequencies. In the present scheme, light from the trace of the display cathode-ray tube reaches a photomultiplier through a sector-shaped slit, rotating in front of the screen at about 300 r.p.m. [Fig. 1(a)]. A pulse, whose sharpness depends on the major-to-minor axis ratio of the elliptical trace, is produced in the final anode of the photomultiplier [Fig. 1(b)]. The azimuth of the major axis of the ellipse may now be measured in terms of a time-varying pulse on a time-base synchronized with the mechanical scanner. The time-base is conveniently generated using the facsimile printer method. A cylinder, having a raised linear spiral thread on its surface, is directly coupled to the shaft of the scanner. Over this cylinder, 8-inch wide recording paper is pulled at a suitable rate. Parallel to the axis of the cylinder, and mounted close to its surface, is an electromechanical printer bar, which marks the paper through a carbon sheet when supplied with a current pulse of at least 1 millisecond duration. Such a pulse is generated from the waveform of Fig. 1 (b) at its peak amplitude. Errors can be caused by uncertainty in the trigger time of the pulse owing to the presence in the circuits of noise and hum. These become significant when the waveform amplitude is low. For instance, when the ellipse ratio is less than 3 :1 or a straight-line trace is shorter than 1 inch (on a 5-in. display) an error of $1^1/_2^\circ$ r.m.s. is possible. Under slightly worse conditions the pulse generator refuses to fire. A further difficulty arises out of the presence of modulation on the received carrier. In the worst case, that of on-off keying, the response curve of Fig. 1(b) may be seriously distorted by the changes of carrier amplitude during a scanning cycle, to the extent that printer responses will have little or no relation to the true azimuth. To reduce this effect, a long-persistence c.r.t. screen is used which provides sufficient afterglow to give a continuous indication of azimuth. A further reduction in the relative effect of modulation may be achieved by simultaneously applying brightening pulses to the c.r.t. and blanking pulses to the photomultiplier, so that only the afterglow pattern is scanned. If the pulses are of short duration, they can easily be filtered from the output waveform. Of course, if variations in azimuth are to be faithfully recorded, the effective persistence time of the c.r.t. screen should not compare with the fading period of received signals, or a form of integration or smoothing will occur.

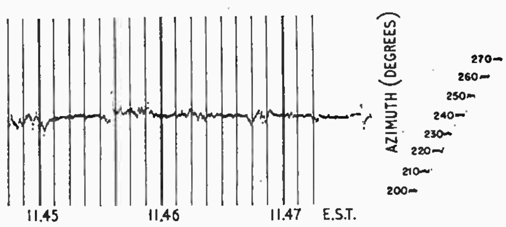


Fig. 3. *Typical bearing-time record of sky-wave transmission on* 6070 *kc/s*

Finally, to reduce the dynamic range, in the photo-

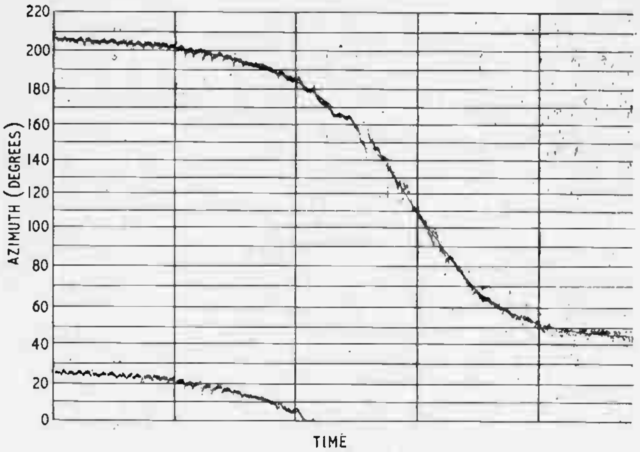


Fig. 4. *Bearing-time record of Russian earth-satellite transmission on 20 Mc/s*

multiplier output, of the c.r.t.-screen brightness which we wish to use, a non-linear resistance element* acts as anode load. The voltage across this element is roughly proportional to the cube root of the anode current. This has been done, of course, at the expense of some sharpness of the output-response curve of Fig. 1(b).

Fig. 2 is a block diagram of the components of the above system. A portion of a record, shown in Fig. 3, has time markers on it which are generated by a clock-operated switch connected to the printer amplifier. Bearing calibrations are put on each record manually by injecting at the input to the d.f. receiver by means of a goniometer, a steady signal at known azimuth steps.

An interesting application of this form of recording arose in connection with the tracking of the first Russian earth-satellite. An example of a record made during one pass close to Ottawa is shown in Fig. 4. The two parallel traces evident on part of the record are the responses from both ends of the ellipse on the bearing display.

(*b*) *Comparison Bearing-Time*

Simultaneous recordings of bearing variations on two direction-finders may be made by switching their i.f. outputs at high speed on to the cathode-ray tube in the scanner. To prevent confusion, the output of one system is rotated 90 degrees so as to separate the displays. Fig. 5 is an example of recorded bearing variations from a four-element Adcock aerial compared with those from an eight-element aerial.

* Thyrite, manufactured by General Electric Co. (U.S.A.)

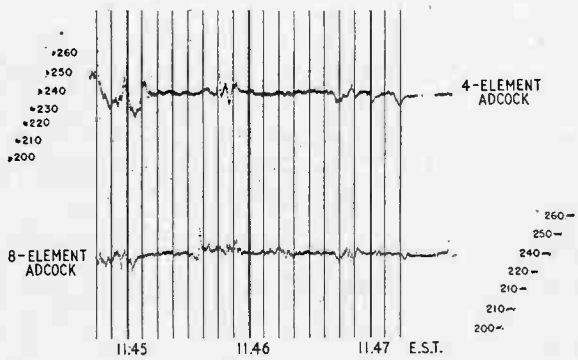


Fig. 5. *Comparison bearing-time record of sky-wave transmission on* 6070 *kc/s*

(*c*) *Bearing versus Amplitude*

A rather striking demonstration of the relation between signal amplitude and bearing wander on a narrow-aperture d.f. aerial is shown in Fig. 6. Over the observation period of 5 minutes in this record, upwards of 1,500 bearing samples are printed (some are lost in deep amplitude fades). The physical arrangement for recording the scatter diagram is the same as that in Fig. 2, with the exception of the paper drive, which is now arranged to position the paper longitudinally, according to the amplitude of an omnidirectional d.c. voltage developed in the d.f. receiver from the combined carrier levels of the two channels

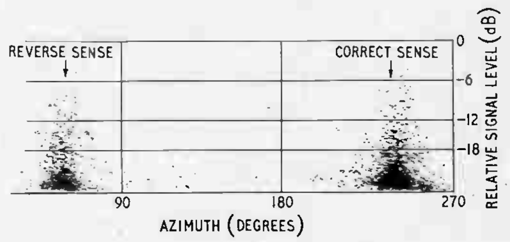


Fig. 6. *Typical bearing-amplitude paper record*

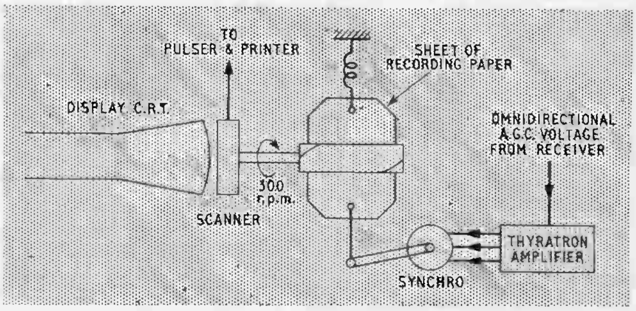


Fig. 7. *Bearing-amplitude paper recording system*

(the a.g.c. voltage). Any number of methods might be used, but a convenient one is to derive linear motion from a radial arm on a synchro, which has its windings excited by d.c.

The current in one winding is controlled by a thyratron bridge rectifier which is in turn controlled by the a.g.c. output from the receiver. A block diagram of the arrangement is given in Fig. 7 and the photograph, (Fig. 8), illustrates the physical construction of the paper recorder.

A disadvantage of the above system is the mechanical inertia of the synchro itself, which limits the response time of the system to about half a second. Therefore, during very rapid fading this method of printing is not

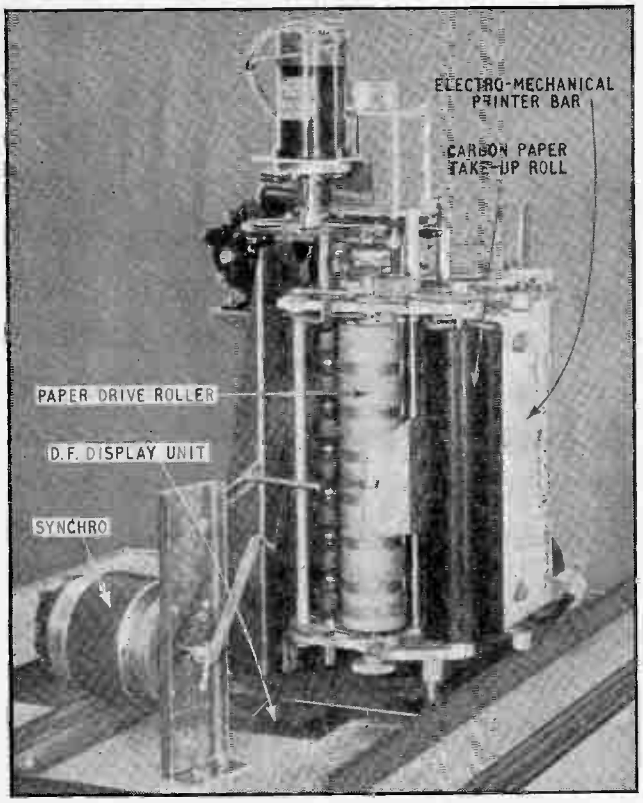


Fig. 8. *Paper recording equipment*

satisfactory. An alternative method is to record photographically from a c.r.t. presentation of the data. This is done as shown in Fig. 9.

Good scatter diagrams have been obtained at the highest fading rates encountered. Fig. 10 is a photographic scatter diagram made on 35-mm film. The azimuth and amplitude scales are calibrated using injection signals of known bearing and level. The lower extension or tail on the example shown is due to the use of a cathode-ray tube screen of too long persistence, which continues to print on the afterglow when the signal fades to very low levels.

(*d*) *Comparison Scatter Diagrams*

Differences in performance of two systems on the same transmission may be more apparent by visual inspection of the scatter diagram than of the bearing versus time records. Because the output amplitudes of the two systems being examined may not be correlated, the mechanically-operated recorder is not suitable to make comparison scatter diagrams, for it would have to operate on the amplitude scale as quickly as it does on the azimuth scales. Recording is therefore done on film using a double-beam d.c. oscilloscope. Both X sweeps are generated by a common linear sweep generator, and the Y deflection is separately controlled on each sweep from the a.g.c. voltage of each direction-finder. Brightening of the traces occurs whenever the major axis of an ellipse is crossed by the scanner, thus producing four separate scatter diagrams in each 180 degrees of rotation. For instance, the top sweep may have a scatter diagram of azimuth of system A versus amplitude of system A, followed in approximately 90 degrees by a diagram of azimuth of system B versus amplitude of system A. The bottom sweep may have the same two azimuth sequences recorded with respect to amplitude of system B. Therefore, for the purposes of inspection and analysis, the two diagrams of interest would be the upper left (A) and lower right (B). Fig. 11 is a record made in this manner in which the uncorrelated sections have been blanked out.

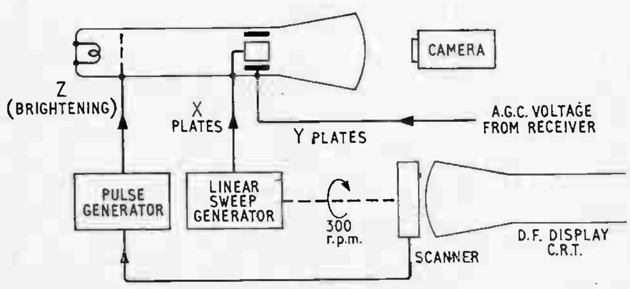


Fig. 9. *Bearing-amplitude photographic recording system*

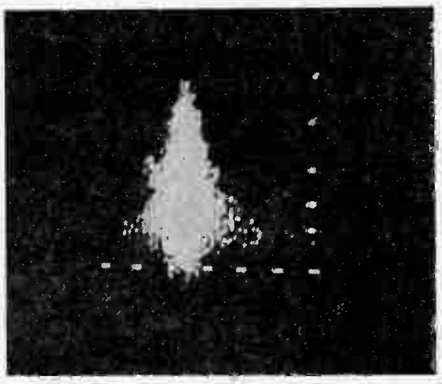
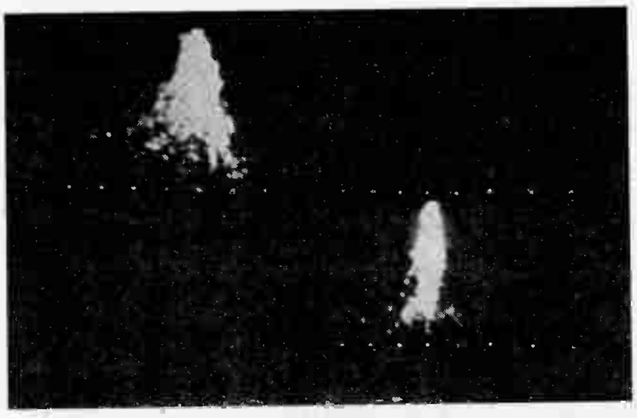


Fig. 10. *Photographic scatter diagram* (10-*minute exposure*)

Fig. 11. *Comparison scatter diagram* (5-*minute exposure*)



Remarks

Although the techniques outlined in this report are not highly refined, it is anticipated that investigations of some of the major effects of abnormal propagation may be carried out using them. Also, a coarse comparison of performance of d.f. aerial systems is possible, using both bearing-versus-time and bearing-versus-amplitude records. The conversion of the twin-channel display into a time-varying pulse, which has been accomplished, will enable further extension of the recording technique to produce more directly usable data.

Acknowledgement

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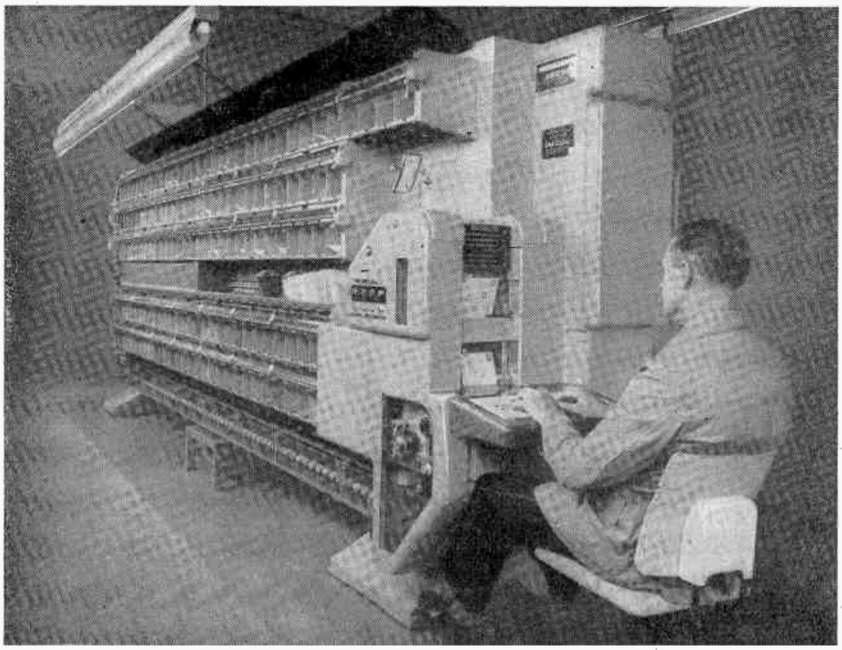


Mechanized Letter Sorting

ELECTROMECHANICAL MACHINE WITH ELECTRONIC MEMORY

The first of the twenty electronic letter-sorting machines ordered by the Post Office for extended trials throughout the United Kingdom has now been delivered.

An operator will be able to sort letters on these machines very much faster than by hand, with the added advantage that letters can be directed into 144 separate boxes as against the usual 48 associated with manual sorting.

The speed of sorting is entirely under the control of the operator. A skilled operator can deal with 70 letters a minute. Although the machine has a cycle time rhythm, the operator can work at his own speed and the machine automatically compensates and adjusts the timing to synchronize as necessary.

Letters are automatically fed to a viewing window. The operator notes the destination and then presses one of 12 keys with his left hand and one of a similar group with his right hand. The letter is then automatically moved into a 'waiting' compartment and the next letter comes into the reading position. While a letter is in the 'waiting' compartment, its destination is stored electronically and, if the operator considers that he has misread the address, he can cancel his previous keying by pressing a cancel key. This causes the letter to be delivered to a special box.

The main store of the machine is a 12 by 12 matrix of cold-cathode trigger tubes, operated by coincident signals after the manner of a ferrite memory matrix. However, in order to provide for the operator working at random speed, temporary stores are interposed between his keyboard and the matrix. The arrangement is shown in Fig. 1. There are three temporary stores. When the operator presses his keys, two cold-cathode tubes in the first store (one for each hand) are struck. The machine presents another letter to the operator and, at the same time, transfers the information to the second store. As the main timing shaft of the machine revolves, the information is transferred to the third store, the original letter passes to the conveyor belt of the machine, and the information from the third store goes to the matrix.

It will be seen that the operator can deal with three

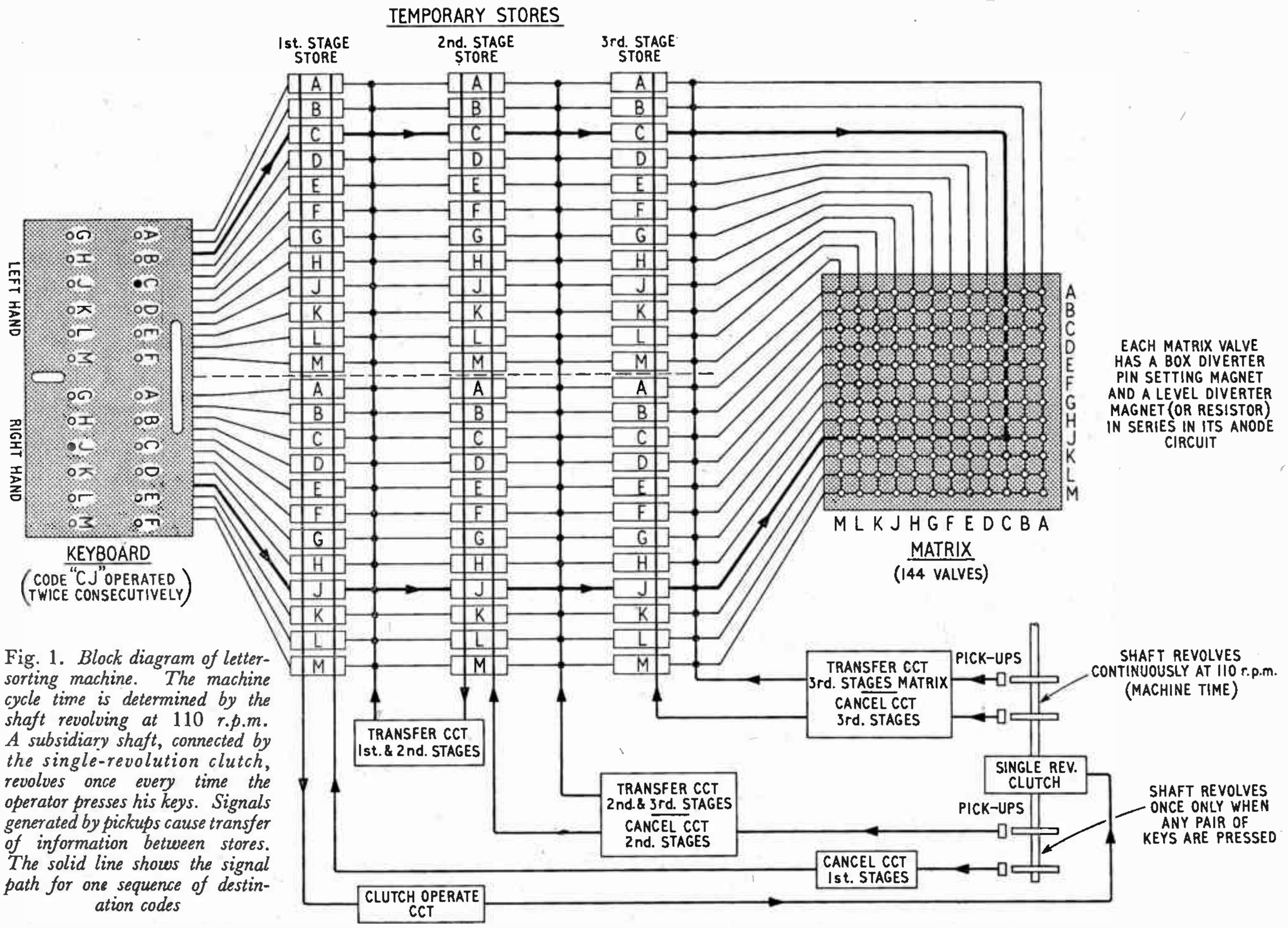


Fig. 1. *Block diagram of letter-sorting machine. The machine cycle time is determined by the shaft revolving at 110 r.p.m. A subsidiary shaft, connected by the single-revolution clutch, revolves once every time the operator presses his keys. Signals generated by pickups cause transfer of information between stores. The solid line shows the signal path for one sequence of destination codes*

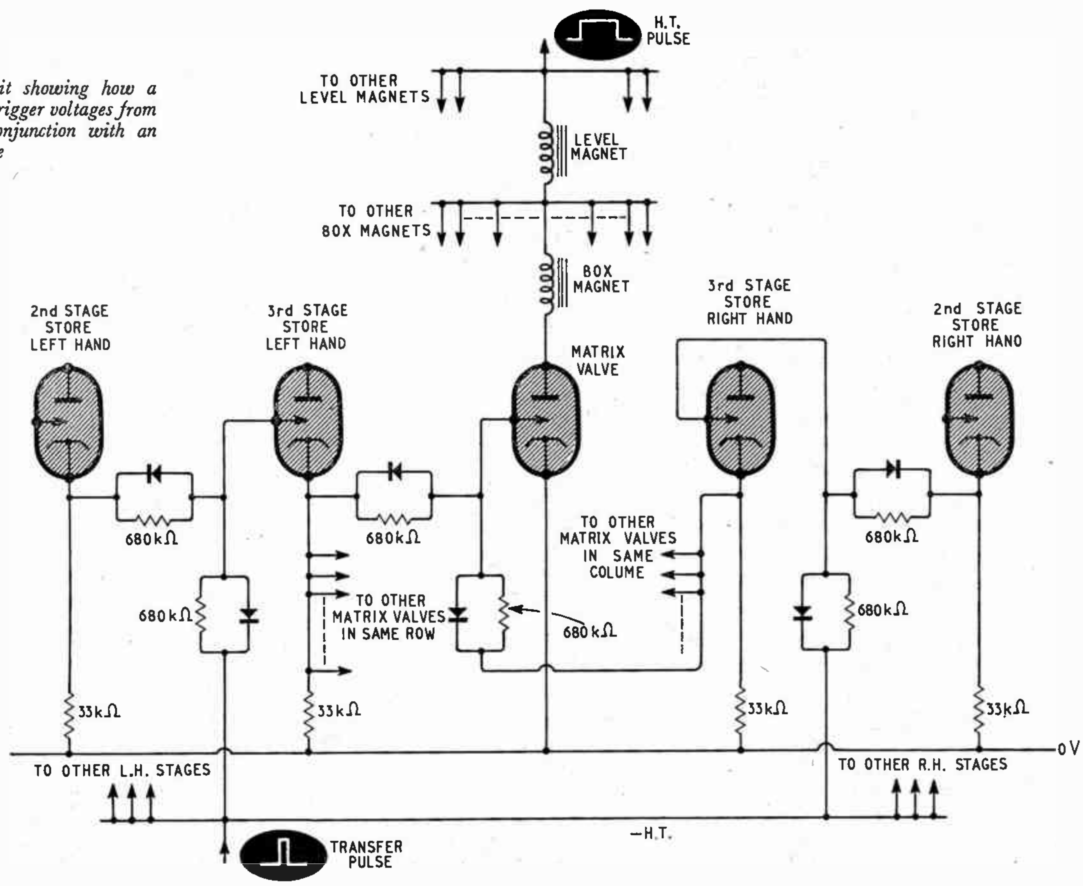


Fig. 2. *Simplified circuit showing how a matrix tube is operated by trigger voltages from the temporary stores in conjunction with an h.t. pulse*

D

letters before the machine takes over the first. It is therefore of no importance if he codes two successive destinations more rapidly than is allowed for by the machine's mechanical rate of working (120 letters per minute), nor is he obliged to keep up with the machine's speed. In addition, a reasonable amount of time is allowed for correcting errors.

The link between the matrix store and the mechanical part of the machine is made by means of electromagnets which are energized by the anode currents of the matrix valves. The way in which a letter is guided to the appropriate box is as follows: the 144 boxes are divided into five 'levels', with appropriate branchings in the conveyor system. It is necessary, therefore, to divert a letter mechanically to the appropriate level as well as open the appropriate box. Each matrix valve, therefore, has two electromagnets in its anode circuit, one to operate a level-diverter and one to set the box-opening mechanism. The level-diverter magnets are, of course, common to other matrix valves.

It will be appreciated that the time taken for a letter to reach its box will vary according to the position of the box along its 'level'. Information about the box must therefore be retained by the machine for varying periods. The time of storage in the electronic memory, however, is governed by the machine cycle time. Thus, the mechanical part of the system must also serve as a memory.

Each letter-box is opened by a kind of cam which takes the form of a pin which passes through a rotating disc near the latter's periphery and projects from it. The pins can be moved in or out. In one position, they operate the box-opening mechanisms and, in the other, they do not. Each box has its disc or pin wheel, which carries many pins. The pins pass an electromagnet which moves the particular pin aligned with it when it is energized by a matrix valve. Once a pin has been set, it functions as a mechanical memory device, eventually opening the box as the shaft carrying the pin wheel rotates. This takes care both of the necessity to have a variable-length memory and also the situation which arises when a letter destined for a distant position on a level must pass over a box which has to be opened for the next letter sorted, the latter's code address having been fed into the machine by the operator. The spacing of the box-opening pins is arranged so that a box can be opened immediately a distant letter has got clear of it and in time for a closely-following letter to fall in.

It is necessary for mechanical reasons that a pin is in exact alignment with a pin-setting magnet before the latter is operated. The magnets are therefore allowed to operate only at discrete points in the machine cycle. This is simply arranged by supplying high-tension voltage to the matrix valves in pulses, a pulse being generated at the appropriate instant. A matrix valve must therefore receive three operating voltages (Fig. 2), two on its trigger and one on its anode, before it can fire.

The machine was developed from a Post Office prototype by the Thrissell Engineering Co. Ltd., of Bristol, and the electronic parts are due to Electronic Instruments Ltd., of Richmond, Surrey.

Dynamic Conductance Meter

By M. R. Barber, B.Sc., B.E.(Hons), and A. G. Bogle, B.E.(Hons), D.Phil., M.I.E.E.

SUMMARY. *The negative conductance, for small excursions of voltage and current, of the screen circuit of a transitron-connected pentode (EF50) has been found to vary linearly with cathode current over a useful range. This fact has been used as the basis of an instrument giving direct indication of the dynamic conductance of a resonant circuit. Although the transitron is capable of oscillation at frequencies up to 30 Mc/s, the utility of the instrument for conductance measurement appears to be limited by the inherent capacitance of the circuit to frequencies below about 1·5 Mc/s.*

In a previous paper[1] one of the authors has described experiments showing that the negative resistance of the screen circuit of a transitron-connected pentode is, with fair approximation, inversely proportional to the cathode current I_k over a useful range of magnitude of negative resistance. Under the conditions of measurement, the negative conductance $(-G)$ of an EF50 valve was found to be within 10% of $0{\cdot}108\ I_k$ mho between 0·0108 millimho and 0·324 millimho.

This property has been used in the instrument described here to provide a direct indication of the dynamic conductance of parallel-resonant circuits. When a resonant circuit is connected in the screen circuit, the transitron oscillates; the oscillatory potential is amplified and rectified and fed back to the control grid of the transitron, automatically adjusting the cathode current to a value just sufficient to maintain oscillation at a small amplitude. Then the dynamic conductance of the circuit is equal to the negative conductance of the transitron and, since this is approxi-

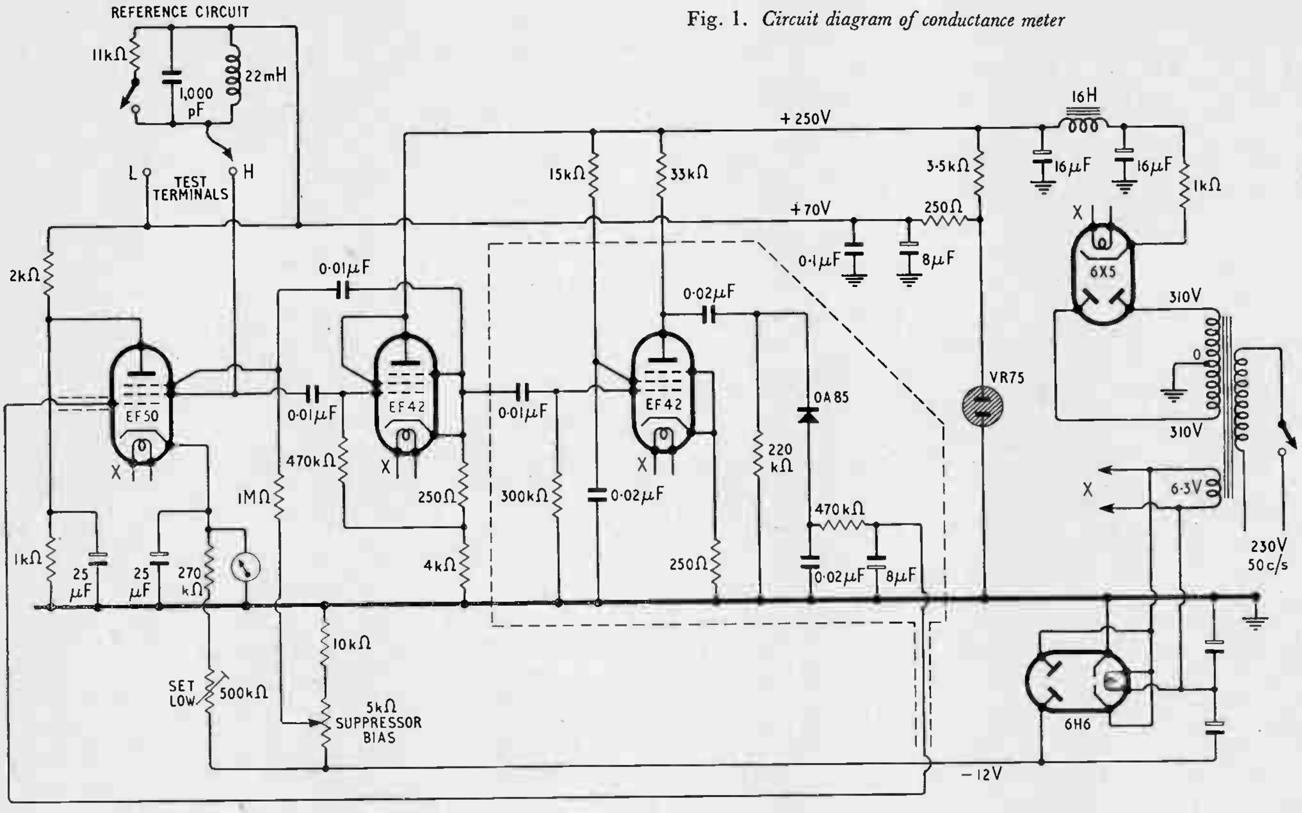


Fig. 1. *Circuit diagram of conductance meter*

mately proportional to cathode current, the cathode-current meter may usefully be calibrated directly in micromhos.

In addition to the negative conductance provided by the screen-voltage–screen-current characteristic of the transitron, the screen circuit unavoidably places across the tuned circuit a positive conductance and also a fairly substantial capacitance. This residual capacitance necessarily limits the maximum frequency at which the negative conductance is useful (although the negative conductance property is present at frequencies up to 30 Mc/s) and the instrument has accordingly been designed for frequencies up to about 1·5 Mc/s.

The Circuit

In the circuit of Fig. 1, the EF50 is operated under approximately the same conditions as those at which the measurements described in the previous paper were made, namely 70 V (stabilized) on the screen, about 23 V on the anode, and adjustable negative supply to the suppressor. Cathode current is measured by a 100-μA meter with a three-range shunt and adjustable sensitivity (Fig. 2).

In an effort to reduce the inherent capacitance and conductance of the instrument, coupling between the screen grid and the suppressor is provided through a cathode-follower, which imposes negligible conductive loading on the screen circuit and reduces the capacitive loading due to the suppressor coupling to about 5 pF. Nevertheless the total capacitance to earth of the screen is about 20 pF, to which the interelectrode capacitance of the EF50 and the capacitances of the valveholder and the wiring contribute.

The same cathode-follower supplies the amplifier, the output of which, rectified by a crystal diode, provides the automatic bias for the EF50 control grid.

Sufficient overall amplification is provided in this arrangement to limit the oscillation to about 0·15 V r.m.s.; i.e., total excursion of about 0·4 V, over which range the screen characteristic may be regarded as linear. It is essential that the amplifier and detector stages be well screened from the oscillator, because it was found that r.f. coupling between the output of the amplifier and the oscillator had the effect of loading the oscillator and causing the conductances indicated at the higher frequencies to be seriously in error.

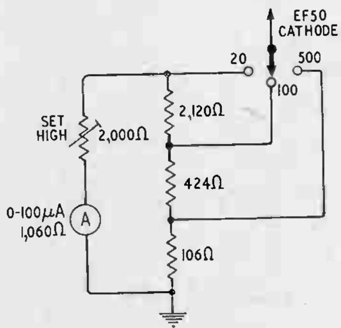


Fig. 2. *Meter and shunt*

Front-panel control of the suppressor bias was found to be necessary, to obtain consistent measurements, since the optimum bias was found to depend to some extent on time and to a larger extent on the magnitude of the conductance being measured. Furthermore, it is usually only at the optimum bias; i.e., that which gives the lowest value of I_k for oscillation, that the oscillation is stable in amplitude; other settings introduce some backlash in the $-G/I_k$ relationship and result in a squegging oscillation.

Calibration

The method of calibration was to use a 400-kc/s resonant circuit loaded with various resistors to obtain a range of conductance values, its dynamic conductance G being determined by a resonance method. The circuit was then connected to the "Test Terminals", and readjusted to 400 kc/s by reducing its shunt capacitance to compensate for the capacitance of the conductance meter. The "Suppressor Bias" control was set to give minimum I_k, and the reading of I_k was recorded for plotting against the corresponding value of G. The meter shunts have been designed to give nominal G ranges of 20, 100 and 500 micromhos for full-scale deflection; by adjusting the meter sensitivity control (Set High) the readings can be made to correspond closely to the true values of G.

When this procedure is followed for an arbitrary setting of the sensitivity control a plot such as curve A in Fig. 3 is obtained. As a calibration this shows two types of error. The slope of the line is not unity, and the line does not pass through the origin. Adjustment of the sensitivity control corrects the slope, as shown in curve B. This line still does not pass through the origin: its intercept on the G nominal axis indicates the inherent positive conductance of the meter. To eliminate this source of error a backing-off current is fed through the meter from the negative bias line through another adjustable control (Set Low). With correct setting of this control, a line such as C is obtained, which evidently indicates useful accuracy of measurement over a good range of G.

To avoid relying on such a protracted method of checking calibration a built-in reference circuit is used, consisting of a high-Q 22-mH inductor and a 1000-pF capacitor, with an 11-kΩ shunt resistor controlled by a switch. After careful calibration as above, the readings for this reference circuit with the switch open and the switch closed are found. Then, for subsequent checks, it is only necessary to adjust "Set Low" with the reference circuit without its 11-kΩ shunt, and to adjust "Set High" with the 11-kΩ shunt until both high and low readings are correct.

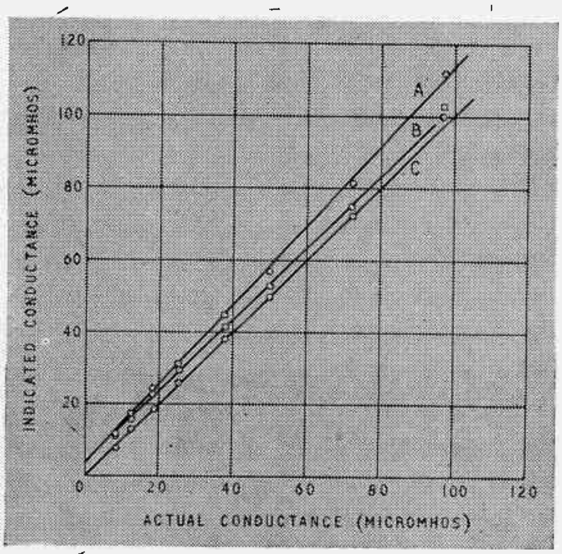


Fig. 3. *Calibration at 400 kc/s*

Fig. 4 shows a check plot of conductance measurements made at 1·4 Mc/s after the meter had been set up in this way.

Use of Instrument

The utility of the instrument is limited to those situations and frequencies where a shunt capacitance of 20 pF

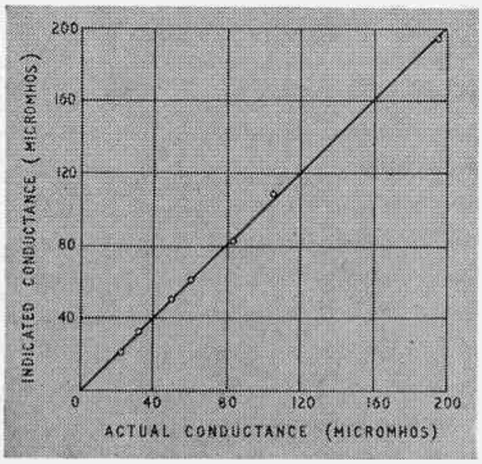


Fig. 4. *Calibration check at 1·4 Mc/s*

is tolerable. Also, since the result of the measurement is the dynamic conductance, the Q-value $(= 1/\omega LG)$ is obtainable only indirectly, requiring two frequency measurements with different tuning capacitances in order to avoid errors due to the self- and stray-capacitances of the coil and circuit. The accuracy of measurement appears to be of the same order as that normally expected from Q-meters, but the latter are much more convenient to use when it is the Q-value that is required. However, a useful application would be in routine comparative tests of nominally equal inductors for inductance and Q. Using a fixed tuning capacitor the oscillation frequency is a sensitive indication of the inductance, and the dynamic conductance is a satisfactory comparative indication of Q.

Conclusion

An instrument has been developed which provides direct and rapid indication of dynamic conductance of tuned circuits at frequencies up to about 1·5 Mc/s, from which can be deduced the Q of inductors, dielectric losses of components, and variation of resistance of resistors with frequency. The results of measurement are not in notably convenient form, but within its limitations the instrument appears to have useful possibilities.

REFERENCE

A. G. Bogle, "Transitron Negative Resistance", *Electronic and Radio Engineer*, May 1957, p. 170.

Correspondence

Letters to the Editor on technical subjects are always welcome. In publishing such communications the Editors do not necessarily endorse any technical or general statements which they may contain.

Simple Phase Shifter

SIR,—A well-known phase-adjusting circuit[1] consists of a resistance R and a capacitance C in series connected across a source of balanced voltage. The latter may be a single-valve concertina phase-splitter of the type shown in Fig. 1.

R_1 is absent in the normal form of the phase shifter. As R is altered from an infinite value to zero, a simple analysis indicates that, *with respect to the voltage e applied across the phase shifter*, the phase of the output voltage e_0 varies over a range from 0° to 180°, the amplitude remaining at $|e|$. The words in italics are significant because as R is reduced from an infinite value to zero, due to the loading effect of C, in addition to slight amplitude variations, the phase of e with respect to e_g alters by an amount δ so that the useful range of phase shifts is only from 0° to (180° − δ). It can be easily shown that, at the frequency f, δ is given by

$$\delta = \arctan \frac{4\pi r\, r_p f C}{r_p + (\mu + 2)r},$$

where r_p and μ are respectively the anode resistance and amplification factor of the valve. For one-half of a 6SN7, with $C = 0{\cdot}02\ \mu$F, $r = 2$ kΩ, $r_p = 7{\cdot}7$ kΩ, $\mu = 20$, the values of δ at frequencies 10^2, 10^3, 10^4, and 10^5 c/s, are respectively 0° 26′, 4° 17′, 36° 49′ and 82° 24′. For a given amplifier at a particular frequency, the value of δ can no doubt be reduced by reducing the value of C. But this will necessitate a corresponding increase in the value of R_{max} to get the same minimum value of phase shift, 2 arctan $(1/2\pi f C R_{max})$.

It is suggested that by the use of an additional variable resistance R_1 in the arm containing C (as shown in the figure) which is kept at zero until R has been reduced to zero and is then increased to a large value, the amplifier may be 'unloaded' and thus the phase deficit from (180° − δ) to 180° recovered. (Actually, a single potentiometer in conjunction with a s.p.d.t. switch can serve as both R and R_1.)

Experiments have shown the method to be quite effective. The modification may be of particular utility when a phase shifter is being employed for a wide range of frequencies. It may be added

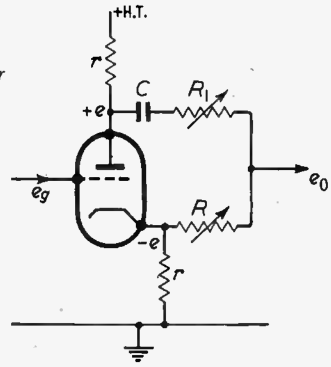


Fig. 1. *Modified RC phase shifter*

that the procedure may also be adopted in other types of phase shifters[2,3] where such loading difficulties are encountered.

I am grateful to Prof. R. S. Krishnan and Dr. G. Suryan for guidance and encouragement.

Physics Department,
Indian Institute of Science,
Bangalore 3, South India.
20th August 1958.

R. CHIDAMBARAM.

REFERENCES

[1] O. S. Puckle, "Time Bases", Chapman and Hall, London, 1955, p. 369.

[2] J. W. R. Griffiths and J. H. Mole, "Phase-Adjusting Circuits", *Electronic and Radio Engr*, 1957, Vol. 34, p. 26.

[3] W. G. Shepard, "Phase Shifter Range Exceeds 180°", *Electronics*, 9th May, 1958, Vol. 31, p. 96.

New Books

Dilogarithms and Associated Functions

By L. LEWIN, A.M.I.E.E. Pp. 353 + xvi. Macdonald & Co. (Publishers) Ltd., 16 Maddox Street, London, W.1. Price 65s.

The title name 'dilogarithm' is given to an expression which is more closely related to 'natural' logarithms (to base e) than is at first obvious. It is well known that

$$-\log_e (1-z) = \frac{z}{1} + \frac{z^2}{2} + \frac{z^3}{3} + \text{-----} + \frac{z^k}{k} + \text{---} \text{ to infinity} \quad (1)$$

provided that the modulus of z is less than unity. The functions studied (and tabulated) in this book are associated with the series

$$\mathrm{Li}_n(z) = \frac{z}{1^n} + \frac{z^2}{2^n} + \frac{z^3}{3^n} + \text{---} + \frac{z^k}{k^n} + \text{---} \text{ to infinity} \quad .. \quad (2)$$

(when the modulus of z is less than or equal to unity) with particular reference to the case when $n = 2$. The name 'dilogarithm' is suggested by the fact that

$$\mathrm{Li}_2(z) = \int_0^z \frac{dt}{t} \int_0^t \frac{dx}{1-x} \quad .. \quad .. \quad .. \quad .. \quad .. \quad (3)$$

and Equ. (3) is not restricted to the case when $|z| \leqslant 1$.

Although the author is head of the Microwave Department, Standard Telecommunications Laboratories, the book was mainly written because he enjoyed investigating the mathematical properties of these and related functions. The reviewer shares the view that interesting mathematical functions are worth investigating for their own sake, and the author has neatly welded together a remarkable collection of identities and properties of these functions, which were first investigated as far back as 1809. The author has done his best to introduce a self-consistent notation, when each of the early authors had a different notation. But from the point of view of readers of *Electronic & Radio Engineer* the question must be asked: What is the use of studying such functions ? The point is that expressions which arise in practical problems (e.g., network problems) can often be expressed as finite combinations of the functions tabulated in this book. It is therefore a book which should be made available in libraries, so that specialists in various fields can become aware that their problem may be one of many on which the study of dilogarithms throws new light, especially where detailed numerical calculation is required. At the same time it is not a book which can be of much help to the engineer who dislikes mathematics and avoids the subject as much as possible. Perhaps there should be at least one person in any large research organization who is 'sound' on dilogarithms; he can then do much to lighten the labours of his colleagues.

J.W.H.

Communications and Electronics Buyers' Guide, Who's Who and Reference Book

Edited by C. C. GEE. Pp. 520. Heywood & Co. Ltd., Drury House, Russell Street, London, W.C.2. Price £5 5s.

Contains three main sections: a buyers' guide, a who's who, and a reference section. The buyers' guide contains a classified index of products, indexes of trade names, manufacturers, Government departments, and establishments, professional, trade and research organizations, and education centres. There is also a section showing the geographical distribution of manufacturers (by counties and large towns). The major part of the reference section is given to classified lists of particular types of products.

Electrostatics

Edited by ALEXANDER SCHURE, Ph.D., Ed.D. Electronic Technology Series No. 166–17. Pp. 64. Price $1.35.

Impedance Matching

Edited by ALEXANDER SCHURE, Ph.D., Ed.D. Electronic Technology Series No. 166–23. Pp. 119. Price $2.90.

Basics of Digital Computers

By JOHN S. MURPHY. Vol. 1: pp. 116; Vol. 2: pp. 133; Vol. 3: pp. 136. Price per volume $2.50, set of three $6.95, all three volumes in single cloth binding $7.95.

An elementary non-mathematical 'picture-book' course on digital computing systems.

The above are published by John F. Rider Publisher Inc., 116 West 14th Street, New York 11, U.S.A.

MEETINGS

I.E.E.

9th October. Presidential address by S. E. Goodall.

13th October. "The Rationalization of the Avenues of Higher Education for Electrical Engineers", discussion to be opened by the President.

20th October. "The Presentation of Electrical Science in Schools", discussion to be opened at 6 o'clock by G. R. Noakes.

22nd October. "Random Thoughts of a Propagation Engineer", by G. Millington.

27th October. "Rating of Speech Links and Performance of Telephone Networks" and "Assessment of Speech Communication Links", by Dr. J. Swaffield and D. L. Richards.

28th October. "Electronic Control of Machine Tools", discussion to be opened by D. T. N. Williamson.

4th November. "Operating Experience with a Transistor Digital Computer," by R. C. M. Barnes and J. H. Stephen. "A New High-Speed Digital Technique for Computer Use," by D. Eldridge.

These meetings will be held at the Institution of Electrical Engineers, Savoy Place, Victoria Embankment, London, W.C.2, and will commence at 5.30, *except where otherwise stated.*

Brit. I.R.E.

29th October. "Computers and Ferro-Electric Storage", by M. Prutton, Ph.D., to be held at 6.30 at the London School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, London, W.C.1.

The Television Society

24th October. "The Present Position of Amateur Television", by J. Royle, to be held at 7 at the Cinematograph Exhibitors' Association, 164 Shaftesbury Avenue, London, W.C.2.

B.S.R.A.

17th October. "Use of White Noise in Audio Testing", by J. Moir, to be held at 7 at the Royal Society of Arts, John Adam Street, Strand, London, W.C.2.

The Society of Instrument Technology

20th October. "A Simple Data Read-Out System", by G. P. Tonkin and J. B. Bownas.

28th October. "Basic Measurements of Time and Frequency", by Dr. L. Essen.

These meetings will be held at 6 *o'clock at Manson House, Portland Place, London, W.*1.

U.S.A. SYMPOSIUM ON RELIABILITY

The 5th National Symposium on Reliability and Quality Control in Electronics will be held on 12th, 13th and 14th January 1959, at the Bellevue-Stratford Hotel, Philadelphia Pa., U.S.A. Although this annual event has hitherto contained papers almost exclusively of U.S.A. origin, the organizing committee is anxious to make it clear that papers from outside the U.S.A. will be most welcome.

Mr. R. Brewer of Research Laboratories of The General Electric Co. Ltd., Wembley, Middx., has been appointed Publicity Area Chairman for United Kingdom and Western Europe and can supply further information about the Symposium and the procedure for submitting papers.

ELECTRONICS FOR INDUSTRY

An electronics exhibition is to be held in The Bennett Hall, Y.M.C.A., Snow Hill, Birmingham 4, on 21st and 22nd October. Tickets are obtainable from the organizers, Hawnt & Co. Ltd., 59 Moor Street, Birmingham 4.

CORRECTION

Two errors occurred in the article "Ringing Amplifier" in the September issue. In the Appendix, p. 331, the term $1/4R^2$ in equation (5) should be $1/4Q^2$. In equation (6), the left-hand side should be $E_{3T}(t)$.

STANDARD-FREQUENCY TRANSMISSIONS

(Communication from the National Physical Laboratory)

Resumption of Day-Time Transmission by MSF 60 kc/s

The extensive work of aerial maintenance at Rugby is now almost complete and from the 15th November it is planned that MSF 60 kc/s will revert to its customary transmitting period at 14.29–15.30 G.M.T. each day. By the same date the high-power telegraphy transmitter, GBR 16 kc/s, will also be in operation after an absence of nearly two years. It will be recalled that the carrier frequency of this station is derived from the crystal oscillator controlling the MSF signals and the published values of frequency deviation therefore relate to both MSF and GBR.

Deviations from nominal frequency for August* 1958

Date 1958 August	MSF 60 kc/s 2030 G.M.T. Parts in 10^9	Droitwich 200 kc/s 1030 G.M.T. Parts in 10^8
1	0	−1
2	0	N.M.
3	0	N.M.
4	0	N.M.
5	0	0
6	0	0
7	0	0
8	0	0
9	0	N.M.
10	0	N.M.
11	0	+1
12	0	+1
13	0	+1
14	0	+1
15	0	+1
16	0	N.M.
17	0	N.M.
18	0	+2
19	0	+2
20	0	N.M.
21	+1	+2
22	+1	+2
23	+1	N.M.
24	+1	N.M.
25	+1	+3
26	+1	+3
27	+1	+3
28	+1	+3
29	+1	+4
30	N.M.	N.M.
31	N.M.	N.M.

* *Nominal frequency is defined to be that frequency corresponding to a value of* 9 192 631 830 *c/s for the N.P.L. caesium resonator. N.M. = Not Measured.*

New Products

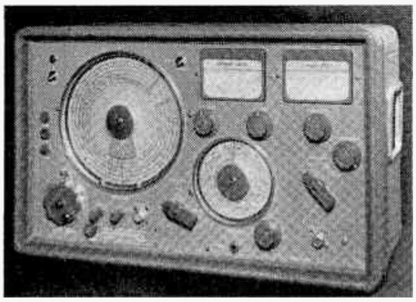
A.M. Signal Generator

The salient features of the TF801C a.m. signal generator include a frequency cover of 10 to 500 Mc/s with 5% tuning accuracy, a built-in crystal calibrator, exceptionally low spurious f.m. and a high-quality 50-Ω output with a v.s.w.r. of less than 1·2.

Its carrier level is continuously variable from 0·1 to 0·5 V, and 1,000-c/s sine wave a.m. may be applied internally at any modulation depth up to a maximum of at least 30% and, at most carrier frequencies, 90%. An alternative high output condition yields a maximum of 1 V modulated or 2 V unmodulated at most frequencies.

Modulation may also be applied externally. For sine-wave inputs, the modulation frequency range is 30 c/s to 20 kc/s and the modulation depth is monitored up to 90%. For pulse inputs, the modulating circuit is direct-coupled and will accept p.r.fs up to at least 50 kc/s.

The main tuning dial has approximately 75 inches of scale and allows fast and accurate reading; the auxiliary incremental dial allows precise and easy interpolation for bandwidth measurements. Output stability during tuning is ensured by an automatic level control system.



The circuit includes a tuned power amplifier and is said to give an r.f. output of unusual purity. Modulation is applied to the power amplifier without disturbance to the operating parameters of the master oscillator; the low incidental f.m. and good response to pulse modulation are due to this arrangement.

Marconi Instruments Ltd.,
St. Albans, Herts.

A.C. Valve Voltmeter

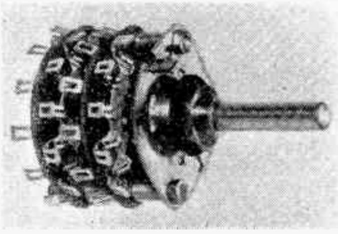
This valve voltmeter is described as an extremely compact and portable instrument of high performance. Its dimensions are the smallest which its makers consider compatible with good instrument design. It incorporates a four-stage amplifier with bridge rectification to the meter. There are twelve ranges covering from 0·001 V to 300 V a.c. and measurements are possible down to 100 μV. A very low capacitance screened lead (PL40) is provided for use on the more sensitive ranges. The scale is calibrated in r.m.s. volts and also dB referred to 1 mW in 600 Ω. Measurements may be made between 10 c/s and 5 Mc/s and, having a high input impedance (10 MΩ), the instrument is useful for amplifier measurements and voltage measurements generally. It can also be used as a null detector, indicator or amplifier for frequencies between 10 c/s and 10 Mc/s. Calibration from 15 c/s to 2 Mc/s is $\pm$ 3% $\pm$ 3% f.s.d. From 2 Mc/s to 4·5 Mc/s the meter reads within $\pm$2 dB.

The Type 77 can also be used as an amplifier with a gain of 1,000, adjustable in 10-dB steps, up to 5 Mc/s. It is claimed to be very useful as an oscilloscope amplifier, and high impedance loads do not affect the voltmeter reading. A low capacitance lead which completely screens the input, and incorporating a screened test-prod, is supplied with the instrument. A device is incorporated in this lead to enable measurements to be made with an input capacitance of less than 5 pF. The instrument has a 4½-in. scale fitted with an anti-parallax mirror, and is fused by a slow-blow device which permits temporary short-circuits. The application of an incorrect high voltage at the input terminals cannot damage the meter movement or the instrument. The h.t. supply is stabilized.

Advance Components Ltd.,
Roebuck Road, Hainault, Ilford, Middx.

Compact Switch for Restricted Spaces

The new type G.R. switch has been designed for radio band change and instrument circuit switching where space is restricted. It could be used in computers and other devices. This switch occupies a space of less than 1½-in. diameter to a depth ranging from ½ in. for a single wafer to a maximum determined by the number of wafers and spacings. It is constructed on a contact clip and knife-action rotor-blade principle, and it is stated that special measures have been taken to ensure rigid contact fixing and positive indexing. Both sides of the wafer may carry completely-insulated contacts and 22 contact positions are available.



The following switching combinations can be provided on each wafer: 1 pole, up to 12 positions; 2 poles, up to 9 positions; 3 poles, up to 5 positions; 5 poles, up to 4 positions; 5 poles, up to 3 positions.

Specification

Contact rating: 250 mA at 100 V r.m.s.; current: 5 A r.m.s. continuous load; resistance: less than 5 mΩ; insulation resistance: 500 Ω at 500 V d.c. between any contact and spindle. Fixing centres 1¼ in.; wafer area, 1½ in. $\times$ $1\frac{7}{16}$ in.

Fixing is one-hole, by ⅜-in. nut and shake-proof washer. For the front control spindle there is a choice of flats, slots or drilling to specification.

Walter Instruments Ltd.,
Garth Road, Morden, Surrey.

Cable Fault Locator

This instrument utilizes a conventional Wheatstone bridge circuit in which the two sections of the faulted conductor, one on each side of the fault, comprise the two external arms of the bridge. The other two arms are contained within the instrument. By use of a detector circuit of extremely high input resistance, it is possible to locate high resistance faults without loss of sensitivity. With this bridge arrangement, faults having resistance from zero up to at least 200 MΩ in dielectrics such as rubber, and much higher in the case of polythene, can be located with an accuracy well within $\pm$ 0·5%, a typical error being 6 in. in 500 ft. or $\pm$0·1%.

A guard terminal is provided so that the effect of surface leakage on accuracy may be eliminated, and corrections for internal cable leakage may easily be applied, if necessary.

Coarse and fine controls are provided for initially balancing the bridge under shorted

input conditions. The bridge is balanced under measuring conditions by adjustment of a precision potentiometer having ten rotations for full travel. A robust pointer meter is used as a null indicator.

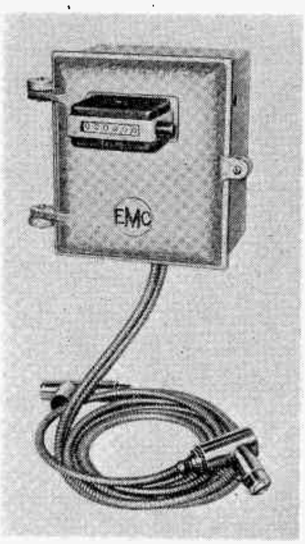
The instrument, complete with self-contained batteries, is in a portable case measuring 15¼ in. × 8 in. × 9 in. A carrying handle is provided, the total weight being 35 lb.

H. Tinsley & Co. Ltd.,
Werndee Hall, South Norwood, London, S.E.25.

Photoelectric Counting Unit

The P.12.C counting unit contains a small transistor amplifier, driven by a selenium barrier-type photocell. The amplifier output operates a relay.

The selenium barrier-type photocell is



said to have a much larger active area than other types of photocell. Operation is possible with a 6-V, 6-W bulb at 1½ ft. and, with a 6-V, 24-W bulb at 4 ft. The P.12.C unit has a maximum rated counting speed of 300 per minute.

Electronic Machine Co. Ltd.,
Mayday Road, Thornton Heath, Surrey.

Transistorized Counter

The Racal 'Computing Counter Controller' is claimed to be the first transistorized counter with in-line read-out to be manufactured in the U.K. Transistors and ferrite cores are used in the counting circuits. The instrument counts up to 9,999 and is then automatically re-set. The maximum counting speed is 50,000 per second. An internal variable time-base is incorporated for frequency measurements, and a crystal oscillator for chronometry, time being then indicated by counting the number of cycles between start and stop signals. The instrument may be used for batching (when the total number of batches is displayed), for frequency division by factors of 2 to 10,000, pulse delaying, and tachometry. A 'power read-out' facility is provided for remote indication of counts, etc.

Racal Engineering Ltd.,
Western Road, Bracknell, Berks.

In-Line Digital Display Unit

Each of these units comprises a system of lenses whereby a figure or letter is projected on to a screen by means of 12 lamps. The main advantage of this method is that the image always appears in the same plane, giving a very wide angle of view.

The large illuminated figure, 1 in. by ⅝ in., is said to give high contrast and good visibility. The standard model has provision for projecting the figures 0–9 and two

decimal points. The dimensions are 2⅝ in. high by 1$\frac{9}{16}$ in. wide by 5$\frac{13}{32}$ in. long. Standard models are available for 6, 12 and 24 volts.

Counting Instruments Ltd.,
5 Elstree Way, Boreham Wood, Herts.

Counting and Selector Tubes

Two cold-cathode decimal stepping tubes have been introduced. They are the Z303C counter tube, which is equivalent to CV2271, and the Z502S selector tube (illustrated), equivalent to CV2325.

The counter tube is mounted on an international octal base on which cathodes 1 to 9 are brought out to a common pin and cathode 0 is taken to a separate pin. The glow discharge is stepped round the tube by applying sequential negative pulses to the two sets of guide electrodes. The glow is viewed through the dome of the bulb and its position may be identified by a numbered escutcheon (supplied separately). Counting may be in a clockwise or anti-clockwise direction.

The selector tube operates in a similar manner, but has all ten main cathodes brought out separately to a special 12-pin (B12E) base. This allows an electrical signal to be obtained at each of the main cathode positions.

The tubes are claimed to be free from photoelectric effects, the ignition characteristics remaining constant during daylight and darkness.

The maximum counting rate for both tubes is 4 kc/s. Normal operating current is approximately 340 μA at a supply voltage of 475 V.

Mullard Ltd.,
Torrington Place, London, W.C.1.

Low-Voltage Stabilized Power Units

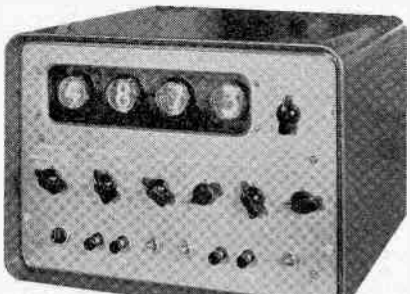
Transistorized power units giving stabilized d.c. outputs up to 1 A at 1·4–24 V are now available. The output voltage of an individual unit is fixed, but a unit giving any required voltage in the range can be supplied. The specified output impedance is 0·5 Ω and ripple voltage 1 mV. The output-voltage variation for a mains variation of ± 10% is given as less than 1 part in 1,000. Units catering for mains variations of ± 10%, + 5% to − 10%, ± 7½% and ± 5% are manufactured, the output current being somewhat restricted in high-voltage units for large mains variations; e.g., 625 mA for a 24-V ± 10% mains-variation unit, as against 1 A for ± 5% unit.

Two voltage-reference tubes are employed.

Roband Electronics Ltd.,
33 Mountgrove Road, Highbury, London, N.5.

High-Frequency Stroboscope

The Type 1205 high-frequency stroboscope avoids the difficulties of a long de-ionizing time by using as the light source a 2-in. cathode-ray tube instead of a gas-discharge tube. Flash rates of up to 600,000 per minute (10 kc/s) are achieved by using the variable-frequency square wave from a built-in oscillator to trigger a pulse generator which, in turn, modulates the intensity of the electron beam of the cathode-ray tube. The pulse duration is variable from 1 μsec



to 3 μsec in six steps, an electrical interlock being provided to prevent overloading of the cathode-ray tube should a longer pulse be accidentally selected at the higher oscillator frequencies.

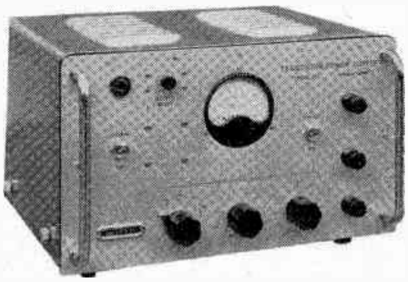
The light output of the unit depends on the type of phosphor. The standard phosphor has a green luminescence and gives a light output of some 3,000 candelas and a decay time of less than 1 μsec. This output is of the same order as that of a typical neon stroboscopic lamp. Where greater intensity is desirable, a yellow-green phosphor gives an increased light output of around 7,000 candelas with a decay time of 6 μsec.

The flash rate can be read off a calibrated scale. This enables the unit to be used as an electronic tachometer by noting the speed setting at which motion appears 'frozen'. The instrument can be driven from an external oscillator if required.

Dawe Instruments Ltd.,
99 *Uxbridge Road, London, W.*5.

Regulated Power Supplies

These units are suitable for bench use in laboratories engaged on design and development of transistorized equipment. Type AS.758 can be mounted in a standard 19-in. rack and has the additional feature of a



warning light to monitor heat-sink temperature.

Three-dial decade switching enables the output voltage from either unit to be set to an accuracy of 0·1 volt in 30 or 50 V.

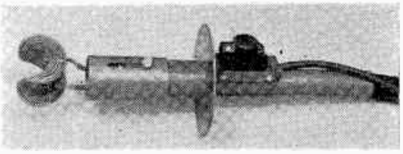
Specification

	A.S.757	AS.758
Output voltage	±0–50 V	±0–30 V
	in 0·1-V steps by 3-decade switching	
Output current	0–1 A	0–10 A
Output resistance	0·01 Ω	0·01 Ω
Output impedance	0·2 Ω up to 100 kc/s	
Noise and ripple	Less than 1 mV p-p	
Stability factor	200 : 1	150 : 1
Mains input	90/130 V or 200/240 V, 40/60 c/s	
Permissible mains variation	±7% from nominal	

Solartron Electronic Group Ltd., Thames Ditton, Surrey.

Mobile Induction Unit for Getter-Firing

The Radyne 1-kW induction heating equipment is now available with an inexpensive mobile water re-circulator trolley. The reservoir tank is said to have sufficient capacity to enable the heater to be used



continuously all day without over-heating.

The illustration shows a hand applicator with a standardized coil design for firing television picture-tube getters. The same coil can also be used for heating gun assemblies.

Radio Heaters Ltd.,
Eastheath Avenue, Wokingham, Berks.

Precision Measuring Relays

The 'Sensitact' relay, developed by Brion Leroux et Cie, consists of a galvanometer movement, complete with scale and pointer, to which is added a moving contact. On each side of this are arranged two fully-adjustable contacts which are instantly accessible beneath a transparent plastic dust cover, and are adjustable over the full range of the scale.

The relays are magnetically shielded and are available in 16 different models, with moving-coil resistances ranging from 2·5 Ω to 7,500 Ω, and with full-scale deflection currents from 10 mA down to 0·2 mA. In the case of the most sensitive model, the minimum change of control power necessary to make or break contact is said to be of the order of 0·05 μW. The relay contacts have a power-handling capacity of 200 mW. Two types of scale can be provided, one covering 90° and calibrated 0–100 divisions, and the other in centre-zero form with calibrated 50–0–50 divisions. Available from:

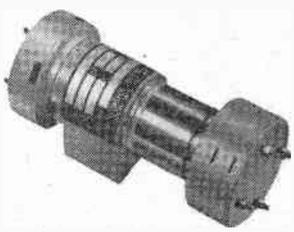
Leland Instruments Ltd.,
22 *and* 23 *Millbank, Westminster, London, S.W.*1.

High-Speed Rotary Switch

This switch, claimed by the makers to be one of the smallest of its kind, has been specially designed to fulfil many of the requirements now demanded by remotely-operated systems.

The composite unit shown comprises two 24-way low-speed switches, driven from a 6-V d.c. motor (of approximately 6,000 r.p.m.) via a precision 80 : 1 reduction gearhead and one 24-way high-speed switch driven directly at motor speed.

Performance details include an on/off ratio of 10 : 1 for 24-way and 5 : 1 for 48-way; scanning speed of up to 12,000 r.p.m., set as required to within ±10%; timing accuracy of ±10 minutes of arc; ganging accuracy of ±1°; contact resistance of 0·2 Ω (static), 1·52 Ω (running); noise figure of 100 μV r.m.s.

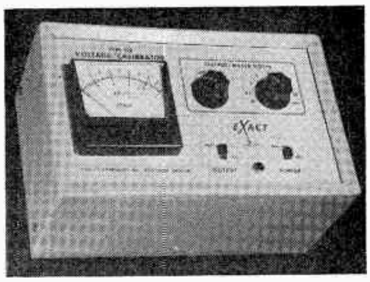


maximum for full life of switch at 0·0015 V signal level in a load of 1 kΩ; life expectancy of over 200 hours at 6,000 r.p.m.; operating on 6 to 24 V for d.c. motors, 6 to 115 V for 400 c/s a.c. motors.

Vactric (Control Equipment) Ltd.,
196 *Sloane Street, London, S.W.*1.

Voltage Calibrator

Exact Electronics Inc. have announced a new voltage calibrator Type 100, primarily designed for the calibration of oscilloscopes, a.c. or d.c. voltmeters, and measurement types of test equipment. The main feature



of the calibrator is the ¼% accuracy of the directly-metered d.c. or symmetrical 1-kc/s square-wave output. This direct metering of the output voltage gives accurate results under conditions of extreme external loading. Output range is continuously variable from 2 mV to 100 V.

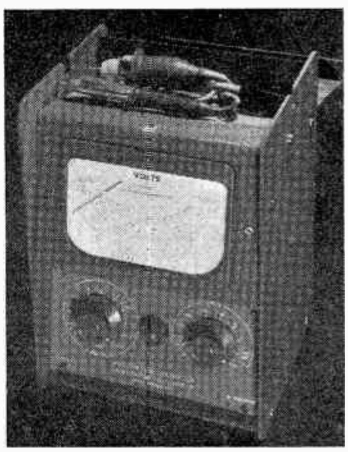
Exact Electronics Inc.,
P.O. Box 552, *Portland* 7, *Oregon, U.S.A.*

1,500-Mc/s Valve Voltmeter

Marconi Instruments Ltd. announce the latest addition, type TF1041B, to their range of voltmeters, and claim that it is the first instrument of its kind with a frequency range extending to 1,500 Mc/s.

For a.c. measurement, the frequency range is given as 20 c/s to 1,500 Mc/s; the voltage range is 0·025 to 300 V, but can be extended to 2 kV and 20 kV with the use of multipliers. D.C. voltages from 0·01 to 1,000 V can be measured. As an ohmmeter, the instrument measures resistance from 0·02 Ω to 500 MΩ. D.C. volts and ohms measurement is simplified by the special dual-purpose d.c. probe with its finger-tip V/Ω selector. Both a.c. and d.c. inputs are isolated from chassis.

A.C. measurements are made with a



light-weight cylindrical probe which houses a disc-seal diode rectifier. A frequency response which is flat to within 1 dB up to 1,000 Mc/s and showing a rise of less than 3 dB at 1,500 Mc/s is claimed.

The d.c. section of the instrument is essentially a two-stage impedance convertor, embodying two cathode followers. Heavy degeneration ensures that the accuracy of measurement is virtually independent of valve characteristics. The filament supply to all valves is stabilized, and the effects of meter temperature coefficient are offset by a series thermistor. Stability and freedom from drift, resulting from these refinements, are indicated by a steady zero, which needs only one setting to suit all ranges.

The instrument has no conventional chassis, all components being mounted on the rear of the hinged front panel.

Marconi Instruments Ltd.,
St. Albans, Herts.

Transistorized Power Supplies

A new range of transistor regulated d.c. power supplies has been produced by J. Langham Thompson Ltd.

At present, three models are available and are intended for low-voltage high-current applications. The model illustrated

has a variable output of 4·5 to 14 V d.c. (regulation accuracy of $\pm 0{\cdot}15\%$) at 500 mA. The other models have fixed outputs of 12·5 V d.c. (regulation accuracy of $\pm 0{\cdot}1\%$) at 750 mA or 1·5 A. The variable-output unit weighs $7\frac{1}{2}$ lb and measures $10\frac{3}{4}$ in. × $7\frac{7}{8}$ in. × $8\frac{1}{2}$ in. deep; the fixed-output units both weigh $4\frac{3}{4}$ lb and measure 8 in. × $3\frac{1}{2}$ in. × $3\frac{1}{4}$ in. deep.

J. Langham Thompson Ltd.,
Springland Laboratories, Bushey Heath, Herts.

Gamma-Ray Electrometer

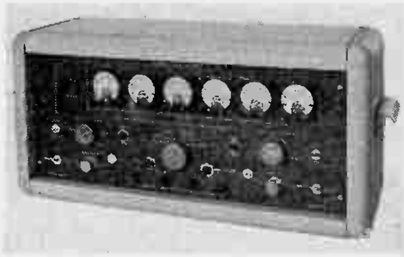
A new gamma-ray electrometer has been developed by Electronic Instruments Ltd., in conjunction with the U.K.A.E.A., for measuring the concentration of uranium ore in a slurry.

The instrument is designed around the E.I.L. Vibron unit, an electromechanical device, and is said to be capable of measuring small changes in gamma-ray absorption while the slurry flows through a steel pipe in an ore-treatment plant.

Electronic Instruments Ltd.,
Lower Mortlake Road, Richmond, Surrey.

Microsecond Stopclock

This transistorized microsecond stopclock, type TSA24, employs a new range of high-speed counting stages and is capable of measuring pulse widths, mark/space ratios and periods of pulse or other waveforms having amplitudes between 0·75 and



500 V (peak). Measurements can also be carried out on contacts without the use of ancillary power supplies.

The applied waveform is inherently self-checked and six internally-generated waveforms of frequencies 10 c/s to 1 Mc/s are available from the output-frequency socket.

The time range of the basic equipment extends from 3 μsec to 1 sec and, if required, can be extended to 27·8 hours by means of a plug-in counter.

Using transistors throughout, the instrument can be supplied to operate from 12 V d.c. or 230 V a.c. supplies.

Venner Electronics Ltd.,
Kingston By-Pass, New Malden, Surrey.

Plugs and Sockets

A new range of plugs and sockets, the UK—AN series, has been introduced by The Plessey Co. Ltd. This range is fully interchangeable with the American AN or MS series of plugs and sockets, the design embodying the more desirable attributes of 30 American types in one connector.

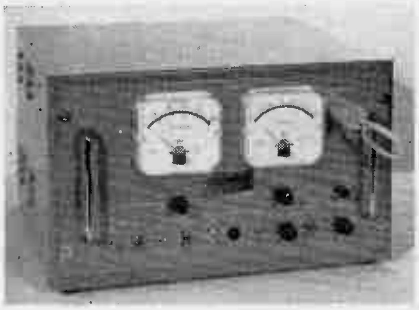
The components have been subjected to an exhaustive series of tests, covering all aspects of possible environmental conditions, and are claimed to work satisfactorily in an atmosphere of 95% humidity, resist a 1,100 °C flame for 15 minutes while carrying full-rated current, and withstand 5 kV at sea level and 2·5 kV at an altitude of 70,000 feet. They are also capable of working at temperatures ranging from — 60 °C to + 190 °C.

The Plessey Co. Ltd.,
Ilford, Essex.

E.H.T. Power Supply

A new combined stabilized power supply and breakdown tester, giving a reversible d.c. output of 3 to 30 kV at 1 mA, has been produced by Hivolt Ltd.

The equipment incorporates the latest r.f. high-voltage techniques and epoxy-resin moulded e.h.t. components are used throughout.



A built-in e.h.t. voltmeter and three-range current meter are included in the unit, as well as a variable-trip circuit, which will automatically switch off the e.h.t. if the output exceeds the trip setting.

Hivolt Ltd.,
91-93 Princedale Road, London, W.11.

Potentiometers

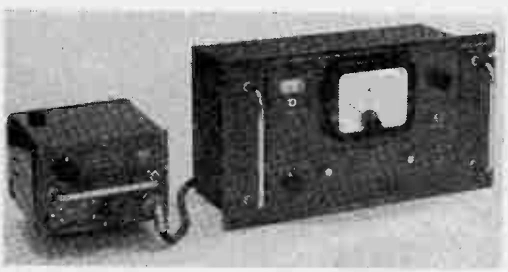
The range of Fox potentiometers has been extended to include additional precision-type potentiometers with servo mountings. These servo types are of a completely new design; their high-precision windings are contained with a special aluminium-alloy housing to ensure a high rate of heat dissipation while still retaining the low-torque characteristics of previous designs.

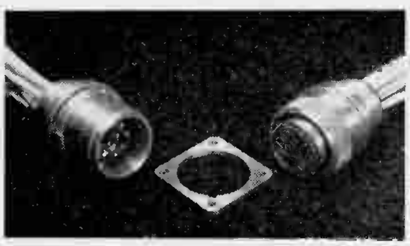
They are available in the following types and can be supplied in either single or ganged form with the maximum resistances per winding shown:—

SF : 1·888 in. o.d., 50 kΩ
SG : 1·586 in. o.d., 50 kΩ
SB : 2·528 in. o.d., 100 kΩ

The torque ranges from 0·5 gm per cm and varies with the number of ganged units.

P. X. Fox Ltd.,
Hawksworth Road, Horsforth, Leeds.





Abstracts and References

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The abstracts are classified in accordance with the Universal Decimal Classification. They are arranged within broad subject sections in the order of the U.D.C. numbers, except that notices of book reviews are placed at the ends of the sections. U.D.C. numbers marked with a dagger (†) must be regarded as provisional. The abbreviations of journal titles conform generally with the style of the World List of Scientific Periodicals. An Author and Subject Index to the abstracts is published annually; it includes a selected list of journals abstracted, the abbreviations of their titles and their publishers' addresses. Copies of articles or journals referred to are not available from Electronic & Radio Engineer. *Application must be made to the individual publishers concerned.*

ACOUSTICS AND AUDIO FREQUENCIES

534.1-8-14 : 621.391.63 **2944**

Light Modulation by Standing Waves in Liquids.—H. F. Reimann. (*NachrTech.*, Nov. 1957, Vol. 7, No. 11, pp. 515–518.) A light beam is modulated in passing through a liquid subjected to ultrasonic vibrations; a photomultiplier circuit is used for demodulation. Applications of the method may include communications and television projection.

534.2 : 621.395.623.52 **2945**

On the Attenuation of High-Amplitude Waves of Stable Sawtooth Form Propagated in Horns.—I. Rudnick. (*J. acoust. Soc. Amer.*, April 1958, Vol. 30, No. 4, pp. 339–342.) A theoretical expression for the power loss for a generalized horn is obtained, and applied to horns of particular shape.

534.2-8-14 **2946**

Ultrasonic Dispersion in Oxygen.—J. V. Connor. (*J. acoust. Soc. Amer.*, April 1958, Vol. 30, No. 4, pp. 297–300.)

534.21-8-13 **2947**

Sound Propagation in Gases at High Frequencies and Very Low Pressures.—E. Meyer & G. Sessler. (*Z. Phys.*, 23rd Aug. 1957, Vol. 149, No. 1, pp. 15–39.) Sound absorption and dispersion in argon, air and hydrogen is calculated and measured for frequency/pressure ratios of 10^7–10^{11} c/s per atm.

534.222.1 **2948**

Propagation of Sound Across a Boundary between Two Superfluid Phases.—R. G. Arkhipov & I. M. Kholatnikov. (*Zh. eksp.teor.Fiz.*, Sept. 1957, Vol. 33, No. 3(9), pp. 758–764.) Theoretical treatment of the propagation of two different sound waves across a phase boundary showing that mode conversion can occur. Formulae are derived for the energy flux of the reflected, refracted and converted waves.

534.614-8-16 **2949**

On the Measurement of Ultrasonic Velocity in Solids.—J. Williams & J. Lamb. (*J. acoust. Soc. Amer.*, April 1958, Vol. 30, No. 4, pp. 308–313.) The method is based on the cancellation of a travelling wave train after several reflections at the ends of the specimen by a second wave train from the same source. The velocity of propagation can be evaluated to within 1 part in 10^4 after taking account of phase shift.

534.78 **2950**

Frequency of Usage and the Perception of Words.—M. R. Rosenzweig & L. Postman. (*Science*, 7th Feb. 1958, Vol. 127, No. 3293, pp. 263–266.) Conclusions drawn from tests on intelligibility and visual perception of words are summarized. More highly intelligible alphabetic equivalents may be obtained by selecting frequently used words which are longer than those in the current lists.

534.78 **2951**

Interaural Effects upon Speech Intelligibility at High Noise Levels.—I. Pollack & J. M. Pickett. (*J. acoust. Soc. Amer.*, April 1958, Vol. 30, No. 4, pp. 293–296.) By presenting speech and noise to one ear and noise alone to the other, speech intelligibility was substantially decreased, compared with either monaural or binaural listening conditions. See also 2286 of August.

534.78 : 621.391 **2952**

Construction and Investigation of a Transmission System for Synthetic Speech.—E. Krocker. (*NachrTech.*, Dec. 1957, Vol. 7, No. 12, pp. 553–564.) Laboratory tests were carried out on a 'vocoder' system [513 of 1949 (Halsey & Swaffield)] to investigate its performance and assess its practical value.

534.845 **2953**

The Effects of a Surface Covering on the Acoustic Absorption of Porous Materials.—E. Brosio. (*Alta Frequenza*, Dec. 1957, Vol. 26, No. 6, pp. 632–638.) Covering absorbent panels by protective material, such as varnish, paper, etc. increases the absorptive power at low frequencies and diminishes it at high frequencies. Experimental results are in agreement with theoretical predictions.

621.395.623.7 **2954**

Investigations of Transients in Loudspeakers.—G. Kaszynski. (*Hochfrequenztech. u. Elektroakust.*, Sept. 1957, Vol. 66, No. 2, pp. 37–52.) The transients considered are those occurring at the beginning and end of each sound. Transient waveforms are derived theoretically from the characteristics of the loudspeaker, the source impedance and transmission coefficient, and are compared with experimentally obtained response curves and oscillograms.

621.395.623.8 **2955**

The Directivity of Acoustic Radiators Arranged in a Circular Arc.—K. Feik. (*Hochfrequenztech. u. Elektroakust.*, Sept. 1957, Vol. 66, No. 2, pp. 29–37.) The radiation patterns of loudspeakers arranged in arcs subtending different angles up to 180° are derived theoretically and by experiment for frequencies ranging from 0·9 to 11·4 kc/s. Approximately circular radiation patterns can be obtained with suitably proportioned arrays.

621.395.625.3 **2956**

High-Resolution Magnetic Recording Structures.—A. S. Hoagland. (*IBM J. Res. Developm.*, April 1958, Vol. 2, No. 2, pp. 91–104.) Design concepts are established and their application demonstrated. In addition to the conventional ring head two new devices are considered. These are a probe-type unit which lends itself to high-density vertical magnetic recording and a wire-grid array which yields high resolution.

621.395.625.3 : 621.317.616 **2957**

The Determination of Frequency Characteristics of Recording-Tape Magnetization.—Schmidbauer. (See 3205.)

AERIALS AND TRANSMISSION LINES

621.315.212 : [621.395.4+621.397.5 **2958**

Multichannel Systems along Coaxial Cables.—J. Bauer. (*Bull. schweiz. elektrotech. Ver.*, 26th April 1958, Vol. 49, No. 9, pp. 412–416..427.) The reference systems for telephony and television transmission via multichannel coaxial-cable links based on C.C.I.T.T. and C.C.I.R. recommendations are discussed. A 12-Mc/s system is described which provides 2 700 telephony channels, or one television and 1 200 telephony channels.

621.315.212.4 : 621.315.513 **2959**

Multilayer Conductor having Low Resistance at High Frequencies.—M. Sugi & K. Murai. (*Elect. Commun.*, Dec. 1957, Vol. 34, No. 4, pp. 332–336.) A cylindrical conductor consisting of layers of helically wound thin conducting tape each separated from the other by insulation is considered. Skin effect is reduced by equalizing the effective inductance of all layers. The theory of the design and some experimental results are given.

621.372.2 + 621.396.11 **2960**

Surface Waves.—Barlow. (See 3228.)

621.372.2 : 621.396.67 : 621.396.65 **2961**

Aerial Feeders for Multichannel Links.—L. Lewin & J. Payne. (*Electronic Engng*, July 1958, Vol. 30, No. 365, pp. 414–419.) The reflections from coaxial-cable and waveguide feeders are investigated and the requirements for wide-band links given. The suitability of the various types of feeder for different frequency bands is outlined. In general, coaxial cables can meet most requirements up to 2 000 Mc/s, but above 3 000 Mc/s waveguides are to be preferred.

621.372.22 : 621.372.8 **2962**

Propagation in Coupled Transmission-Line Systems.—J. Brown. (*Quart. J. Mech. appl. Math.*, May 1958, Vol. 11, Part 2, pp. 235–243.) A system of transmission lines coupled by reactive networks at regular intervals is examined.

621.372.3 : 621.318.134 : 537.226 **2963**

Theory of Nonreciprocal Ferrite Phase Shifters in Dielectric-Loaded Coaxial Line.—K. J. Button. (*J. appl. Phys.*, June 1958, Vol. 29, No. 6, pp. 998–1000.) An antisymmetrically loaded line can produce a differential phase shift of 180°/in. in the 2 800-Mc/s range. Such a line is described theoretically. See also *ibid.*, Aug. 1957, Vol. 28, No. 8, pp. 921–922 (Sucher & Corlin).

621.372.82 **2964**

Orthogonality Properties for Modes in Passive and Active Uniform Waveguides.—A. D. Bresler, G. H. Joshi & N. Marcuvitz. (*J. appl. Phys.*, May 1958, Vol. 29, No. 5, pp. 794–799.) Orthogonality relations are given for the four-vector guided modes of anisotropic uniform waveguides and for the six-vector guided modes in waveguides containing unidirectional electron beams with axially independent d.c. velocities.

621.372.831.4 : 621.318.134 **2965**

Coupling through an Aperture containing an Anisotropic Ferrite.—D. C. Stinson. (*Trans. Inst. Radio Engrs*, July 1957, Vol. MTT-5, No. 3, pp. 184–191. Abstract, *Proc. Inst. Radio Engrs*, Sept. 1957, Vol. 45, No. 9, p. 1312.)

621.372.837.3 : 621.318.134 **2966**

Two Short Low-Power Ferrite Duplexers.—R. S. Cole & W. N. Honeyman. (*Electronic Radio Engr*, Aug. 1958, Vol. 35, No. 8, pp. 282–286.) Two rotation-type duplexers, one of which uses a turnstile junction are described. Transmitter-receiver isolations of about 25 dB are obtained over a bandwidth of 1·3 % at 3 cm λ.

621.372.85 **2967**

Application of Rayleigh-Ritz Method to Dielectric Steps in Waveguides.—R. E. Collin & R. M. Vaillancourt. (*Trans. Inst. Radio Engrs*, July 1957, Vol. MTT-5, No. 3, pp. 177–184. Abstract, *Proc. Inst. Radio Engrs*, Sept. 1957, Vol. 45, No. 9, p. 1312.)

621.372.85 : 538.221 : 621.318.134 **2968**

The Application of Ferrites in the Construction of Nonreciprocal Microwave Devices.—W. H. Dörre. (*NachrTech.*, Dec. 1957, Vol. 7, No. 12, pp. 542–548.) Survey of applications including isolators, phase shifters and gyrators. 27 references.

621.372.852.2 : 621.372.832.6 **2969**

Errors in a Magic-Tee Phase Changer.—M. Vaillancourt. (*Trans. Inst. Radio Engrs*, July 1957, Vol. MTT-5, No. 3, pp. 204–207. Abstract, *Proc. Inst. Radio Engrs*, Sept. 1957, Vol. 45, No. 9, p. 1312.)

621.372.852.323 : 621.318.134 **2970**

Field-Displacement Isolators at 4, 6, 11 and 24 kMc/s.—S. Weisbaum & H. Boyet. (*Trans. Inst. Radio Engrs*, July 1957, Vol. MTT-5, No. 3, pp. 194–198. Abstract, *Proc. Inst. Radio Engrs*, Sept. 1957, Vol. 45, No. 9, p. 1312.) See also 1628 of June.

621.372.852.4 **2971**

A Method of Producing Broad-Band Circular Polarization employing an Anisotropic Dielectric.—H. S. Kirschbaum & S. Chen. (*Trans. Inst. Radio Engrs*, July 1957, Vol. MTT-5, No. 3, pp. 199–203. Abstract, *Proc. Inst. Radio Engrs*, Sept. 1957, Vol. 45, No. 9, p. 1312.)

621.372.853.1 **2972**

The Propagation of Constant Longitudinal Magnetic Waves in Dielectric-Filled Waveguides.—L. G. Chambers. (*Quart. J. Mech. appl. Math.*, May 1958, Vol. 11, Part 2, pp. 244–252.) "The propagation of electromagnetic waves in an inhomogeneously filled waveguide is discussed and it is shown that, when the phase velocity of the wave down the guide is equal to the velocity of propagation in one of the dielectric media, then the longitudinal component of magnetic field is constant across that dielectric. Limits are also given for the propagation constants of TE and TM waves." See also 638 of 1955.

621.372.855 **2973**

An Adjustable Sliding Termination for Rectangular Waveguide.—R. W. Beatty. (*Trans. Inst. Radio Engrs*, July 1957, Vol. MTT-5, No. 3, pp. 192–194. Abstract, *Proc. Inst. Radio Engrs*, Sept. 1957, Vol. 45, No. 9, p. 1312.)

621.396.67 **2974**

A New Method of Solving the Problem of Wide-Band Aerials.—H. Meinke. (*Nachrichtentech. Z.*, Dec. 1957, Vol. 10, No. 12, pp. 594–601.) Considering the aerial to be an inhomogeneous transmission line with attenuation due to radiation, an explanation is given for the dependence of aerial input impedance and radiation patterns on frequency. By means of a curvilinear coordinate system, field equations of convenient form are derived which result in adequate approximations for wide-band aerials of simple shape.

621.396.674.1.029.51 **2975**

Loop Aerials for Long Waves.—J. Wüstenhagen. (*Rundfunktech. Mitt.*, Dec. 1957, Vol. 1, No. 6, pp. 237–243.) The suitability of loop aerials for transmission in the long-wave band is discussed with reference to input impedance, efficiency and bandwidth. A method of calculating input impedance over a wide frequency range is given; results of model tests confirm its accuracy. An advantage of loop aerials is that their input impedance can be varied within wide limits by appropriate structural changes.

621.396.674.3-41 + 621.396.677.3-41 **2976**

Investigations of Plane Surface Dipoles and Dipole Arrays.—G. Arlt. (*Z. angew. Phys.*, Aug. 1957, Vol. 9, No. 8, pp. 379–388.) Radiation and impedance diagrams of surface aerials of different shape are examined to determine those with the best wide-band characteristics. A rhombus dipole with side links has good input impedance and directivity characteristics over a wide band of frequencies. A chequer-board array composed of such dipoles permits wide-band matching, and radiation and reception with any type of polarization. Measurements were made on a two-element rhombus dipole whose directivity characteristics compare favourably with those of a tubular dipole. See also 2118 of 1952 (Wolter).

621.396.677 : 621.396.712.029.53 **2977**

The Medium-Wave Aerial at Hamburg for the Suppression of Sky-Wave Radiation towards Langenberg.—E. Mohr & F. von Rautenfeld. (*Rundfunktech. Mitt.*, Dec. 1957, Vol. 1, No. 6, pp. 209–220.) The design is described of the directive aerial system of the 971-kc/s, 100-kW transmitter at Hamburg which provides a minimum of sky-wave radiation at an elevation of about 30° in the direction of Langenberg where a second 100-kW transmitter operating at the same frequency is situated. Details are given of model tests at 100 Mc/s and of field plotting in a specially equipped aircraft. See also 592 of February (von Rautenfeld & Thiessen).

621.396.677.029.6 **2978**

Considerations on the Phase Centre of Radiating Systems.—C. Montebello & F. Serracchioli. (*Note Recensioni Notiz.*, Jan./Feb. 1958, Vol. 7, No. 1, pp. 57–66.) A simple criterion is derived for ascertaining the existence and location of a phase centre defined with reference to equiphase surfaces. Some practical applications are discussed.

621.396.677.43 : 621.397.62 **2979**

Rhombic Antennas for TV.—R. B. Cooper, Jr. (*Radio TV News*, Feb. 1958, Vol. 59, No. 2, pp. 64–65..109.) Details of the electrical design suitable for reception in fringe areas are given and the practical construction is indicated.

621.396.677.832 : 537.226 **2980**

Field of a Dielectric-Loaded, Infinite Corner Reflector.—A. W. Adey. (*Canad. J. Phys.*, April 1958, Vol. 36, No. 4, pp. 438–445.) Calculations show that the radiation resistance and far-field amplitude are sensitive to the presence of the loading, particularly for small spacings between the feeding element and the apex. Unlike the no-dielectric case, there is no monotonic fall-off in amplitude with increasing element/apex spacing.

AUTOMATIC COMPUTERS

681.142 **2981**

The Logical Design of a Simple General-Purpose Computer.—S. P. Frankel. (*Trans. Inst. Radio Engrs*, March 1957, Vol. EC-6, No. 1, pp. 5–14.) "The logical design described here is used in MINAC, partially constructed at the California Institute of Technology, and LGP-30, manufactured by Librascope Inc. These serial binary digital computers make use of magnetic-drum bulk storage and use three circulating registers and fifteen flip-flops."

681.142 **2982**

Digital Computer Adding and Complementing Circuits.—C. D. Florida. (*Electronic Engng*, July 1958, Vol. 30, No. 365, pp. 429–435.) Various direct-coupled transistor circuits are described, suitable for use with double-gate shifting registers. The performance of these circuits operating with a digit spacing of 5 μs is illustrated with waveform photographs.

681.142 **2983**

An Algorithm for Determining Minimal Representations of a Logic Function.—B. Harris. (*Trans. Inst. Radio Engrs*, June 1957, Vol. EC-6, No. 2, pp. 103–108. Abstract, *Proc. Inst. Radio Engrs*, Sept. 1957, Vol. 45, No. 9, p. 1311.)

681.142 **2984**

Computing Techniques for the Sampling Parametric Computer.—C. J. Hirsch & F. C. Hallden. (*Trans. Inst. Radio Engrs*, June 1957, Vol. EC-6, No. 2, pp. 108–119. Abstract, *Proc. Inst. Radio Engrs*, Sept. 1957, Vol. 45, No. 9, p. 1311.)

681.142 **2985**

Dynamic Accuracy as a Design Criterion of Linear Electronic Analogue Differential Analyzers.—A. Nathan. (*Trans. Inst. Radio Engrs*, June 1957, Vol. EC-6, No. 2, pp. 74–86. Abstract, *Proc. Inst. Radio Engrs*, Sept. 1957, Vol. 45, No. 9, p. 1311.)

681.142 **2986**

Fine Graduation of the Timing-Pulse Generator Disk of an Electronic Computer.—H. J. Dreyer, T. Gorr & W. Schütte. (*VDI Z.*, 11th March 1958, Vol. 100, No. 8, pp. 329–331.) The construction is described of a disk providing the synchronizing pulses for the storage system of a digital computer. The nonferromagnetic disk of about 40 cm diameter carries a thin layer of nickel near the rim. The layer is cut by radial grooves of width 150 μ, and there are five concentric tracks with differing numbers of grooves. The outer track thus consists of 4 200 ferromagnetic 'teeth' which at 3 000 rev./min generate pulses at a repetition frequency of about 200 kc/s. Details of the dividing and engraving machinery are given.

681.142 **2987**

Nondestructive Memory employing a Domain-Oriented Steel Wire.—U. F. Gianola. (*J. appl. Phys.*, May 1958, Vol. 29, No. 5, pp. 849–853.) A magnetic storage system using a steel wire under tension is described. A small solenoid is used to magnetize the wire locally and for observing the flux change produced by an interrogative current pulsed through the wire itself.

681.142 **2988**

An Electronic Analogue Multiplier using Carriers.—E. S. Weibel. (*Trans. Inst. Radio Engrs*, March 1957, Vol. EC-6, No. 1, pp. 30–34.) "An electronic analogue multiplier is described, which is based on a modulation technique. No d.c. amplifiers are used, which makes the output entirely free of drifts. All distortions up to the fourth order are eliminated. The experimental model that has been built handles inputs from d.c. to 7 kc/s and gives an output from d.c. to 14 kc/s. The amplitude range of the output is 50 dB."

681.142 **2989**

Trigonometric Resolution in Analogue Computers by means of Multiplier Elements.—R. M. Howe & E. G. Gilbert. (*Trans. Inst. Radio Engrs*, June 1957, Vol. EC-6, No. 2, pp. 86–92. Abstract, *Proc. Inst. Radio Engrs*, Sept. 1957, Vol. 45, No. 9, p. 1311.)

681.142 **2990**

Stability and Convergence Limitations on the Use of Analogue Computers with Resistance-Network Analogues.—M. E. Fisher. (*Brit. J. appl. Phys.*, July 1958, Vol. 9, No. 7, pp. 288–291.) It is shown that the solution of equations such as $\nabla^2\phi=f(\phi)$ breaks down if the gradient of $f(\phi)$ is negative and sufficiently large to cause the correct solution to be 'wavelike'. See also 673 of 1956 (Karplus) and 367 of February (Hutcheon).

681.142 **2991**

Electronic Integrator with Immediate Digital Output.—B. L. Hisey & E. R. Perl. (*Rev. sci. Instrum.*, May 1958, Vol. 29, No. 5, pp. 355–359.) Details are given of a technique for obtaining an instantaneous numerical value proportional to the area of a recurring voltage transient. The basic principle is to summate the pulses from a generator whose repetition rate is a linear function of the instantaneous input voltage. The system has a high order of linearity, approximately $\pm 0 \cdot 1$ %, and is used for roughly triangular pulses of 0·5–10 ms duration.

681.142 **2992**

An Improved Electromagnetic Integrator.—A. J. Dyer. (*J. sci. Instrum.*, July 1958, Vol. 35, No. 7, pp. 240–242.) Description of a permanent-magnet moving-coil system for integrating an electrical signal of varying polarity over integration times as long as one day.

681.142 : 061.3 **2993**

Symposium on Computers.—(*Aust. J. Instrum. Tech.*, Feb. 1958, Vol. 14, No. 1, pp. 5–71.) The text is given of seven papers read at a symposium held at Mt. Eliza, Victoria, 3rd–6th December 1957.

681.142 : 538.652 **2994**

Magnetostrictive Delay Line.—V. N. Kostic. (*Bull. Inst. nuclear Sci. 'Boris Kidrich'*, March 1957, Vol. 7, pp. 97–101.) "Equivalent electromechanical circuit for a magnetostrictive nickel delay line is given. The optimum matching at the input and output end is discussed."

681.142 : 621.318.134 **2995**

Magnetic-Core Memory Cell with Nondestructive Read-Out.—T. Z. Aleksic. (*Bull. Inst. nuclear Sci. 'Boris Kidrich'*, March 1957, Vol. 7, pp. 93–101.) Outline of a method of using different values of incremental permeability of a d.c. biased magnetic core to obtain a binary storage cell. One of the possible applications is for visible indication of binary states in magnetic shift registers.

681.142 : 621.318.134 : 621.314.7 **2996**

A Transistor-Driven Magnetic-Core Memory.—E. L. Younker. (*Trans. Inst. Radio Engrs*, March 1957, Vol. EC-6, No. 1, pp. 14–20.) Description of a storage system, with a capacity of 1 024 18-bit words designed for a transistor airborne digital computer TRADIC at Bell Telephone Laboratories. Both the 'read' and 'write' operations are based on a coincident-current technique.

681.142 : 621.318.134 : 621.318.57 **2997**

Current Steering in Magnetic Circuits.—J. A. Rajchman & H.D. Crane. (*Trans. Inst. Radio Engrs*, March 1957, Vol. EC-6, No. 1, pp. 21–30.) Magnetic switches are described in which the current from an energizing source is guided or steered through one out of many possible parallel branches, the conducting branch being selected by the presetting of appropriate magnetic elements.

681.142 : 621.374.32 **2998**

The Logic of Bidirectional Binary Counters.—M. J. E. Golay. (*Trans. Inst. Radio Engrs*, March 1957, Vol. EC-6, No. 1, pp. 1–4.) See also 42 of 1954 (Ware).

681.142 : 621.385.2 **2999**

A New Diode Function Generator.—T. Miura, H. Amemiya & T. Numakura. (*Trans. Inst. Radio Engrs*, June 1957, Vol. EC-6, No. 2, pp. 95–100. Abstract, *Proc. Inst. Radio Engrs*, Sept. 1957, Vol. 45, No. 9, p. 1311.)

681.142 : 621.385.832 **3000**

A Cathode-Ray-Tube Analogue-to-Serial Digital Converter.—J. Willis & M. G. Hartley. (*J. sci. Instrum.*, June 1958, Vol. 35, No. 6, pp. 197–202.) Small fluctuations of the c.r. tube screen equilibrium potential cause proportionate fluctuations in the steady secondary-emission current arriving at a collector anode. The parameters affecting changes in this current are investigated using an external electrode on the c.r. tube face to modulate the screen potential. Experiments are described to determine minimum electrode width and spacing, consistent with the production of a discrete pulse output from each electrode when a pattern is scanned.

CIRCUITS AND CIRCUIT ELEMENTS

621.3.049.75 **3001**

Printed Circuits.—N. Osifchin & S. J. Stockfleth. (*Bell Lab. Rec.*, April 1958, Vol. 36, No. 4, pp. 117–121.) A review of printed-circuit techniques suitable for modular equipment.

621.314.22 : 621.375.125 **3002**

Divided Output Transformers.—R. Guelke. (*Wireless World*, Aug. 1958, Vol. 64, No. 8, pp. 384–385.) To overcome self-capacity in the primary winding of an a.f. output transformer at high frequencies, the output from the final stage may be fed to two transformers: one for the low-frequency and the other for the high-frequency range. This overcomes the necessity for a single high-quality transformer and the output can be fed directly to two separate loudspeakers.

621.314.67 **3003**

Contribution to the Study of a Rectifier in Series with an Inductive Resistance.—C. Maizières (*Rev. gén. Élect.*, Nov. 1957, Vol. 66, No. 11, pp. 565–568.) Different hypotheses are considered for expressing the voltage drop across the rectifier at low frequencies. Values of mean and maximum current are calculated according to each hypothesis and compared with values measured using a coil of inductance 0·99 H and resistance 98 Ω, in series with a valve rectifier. A circuit for measuring low peak voltages using a gas-filled tetrode is described.

621.316.727 **3004**

Capacitive Phase Shifters.—B. Senf. (*NachrTech.*, Nov. 1957, Vol. 7, No. 11, pp. 507–511.) The design is described of a continuous phase shifter consisting of a variable capacitor with four groups of stator plates and one group of kidney-shaped rotor plates.

621.316.82 : 621.314.63 **3005**

A Field-Effect Varistor.—(*Bell Lab. Rec.*, April 1958, Vol. 36, No. 4, p. 150.) A two-terminal passive semiconductor is described in which the current can be held constant within 1% in the voltage range 20–120 V. Currents from 10 μA to 10 mA can be handled; the a.c./d.c. resistance ratio in this region is of the order of 100.

621.372.4 **3006**

Elementary Proof of an Extended Reactance Theorem for Two-Terminal Networks.—H. Wolter. (*Z. angew. Phys.*, July 1957, Vol. 9, No. 7, pp. 340–347.) A proof is derived for Foster's reactance theorem which is also applicable to its extended form covering loss-free circuit elements and transmission lines.

621.372.412 : 549.514.51 **3007**

High-*Q* Quartz Crystals at Low Temperatures.—D. L. White. (*J. appl. Phys.*, May 1958, Vol. 29, No. 5, pp. 856–857.) *Q* measurements in the range 4·2°K to over 100°K for several modes of vibration are described. In one case a value of $5 \cdot 5 \times 10^7$ was obtained.

621.372.413 **3008**

Elimination of Unwanted Modes of Oscillation in Cylindrical Cavities.—L. Grifone. (*Alta Frequenza*, Dec. 1957, Vol. 26, No. 6, pp. 580–602.) The possible modes in high-*Q* cylindrical cavity resonators are analysed and the suppression of residual modes by special coupling systems or discontinuities inside the cavity is discussed. Measurements were made on ten tunable cavities of different size covering the frequency range 3·6–36 kMc/s. A frequency-modulated source was used to determine the permissible limits of the cavity tuning range and the dimensions of the discontinuities for obtaining the desired attenuation of unwanted modes without reducing *Q* by more than 5%. The modes and their amplitudes are tabulated.

621.372.413 : 621.372.2 **3009**

***Q* Factors of a Transmission-Line Cavity.**—L. Young. (*Trans. Inst. Radio Engrs*, March 1957, Vol. CT-4, No. 1, pp. 3–5. Abstract, *Proc. Inst. Radio Engrs*, July 1957, Vol. 45, No. 7, p. 1034.)

621.372.414 **3010**

Exponential Transmission Lines as Resonators and Transformers.—R. N. Ghose. (*Trans. Inst. Radio Engrs*, July 1957, Vol. MTT-5, No. 3, pp. 213–217. Abstract, *Proc. Inst. Radio Engrs*, Sept. 1957, Vol. 45, No. 9, p. 1312.)

621.372.5 **3011**

General Method of Analyzing Bilateral, Two-Port Networks from Three Arbitrary Impedance Measurements.—E. F. Bolinder. (*Ericsson Tech.*, 1958, Vol. 14, No. 1, pp. 3–37.) The method consists in mapping stereographically on the surface of the Riemann unit sphere three given output quantities and their corresponding measured input quantities. The fixed points and the multiplier of the normal (canonic) form of the linear fractional transformation representing the network can be obtained by using Klein's three-dimensional generalization of the Pascal theorem. The different constructions of the geometric part can also be performed analytically. Simple numerical examples are worked out.

621.372.51 **3012**

Transformation Quadripoles according to the Insertion-Loss Theory.—C. Kurth. (*Frequenz*, Jan. 1958, Vol. 12, No. 1, pp. 1–8.) The design of filter networks with prescribed attenuation characteristics and impedance transformation in the pass band is discussed. See also 2369 of 1957.

621.372.51 **3013**

Graphical Determination of Matching Sections.—C. J. Vedin & P. O. Leine. (*Ericsson Tech.*, 1958, Vol. 14, No. 1, pp. 91–99.) A description of graphical methods, using the Smith chart, for matching impedances by means of L, Π or T sections.

621.372.54 **3014**

Degenerate Solutions and an Algebraic Approach to the Multiple-Input Linear-Filter Design Problem.—R. M. Stewart & R. J. Parks. (*Trans. Inst. Radio Engrs*, March 1957, Vol. CT-4, No. 1, pp. 10–14. Abstract, *Proc. Inst. Radio Engrs*, July 1957, Vol. 45, No. 7, p. 1035.)

621.372.54 : 621.391 **3015**

Optimum Filters for Independent Measurements of Two Related Perturbed Messages.—J. S. Bendat. (*Trans. Inst. Radio Engrs*, March 1957, Vol. CT-4, No. 1, pp. 14–19. Abstract, *Proc. Inst. Radio Engrs*, July 1957, Vol. 45, No. 7, p. 1035.)

621.372.54 : 621.396.67 **3016**

Antenna Filters for a Military Radio System.—M. D. Brill & R. M. Jensen. (*Bell Lab. Rec.*, April 1958, Vol. 36, No. 4, pp. 142–145.) High-Q coaxial filters are described covering both transmission and reception over the range 50–600 Mc/s in only 22 sub-bands.

621.372.55 + 621.375.4.126 **3017**

Bandwidth Limitations in Equalizers and Transistor Output Circuits.—J. L. Stewart. (*Trans. Inst. Radio Engrs*, March 1957, Vol. CT-4, No. 1, pp. 5–9. Abstract, *Proc. Inst. Radio Engrs*, July 1957, Vol. 45, No. 7, pp. 1034–1035.)

621.373.421.13 **3018**

Temperature-Compensated Crystal Oscillators.—(*Electronic Radio Engr*, Aug. 1958, Vol. 35, No. 8, p. 314.) In the method described a passive network containing a thermistor is enclosed in the same envelope as the crystal.

621.373.431.1 **3019**

The Cathode-Coupled Multivibrator considered as a Coupled Pair of Two-Terminal Networks.—P. Schiaffino. (*Alta Frequenza*, Dec. 1957, Vol. 26, No. 6, pp. 603–631.) The multivibrator is considered as an active two-terminal network with negative differential resistance, together with a passive two-terminal network. Formulae derived on this basis for determining the multivibrator operating characteristics give results in close agreement with experimental values.

621.373.44 : 621.317.755 **3020**

Sawtooth Generators with Commercial-Type Valves for Producing Deflection Voltages of High Amplitude and Extremely Short Duration.—W. Kroebel & G. Olk. (*Z. angew. Phys.*, Aug. 1957, Vol. 9, No. 8, pp. 394–403.) The circuit of a special high-speed oscillograph with a time-base resolution of 4×10^{-9} s/mm is described which was used for examining the waveforms produced by various pulse generators investigated. Pulse amplitudes of 700 V with rise time 3×10^{-8} s, and 520 V, $1\cdot8\times10^{-8}$ s have been obtained.

621.374.32 : 621.383.27 **3021**

Transistorized Photomultiplier has 0·1-μsec Resolution.—G. S. Brunson. (*Nucleonics*, July 1957, Vol. 15, No. 7, pp. 86–87.) Description of high-sensitivity photomultiplier circuit for use in a scintillation counter.

621.374.32 : 621.385.15 **3022**

Secondary-Emission Tubes in Coincidence Circuits.—M. M. Vojinovic. (*Bull. Inst. nuclear Sci. 'Boris Kidrich'*, March 1957, Vol. 7, pp. 103–108.) Switching waveforms of a trigger circuit based on a valve Type EFP60 are analysed, and switching speed and operating conditions are discussed.

621.374.4 **3023**

Harmonic Amplifier for X-Band Local Oscillator.—W. J. Dauksher. (*Electronics*, 20th June 1958, Vol. 31, No. 25, pp. 80–82.) The final frequency tripler in a harmonic-amplifier cascade uses an u.h.f. triode with coaxial cathode input resonator and a wave-guide output resonator giving about 3–5 mW output.

621.375.2.024 **3024**

A One-Valve D.C. Amplifier with High-Impedance Input.—P. Belton. (*Electronic Engng*, July 1958, Vol. 30, No. 365, pp. 454–456.) A simple one-valve high-impedance probe circuit intended for direct connection to a d.c. amplifier is described. Drift is about 1 mV in the first half-hour of use. A simple method of reducing the input time constant is also given.

621.375.2.029.6 **3025**

Low-Noise 30-Mc/s Amplifier.—J. K. D. Verma. (*Rev. sci. Instrum.*, May 1958, Vol. 29, No. 5, pp. 371–374.) Circuit details are given of a 30-Mc/s cascode amplifier using disk-seal triodes, designed for the study of semiconductor noise at low temperatures. The theoretical noise figure of the amplifier is calculated and compared with the value obtained from radiometer measurements.

621.375.4 **3026**

Temperature Stability of Transistor Class-B Amplifiers.—P. Tharma. (*Mullard tech. Commun.*, March 1958, Vol. 3, No. 29, pp. 265–277.) This is discussed generally and in relation to three types of circuit commonly used. Graphical design methods for achieving optimum stability are developed and comparative practical results are given.

621.375.9 : 538.569.4.029.6 **3027**

The Maser.—W. H. Culver. (*Science*, 25th Oct. 1957, Vol. 126, No. 3278, pp. 810–814.) A review of development describing the principles of molecular-beam, 'negative-temperature', 'optically pumped' and solid-state masers.

621.375.9 : 538.569.4.029.6 **3028**

Maser Amplifier Characteristics for Transmission and Reflection Cavities.—M. L. Stich. (*J. appl. Phys.*, May 1958, Vol. 29, No. 5, pp. 782–789.) The noise temperature, bandwidth and gain modulation for transmission- and reflection-type masers are compared. The latter type is superior in most respects, although the same noise temperature may be obtained with the transmission type with some sacrifice in bandwidth and gain modulation. A figure of merit for both types is given.

621.375.9 : 538.569.4.029.64 : 621.372.632 **3029**

A Ferromagnetic-Resonance Frequency Converter.—K. M. Poole & P. K. Tien. (*Proc. Inst. Radio Engrs*, July 1958, Vol. 46, No. 7, pp. 1387–1396.) An experimental and theoretical study of a converter using a magnetized disk of single-crystal yttrium iron garnet. Inputs at 4·2 and 6·4 kMc/s are used to produce an output at 10·6 kMc/s in a cavity resonant at all three frequencies. The output power agrees with that expected theoretically, within experimental error. See also 3076 of 1957 (Suhl).

621.375.9 : 621.3.011.23 **3030**

A Parametric Amplifier using Lower-Frequency Pumping.—K. K. N. Chang & S. Bloom. (*Proc. Inst. Radio Engrs*, July 1958, Vol. 46, No. 7, pp. 1383–1386.) Experimental verification of the principle of parametric amplification using a pumping frequency lower than the signal frequency is described. Variable-inductance (ferrite-core) and variable-capacitance (semiconductor diode) elements have both been used, the former at 10 Mc/s with pumping at 7 Mc/s and the latter at 380 Mc/s with pumping at 300 Mc/s. Bandwidth and noise have been measured as functions of gain for the diode amplifier, and the results compared with theory. See also 1690 of June and 2034 of July (Bloom & Chang).

621.376.332 **3031**

Linear Frequency Discriminator for Subcarrier Frequencies.—P. Kundu. (*Electronic Radio Engr*, Aug. 1958, Vol. 35, No. 8, pp. 309–313.) The discriminator uses a heptode valve with out-of-phase signals on its two control grids. It is suitable for low-frequency f.m. signals having large deviations.

GENERAL PHYSICS

537/538 **3032**

The Electrodielectric Induction.—P. de Belatini. (*Bull. tech. Univ. Istanbul*, 1957, Vol. 10, No. 1, pp. 84–111.) An analogy between magnetic and dielectric quantities discussed earlier (2581 of 1955) is developed with special reference to dynamic phenomena.

537/538 : 519 **3033**

The Method of 'Secondary Quantization' in Phase Space.—Yu. L. Klimontovich. (*Zh. eksp. teor. Fiz.*, Oct. 1957, Vol. 33, No. 4(10), pp. 982–990.) A statistical analysis of systems of interacting particles in which use is made of the number of particles in various points of coordinate-momentum phase space, which at every point of phase space are random functions of time. This method can be used for considering particles and fields in electromagnetic interaction.

537/538].081 **3034**

Dimensions for a Unified Theory of Electromechanics.—L. W. Allen. (*Elect. Engng, N.Y.*, Feb. 1958, Vol. 77, No. 2, pp. 134–140.) A dimensional relation between voltage and mechanical force is derived, and a set of three dimensions, length, time and the square root of force, is proposed for a unified theory.

537.226 **3035**

Interaction of Charged Particles in a Dielectric.—W. Kohn. (*Phys. Rev.*, 15th May 1958, Vol. 110, No. 4, pp. 857–864.) Analytical results may be summarized by the statement that, if sufficiently distant, external charges in a dielectric interact with each other and with the charge of an extra electron or hole as if all charges were renormalized according to the expression $Q\rightarrow Q/\kappa^{\frac{1}{2}}$.

537.226 : 538.569.4 **3036**

Absorption in a Dielectric Slab.—M. P. Bachynski. (*Canad. J. Phys.*, April 1958, Vol. 36, No. 4, pp. 456–461.) Energy incident on a parallel slab of high-loss material with high dielectric constant is considered. At angles of incidence greater than 60°, the reflected energy is smaller the more lossy the material. The absorbed energy is a maximum at certain angles of incidence depending on the polarization and dielectric constant.

537.533 : 538.63 **3037**

Magnetic Forces and Relativistic Speeds in Stationary Electron Beams.—B. Meltzer. (*J. Electronics Control*, April 1958, Vol. 4, No. 4, pp. 350–354.) In nonrelativistic electron beams magnetic forces may have to be considered; they are still more important in relativistic beams. Care must be taken in using the results of calculations in which these forces are neglected.

537.533 : 621.385.029.6 **3038**

Note on Positive-Ion Effects in Pulsed Electron Beams.—J. T. Senise. (*J. appl. Phys.*, May 1958, Vol. 29, No. 5, pp. 839–841.) Experimental results are given for electron beams of 0·5–5 μs duration under conditions normally encountered in high-power microwave valves.

537.533.7 **3039**

Energy Spectrum of an Electron Beam after Passing through a Thin Metallic Film.—C. Fert & F. Pradal. (*C. R. Acad. Sci., Paris*, 13th Jan. 1958, Vol. 246, No. 2, pp. 252–255.) The energy loss is determined for films of Al, Cr, Bi, Au, Ag and Cu.

537.533.73 **3040**

Very-High-Voltage Electron Diffraction.—R. Papoular. (*Cah. Phys.*, May 1957, Vol. 11, No. 81, pp. 202–216.) Description of a diffractograph operating at voltages up to 1·2 MeV.

537.533.73 : 621.317.42 **3041**

The Use of Electron Diffraction for Magnetic Analysis.—S. Yamaguchi. (*Naturwissenschaften*, Jan. 1958, Vol. 45, No. 1, pp. 7–8.) Brief note on a method of evaluating magnetic field strength from the eccentricity of superposed diffraction rings.

537.533.74 **3042**

Electron Scattering Phenomena.—L. Marton. (*J. sci. industr. Res.*, June 1957, Vol. 16A, No.6, pp. 221–230.) New methods of investigation are reviewed.

537.56 **3043**

Diffusion and Elastic Collision Losses of the 'Fast Electrons' in Plasmas.—G. Medicus. (*J. appl. Phys.*, June 1958, Vol. 29, No. 6, pp. 903–908.) When the energy spectrum in Ne at 1 mm Hg pressure can be separated into a primary high-energy and a secondary low-energy Maxwellian group, then the mean free path l of the fast electrons can be evaluated by use of the diffusion law; l is found to be independent of the plasma density. It is remarkable that there is little interaction between fast and slow groups even when the density of the slow one becomes comparable to, or even higher than that of the fast group.

537.56 **3044**

Electron Energy Distributions in Uniform Electric Fields and the Townsend Ionization Coefficient.—T. J. Lewis. (*Proc. roy. Soc. A*, 11th March 1958, Vol. 244, No. 1237, pp. 166–185.) The second-order differential equation which expresses the equilibrium conditions of an electron swarm in a uniform electric field in a gas, the electrons suffering both elastic and inelastic collisions with the gas molecules, is solved using the Jeffreys or WKB method of approximation. The theory is illustrated by a comparison of calculated and observed results for hydrogen.

537.56 **3045**

Experimental Examination of Holtsmark's Theory of Line Broadening.—P. Bogen. (*Z. Phys.*, 23rd Aug. 1957, Vol. 149, No. 1, pp. 62–72.)

537.56 **3046**

Deviation from the Holtsmark Shape of the Balmer Lines in Plasma.—G. Ecker. (*Z. Phys.*, 2nd Oct. 1957, Vol. 149, No. 2, pp. 254–266.) See also 2695 of September.

537.56 : 538.56 **3047**

Scattering of Electromagnetic Waves in a Plasma.—A. I. Akhiezer, I. G. Prokhoda & A. G. Sitenko. (*Zh. eksp. teor. Fiz.*, Sept. 1957, Vol. 33, No. 3(9), pp. 750–757.) The intensity of combination scattering due to plasma density oscillations is determined with and without a constant uniform magnetic field.

537.56 : 538.56 **3048**

Suppression of Plasma Oscillations.—D. W. Mahaffey & K. G. Emeleus. (*J. Electronics Control*, April 1958, Vol. 4, No. 4, pp. 301–304.) In a hot-cathode discharge tube containing gas at low pressure, oscillations of frequency 10^3–10^4 Mc/s can be generated. The oscillations can be suppressed by mounting a plane anode and cathode sufficiently close together; the discharge can still be maintained.

537.56 : 538.6 **3049**

On the Propagation of Hydromagnetic Waves in Compressible Ionized Fluid.—T. Taniuti. (*Progr. theor. Phys.*, Jan. 1958, Vol. 19, No. 1, pp. 69–76.) Mathematical treatment based on a method of characteristics.

537.56 : 538.63 **3050**

The Behaviour of a Completely Ionized Plasma in a Strong Magnetic Field.—S. I. Braginskii. (*Zh. eksp. teor. Fiz.*, Sept. 1957, Vol. 33, No. 3(9), pp. 645–654.)

537.563 : 535.336.2 **3051**

Mass-Spectroscopy Investigations of Photoionization in Gases.—E. Schönheit. (*Z. Phys.*, 2nd Oct. 1957, Vol. 149, No. 2, pp. 153–179.) Experimental equipment is described and 88 references are given.

538.221 : 538.569.4 **3052**

The Theory of Ferromagnetic Resonance at High Signal Powers.—H. Suhl. (*Phys. Chem. Solids*, Jan. 1957, Vol. 1, No. 4, pp. 209–227.) It is shown that two anomalous effects in the microwave absorption of ferromagnets are connected with two kinds of instability of the uniform precessional motion of the total magnetization against certain spin-wave disturbances. The susceptibilities are calculated for the final state attained by the medium with high signal levels, and are shown to agree with experiment.

538.3 : 52 **3053**

Reflection and Refraction in Magnetohydrodynamics.—C. Totaro. (*R. C. Accad. naz. Lincei*, March 1958, Vol. 24, No. 3, pp. 310–316.) Fluids of finite conductivity are considered on the basis of the Euler-Minkowski system, for hydromagnetic waves propagated in a direction differing from that of the external magnetic field.

538.311 : 621.318.3 **3054**

Investigation of and Compensation for the Inhomogeneity of the Magnetic Field of an Electromagnet.—H. Benoit & M. Sauzade. (*C. R. Acad. Sci., Paris*, 27th Jan. 1958, Vol. 246, No. 4, pp. 579–582.)

538.311 : 621.318.3 : 538.569.4 **3055**

Stabilization and Control of an Electromagnet by means of Magnetic Proton Resonance.—H. Andresen. (*Z. angew. Phys.*, July 1957, Vol. 9, No. 7, pp. 326–333.) Long-term magnetic-field stability $\Delta H/H$ of the order of 10^{-6} is obtained by means of a proton-resonance system incorporating a magnetic-field discriminator circuit and a variable-frequency transitron circuit.

538.566 **3056**

On the Reflection of Electromagnetic Waves on a Rough Surface.—M. A. Biot. (*J. appl. Phys.*, June 1958, Vol. 29, No. 6, p.998.) Note of correction to 1392 of May.

538.566 **3057**

Propagation of Plane Electromagnetic Waves in a Directional Conductor with Variable Direction of Conductivity.—C. Banfi. (*R. C. Accad. naz. Lincei*, March 1958, Vol. 24, No. 3, pp. 306–310.) Propagation through a series of directional screens is considered, each screen being rotated by the same angle with respect to the adjacent screen. See also 3705 of 1956 (Toraldo di Francia).

538.566 **3058**

The Theory of Electromagnetic Waves in a Crystal in which Excitons are Produced.—S. I. Pekar. (*Zh. eksp. teor. Fiz.*, Oct. 1957, Vol. 33, No. 4(10), pp. 1022–1036.) It is shown that in a crystal several waves of the same frequency, polarization and propagation direction exist, but with different indices of refraction. This phenomenon differs from double refraction of light and occurs even in isotropically polarizing (cubic) crystals.

538.566 : 535.42 **3059**

Diffraction Patterns at the Plane of a Slit in a Reflecting Screen.—R. K.

Hadlock. (*J. appl. Phys.*, June 1958, Vol. 29, No. 6, pp. 918–920.) Measurements were made of the diffraction pattern in slits ranging in width from 0·2 to 2·5 λ. Microwave radiation of 10·4 and 16 cm λ was used. Ratios of intensity in the slit to intensity of the unperturbed beam were determined for plane-polarized radiation incident on the conducting screen.

538.566 : 535.42 **3060**

Diffraction by a Perfectly Absorbing Thin Screen.—C. C. Derwin. (*J. appl. Phys.*, June 1958, Vol. 29, No. 6, pp. 921–922.) Comparative measurements of the diffraction patterns in and near slits of perfectly absorbing and reflecting thin screens show that the reflected diffraction patterns of the slits are the same for distances greater than λ/2.

538.566 : 535.42 **3061**

The Edge Conditions and Field Representation Theorems in the Theory of Electromagnetic Diffraction.—A. E. Heins & S. Silver. (*Proc. Camb. phil. Soc.*, Jan. 1958, Vol. 54, Part 1, pp. 131–133.) Addendum to 1959 of 1955.

538.566 : 535.43-15 **3062**

Wavelength Dependence of Scattering Coefficient for Infrared Radiation in Natural Haze.—M. G. Gibbons. (*J. opt. Soc. Amer.*, March 1958, Vol. 48, No. 3, pp. 173–176.) A formula consistent with the Mie scattering coefficient is given for 0·61–11·48 μ. See 1705 of June (Penndorf).

538.566.2 **3063**

Propagation in a Gyrational Medium.—L. G. Chambers. (*Quart. J. Mech. appl. Math.*, May 1958, Vol. 11, Part 2, pp. 253–255.) Addendum to 1731 of 1957.

538.569.4 : 530.145 **3064**

Cooperative Phenomena in Quantum Theory of Radiation.—A. Gamba. (*Phys. Rev.*, 1st May 1958, Vol. 110, No. 3, pp. 601–603.) Cooperative effects in systems having dimensions small relative to the wavelength are investigated in relation to the quantum-mechanical identity principle. The application of this effect to a gas maser is mentioned.

GEOPHYSICAL AND EXTRATERRESTRIAL PHENOMENA

523.164.3 **3065**

The Radio Source in the Direction of the Galactic Centre.—F. G. Smith, P. A. O'Brien & J. E. Baldwin. (*Mon. Not. R. astr. Soc.*, 1956, Vol. 116, No. 3, pp. 282–287.) Observations of radio flux densities at frequencies from 38 to 500 Mc/s show that the radiation could originate from a nonthermal source lying behind ionized hydrogen.

523.164.3 : 523.3 **3066**

Radio Observations of a Lunar Occultation of the Crab Nebula.—C. H. Costain, B. Elsmore & G. R. Whitfield. (*Mon. Not. R. astr. Soc.*, 1956, Vol. 116, No. 4, pp. 380–385.) Comparison of brightness distributions at 3·7 and 7·9 m λ shows a difference in apparent size of the radio source. Details of the lunar atmosphere are also obtained (see 3067 below).

523.164.3 : 523.3 **3067**

Radio Observations of the Lunar Atmosphere.—B. Elsmore. (*Phil. Mag.*, Aug. 1957, Vol. 2, No. 20, pp. 1040–1046.) The refraction occurring in the lunar atmosphere is estimated from observations at 3·7 m λ of the lunar occultation of the Crab Nebula on 24th January 1956. The electron density at the moon's surface is derived for an atmosphere in hydrostatic equilibrium and for a continuously escaping atmosphere.

523.164.32 **3068**

The Distribution of Brightness at Metre Wavelengths across the Sun's Disk.—R. G. Conway & P. A. O'Brien. (*Mon. Not. R. astr. Soc.*, 1956, Vol. 116, No. 4, pp. 386–394.)

523.72 : 621.317.794 **3069**

Apparent Temperatures of some Terrestrial Materials and the Sun at 4·3-Millimetre Wavelengths.—A. W. Straiton, C. W. Tolbert & C. O. Britt. (*J. appl. Phys.*, May 1958, Vol. 29, No. 5, pp. 776–782.) Report of measurements made using a Dicke-type radiometer. The apparent temperature of the sun was between 10^4 °K and $1·2 \times 10^4$ °K. At vertical angles the sky temperature was 90°K under clear conditions, but cumulus-nimbus cloud raised this to a value nearly equal to that for ground-level air.

523.755 : 523.164.32 **3070**

Magnetohydrodynamic Shock Waves in the Solar Corona, with Applications to Bursts of Radio-Frequency Radiation.—K. C. Westfold. (*Phil. Mag.*, Nov. 1957, Vol. 2, No. 23, pp. 1287–1302.) Shock fronts ahead of corpuscular streams may account for Type II and Type III bursts. Detailed calculations are given, based on a set of transport equations previously derived for an ionized gas (115 of 1954).

525.35 : 529.786 **3071**
: 621.3.018.41(083.74)

Variation in the Speed of Rotation of the Earth since June 1955.—Essen, Parry, Markowitz & Hall. (See 3195.)

550.371 : 551.594 **3072**

The General Expression of the Diurnal Variation of the Atmospheric Electric Field considering the Influence of the Eddy Diffusion near the Ground.—M. Kawano. (*J. Geomag. Geoelect.*, 1957, Vol. 9, No. 3, pp. 123–132.)

550.371 : 551.594 : 621.317.792 **3073**

Simultaneous Measurement of Air-Earth Current and the Atmospheric Electric Potential Gradient.—M. Goto. (*J. Geomag. Geoelect.*, 1957, Vol. 9, No. 3, pp. 133–139.)

550.38 : 538.3 **3074**

Oscillations of a System of Disk Dynamos.—T. Rikitake. (*Proc. Camb. phil. Soc.*, Jan. 1958, Vol. 54, Part 1, pp. 89–105.) "The behaviour of two disk dynamos coupled to one another is examined in relation to the earth's magnetic field. It is found that reversals of electric current and magnetic field occur, unlike the case of a single disk dynamo." See also 1401 of 1956 (Bullard).

550.382.4 **3075**

The Earth's Magnetic Field above WSPG, New Mexico, from Rocket Measurements.—J. P. Heppner, J. D. Stolarick & L. H. Meredith. (*J. geophys. Res.*, June 1958, Vol. 63, No. 2, pp. 277–288.) The absolute magnetic field was measured from ground level to 163 km with a proton precessional magnetometer. The typically quiet field differed significantly from that of a dipole, but no ionospheric discontinuity was found.

550.385 **3076**

Some Observations of Geomagnetic Micropulsations.—H. J. Duffus & J. A. Shand. (*Canad. J. Phys.*, April 1958, Vol. 36, No. 4, pp. 508–526.) These new observations of diurnal variation, direction and frequency spectrum are viewed in comparison with published data and it is suggested that they have a solar time dependence and may occur locally. At two stations 60° in longitude apart, related signals are only occasionally observed; however the phase relationship of the few which are related, together with differences in direction characteristics reported by other observatories, are not in agreement with recent theories of the origin of micropulsations.

550.385 **3077**

The Propagation Velocity of World-Wide Sudden Commencements of Magnetic Storms.—A. J. Dessler. (*J. geophys. Res.*, June 1958, Vol. 63, No. 2, pp. 405–408.) A model is presented in which a longitudinal hydromagnetic wave, generated by impact between a plasma cloud from the sun and the earth's field, travels east and west round the geomagnetic equator. The wave will be stable at 400 km altitude and travel at about 130 km/s.

550.385 : 523.72 : 523.165 **3078**

The Magnetic-Storm Effects and the Interplanetary Electromagnetic State.—D. Venkatesan. (*Tellus*, May 1957, Vol. 9, No. 2, pp. 209–219.) Alfvén's theory (see 2620 of 1955) that a beam of rarefied ionized gas is ejected from the sun can be applied to explain terrestrial cosmic-ray observations and magnetic-storm effects.

550.389.2 : 629.19 **3079**

Visual Thresholds for Detecting an Earth Satellite.—I. S. Gulledge, M. J. Koomen, D. M. Packer & R. Tousey. (*Science*, 23rd May 1958, Vol. 127, No. 3308, pp. 1242–1243.)

550.389.2 : 629.19 **3080**

Effect of Length of Observing Time on the Visual Threshold for Detecting a Faint Satellite.—W. D. Garvey, I. S.

Gulledge & J. B. Henson. (*Science*, 23rd May 1958, Vol. 127, No. 3308, pp. 1243–1244.)

550.389.2 : 629.19 **3081**

Formula for Inferring Atmospheric Density from the Motion of Artificial Earth Satellites.—T. E. Sterne. (*Science*, 23rd May 1958, Vol. 127, No. 3308, p. 1245.)

550.389.2 : 629.19 **3082**

Effect of the Earth's Equatorial Bulge on the Lifetime of Artificial Satellites and its Use in Determining Atmospheric Scale-Heights.—G. V. Groves. (*Nature, Lond.*, 12th April 1958, Vol. 181, No. 4615, p. 1055.)

550.389.2 : 629.19 **3083**

Calculation of the Lifetime of a Satellite.—D. G. Parkyn. (*Nature, Lond.*, 19th April 1958, Vol. 181, No. 4616, pp. 1156–1157.)

550.389.2 : 629.19 **3084**

Explorer (Satellite 1958α) over Africa.—D. S. Evans. (*Nature, Lond.*, 26th April 1958, Vol. 181, No. 4617, pp. 1173–1174.) Records of visual observations made in South Africa.

550.389.2 : 629.19 **3085**

Determination of Radio-Propagation Elements due to an Artificial Earth Satellite.—E. Woyk-Chvojková. (*Nature, Lond.*, 26th April 1958, Vol. 181, No. 4617, pp. 1195–1196.) A simple formula is given expressing path length for determining the virtual position of a radiating source.

550.389.2 (54) **3086**

The International Geophysical Year—Indian Programme.—(*J. sci. industr. Res.*, June 1957, Vol. 16A, No. 6, pp. 231–233.)

551.510.5 : 535.334.08 **3087**

High-Altitude Infrared Studies of the Atmosphere.—D. Murcray, J. Brooks, F. Murcray & C. Shaw. (*J. geophys. Res.*, June 1958, Vol. 63, No. 2, pp. 289–299.) A balloon flight with a Littrow spectrometer gave spectra from ground level to 65 000 ft. Water vapour bands ($1 \cdot 4$ and $1 \cdot 9\,\mu$) had completely disappeared above 46 000 ft.

551.510.535 **3088**

Calculation of True Heights of Electron Density in the Ionosphere.—N. Ganesan. (*Tijdschr. ned. Radiogenoot.*, Sept. 1957, Vol. 22, No. 5, pp. 277–291. In English.) By assuming that the electron density distribution can be approximated by taking linear sections of variable length, $h'(f)$ records may be manually converted to true-height/electron-density profiles. The method takes into account the earth's magnetic field and is similar to that used by Jackson (2381 of 1956). Results are compared with actual electron density profiles derived from rocket observations.

551.510.535 **3089**

The Analysis of Rocket Experiments in Terms of Electron-Density Distributions.—W. Pfister & J. C. Ulwick. (*J. geophys. Res.*, June 1958, Vol. 63, No. 2, pp. 315–333.) The relative delay of a pulsed signal as a function of rocket position (USAF Aerobee No. 38) is used to deduce the electron-density distribution to heights of about 135 km. The data are analysed for ascent and descent, at frequencies of $4 \cdot 05$ and $4 \cdot 87$ Mc/s; peaks are shown at 106, 111, 117 and 128 km, and an intense irregularity on ascent at 98 km. Good agreement with a simultaneous $P'(f)$ record is obtained.

551.510.535 : 621.396.11 **3090**

Solar Activity and Radio Communication.—R. Naismith. (*Nature, Lond.*, 5th April 1958, Vol. 181, No. 4614, pp. 954–956.) The monthly median value of the F_2 critical frequency for noon during December 1957 was $15 \cdot 2$ Mc/s, the highest December average value ever recorded at Slough. This gives a value close to 50 Mc/s for the 'demarcation' frequency, used for planning radio communication, in temperate latitudes.

551.594.2 : 621.396.969.36 **3091**

Correlation of the Initial Electric Field and the Radar Echo in Thunderstorms.—S. E. Reynolds & M. Brook. (*J. Met.*, Aug. 1956, Vol. 13, No. 4, pp. 376–380.) Precipitation, as detected with 3-cm radar, is a necessary, but not sufficient, condition for significant cloud electrification. The presence of detectable precipitation does not lead to thunderstorm electrification unless the precipitation echo shows rapid vertical development.

551.594.21 **3092**

The Development and Masking of Charges in Thunderstorms.—J. Kuettner. (*J. Met.*, Oct. 1956, Vol. 13, No. 5, pp. 456–470.)

551.594.5 : 523.164 **3093**

Auroral Absorption of 18-Mc/s Cosmic Radio Waves on February 11th 1958.—R. Fleischer. (*Nature, Lond.*, 19th April 1958, Vol. 181, No. 4616, p. 1156.) A relative absorption of approximately 11dB was recorded near Troy, N.Y., during a spectacular auroral display.

551.594.5 : 621.396.11 : 551.510.535 **3094**

The Role of F-Layer Tilts in Detection of Auroral Ionization.—S. Stein. (*J. geophys. Res.*, June 1958, Vol. 63, No. 2, pp. 391–404.) Back-scatter echoes received at Stanford, California, from the auroral E region are shown to be propagated by way of a tilted F layer. The rays returned from the E-region scattering source proceed to the F layer without intermediate earth reflection. The F layer is so tilted that the rays are then returned to the receiver. A tilted mirror model of the F layer demonstrates the effect. This explanation is shown to be more probable than that in which the echoes are presumed to be returned from auroral ionization at great heights, although this latter explanation may occasionally be true.

551.594.6 **3095**

Natural Electrical Oscillations in the Earth-Air-Ionosphere Cavity Excited by Lightning Discharges.—W. O. Schumann. (*Z. angew. Phys.*, Aug. 1957, Vol. 9, No. 8, pp. 373–378.) The theory underlying the experimentally observed resonance effects [2948 of 1954 (Schumann & König)] is discussed. See also 2195 of 1954 and back references.

LOCATION AND AIDS TO NAVIGATION

621.396.933 : 621.396.676 **3096**

TACAN Data Link.—(*Elect. Commun.*, Sept. 1957, Vol. 34, No. 3, pp. 150–275.) A symposium comprising the following papers:—

(*a*) Electronic System in Air-Traffic Control.—P. C. Sandretto (pp. 153–159).

(*b*) Background and Principles of Tacan Data Link.—B. Alexander & R. C. Renick (pp. 160–178).

(*c*) History of Tacan Data Link.—R. I. Colin (pp. 179–185).

(*d*) Tacan Data Link for Common-System Air-Traffic Control.—M. Block (pp. 186–191).

(*e*) Vortac Data Link.—R. C. Renick (pp. 192–197).

(*f*) Operation of AN/URN-6 Data-Link Surface Equipment.—J. F. Sullivan (pp. 198–208).

(*g*) Input and Output Facilities of Data-Link Surface Equipment.—G. W. Reich, Jr, & H. J. Mills (pp. 209–218).

(*h*) Standardization of Circuits for Data-Link Surface Equipment.—H. J. Mills & F. L. Van Steen (pp. 219–227).

(*i*) Airborne Tacan Data-Link Equipment AN/ARN-26.—E. R. Altonji (pp. 228–242).

(*j*) Techniques Developed for Airborne Tacan Data Link.—E. R. Altonji, E. A. Kunkel, H. G. Whitehead & R. Mead (pp. 243–263).

(*k*) Data-Link Airborne Instrumentation.—M. A. Argentieri & F. E. Lind (pp. 264–270).

(*l*) Evaluator and Trainer for Tacan Data Link.—W. B. Sudduth & J. F. Sullivan (pp. 271–275).

See also 3386 of 1956.

621.396.933.1 : 621.396.962.23 **3097**

Doppler Navigation.—(*J. Inst. Nav.*, April 1958, Vol. 11, No. 2, pp. 117–145. Discussion, pp. 146–149.)

(*a*) Airborne Doppler Equipment.—G. E. Beck (pp. 117–124). An account of the basic principles of Doppler navigation, including aerial patterns, presentation of data and various sources of error.

(*b*) The Navigational Applications of Doppler Equipments.—C. N. Moorhen (pp. 125–130). A description of operational procedures and the accuracy achieved in military aircraft.

(*c*) The Future Development of Doppler Navigation.—P. A. Houghton (pp. 130–137). Various possible improvements in equipment are described. These mainly concern the use of automatic computers to simplify the presentation of data. Experimental models of units are discussed.

(*d*) Doppler and Civil Aviation.—D. O. Fraser (pp. 138–143). A discussion of accuracy requirements, and integration with other navigational aids.

(*e*) The Sea Surface and Doppler.—C.S. Durst (pp. 143–145). Data on the frequency of occurrence of calm conditions in various sea areas, and of the dependence of the sea roughness on wind speed.

621.396.933.23 **3098**

The Power Level Controls in the Transmitters of the Instrument Landing System (ILS).—K. May. (*Nachrichtentech. Z.*, Dec. 1957, Vol. 10, No. 12, pp. 612–617.) Bridge-type power control circuits are described which are used for ensuring the correct balance of the power radiated by the two transmitters of the system. A detailed analysis of the operation of the controls indicates that undesirable phase shifts can occur in the approach-course transmitter; these can be cancelled by compensation.

621.396.963 **3099**

Radar Plotting Errors.—H. Topley. (*J. Inst. Nav.*, April 1958, Vol. 11, No. 2, pp. 167–171.) A discussion of methods of plotting and of errors in the derived course and speed of an observed vessel.

621.396.963.3 : 551.576/.578 **3100**

Interpretation of the Height-versus-Time Presentation of Radar Echoes.—V. G. Miles. (*J. Met.*, Aug. 1956, Vol. 13, No. 4, pp. 362–368.) Discussion of meteorological factors affecting the echo trace on a 1·25-cm radar used for detection of precipitation and clouds. See 2749 of 1956 (Plank et al.).

621.396.969.33 **3101**

The Accuracy of Radar Plotting in Estimating Course and Speed.—S. Holmström. (*J. Inst. Nav.*, April 1958, Vol. 11, No. 2, pp. 157-166.) A statistical assessment of errors and their influence on the accuracy of the measurement from one ship of the movements of another.

MATERIALS AND SUBSIDIARY TECHNIQUES

535.215 **3102**

Analysis of Photoconductivity Applied to Cadmium-Sulphide-Type Photoconductors.—R. H. Bube. (*Phys. Chem. Solids*, Jan. 1957, Vol. 1, No. 4, pp. 234–248.) A model of a photoconductor having two different types of recombination centre is used to describe phenomena such as supralinearity, temperature dependence, infrared quenching and variations in speed of response. When applied to experimental data a ratio 8×10^5 is given for the capture cross-section of the sensitizing centres for holes, to that for electrons, and a value 0·64 eV for the energy difference between the level corresponding to this type of centre and the top of the valence band.

535.215 : 546.482.21 **3103**

Observation of the Photovoltaic Effect in a Film of Cadmium Sulphide.—F. Cabannes. (*C. R. Acad. Sci., Paris*, 13th Jan. 1958, Vol. 246, No. 2, pp. 257–260.) Report of measurements made on a CdS film between Cu (or Ag) and In electrodes.

535.37 : 546.472.21 **3104**

The Luminescence of Self-Coactivated ZnS:Cu.—M. H. Aven & R. M. Potter. (*J. electrochem. Soc.*, March 1958, Vol. 105, No. 3, pp. 134–140.) Phosphors prepared by firing ZnS with Cu in purified H_2S show a simple orange emission band, with no other bands in evidence even at 90°K. Possible models for the orange centre are discussed.

535.37 + 535.215] : 546.482.21 **3105**

Fluorescence and Photoconduction of Silver-Activated Cadmium Sulphide.—W. van Gool. (*Philips Res. Rep.*, April 1958, Vol. 13, No. 2, pp. 157–166.) With Ga or Cl as coactivator, the fluorescence at low temperature shows two bands with maxima at 6 200 Å and 7 300 Å. The proportion of each emission can be varied by altering the concentrations of activator and coactivator. Previous conclusions regarding the impurity level responsible for the 6 200 Å Ag emission in CdS cannot be applied to the normal blue Ag emission in ZnS-Ag and this has led to an improvement in the properties of a red colour-television phosphor.

535.37 : 546.482.21 **3106**

The Nature of the Edge Emission in CdS.—G. Diemer, G. J. van Gurp & H. J. G. Meyer. (*Physica*, Oct. 1957, Vol. 23, No. 10, pp. 987–988.) Experiments on relatively pure crystals give support to the views of Lambe et al. (797 of 1957) and Smith (2467 of 1957).

535.376 : 537.311.33 : 546.26-1 **3107**

Electroluminescence of Diamonds.—A. Fischer. (*Z. Phys.*, 23rd Aug. 1957, Vol. 149, No. 1, pp. 107–110.) Preliminary report and interpretation of test results. See also 2468 of 1957 (Wolfe & Woods).

537.226/.228.2 : 546.431.824-31 **3108**

Electrostriction in Barium Titanate above the Curie Point.—G. Schmidt. (*Naturwissenschaften*, Jan. 1958, Vol. 45, No. 1, pp. 8–9.) Preliminary report of tests on single-crystal specimens. See also 2754 of September.

537.226/.227 **3109**

Structural and Electrical Properties of Silver Niobate and Silver Tantalate.—M. H. Francombe & B. Lewis. (*Acta cryst.*, 10th March 1958, Vol. 11, Part 3, pp. 175–178.) At room temperature both $AgNbO_3$ and $AgTaO_3$ possess orthorhombic multiple-cell perovskite-type structures and are isomorphous with $NaNbO_3$. In $AgNbO_3$ the structure changes sharply to near-tetragonal at 325° C, while in $AgTaO_3$ a similar change occurs, more smoothly, at about 375° C. The permittivity of $AgNbO_3$ shows a peak at the orthorhombic-tetragonal transition. Weak hysteresis and pyroelectric effects indicate a low value of spontaneous polarization. With $AgTaO_3$ the nature of its structure transitions and the permittivity data obtained for the solid solution $AgNb_{0·75}$-$Ta_{0·25}O_3$ suggest the absence of ferroelectricity. See 1783 of 1957.

537.226/.227 : 546.431.824-31 **3110**

Examination of the Surface and Domain Structure in Ceramic Barium Titanate.—V. J. Tennery & F. R. Anderson. (*J. appl. Phys.*, May 1958, Vol. 29, No. 5, pp. 755–758.) Polished, etched and free surfaces are examined by the direct carbon replica technique. Domain configurations are studied at a higher magnification than that obtained in optical methods.

537.227 **3111**

Growing of Ferroelectric $PbTiO_3$ Crystals.—J. Kobayashi. (*J. appl. Phys.*, May 1958, Vol. 29, No. 5, pp. 866–867.)

537.227 : 537.533.8 **3112**

Interaction of Low-Energy Electrons with Ferroelectric Materials.—R. C. Miller & R. D. Heidenreich. (*J. appl. Phys.*, June 1958, Vol. 29, No. 6, pp. 957–963.) An investigation of the effects of low-energy electron bombardment on $BaTiO_3$ and triglycine sulphate.

537.227 : 546.431.824-31 **3113**

Free Energy, Internal Fields and Ionic Polarizibilities in $BaTiO_3$.—S. Triebwasser. (*Phys. Chem. Solids*, 1957, Vol. 3, Nos. 1/2, pp. 53–62.) Calculations are made allowing for the atomic displacements found from neutron diffraction data.

537.227 : 547.476.3 **3114**

Theory of Rochelle Salt.—A. F. Devonshire. (*Phil. Mag.*, Aug. 1957, Vol. 2, No. 20, pp. 1027–1039.) An attempt is made to explain the results of Bancroft's high-pressure measurements of dielectric constant (*Phys. Rev.*, 1st April 1938, Vol. 53, No. 7, pp. 587–590) by a modification of Mason's theory (*Phys. Rev.*, 1st Nov. 1947, Vol. 72, No. 9, pp. 854–865).

537.311.31 : 539.234 : 538.63 **3115**

Magneto-electric Properties of Thin Films of Nickel Magnetized to Saturation.—T. Rappeneau. (*C. R. Acad. Sci., Paris*, 27th Jan. 1958, Vol. 246, No. 4, pp. 571–574.) Investigation of the variation of resistance as a function of magnetic field strength and direction for field strengths of 4 000–8 000 oersteds. For earlier experiments see 1107 of 1957.

537.311.32 : 546.212-16 **3116**

Conduction of Electricity through Ice and Snow.—R. Siksna & A. Metnieks. (*Ark. Fys.*, 1957, Vol. 11, Part 6, pp. 495–528, 567–585.) The article, which is in four parts, describes a series of measurements of the conductivity of ice and snow designed to serve as a basis for investigations of more general problems in that field.

537.311.33 **3117**

On the Statistical Mechanics of Impurity Conduction in Semiconductors.—P. J. Price. (*IBM J. Res. Developm.*, April 1958, Vol. 2, No. 2, pp. 123–129.) The case of low donor density with partial acceptor compensation is analysed on the basis of the Mott model. An expression for the thermoelectric power is obtained. The special case of mixed donors in disparate proportions is also considered.

537.311.33 **3118**

Scattering of Carriers by Ionized Impurities in Semiconductors.—F. J. Blatt. (*Phys. Chem. Solids*, Jan. 1957, Vol. 1, No. 4, pp. 262–269.) The scattering cross-section due to ionized impurities has been calculated assuming the surfaces of constant energy in $\boldsymbol{k}$ space to be spheres. The results have been compared with the Born approximation. This gives incorrect results at low temperatures. Calculation of Hall and drift mobilities have been made. This shows that the $T^{3/2}$ law for scattering is not followed accurately.

537.311.33 **3119**

On Impact Ionization in Semiconductors.—H. L. Armstrong. (*J. Electronics Control*, April 1958, Vol. 4, No. 4, pp. 355–357.) An alternative treatment to that of Rose (624 of February) giving somewhat different results.

537.311.33 **3120**

New Semiconducting Ternary Compounds.—J. H. Wernick & K. E. Benson. (*Phys. Chem. Solids*, 1957, Vol. 3, Nos. 1/2, pp. 157–159.) Preliminary resistivity/temperature data on impure polycrystalline specimens of synthesized sulpharsenates of copper and silver and analogous compounds indicate that the intrinsic energy gaps lie in the range 0·2–1·0 eV.

537.311.33 **3121**

Infrared Measurements of the Temperature Dependence of the Electron Activation Energy in Trivalent Tellurides.—G. Harbeke & G. Lautz. (*Optik, Stuttgart*, Dec. 1957, Vol. 14, No. 12, pp. 547–554.) Report on measurements of infrared transmission through crystals of Ga_2Te_3 and In_2Te_3 in the temperature range 20°–650°K. The temperature dependence of the forbidden band is found to be $-7·7 \times 10^{-4}$ eV/degree for Ga_2Te_3 and $-5·59 \times 10^{-4}$ eV/degree for In_2Te_3. Results obtained by optical and by electrical methods are compared.

537.311.33 : 537.29 **3122**

The Behaviour of Nonmetallic Crystals in Strong Electric Fields.—L. V. Keldysh. (*Zh. eksp. teor. Fiz.*, Oct. 1957, Vol. 33, No. 4(10), pp. 994–1003.) Expressions are derived for the number of electron-hole pairs generated in a semiconductor by a uniform electric field. In the absence of electron-phonon collisions and collisions between electrons themselves the magnitude of the effective potential barrier is determined not by the width of the forbidden band, but by the lower edge of optical absorption.

537.311.33 : 537.32 **3123**

Theory of Thermoelectric Effects in Semiconductors.—O. Madelung. (*Z. Naturf.*, Jan. 1958, Vol. 13a, No. 1, pp. 22–25.) Some inconsistencies in the relevant literature are critically discussed. See e.g. 3771 of 1956 (ter Haar & Neaves).

537.311.33 : [546.28 + 546.289 **3124**

On Spiral Etch Pits in Germanium and Silicon.—S. G. Ellis. (*Phil. Mag.*, Oct. 1957, Vol. 2, No. 22, p. 1285.) The author's earlier theories (see 466 of 1956) are reconsidered in the light of subsequent work by others.

537.311.33 : 546.28 **3125**

Solubility of Lithium in Silicon.—E. M. Pell. (*Phys. Chem. Solids*, 1957, Vol. 3, Nos. 1/2, pp. 77–81.) Measurements from 592°C to 1 382°C show a maximum impurity atom fraction of $1·3 \times 10^{-3}$ at about 1 200°C. A Li-Si eutectic point at 58 ± 5 atom % of Li was found at 590 ± 10°C.

537.311.33 : 546.28 **3126**

Electrolysis of Copper in Solid Silicon.—C. J. Gallagher. (*Phys. Chem. Solids*, 1957, Vol. 3, Nos. 1/2, pp. 82–86.) Transport measurements indicate that a large fraction, possibly 50%, of the Cu in solution is positively charged, interstitial, and diffuses rapidly at 1 100°C. Cu also diffuses in Ge with a positive charge at 700°C.

537.311.33 : 546.28 **3127**

Lifetime and Nickel Precipitation in Silicon.—W. J. Shattes & H. A. R. Wegener. (*J. appl. Phys.*, May 1958, Vol. 29, No. 5, p. 866.)

537.311.33 : 546.28 **3128**

Two Chemical Stains for Marking *p-n* Junctions in Silicon.—P. J. Whoriskey. (*J. appl. Phys.*, May 1958, Vol. 29, No. 5, pp. 867–868.)

537.311.33 : 546.28 **3129**

Junction Delineation in Silicon by Gold Chemiplating.—S. J. Silverman & D. R. Benn. (*J. electrochem. Soc.*, March 1958, Vol. 105, No. 3, pp. 170–172.) The method described is based on the preferential plating of gold on *n*-type material in the presence of light.

537.311.33 : 546.28 **3130**

Energy of Ionization by Electrons in Silicon Crystals.—V. M. Patskevich, V. S. Vavilov & L. S. Smirnov. (*Zh. eksp. teor. Fiz.*, Sept. 1957, Vol. 33, No. 3(9), pp. 804–805.) The mean ionization energy ϵ for primary electron energies up to 30 keV was determined from the excess carrier current through a *p-n* junction located about 20 μ beneath the irradiated surface. The value of ϵ obtained was 4·2 ± 0·6 eV. See 2502 of 1957 (Vavilov et al.).

537.311.33 : 546.28 **3131**

Breakdown in Silicon.—B. Senitzky & J. L. Moll. (*Phys. Rev.*, 1st May 1958, Vol. 110, No. 3, pp. 612–620.) The characteristics of Si junctions in the breakdown region are investigated for uniform diffused junctions and an alloyed junction having only one small breakdown region (microplasma). The *V/I* characteristic of a single microplasma junction is compared with a previous theoretical prediction of Rose (2183 of 1957). The behaviour of a uniform junction is explained in terms of the results obtained for the single microplasma junction.

537.311.33 : 546.28 **3132**

Birefringence Caused by Edge Dislocations in Silicon.—R. Bullough. (*Phys. Rev.*, 1st May 1958, Vol. 110, No. 3, pp. 620–623.) The intensity distribution of a beam of infrared light transmitted by a Si crystal containing a dislocation is calculated. The difference between an edge dislocation and an inclusion is noted. See also 2438 of 1956 (Bond & Andrus).

537.311.33 : 546.28 : 621.314.63 **3133**

Crack-Free Alloyed Junctions in Silicon using Pure Aluminium.—T. C. Taylor. (*J. appl. Phys.*, May 1958, Vol. 29, No. 5, pp. 865–866.) The technique involves removing the molten-phase Al-Si alloy from the fusion cavity after sufficient cooling but before total solidification. A gold wire or ribbon plunged into the molten alloy forms solid reaction products which are readily lifted or blown out.

537.311.33 : 546.28 : 621.314.7 **3134**

Improved Diffusion Boundary Junctions in Silicon due to Scratch-Free Polishing.—F. Keywell. (*J. appl. Phys.*, May 1958, Vol. 29, No. 5, pp. 871–872.) A surface preparation is discussed which permits fabrication of diffused silicon *p-n-i-p* transistors of 10^{-2}-cm² emitter area with 1·5-μ base layer.

537.311.33 : 546.281.26 **3135**

Electrical Properties of Silicon Carbide.—R. Goffaux. (*Rev. gén. Élect.*, Nov. 1957, Vol. 66, No. 11, pp. 569–576.) It is suggested that the boundaries of SiC grains are covered with a semiconducting layer, probably SiO_2, and that the interior acts as a conductor. Experimental results are found to be consistent with this theory. See also 2786 of September.

537.311.33 : 546.281.26 : 621.314.63 **3136**

Electrical Contacts to Silicon Carbide.—R. N. Hall. (*J. appl. Phys.*, June 1958, Vol. 29, No. 6, pp. 914–917.) Rectifying junctions may be made by heating Si-Al or Si-B alloys in contact with *n*-type SiC. Visible radiation is emitted uniformly over the rectifying junctions when current is passed in the forward direction, with a quantum efficiency of the order of 10^{-6}.

537.311.33 : 546.289 **3137**

Solubility of Lithium in Germanium.—E. M. Pell. (*Phys. Chem. Solids*, 1957, Vol. 3, Nos. 1/2, pp. 74–76.) Measurements from 593°C to 899°C show a maximum impurity atom fraction of $1·7 \times 10^{-4}$ at about 800°C. A Li-Ge eutectic point at 49 ± 5 atom % of Li was found at 525 ± 10°C.

537.311.33 : 546.289 **3138**

Variation of Contact Potential with Crystal Face for Germanium.—F. G. Allen & A. B. Fowler. (*Phys. Chem. Solids*, 1957, Vol. 3, Nos. 1/2, pp. 107–114.) The areal average work functions of the different crystal faces for Ge are measured and found to give a reproducible pattern of values correlated with crystallographic directions. Results are insensitive to bulk doping.

537.311.33 : 546.289 **3139**

Characteristics of Junctions in Germanium.—N. J. Harrick. (*J. appl. Phys.*, May 1958, Vol. 29, No. 5, pp. 764–770.) Junction theory is tested by measuring the current/carrier-density characteristics by an infrared technique. The results agree with existing theories in the case of highly doped Ge regions and low injection levels, but an extended theory is necessary for other conditions.

537.311.33 : 546.289 **3140**

Thermal Restoration of Oxygenated Germanium Surfaces.—A. J. Rosenberg, P. H. Robinson & H. C. Gatos. (*J. appl. Phys.*, May 1958, Vol. 29, No. 5, pp. 771–775.) The oxygen-adsorbing capacity of cleaved Ge surfaces was restored by heating in vacuo above 575°C; this effect was absent below 425°C.

537.311.33 : 546.289 **3141**

Majority-Carrier Lifetime in Copper-Doped Germanium at 20°K.—D. A. H. Brown. (*J. Electronics Control*, April 1958, Vol. 4, No. 4, pp. 341–349.) The time constant for recombination of a hole with a negatively charged Cu impurity centre in Ge at 20°K has been derived experimentally by two independent methods. The values obtained agree in order of magnitude, but are several orders of magnitude less than the theoretical ones; this confirms previous results. The recombination time constants did not decrease as the impurity concentration rose; this too is not in accordance with theory. See 3641 of 1955 (Sclar & Burstein).

537.311.33 : 546.289 **3142**

Isotopic and Other Types of Thermal Resistance in Germanium.—T. H. Geballe & G. W. Hull. (*Phys. Rev.*, 1st May 1958, Vol. 110, No. 3, pp. 773–775.) The occurrence of isotopes in a crystal disturbs the periodicity of the lattice and produces thermal resistance. This effect has been shown to occur in crystals of Ge.

537.311.33 : 546.289 **3143**

Rate Processes and Low-Temperature Electrical Conduction in *n*-Type Germanium.—S. H. Koenig. (*Phys. Rev.*, 15th May 1958, Vol. 110, No. 4, pp. 986–988.) Discussion of experimental results and their theoretical implications.

537.311.33 : 546.289 **3144**

Recombination of Thermal Electrons in *n*-Type Germanium below 10°K.—S. H. Koenig. (*Phys. Rev.*, 15th May 1958, Vol. 110, No. 4, pp. 988–990.) The thermal recombination coefficient is derived from measurements of the current decay time constant using very rapidly changing voltage steps.

537.311.33 : 546.289 **3145**

Chill Casting of Thin Plates of Single-Crystal Germanium.—W. Bösenberg. (*Z. angew. Phys.*, July 1957, Vol. 9, No. 7, pp. 347–349.) Germanium is cast in water-cooled graphite or quartz moulds; the thickness of the plate is of the order of 0·5 mm.

537.311.33 : 546.289 **3146**

Solid-State Dissolution of Germanium by Indium in Semiconductor Devices.—J. Roschen & C. G. Thornton. (*J. appl. Phys.*, June 1958, Vol. 29, No. 6, pp. 923–928.) Small cavities have been observed to develop in Ge semiconductor devices with In metal contacts. These occur below the melting point of In and are due to a solid-state dissolution of Ge by In with a subsequent more rapid diffusion of Ge in In. This is limited by a 0·001%–0·011% solubility of the one in the other.

537.311.33 : 546.289 **3147**

Germanium Arsenide as Diffusion Surface Compound.—W. Waring, D. T. Pitman & S. R. Steele. (*J. appl. Phys.*, June 1958, Vol. 29, No. 6, pp. 1002–1003.) On doping Ge with arsenic, GeAs and $GeAs_2$ are formed on the surface of the Ge. X-ray spectrometer data on lattice spacings and relative intensities are given.

537.311.33 : 546.289 : 537.533.8 **3148**

Investigation of Characteristic Energy Losses of Electrons and the Secondary Electron Emission from GeO_2.—N. B. Gornyĭ & A. Yu. Reĭtsakas. (*Zh. eksp. teor. Fiz.*, Sept. 1957, Vol. 33, No. 3(9), pp. 571–575.) The energy loss of reflected electrons has been determined from measurements on GeO_2-coated plates of *n*- and *p*-type Ge. Characteristics for both types are similar. The secondary-electron yield from GeO_2 is almost twice that from Ge.

537.311.33 : 546.289 : 539.32.08 **3149**

Elastic Moduli of Single-Crystal Germanium as a Function of Hydrostatic Pressure.—H. J. McSkimin. (*J. acoust. Soc. Amer.*, April 1958, Vol. 30, No. 4, pp. 314–318.) Report of measurements made at 62·5 and 125 Mc/s using a quartz crystal transducer and a phase comparison technique.

537.311.33 : 546.289 : 539.433 **3150**

Temperature Dependence of Internal Friction in Germanium.—P. D. Southgate. (*Phys. Rev.*, 15th May 1958, Vol. 110, No. 4, pp. 855–857.) The friction has been measured as a function of temperature at 100 kc/s. All crystals showed a peak at 420°C. A specimen strained in tension showed a rapid rise with temperature above 500°C. A small peak at 770°C is attributed to the presence of oxygen. See also 3540 and 3541 of 1957 (Kessler).

537.311.33 : 546.47-31 **3151**

Concentration of Hydrogen and Semiconductivity in ZnO under Hydrogen-Ion Bombardment.—J. J. Lander. (*Phys. Chem. Solids*, 1957, Vol. 3, Nos. 1/2, pp. 87–94.)

537.311.33 : 546.561-31 **3152**

Discussion of some Optical and Electrical Properties of Cu_2O.—J. Bloem. (*Philips. Res. Rep.*, April 1958, Vol. 13, No. 2, pp. 167–193.) From known data a band scheme is constructed for this semiconductor, and equilibrium conditions for solid constituents at high temperatures with an applied partial pressure of oxygen are calculated. An evaluation of conductivity and the concentrations of defect centres is in good agreement with experiment. The change in properties observed after quenching is attributed to association between defects and the chemisorption of oxygen.

537.311.33 : 546.621.86 **3153**

Single Crystals and *p-n*-Layer Crystals of Aluminium Antimonide.—H. A. Schell. (*Z. Metallkde*, March 1958, Vol. 49, No. 3, pp. 140–144.) Techniques of crystal pulling and zone refining are described. AlSb of *n* type can be produced by adding Te or Se. The barrier voltage of junction-type rectifiers may be raised above 30 V, with a reverse current of less than 300 μA and a forward current greater than 500 mA/cm² at 2 V.

537.311.33 : 546.682.19 : 538.63 **3154**

Magnetoresistance Oscillations in Single-Crystal and Polycrystalline Indium Arsenide.—R. J. Sladek. (*Phys. Rev.*, 15th May 1958, Vol. 110, No. 4, pp. 817–826.) Resistivity measurements were made on both crystal forms of *n*-type InAs with magnetic fields up to 29 000 G and temperatures between 1·25°K and 20·2°K. In both crystals oscillations in resistivity occur as the field strength is varied. Very good agreement is obtained between the calculated and observed periods. The phase and temperature dependence of the oscillations are discussed.

537.311.33 : 546.682.19 : 538.63 **3155**

Oscillatory Galvanomagnetic Effects in *n*-Type Indium Arsenide.—H. P. R. Frederikse & W. R. Hosler. (*Phys. Rev.*, 15th May 1958, Vol. 110, No. 4, pp. 880–883.) The period of the de Haas-van Alphen oscillations was found to be in good agreement with theoretical predictions.

537.311.33 : 546.682.86 **3156**

Band Structure of Indium Antimonide.—E. O. Kane. (*Phys. Chem. Solids*, Jan. 1957, Vol. 1, No. 4, pp. 249–261.) The band structure of InSb has been calculated using perturbation theory. The small band gap requires an accurate treatment of conduction and valence-band interactions. A nonparabolic conduction band is found, whilst the valence band is similar to Ge. An absolute calculation of optical absorption is made for *n*-type InSb, which agrees with experimental results. See 2468 of August (Ehrenreich).

537.311.33 : 546.682.86 **3157**

On the Mechanical Properties of Indium Antimonide.—J. W. Allen. (*Phil. Mag.*, Dec. 1957, Vol. 2, No. 24, pp. 1475–1481, plate.)

537.311.33 : 546.682.86 **3158**

Distribution Coefficients for Solute Elements in Single-Crystal Indium Antimonide.—J. B. Mullin. (*J. Electronics Control*, April 1958, Vol. 4, No. 4, pp. 358–359.)

537.311.33 : 546.682.86 : 538.63 **3159**

Hall Effect and Magnetoresistance in Indium Antimonide.—G. Fischer & D. K. C. MacDonald. (*Phil. Mag.*, Nov. 1957, Vol. 2, No. 23, pp. 1393–1395.) Note of measurements made at field strengths up to 40 k oersteds at −12°C, −4°C and 0°C. See also 1468 and 1469 of May (Frederikse & Hosler).

537.311.33 : 548.0 **3160**

Crystal Structure of Ternary Compounds of Type $A^{II}B^{IV}C_2^{V}$.—H. Pfister. (*Acta cryst.*, 10th March 1958, Vol. 11, Part 3, pp. 221–224. In German.)

537.583 **3161**

Thermionic and Related Properties of Calcium Oxide.—B. J. Hopkins & F. A. Vick. (*Brit. J. appl. Phys.*, July 1958, Vol. 9, No. 7, pp. 257–264.) Changes in thermionic emission and conductivity of cathodes of CaO on Ni during activation and poisoning are described. The mean nominal thermionic work function is 1·69 eV for the fully activated cathode. A linear relation was found between the logarithms of emission and conductivity during activation, and gives a mean value of 0·7 eV for the surface work function.

537.583 : 621.385.032.213.13 **3162**

Diffusion of Tungsten in Nickel and Reaction at Interface with SrO.—H. W. Allison & G. E. Moore. (*J. appl. Phys.*, May 1958, Vol. 29, No. 5, pp. 842–848.)

538.22 **3163**

Antiferromagnetism of $CuF_2.2H_2O$ and MnF_3.—R. M. Bozorth & J. W. Nielsen. (*Phys. Rev.*, 15th May 1958, Vol. 110, No. 4, pp. 879–880.) Measurements of the molar susceptibility were made at temperatures between 1·3 and 260°K.

538.22 : 538.569.4.029.65 **3164**

Paramagnetic Resonance Absorption in Two Copper Salts at Wavelengths of 5·4 mm and 6·6 mm.—K. Ono & M. Ohtsuka. (*J. phys. Soc. Japan*, Feb. 1958, Vol. 13, No. 2, pp. 206–209.) The shape of the absorption lines varies considerably with the orientation of the crystal in the magnetic field. The variation is interpreted in terms of the exchange interaction between copper ions.

538.221 **3165**

The Remanent Magnetization of Single-Domain Ferromagnetic Particles.—E. P. Wohlfarth & D. G. Tonge. (*Phil. Mag.*, Nov. 1957, Vol. 2, No. 23, pp. 1333–1344.) The remanent magnetization is calculated for particles with a number of equivalent easy directions of magnetization, and also for particles with mixed uniaxial anisotropies. Reference is made to a variety of materials, such as Co and αFe_2O_3.

538.221 **3166**

Determination of the Magnetic Anisotropy Constant K_2 of Cubic Ferromagnetic Substances.—H. Sato & B. S. Chandrasekhar. (*Phys. Chem. Solids*, Jan. 1957, Vol. 1, No. 4, pp. 228–233.)

538.221 **3167**

The Anhysteretic Magnetization of Permanent-Magnet Alloys.—E. P. Wohlfarth. (*Phil. Mag.*, June 1957, Vol. 2, No. 18, pp. 719–725.)

538.221 **3168**

Investigation of the Magnetic Properties of a Series of Nickel-Copper Alloys.—A. J. P. Meyer & C. Wolff. (*C. R. Acad. Sci., Paris*, 27th Jan. 1958, Vol. 246, No. 4, pp. 576–579.) Results of measurements of Curie point and magnetization are in agreement with those of Ahern & Sucksmith (1156 of 1957).

538.221 **3169**

The Magnetization of Cobalt-Manganese and Cobalt-Chromium Alloys.—J. Crangle. (*Phil. Mag.*, May 1957, Vol. 2, No. 17, pp. 659–668.)

538.221 **3170**

Observations on the Magnetic Transition in Haematite at −15°C.—G. Haigh. (*Phil. Mag.*, July 1957, Vol. 2, No. 19, pp. 877–890.) The effects of cooling and reheating on a magnetized specimen of αFe_2O_3 are described, and observations are discussed with reference to the two-component magnetic structure suggested by Néel (*Rev. mod. Phys.*, Jan. 1953, Vol. 25, No. 1, pp. 58–63).

538.221 **3171**

The Electric and Magnetic Spectra of γ-Fe_2O_3 Oxides.—J. C. Bluet, I. Epelboin & D. Quivy. (*C. R. Acad. Sci., Paris*, 13th Jan. 1958, Vol. 246, No. 2, pp. 246–249.) Report of measurements made at frequencies from 10 kc/s to 23 kMc/s to determine the complex permittivity and permeability of powder specimens.

538.221 : [538.63 + 538.66 **3172**

Relations between the Coefficients of Transverse Galvanomagnetic and Thermomagnetic Effects in Ferromagnets.—G. Busch, F. Hulliger and R. Jaggi. (*Helv. phys. Acta*, 15th Feb. 1958, Vol. 31, No. 1, pp. 3–16. In German.) Calculation and comparison of parameters based on the investigations of various authors. 41 references.

538.221 : 538.632 **3173**

On the Hall Effect in Ferromagnetics.—N. V. Bazhanova. (*Zh. eksp. teor. Fiz.*, Sept. 1957, Vol. 33, No. 3(9), pp. 567–570.) An investigation of Fe-Ni alloys of the invar group near the Curie temperature.

538.221 : 538.632 **3174**

The Spontaneous Hall Effect in Ferromagnetics: Part 2.—J. Smit. (*Physica*, Jan. 1958, Vol. 24, No. 1, pp. 39–51.) "It is shown that the spontaneous part of the Hall effect arising from the spontaneous magnetization is caused by skew scattering of the magnetized conduction electrons (in this case the 3*d*-electrons) due to their transverse polarization induced by spin-orbit interaction, which acts as an impact parameter in the collision process." Part 1: 1465 of 1956.

538.221 : 621.318.134 **3175**

Microwave Ferrites.—B. Josephson & P. E. Ljung. (*Ericsson Tech.*, 1958, Vol. 14, No. 1, pp. 39–70.) A general description o the structure of ferrites, their electrical properties, and the physical phenomena underlying their use at microwave frequencies. Details are given of the optimum composition of ferrites for Faraday rotation at wavelengths of 3, 6 and 10 cm.

538.221 : 621.318.134 **3176**

Low-Frequency Rotational Hysteresis Losses in Ferrites.—H. Seiwatz. (*J. appl. Phys.*, June 1958, Vol. 29, No. 6, pp. 994–995.) The frequency range covered is 5–55 c/s using magnetic field strengths up to 11 000 oersteds. For sufficiently strong magnetic fields the losses are found to be independent of field strength, and in some ferrites there is essentially no frequency dependence.

538.221 : 621.318.134 **3177**

Effect of Magnetic Viscosity on the Frequency Characteristics of Ferrites.—R. V. Telesin & A. G. Shishkov. (*Zh. eksp. teor. Fiz.*, Oct. 1957, Vol. 33, No. 4(10), pp. 839–844.) Investigation of a series of Ni-Zn ferrites under conditions of free (aperiodic) and forced (sinusoidal) variations of magnetization. Viscosity characteristics obtained from measurements on the same sample by both methods are compared and an estimate is made of the viscous friction constant.

538.221 : 621.318.134 **3178**

Low-Temperature Heat Capacity and Thermodynamic Properties of Zinc Ferrite.—E. F. Westrum, Jr, & D. M. Grimes. (*Phys. Chem. Solids*, 1957, Vol. 3, Nos. 1/2, pp. 44–49.)

538.221 : 621.318.134 **3179**

Time-Dependent Constricted Hysteresis Loops in a Single Crystal of Manganese Ferrous Ferrite.—U. Enz. (*Physica*, Jan. 1958, Vol. 24, No. 1, pp. 68–70.) The initial permeability of a crystal of composition $Mn_{0\cdot 84}\ Fe_{2\cdot 14}\ O_4$ is approximately 2 000 at room temperature and shows a very strong disaccommodation or time-dependent decrease of permeability after demagnetization.

538.221 : 621.318.134 **3180**

The Crystal Structure and Ferrimagnetism of Yttrium-Iron Garnet, $Y_3Fe_2(FeO_4)_3$.—S. Geller & M. A. Gilleo. (*Phys. Chem. Solids*, 1957, Vol. 3, Nos. 1/2, pp. 30–36.) A refinement of the crystal structure of Y-Fe garnet, obtained by application of the least-squares method to single-crystal X-ray data. Interionic distances and angles which are important to the interaction between magnetic ions are calculated.

538.221 : 621.318.134 **3181**

Interpretation of Magnetic Properties of Yttrium Garnet in which the Ions Al^{3+}, Ga^{3+} and Gr^{3+} have been Substituted for Fe^{3+} Ions.—G. Villers & J. Loriers. (*C. R. Acad. Sci., Paris*, 4th Dec. 1957, Vol. 245, No. 23, pp. 2033–2036.)

538.221 : 621.318.134 **3182**

Lattice Changes in Spinel-Type Iron Chromites.—M. H. Francombe. (*Phys. Chem. Solids*, 1957, Vol. 3, Nos. 1/2, pp. 37–43.)

538.221 : 621.318.134 : 537.311.33 **3183**

Electrical Conductivity of Ferromagnetic Semiconductors (Ferrites).—A. A. Yudin. (*Zh. eksp. teor. Fiz.*, Oct. 1957, Vol. 33, No. 4(10), pp. 873–876.) Treatment of conduction in a ferrite, considered as a lattice of classical magnetic dipoles submerged in a dielectric continuum, shows that the conductivity/temperature characteristic must have a break at the Curie point, which is in agreement with experiment and with decreasing activation energy in the ferromagnetic region.

538.221 : 621.318.134 : 538.569.4 **3184**

Magnetic Spectra of Manganese Ferrites.—S. E. Harrison, C. J. Kriessman & S. R. Pollack. (*Phys. Rev.*, 15th May 1958, Vol. 110, No. 4, pp. 844–849.) The complex initial permeability of polycrystalline ferrites of the type $Mn_{1+x}Fe_{2-x}O_4$ has been measured between 20 and 2 000 Mc/s. Two resonances occur below 200 Mc/s and are associated with domain wall motion. A resonance which occurs between 300 and 600 Mc/s, depending on the composition, allows the calculation of an effective polycrystalline anisotropy constant.

538.221 : 621.318.134 : 621.372.85 **3185**

Mixed Garnets for Nonreciprocal Devices at Low Microwave Frequencies.—B. Ancker-Johnson & J. J. Rowley. (*Proc. Inst. Radio Engrs*, July 1958, Vol. 46, No. 7, pp. 1421–1422.) Report on the properties of 2 : 1 and 5 : 1 mixtures of Y-Gd iron garnet and their application in S-band and L-band isolators.

538.221 : 621.318.134 : 621.372.85 **3186**

The Application of Ferrites in the Construction of Nonreciprocal Microwave Devices.—Dörre. (See 2968.)

538.222 **3187**

The Thermal and Magnetic Properties of Ytterbium Ethyl Sulphate between 20°K and 1°K.—A. H. Cooke, F. R. McKim, H. Mayer & W. P. Wolf. (*Phil. Mag.*, July 1957, Vol. 2, No. 19, pp. 929–935.) Report of measurements of susceptibility, magnetic specific heat and spin-lattice relaxation time.

539.2 : 537.311.31 **3188**

The Band Structure of the Transition Metals.—N. F. Mott & K. W. H. Stevens. (*Phil. Mag.*, Nov. 1957, Vol. 2, No. 23, pp. 1364–1386.)

539.2 : 537.311.33 **3189**

Electronic Properties of Transition-Metal Oxides: Part 1—Distortions from Cubic Symmetry.—J. D. Dúnitz & L. E. Orgel. (*Phys. Chem. Solids*, 1957, Vol. 3, Nos. 1/2, pp. 20–29.) It is shown that much of the data on distortions from cubic symmetry in transition-metal oxides, and particularly in spinels, can be understood in terms of crystal (ligand) field theory. Many such distortions are simply related to the electronic configuration of the metal ion and may be considered to arise as a consequence of a Jahn-Teller type of distortion. 45 references.

621.791.9 : 621.3.049.7 : 621.314.7 **3190**

Electrical Contact with Thermocompression Bonds.—H. Christensen. (*Bell Lab. Rec.*, April 1958, Vol. 36, No. 4, pp. 127–130.) By application of heat and pressure, a bond can be formed either with or without the formation of a liquid phase; the appropriate techniques can produce either an ohmic or a rectifying bond between a wire and a semiconductor. See 819 of March.

666 : 621.3.032.53 **3191**

Vacuum-Tight Metal-Ceramic Seals.—K. Müller. (*Elektrotech. Z., Edn B*, 21st March 1958, Vol. 10, No. 3, pp. 69–71.) Ag-Ti alloys are particularly suitable for use as solders.

537.311.33 **3192**

Progress in Semiconductors, Vol. 2. [Book Review]—A. F. Gibson, R. E. Burgess & P. Aigrain (Eds). Publishers: Heywood, London, 1957, 280 pp., 63s. (*Nature, Lond.*, 26th April 1958, Vol. 181, No. 4617, p. 1168). An annual publication containing eight contributions on semiconductor alloys and compounds, effects of irradiation, carrier lifetime, impurities, and effects of electric fields. See also 2157 of 1957.

MATHEMATICS

513.81 : 621.3 **3193**

A Survey of the Use of Non-Euclidean Geometry in Electrical Engineering.—E. F. Bolinder. (*J. Franklin Inst.*, March 1958, Vol. 265, No. 3, pp. 169–186.) 48 references.

516.2 : 517.522.5 **3194**

Analytical Representation of Angular Distribution Data.—S. C. Snowdon, L. Eisenbad & J. F. Marshall. (*J. appl. Phys.*, June 1958, Vol. 29, No. 6, pp. 950–953.) A quick approximate method of curve fitting, using a Legendre polynomial series, is described. It is useful for curves where the experimental points do not justify great accuracy. Eleven equally spaced points are used.

MEASUREMENTS AND TEST GEAR

621.3.018.41(083.74) : 529.786 : 525.35 **3195**

Variation in the Speed of Rotation of the Earth since June 1955.—L. Essen, J. V. L. Parry, W. Markowitz & R. G. Hall. (*Nature, Lond.*, 12th April 1958, Vol. 181, No. 4615, p. 1054.) The rate of rotation of the earth is measured in U.S.A. and compared with the frequency of the Cs standard in England by means of GBR and WWV time signals. Since September 1955, this rate shows a constant deceleration of 5 parts in 10^9 per year.

621.317.31 (083.74) **3196**

Measurement of Current with a Pellat-Type Electrodynamometer.—R. L. Driscoll. (*J. Res. nat. Bur. Stand.*, April 1958, Vol. 60, No. 4, RP 2845, pp. 287–296.) Detailed description of an absolute determination of the ampere using a Pellat-type electrodynamometer with a fused-silica balance beam and single-layer helical coils. See 2182 of July.

621.317.31 (083.74) **3197**

Measurement of Current with the National Bureau of Standards Current Balance.—R. L. Driscoll & R. D. Cutkosky. (*J. Res. nat. Bur. Stand.*, April 1958, Vol. 60, No. 4, RP 2846, pp. 297–305.) The weighted mean of recent measurements made with the National Bureau of Standards current balance and with a Pellat-type balance (see 3196 above) is 1 NBS ampere = 1·000010 ± 0·000005 absolute amperes.

621.317.34 : 621.372.413 **3198**

Measurement of Shunt Impedance of a Cavity.—K. B. Mallory. (*J. appl. Phys.*, May 1958, Vol. 29, No. 5, pp. 790–793.) A simple graphical method is given for the analysis of transmission measurements.

621.317.361 : 621.384.7 **3199**

Frequency Measurements in Microwave Spectroscopy.—G. Erlandsson & H. Selén. (*Ark. Fys.*, 1957, Vol. 11, Part 4, pp. 391–393.) A variable-frequency oscillator in combination with a crystal calibrator may be used to measure line frequencies to within ± 2 Mc/s.

621.317.373 **3200**

An Accurate Phase Meter for Four-Terminal Networks.—B. Chatterjee. (*Indian J. Phys.*, Nov. 1957, Vol. 31, No. 11, pp. 541–552.) Details of a.f. and r.f. measurements made with the phase meter described in 3479 of 1956. A small phase change can be measured within about 0·1°.

621.317.382.029.6 : 538.632 : 537.311.33 **3201**

The Hall Effect and its Application to Microwave Power Measurement.—H. M. Barlow. (*Proc. Inst. Radio Engrs*, July 1958, Vol. 46, No. 7, pp. 1411–1413.) The basic theory of the Hall effect is given and its relation to radiation pressure is shown. A microwave wattmeter depending on the Hall effect for its operation is described. See 2552 of 1957.

621.317.382.029.6 : 621.396.61-181.4 **3202**

Power Measurements on Miniature Transmitters.—K. H. Fischer & C. Fink. (*Elektrotech. Z., Edn A*, 1st March 1958, Vol. 79, No. 5, pp. 150–153.) Methods are reviewed which are suitable for measuring the output of low-power high-frequency transmitters used for radiosondes or medical applications. Results obtained for a 400-Mc/s radiosonde transmitter are given as example.

621.317.4 **3203**

Methods of Deriving the Heterodyne Frequency of a Receiver from the Measurement Frequency of a Transmitter.—R. Kersten. (*Frequenz*, Dec. 1957, Vol. 11, No. 12, pp. 370–379 & Jan. 1958, Vol. 12, No. 1, pp. 15–25.) Methods are discussed for ensuring a constant relation between generator frequency and receiver heterodyne frequency for the measurement of transmission characteristics of filters with sharp cut-off or networks with high crosstalk attenuation. In one method signal generator and receiver are combined in a single unit which incorporates an auxiliary oscillator controlled by the generator frequency; in others the heterodyne frequency is equal to the unmodulated generator frequency.

621.317.616 : 621.317.755 **3204**

Video-Frequency Response Testing.—R. G. Middleton. (*Radio TV News*, Feb. 1958, Vol. 59, No. 2, pp. 59–61.) Describes the technique of testing the response of video-frequency amplifiers, using a sweep-frequency generator and a c.r.o.

621.317.616 : 621.395.625.3 **3205**

The Determination of Frequency Characteristics of Recording-Tape Magnetization.—O. Schmidbauer. (*Elektronische Rundschau*, Dec. 1957, Vol. 11, No. 12, pp. 373–375.) See also 2505 of August.

621.317.7 : 621.373.42 **3206**

A Wide-Range Sine-Wave Generator.—L. H. Dülberger & H. T. Sterling. (*Electronic Engng*, July 1958, Vol. 30, No. 365, pp. 424–428.) Full details of a Wien-bridge oscillator circuit are given for the frequency range 0·9 c/s–510 kc/s, with 0·15% distortion for an output of 2 W into 600 Ω. Frequency stability is within 0·5% for a wide range of temperature and line-voltage variations.

621.317.715.5.087.5 **3207**

Ten-Channel Miniature Galvanometer Recorder.—I. A. W. Halliday & A. L. N. Stephens. (*Instrum. Practice*, March 1958, Vol. 12, No. 3, pp. 242–246.) Description of a compact instrument for recording on 35-mm film the movement of ten 'pencil' galvanometer elements.

621.317.729.1 **3208**

The Electrolytic Tank Analogue.—K. F. Sander. (*Beama J.*, Feb. 1958, Vol. 65, No. 1, pp. 17–23.) Outline of the problems involved in designing and setting up electrolyte-tank equipment. Various types of errors are enumerated and conditions for obtaining accurate and reproducible measurements are formulated. A system for measuring field gradients to 0·1% is briefly described.

621.317.73.012.11 : 518.5 **3209**

A Mechanical Version of the Smith Chart.—J. E. Knowles. (*J. sci. Instrum.*, July 1958, Vol. 35, No. 7, pp. 233–237.) For computing the transmission characteristics of optical or electrical filters, the chart has been replaced by a system of mechanical linkages and a computing element.

621.317.73.012.11 : 621.317.755 **3210**

Two Automatic Impedance Plotters.—R. S. Cole & W. N. Honeyman. (*Electronic Engng*, July 1958, Vol. 30, No. 365, pp. 442–446.) Description and comparison of two methods of automatic impedance plotting at microwave frequencies based on (*a*) a four-probe detector and frequency-swept klystron, (*b*) a three-slot waveguide coupler together with a rotating-crystal head. The single-crystal method is inherently more accurate, although both methods facilitate production testing.

621.317.733 : 681.142 **3211**

A High-Sensitivity D.C. Null Indicator with Automatic Reduction of Sensitivity for Large Inputs.—R. Thorn. (*J. sci. Instrum.*, July 1958, Vol. 35, No. 7, pp. 265–266.) The instrument can be used in bridge measurements which cover large voltage and source resistance ranges, e.g. in the solution of problems by resistance-network analogue methods.

621.317.742 **3212**

Voltage Standing-Wave Ratio Measurement.—E. W. Collings. (*Electronic Radio Engr*, Aug. 1958, Vol. 35, No. 8, pp. 287–290.) A substitution method is described in which a short-circuited attenuator replaces the equipment under test. Various errors inherent in the normal method are eliminated.

621.317.755 **3213**

Wide-Band Oscilloscope.—G. H. Leonard. (*Wireless World*, Aug. 1958, Vol. 64, No. 8, pp. 395–398.) A commercial model can be modified to have a bandwidth of 30 Mc/s without using a distributed amplifier. A circuit is described which uses valves having high figures of merit, with low anode loads and as cathode followers to reduce the effects of input capacitance; a.c. coupling must be used.

621.317.794 : 621.396.822 **3214**

L.F. Random-Signal Generator.—J. L. Douce & J. M. Shackleton. (*Electronic Radio Engr*, Aug. 1958, Vol. 35, No. 8, pp. 295–297.) A simple noise generator having a power spectrum uniform from zero to about 15 c/s.

621.317.799 : 621.314.7 **3215**

The Measurement of Transistor Voltage/Current Characteristics using Pulse Techniques.—B. J. Cooper. (*Electronic Engng*, July 1958, Vol. 30, No. 365, pp. 440–441.) The effects of junction heating and thermal runaway effects are reduced, which enables the ambient temperature characteristics to be read from meters or displayed on an external c.r. tube.

621.317.799 : 621.314.7 **3216**

Transistor Test Set.—J. N. Prewett. (*Wireless World*, Aug. 1958, Vol. 64, No. 8, pp. 369–372.) An inexpensive test set is described which will measure the collector leakage current and current amplification factor of transistors, with up to 200 mW collector dissipation, with an accuracy sufficient to determine their suitability for a particular circuit.

621.317.799 : 621.385.1 **3217**

New Portable Electron-Tube Tester.—A. A. Heberlein. (*Bell Lab. Rec.*, May 1958, Vol. 36, No. 5, pp. 179–181.) The equipment is designed for testing most valves including cold-cathode and subminiature types.

OTHER APPLICATIONS OF RADIO AND ELECTRONICS

531.787 : 621.383.4 **3218**

A Sensitive Defocusing Photoelectric Pressure Transducer.—J. R. Greer. (*Electronic Engng*, July 1958, Vol. 30, No. 365, pp. 436–439.) The instrument depends on the pressure difference existing across an extremely thin aluminized terylene foil diaphragm to focus or defocus the beams of light falling on Ge-type photocells. The frequency response extends to 500 c/s and the maximum sensitivity obtained is approximately 8 V for a pressure change of 1 cm of water.

535.33-15 : 621.383.4 **3219**

A Design for a Multichannel Infrared Spectrometer using Transistor Electronics.—D. G. Avery & R. C. Bowes. (*J. sci. Instrum.*, June 1958, Vol. 35, No. 6, pp. 212–216.) A demonstration instrument in which InSb photoconductive cells form the detectors, each acting as its own 'exit slit'. The fast response of the detectors makes possible the use of low-noise transistor amplifiers.

535.822.5 : 621.397.6 : 535.623 **3220**

Ultraviolet Television Colour-Translating Microscope.—V. K. Zworykin & F. L. Hatke. (*Science*, 25th Oct. 1957, Vol. 126, No. 3278, pp. 805–810.) A microscope projects the image on to the photosensitive targets of a television camera, the video signal from which is used for the reproduction of the image on the screen of a trichromatic receiver. Illumination is so arranged that radiation of the three selected ultraviolet wavelengths falls on the specimen in successive pulses.

621.365.52 **3221**

Frequency and Phase Relations in a Transmitter for R.F. Heating.—K. H. Kerber. (*NachrTech.*, Nov. 1957, Vol. 7, No. 11, pp. 512–514.) Design criteria for maximum efficiency are derived.

621.374.33 : 77 **3222**

Inexpensive Photographic Timer.—J. H. Jowett. (*Wireless World*, Aug. 1958, Vol. 64, No. 8, pp. 385–387.) Description of a simple system, based on a 'bootstrap' circuit, for compensating variations in enlarger-lamp supply voltage.

621.384.622.2 **3223**

New Method of Control of Ultra-High-Frequency Circuits for a Linear Electron Accelerator.—M. Pillon. (*C. R. Acad. Sci., Paris*, 27th Jan. 1958, Vol. 246, No. 4, pp. 582–586.) By controlling the output of a carcinotron by a suitable circuit it is possible to obtain a power constant within ±2 dB at any frequency from 2 to 4 kMc/s.

621.385.833 **3224**

Chromatic Aberration and Resolving Power of Electron Microscopes.—W. E. Meyer. (*Optik, Stuttgart*, Jan. 1958, Vol. 15, No. 1, pp. 43–46.) The resolution limit for very large chromatic aberration is found to exceed the one for vanishing aberration by a factor of only 1·4.

621.385.833 **3225**

Correction of the Aperture Aberrations of a System of Two Four-Pole Magnetic Lenses.—A. Septier. (*C. R. Acad. Sci., Paris*, 4th Dec. 1957, Vol. 245, No. 23, pp. 2036–2039.)

621.387.424 **3226**

Measurements of the Discharge Propagation Time in Geiger-Müller Counter Tubes and their Use in Portraying Fields of Radioactive Radiation.—P. Kienle. (*Z. Naturf.*, Jan. 1958, Vol. 13a, No. 1, pp. 37–47.)

621.398 : 621.396.934 **3227**

Guided Weapon Techniques.—P. Cave. (*Wireless World*, Aug. 1958, Vol. 64, No. 8, pp. 354–359.) Systems are classified in two main groups: (*a*) continuous-data systems in which data relating to the position of the target are analysed whilst the missile is in flight; this system is necessary for interception of moving targets; (*b*) systems of preset trajectory suitable for long-range missiles, in which the missile is programmed to locate its position in flight by terrestrial, inertial, celestial or radio measurements and to adjust its own course to the preset one. The principles of different guidance techniques are described.

PROPAGATION OF WAVES

621.396.11 + 621.372.2 **3228**

Surface Waves.—H. M. Barlow. (*Proc. Inst. Radio Engrs*, July 1958, Vol. 46, No. 7, pp. 1413–1417.) Qualitative discussion of the important characteristics of surface waves, including the launching problem and the effect of surface curvature.

621.396.11 **3229**

The Calculation of the Coefficients of Reflection from the Ground.—C. Rudilosso. (*Note Recensioni Notiz.*, Nov./Dec. 1957, Vol. 6, No. 6, pp. 848–860.) Summary of formulae for various types of surface, and description of the use of a Smith chart instead of Burrows' field strength curves for obtaining the coefficients.

621.396.11 **3230**

Transient Radio-Frequency Ground Waves over the Surface of a Finitely Conducting Plane Earth.—J. R. Johler. (*J. Res. nat. Bur. Stand.*, April 1958, Vol. 60, No. 4, RP 2844, pp. 281–285.) Displacement currents in the conducting earth are neglected. The results of an analysis using Laplace transformations indicate that current sources with sinusoidal form in the time domain can be used to simulate atmospherics and to reconstruct propagated signals of pulsed radio-navigation systems.

621.396.11 : 551.510.535 **3231**

Solar Activity and Radio Communication.—Naismith. (See 3090.)

621.396.11 : 551.510.535 **3232**

Limiting Polarization Curves for Radio Wave Propagation in the Ionosphere.—R. N. Singh & Y. S. N. Murty. (*Curr. Sci.*, May 1958, Vol. 27, No. 5, pp. 161–162.) Application of Bailey's method of conformal representation to conditions at Banaras, India.

621.396.11 : 551.510.535 **3233**

Ray-Tracing Technique in a Horizontally Stratified Ionosphere using Vector Representations.—R. J. Marcou, W. Pfister & J. C. Ulwick. (*J. geophys. Res.*, June 1958, Vol. 63, No. 2, pp. 301–313.) "Vector expressions are derived for tracing oblique ray paths, taking into account the full effect of the earth's magnetic field. The method is an extended analytical treatment of Poeverlein's two dimensional case based upon crystal optics [718 of 1950]. A method for high-speed computers is described for ray tracing in a horizontally stratified ionosphere, for determining, by an iteration process, the index of refraction and wave normal direction, and for determining electron-density distributions from rocket data."

621.396.11.029.55 : 551.510.535 **3234**

The Use of Sweep-Frequency Back-scatter Data for Determining Oblique-Incidence Ionospheric Characteristics.—R. Silberstein. (*J. geophys. Res.*, June 1958, Vol. 63, No. 2, pp. 335–351.) Data from further back-scatter experiments (see 3019 of 1954) at Boulder, Colorado, with aerials beamed on Sterling, Virginia (2 370 km), are compared with (*a*) frequency-sweep point-to-point recorder data for the Boulder-Sterling path, and (*b*) mid-point vertical-incidence data. The difference between m.u.f.s. deduced by skilled personnel from frequency-sweep back-scatter data and actual m.u.f.s. determined by means of (*a*) is shown to be small, provided proper aerials are used. Many records are illustrated.

621.396.11.029.6 **3235**

The Mechanism of Long-Distance Propagation of Ultra Short Waves.—R. Schünemann. (*Hochfrequenztech. u. Elektroakust.*, Sept. 1957, Vol. 66, No. 2, pp. 52–61.) Theoretical investigations indicate that in addition to scattering processes partial reflections by inversion layers may contribute significantly to the propagation of ultra short waves over long distances. Results of field-strength measurements of signals propagated over distances of 195, 360 and 450 km at 88·2, 88·5 and 92·1 Mc/s, respectively, are of the same order of magnitude as those derived theoretically assuming partial reflections.

621.396.11.029.6 : [621.396.41 + 621.397.26] (489) **3236**

Television and Telephone Radio Links in Denmark.—B. Nielsen, P. Christensen, P. Sterndorff & P. Gudmandsen. (*Teleteknik, Copenhagen*, English Edn, 1957, Vol. 1, No. 2, pp. 131–174,194.) English version of 1908 of 1957.

621.396.11.029.62 **3237**

Long-Distance Radio Propagation above 30 Mc/s.—J. A. Saxton. (*Nature, Lond.*, 26th April 1958, Vol. 181, No. 4617, pp. 1184–1187.) Report of an I.E.E. symposium held in London, 28th January 1958. More than 20 papers were read.

621.396.11.029.63 **3238**

Investigation of Long-Distance Over-water Tropospheric Propagation at 400 Mc/s.—H. E. Dinger, W. E. Garner, D. H. Hamilton, Jr, & A. E. Teachman. (*Proc. Inst. Radio Engrs*, July 1958, Vol. 46, No. 7, pp. 1401–1410.) Experimental results of signal strength measurements for oversea paths up to 630 nautical miles are presented. For signals believed to be unaffected by super-refractive conditions, a cyclic variation of attenuation rate with distance was found, but this did not differ substantially from a linear rate of 0·16–0·18 dB per nautical mile.

RECEPTION

621.372.632.029.64 : 538.632 **3239**

A New Microwave Mixer.—G. M. Barlow, J. Brown, K. V. G. Krishna. (*Nature, Lond.*, 5th April 1958, Vol. 181, No. 4614, p. 1008.) Equipment based on the Hall effect for measuring power at microwave frequencies using a semiconductor in a resonant cavity [see 1217 of April (Barlow & Kataoka)], may be modified for use as a mixer. The conversion loss is about 60 dB for InAs with a local-oscillator power of 100 W at 8 cm λ.

621.376.23 **3240**

The Calculation of the Performance of A.M. Detectors with Characteristics represented by Angled Straight Lines.—H. Schneider & G. Petrich. (*NachrTech.*, Dec. 1957, Vol. 7, No. 12, pp. 549–551.) An investigation of harmonic distortion in a.m. detectors shows that freedom from distortion and increased sensitivity are obtained if the operating point moves in accordance with the fluctuations of the modulation. See also 2893 of 1957.

621.396.82 : 621.397.62](083.74) **3241**

Supplement to 'I.R.E. Standards on Receivers: Methods of Measurement of Interference Output of Television Receivers in the Range of 300–10 000 kc/s, 1954' (Standard 54 I.R.E. 17.S1).—(*Proc. Inst. Radio Engrs*, July 1958, Vol. 46, No. 7, pp. 1418–1420.) Standard 58 I.R.E. 27.S1.

621.396.828 **3242**

The Problem of Eliminating Radio Interference Originating from High-Frequency Heating Installations.—H. Stier: E. Rosemann. (*NachrTech.*, Nov. 1957, Vol. 7, No. 11, pp. 523–525.) Comment on 1250 of April and author's reply.

STATIONS AND COMMUNICATION SYSTEMS

621.391 : 519.21 **3243**

On Measures of Information.—A. J. Stam. (*Proc. kon. ned. Akad. Wetensch.*, *B*, 1957, Vol. 60, No. 3, pp. 201–211. In English.) Generalization of Schutzenberger's definition (1769 of 1951).

621.391 : 534.78 **3244**

Construction and Investigation of a Transmission System for Synthetic Speech.—Krocker. (See 2952.)

621.395.4+621.397.5] : 621.315.212 **3245**

Multichannel Systems along Coaxial Cables.—J. Bauer. (See 2958.)

621.396.3 : 621.396.43 : 523.5 **3246**

On the Transmission Error Function for Meteor-Burst Communication.—G. F. Montgomery. (*Proc. Inst. Radio Engrs*, July 1958, Vol. 46, No. 7, pp. 1423–1424.) Addendum and note of correction to 911 of March (Montgomery & Sugar).

621.396.41 **3247**

A Mathematical Analysis of the Kahn Compatible Single-Sideband System.—J. P. Costas. (*Proc. Inst. Radio Engrs*, July 1958, Vol. 46, No. 7, pp. 1396–1401.) Analysis of a system proposed for generating a s.s.b. signal for reception by a conventional a.m. receiver. Computations are made of the signal spectra for various input signal conditions. The theoretical results are used to predict certain system operating characteristics. A comment by Kahn (*ibid.*, pp. 1429–1430) refers to improved systems in operation.

621.396.41+621.397.26] (489) : 621.396.11.029.6 **3248**

Television and Telephone Radio Links in Denmark.—B. Nielsen, P. Christensen, P. Sterndorff & P. Gudmandsen. (*Teleteknik, Copenhagen*, English Edn, 1957, Vol. 1, No. 2, pp. 131–174, 194.) English version of 1908 of 1957.

621.396.43 : 621.396.65 **3249**

Some Problems in Radio Link Equipment for a Small Number of Channels.—I. Wigdorovits. (*Elektrotech. Z., Edn A*, 1st Feb. 1958, Vol. 79, No. 3, pp. 86–89.) Constructional requirements and the relation between quality of transmission and bandwidth are considered for equipment with two to six telephony channels.

621.396.65+621.397.7 **3250**

The NARCOM Plan for Transatlantic Television and other Wide-band Telecommunication Services.—W. S. Halstead. (*J. Soc. Mot. Pict. Telev. Engrs*, March 1958, Vol. 67, No. 3, pp. 134–138.) A proposed North Atlantic Relay Communication System (NARCOM) is discussed in detail. The system is based on propagation by tropospheric scatter between a chain of u.h.f. relay stations located at suitable land sites across the North Atlantic. The longest link would be some 290 miles.

621.396.74.029.62 : 621.376.3 **3251**

The Offset Operation of U.S.W. F.M. Broadcast Transmitters.—P. Klamm. (*Frequenz*, Nov. 1957, Vol. 11, No. 11, pp. 351–360.) The conditions are determined for ensuring minimum mutual interference in operating transmitters with offset carrier frequencies. An arrangement using carrier spacings between 50 and 100 kc/s combined with suitable program allocation and regional distribution of the transmitters is discussed. Improvements in receiver performance are necessary to exploit to the fullest extent the possible advantages of the system. See also 275 of January (Belger et al.).

621.396.931 **3252**

Signal Transmission between Underground Cables and Vehicles.—H. Fricke & H. Rummert. (*Frequenz*, Dec. 1957, Vol. 11, No. 12, pp. 380–385 & Jan. 1958, Vol. 12, No. 1, pp. 9–15.) Investigation of the transmission of signals for traffic supervision and control between a fixed station and trains or road vehicles by means of cables buried along the track or under the road surface. Field strength is calculated and measured for systems operating at 100 Mc/s and 30 kc/s. A comparison of the systems shows that the frequency range 10–100 kc/s is the most advantageous for this purpose.

SUBSIDIARY APPARATUS

621.311.6 : 537.324 **3253**

Thermoelements and Thermoelectric D.C. Generators.—K. Peschke. (*Arch. Elektrotech.*, 29th Nov. 1957, Vol. 43, No. 5, pp. 328–354.) Detailed theoretical investigation of thermodynamic efficiency taking account of the various thermoelectric effects, and changes in resistivity and thermal conductivity. Higher efficiencies should be obtainable [see also 3655 of 1957 (Käch)] than those indicated by other authors. Problems of construction and mechanical strength are also considered.

621.311.62 : 621.314.7 **3254**

A Mains-Operated D.C. Stabilized Transistor Power Supply for Laboratory Use.—W. L. Stephenson. (*Mullard tech. Commun.*, March 1958, Vol. 3, No. 29, pp. 282–284.) Modification of a unit described earlier [281 of January (Brown & Stephenson)] with operating range 0–30 V, 0–100 mA.

621.311.69 **3255**

Investigation of the Utilization of Solar Energy for the Production of Electrical Energy.—G. Réméniéras. (*Rev. gén. Élect.*, Dec. 1957, Vol. 66, No. 12, pp. 593–626.) A description of a Si *p-n*-junction photoelectric generator made in 1954 is included in a comprehensive summary of the meteorological, engineering and economic aspects of the subject.

621.316.722.1 : 621.314.63 **3256**

Zener-Diode Voltage Stabilizer.—S. Welldon. (*Wireless World*, Aug. 1958, Vol. 64, No. 8, pp. 381–383.) The breakdown voltage of a Zener diode is suitable for use in stabilizing the voltage supplied to motors operated from small batteries.

621.316.92 : 621.314.7 **3257**

Transistor Power Supply has Overload Protection.—H. D. Ervin. (*Electronics*, 20th June 1958, Vol. 31, No. 25, pp. 74–75.) The current limiting circuit described has an instantaneous response.

621.396.679.1 **3258**

Low-Resistance Earth Electrodes—their Achievement and Accurate Measurement.—A. N. Richter. (*Trans. S. Afr. Inst. elect. Engrs*, Nov., 1957, Vol. 48, No. 11, pp. 333–347.) The electrical characteristics of various soils and the effects of moisture content, temperature, and additives as well as electrode shape and spacing are discussed.

TELEVISION AND PHOTOTELEGRAPHY

621.397.5 : 061.6 **3259**

The Television Allocations Study Organization.—G. R. Town. (*Elect. Engng, N.Y.*, Feb. 1958, Vol. 77, No. 2, pp. 126–128.) The structure and general objectives of the organization are discussed.

621.397.5 : 535.623 **3260**

Colour Distortion in the N.T.S.C. Colour Television System due to Chrominance Signal Limiting and Vestigial - Side - Band Operation.—G. Emmrich. (*NachrTech.*, Dec. 1957, Vol. 7, No. 12, pp. 538–542.) Distortion effects are calculated and compared.

621.397.5 : 778.5 **3261**

Anamorphic Television Circuit Requirements.—M. Cawein. (*J. Soc. Mot. Pict. Telev. Engrs*, April 1958, Vol. 67, No. 4, Part 1, pp. 257–259.) Theoretical circuit requirements for the production of a wide-screen television image are discussed. The frequency bandwidth required is determined from a consideration of the relation between aspect ratio and pictorial information, defined in terms of contrast and resolution. The anamorphic compression and subsequent decompression of the image are described.

621.397.5 : 621.317](083.74) **3262**

I.R.E. Standards on Television: Measurement of Luminance Signal Levels, 1958.—(*Proc. Inst. Radio Engrs*, July 1958, Vol. 46, No. 7, p. 1417.) Correction to 1567 of May.

621.397.6 : 535.623 : 621.396.664 **3263**

A Stabilized Monitor for Colour-Television Picture Quality Control.—E. E. Gloystein & N. P. Kellaway. (*J. Soc. Mot. Pict. Telev. Engrs*, March 1958, Vol. 67, No. 3, pp. 157–162.)

621.397.6 : 621.317.7 **3264**

Testing of Television Measuring Demodulators and Television Relay Receivers.—H. Thielcke. (*Rundfunktech. Mitt.*, Dec. 1957, Vol. 1, No. 6, pp. 221–231.) The design of test equipment for monitoring and receiving units is discussed. Methods of measuring receiver characteristics are described and details are given of rack-mounted test equipment.

621.397.61 : 621.316.729 **3265**

Some Aspects of the Performance of Television Mains-Hold Circuits.—R. D. A. Maurice. (*Electronic Engng*, July 1958, Vol. 30, No. 365, pp. 447–454.) Phase instability of the electricity supply to a television studio causes transient changes in the repetition frequency of the field synchronizing pulses. This causes the received image to move vertically, particularly during the transmission of film. The effects of film-traction mechanical filters on these transients is examined in detail and recommendations are made on specifying 'mains-hold' performance to avoid excessive vertical movement of the picture.

621.397.61 : 535.316/.319].001.4 **3266**
An Optical Method of obtaining the Frequency Response of a Lens.—K. Hacking. (*Nature, Lond.*, 19th April 1958, Vol. 181, No. 4616, pp. 1158–1159.) Description of a method used to test lenses for television equipment.

621.397.611.2 **3267**
The Modern Camera Tube and its Limitations.—A. E. Jennings. (*Brit. Commun. Electronics*, April 1958, Vol. 5, No. 4, pp. 250–255.) Comparative survey of the various types of storage tube with particular reference to signal/noise ratio.

621.397.611.2 **3268**
Beam-Landing Errors and Signal-Output Uniformity of Vidicons.—R. G. Neuhauser & L. D. Miller. (*J. Soc. Mot. Pict. Telev. Engrs*, March 1958, Vol. 67, No. 3, pp. 149–153.) The uniformity of signal output is markedly affected by the beam-landing characteristics that result when the vidicon is operated in present deflecting and focusing systems. A comparison of various types of vidicon tube is made.

621.397.611.2 **3269**
Improved Developmental One-Inch Vidicon for Television Cameras.—L. D. Miller & B. H. Vine. (*J. Soc. Mot. Pict. Telev. Engrs*, March 1958, Vol. 67, No. 3, pp. 154–156.) Tentative performance data are given and compared with those for present vidicon-type camera tubes. Methods of compensating for beam-landing errors are explained.

621.397.62 : 621.396.677.43 **3270**
Rhombic Antennas for TV.—Cooper. (See 2979.)

621.397.62 : 621.396.82](083.74) **3271**
Supplement to 'I.R.E. Standards on Receivers: Methods of Measurement of Interference Output of Television Receivers in the Range of 300–10 000 kc/s, 1954' (Standard 54 I.R.E. 17.S1).—(*Proc. Inst. Radio Engrs*, July 1958, Vol. 46, No. 7, pp. 1418–1420.) Standard 58 I.R.E. 27.S1.

621.397.62.001.4 : 621.397.8 **3272**
An Aircraft Simulator for Television Signals.—M. C. Gander & P. L. Mothersole. (*Electronic Engng*, July 1958, Vol. 30, No. 365, pp. 408–413.) The circuit enables a delayed signal to be combined with the r.f. source used to test TV receivers. The delay, amplitude and rate of change of phase of the delayed signal are variable and enable the effects of signals reflected from fixed or moving objects to be tested under laboratory conditions.

621.397.7 + 621.396.65 **3273**
The NARCOM Plan for Transatlantic Television and other Wide-Band Telecommunication Services.—Halstead. (See 3250.)

621.397.7 **3274**
Problems of International Television Broadcasting.—T. H. Bridgewater. (*J. Soc. Mot. Pict. Telev. Engrs*, March 1958, Vol. 67, No. 3, pp. 129–133.) The difficulties encountered in the Eurovision system of international television broadcasting are discussed. The main problems are non-compatible line structure and frame rate, relay time and language differences.

621.397.7 : 535.623 : 621.396.65 **3275**
Relay System Diplexes Audio and Colour Video.—T. G. Custin & J. Smith. (*Electronics*, 20th June 1958, Vol. 31, No. 25, pp. 64–67.) Modulated klystrons, locked to a crystal reference oscillator, are used in a wide-band f.m. system at a frequency near 2 kMc/s. Hybrid rings are used to combine sound and vision carriers at the transmitting aerials and to give balanced mixing in the receiver.

621.397.7 : 621.317.799 **3276**
Signal Generator for Tests on Long-Distance Television Links.—E. Giua. (*Note Recensioni Notiz.*, Jan./Feb. 1958, Vol. 7, No. 1, pp. 67–78.) The generator described is capable of producing bursts of 3–7-Mc/s sine waves repeated at line frequency, and is intended to detect ringing in a television link system.

621.397.8 **3277**
Systems Approach to Determination of Television Coverage.—R. M. Bowie. (*Elect. Engng, N.Y.*, Feb. 1958, Vol. 77, No. 2, pp. 129–132.) Description of methods adopted by T.A.S.O. (see 3259 above) for assessing the overall performance of a television system.

TRANSMISSION

621.396.61.029.62 : 621-523 **3278**
Supervision of Unattended Transmitters with Passive Stand-By.—P. G. Zehnel. (*Frequenz*, Dec. 1957, Vol. 11, No. 12, pp. 365–370.) Methods of safeguarding the continuity of service by means of active or inactive stand-by transmitters are outlined and automatic switching systems are described with brief details of modern u.s.w. automatic transmitters. See also 1576 of May (Zehnel & Brose).

VALVES AND THERMIONICS

621.314.63 + 621.314.7 **3279**
Progress in the Development of Semiconductors.—W. Taeger. (*Frequenz*, Nov. 1957, Vol. 11, No. 11, pp. 333–342.) The characteristics of various semiconductor devices such as Ge and Si junction diodes and transistors, including recent high-frequency and high-power types, are reviewed.

621.314.63 : 621.318.57 **3280**
The Forward Switching Transient in Semiconductor Diodes at Large Currents.—F. S. Barnes. (*Proc. Inst. Radio Engrs*, July 1958, Vol. 46, No. 7, pp. 1427–1428.) The phenomenon is explained in terms of the current modulation of the resistance of the bulk of the semiconductor diode. Methods of reducing the voltage transient are noted.

621.314.63.029.6 : 621.374.4 : 621.396.822 **3281**
Excess Noise in Microwave Crystal Diodes used as Rectifiers and Harmonic Generators.—J. M. Richardson & J. J. Faris. (*Trans. Inst. Radio Engrs*, July 1957, Vol. MTT-5, No. 3, pp. 208–212. Abstract, *Proc. Inst. Radio Engrs*, Sept. 1957, Vol. 45, No. 9, p. 1312.)

621.314.632 : 621.316.722.1 **3282**
The Characteristics of Zener Diodes and their Application as Voltage Standards.—G. Meyer-Brötz. (*Elektronische Rundschau*, Dec. 1957, Vol. 11, No. 12, pp. 376–377.) Note on applications of Si reference diodes, particularly for voltage stabilization in transistor circuits. See also 3684 of 1957 (Dobrinski et al.).

621.314.632.1 : 546.321.31 **3283**
Rectifying Effects of Sodium Chloride Crystals.—S. Császár. (*Nature, Lond.*, 19th April 1958, Vol. 181, No. 4616, p. 1158.) Note of I/V characteristics obtained using NaCl crystals at 250°C with point contacts of platinum or tungsten wire. The crystals were grown from the melt and some were coloured electrolytically.

621.314.7 **3284**
The Transistor, 1948-1958.—(*Bell Lab. Rec.*, June 1958, Vol. 36, No. 6, pp. 192–233.) Nine papers, listed below, review progress in selected areas of research and development. Transistors with functional properties of a sufficiently wide range are now available for application in most communication systems. Significant progress has been made in realizing the reliability and long life required for telephone service. Transmission and switching systems, signalling and station facilities employing transistors and other solid-state devices, are being developed.

Titles of the papers are as follows:—

(*a*) Semiconductor Research.—M. Sparks (pp. 193–197).

(*b*) Research in Circuits and Systems.—R. L. Wallace, Jr (pp. 198–201).

(*c*) Transistor Designs: the First Decade.—W. J. Pietenpol (pp. 202–206).

(*d*) Transmission Applications.—M. B. McDavitt (pp. 207–211).

(*e*) Applications in Telephone Switching. A. E. Ritchie (pp. 212–215).

(*f*) Station Apparatus, Power and Special Systems.—W. A. Depp & L. A. Meacham (pp. 216–220).

(*g*) Military Applications.—J. A. Baird (pp. 221–225).

(*h*) Transistor Manufacture.—J. E. Genther (pp. 226–228).

(*i*) Systems Planning.—D. F. Hoth (pp. 229–233).

621.314.7 **3285**

On the Variation of Transistor Small-Signal Parameters with Emitter Current and Collector Voltage.—N. I. Meyer. (*J. Electronics Control*, April 1958, Vol. 4, No. 4, pp. 305–334.) Experimentally determined variations of the low-frequency hybrid parameters are in agreement with calculations, apart from the variation of h_{12} with emitter current, which shows a quantitative disagreement with theory. Misawa's theoretical expression for α cut-off frequency (see 597 of February) is compared with experimental results and is found to lead to a wrong dependence on emitter current.

621.314.7 **3286**

Design Theory for Depletion-Layer Transistors.—J. E. Rosenthal: W. W. Gärtner. (*Proc. Inst. Radio Engrs*, July 1958, Vol. 46, No. 7, pp. 1422–1423.) Comment on 306 of January and author's reply.

621.314.7 : 621.317.799 **3287**

The Measurement of Transistor Voltage/Current Characteristics using Pulse Techniques.—Cooper. (See 3215.)

621.314.7 : 621.317.799 **3288**

Transistor Test Set.—Prewett. (See 3216.)

621.383.2 **3289**

The Temperature Dependence of the Photoeffect of Sb-Cs Photocathodes in the Temperature Range −170°C to + 20°C.—Zs. Náray. (*Ann. Phys., Lpz.*, 30th Nov. 1957, Vol. 20, Nos. 7/8, pp. 386–389.)

621.383.4 : 537.531 **3290**

The Measurement of X-Ray Interference by means of Cadmium Sulphide Photocells.—H. Simon & M. v. Heimendahl. (*Ann. Phys., Lpz.*, 30th Nov. 1957, Vol. 20, Nos. 7/8, pp. 355–367.) Description of apparatus and details of some of its applications.

621.383.42 **3291**

Spontaneous Appearance of an Electromotive Force in Selenium Photocells at Low Temperatures.—G. Blet. (*C. R. Acad. Sci., Paris*, 4th Dec. 1957, Vol. 245, No. 23, pp. 2044–2047.)

621.383.5 + 621.314.63] : 537.533.9 **3292**

Current Amplification by Electron Bombardment in the Semiconductor Barrier Layer.—K. Takeya & K. Nakamura. (*J. phys. Soc. Japan*, Feb. 1958, Vol. 13, No. 2, p. 223.) Current gain is defined as the ratio of excess current to bombarding current. Experimental curves of current gain versus bias voltage, for various bombarding energies, are given for Se, Ge (alloyed), Si (diffused), and Si (grown). See also 2303 of 1951 (Ehrenberg et al.).

621.385 : 537.533 **3293**

Transverse Instability of Electron Beams.—B. Epsztein. (*C. R. Acad. Sci., Paris*, 27th Jan. 1958, Vol. 246, No. 4, pp. 586–588.) The existence of this instability in thin beams is explained. See also 2568 of 1956.

621.385.001.4 **3294**

The Life Test Contribution to the Improvement of Valve Reliability.—R. Brewer. (*Brit. Commun. Electronics*, April 1958, Vol. 5, No. 4, pp. 258–263.) The results are analysed of vibration and electrical life tests made on four types of valves of the CV4000 series intended for highly reliable performance in military applications.

621.385.029.6 **3295**

Beam Focusing in Microwave Amplifiers.—P. P. Cioffi. (*Bell Lab. Rec.*, May 1958, Vol. 36, No. 5, pp. 172–175.) The methods by which the magnetic field may be accurately aligned with the tube axis are discussed. The best adjustments enable 99·9% of the emitted electrons to be delivered to the collector.

621.385.029.6 **3296**

Pumping to Extend Travelling-Wave-Tube Frequency Range.—L. D. Buchmiller & G. Wade. (*Proc. Inst. Radio Engrs*, July 1958, Vol. 46, No. 7, pp. 1420–1421.) Using an S-band travelling-wave valve the small-signal gain for an L-band signal (1 kMc/s) was increased by 33 dB by adding at the input a high-level signal at 3·2 kMc/s. Without readjustment a similar gain enhancement was measured for signals at frequencies well above the S band. An explanation is given in terms of mixing effects associated with electron beams [see 3073 of 1957 (DeGrasse & Wade)].

621.385.032.21 : 537.29 : 621.374.4 **3297**

Harmonic Generation at Microwave Frequencies using Field-Emission Cathodes.—J. R. Fontana & H. J. Shaw. (*Proc. Inst. Radio Engrs*, July 1958, Vol. 46, No. 7, pp. 1424–1425.) An expression for the harmonic amplitudes in the emission current is obtained, from which the performance of any field emitter whose basic properties are known can be calculated.

621.385.032.213.13 **3298**

The High-Temperature Conductivity Mechanism of Oxides with Thermal Electron Emission.—A. Paulisch. (*Z. angew. Phys.*, Aug. 1957, Vol. 9, No. 8, pp. 412–426.) The results of conductivity and emission measurements on a number of oxides confirm the more general applicability of the pore conduction mechanism previously defined for (Ba,Sr)O cathodes [see e.g. Loosjes & Vink (2934 of 1950)].

621.385.032.213.13 : 537.583.08 **3299**

Measurement of Instantaneous Absolute Barium Evaporation Rates from Dispenser Cathodes.—W. C. Rutledge, A. Milch & E. S. Rittner. (*J. appl. Phys.*, May 1958, Vol. 29, No. 5, pp. 834–839.) The evaporation rate and the BaO content of the evaporant are determined by exposing a clean tungsten wire to a stream of Ba and noting the time required to reach maximum emission. Typical results are given for a wide range of Ba-BaO compositions.

621.385.1 : 621.317.799 **3300**

New Portable Electron-Tube Tester.—Heberlein. (See 3217.)

621.385.1 : 621.372.622 : 621.396.822 **3301**

Noise in Mixer Tubes.—A. van der Ziel & R. L. Watters. (*Proc. Inst. Radio Engrs*, July 1958, Vol. 46, No. 7, pp. 1426–1427.) It is proved that the theorem for calculating mixer valve noise by averaging over a complete local-oscillator cycle is valid for noise with a white spectrum. The theorem is incorrect if the spectrum is not white.

621.385.1 (083) : 681.18 **3302**

Automatically Recording Tube-Life Data.—A. T. Ross. (*Bell Lab. Rec.*, May 1958, Vol. 36, No. 5, pp. 176–178.) A system for recording aging data automatically on business-machine cards is described.

621.385.14-713 **3303**

The Utilization of the Waste Heat of Transmitter Valves with Evaporation Cooling.—W. Voigt. (*VDI Z.*, 1st May 1958, Vol. 100, No. 13, pp. 564–565.) In the transmitting station Jülich most of the heat extracted from the valves is used for station heating purposes, resulting in considerable fuel economy. See e.g. 1982 of 1957 (Protze).

621.385.2 **3304**

Transit Time and Space Charge in the Spherical Diode.—L. Gold. (*J. Electronics Control*, April 1958, Vol. 4, No. 4, pp. 335–340.) The transit time and current/voltage relation for a spherical diode have been determined using a time-dependent Poisson equation as applied in the case of a cylindrical diode (1931 of June). The effect of cathode-anode inversion is also examined.

621.385.4 : 621.395.64 **3305**

Electron Tubes for Super Wide-Band Coaxial-Cable Systems.—M. Kuwata, K. Sato, T. Kojima & H. Hara. (*Rep. elect. Commun. Lab., Japan*, Feb. 1958, Vol. 6, No. 2, pp. 35–39.) Characteristics of tetrodes Type ECL 1084 and ECL 1144 are discussed.

MISCELLANEOUS

061.3 : 621.37/.39 **3306**

Twelfth General Assembly of International Scientific Radio Union.—F. H. Dickson. (*Proc. Inst. Radio Engrs*, July 1958, Vol. 46, No. 7, pp. 1350–1383.) The program of the assembly at Boulder, Colo., 22nd August–5th September 1957 is given together with summaries of the principle discussions of the seven commissions.

378.962 : [621.397.5 + 534.86 **3307**

The Training of Sound and Television Technicians for the Broadcasting Organizations of the German Federal Republic.—K. Hoffmann. (*Rundfunktech. Mitt.*, Dec. 1957, Vol. 1, No. 6, pp. 232–236.)

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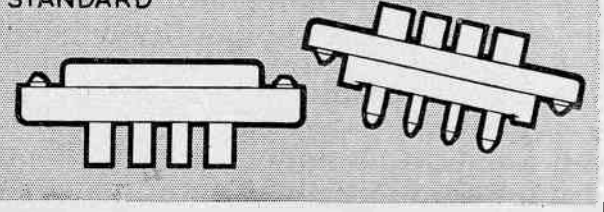

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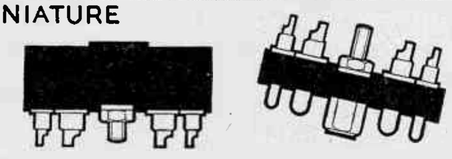

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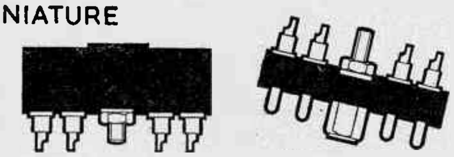

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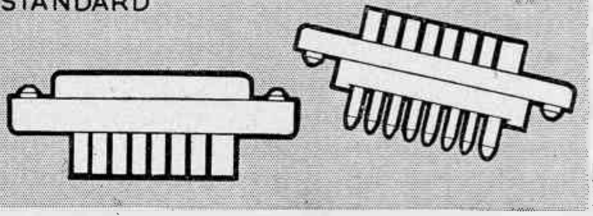

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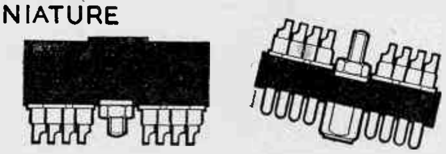

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L./1387/P	·990 x ·366 x ·593	0·18	8 (four large)
L./1387/S	·990 x ·366 x·562	0·18	
L./1388/P	·990 x ·366 x ·593	0·13	8
L./1388/S	·990 x ·366 x ·562	0·16	
L./655/P	1·500 x ·843 x ·640	0·35	12 (two large)
L./655/S	1·500 x ·843 x ·531	0·34	
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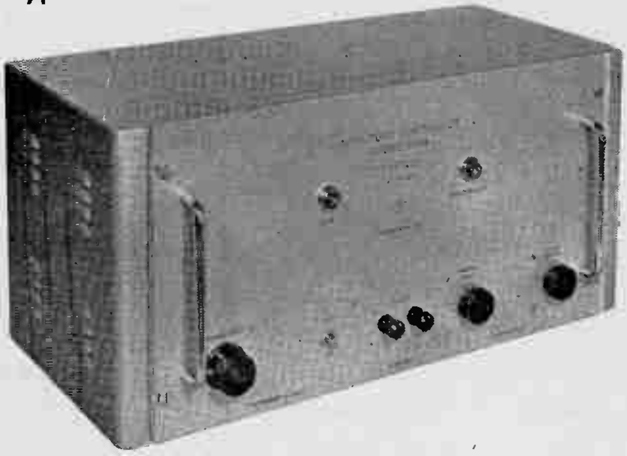

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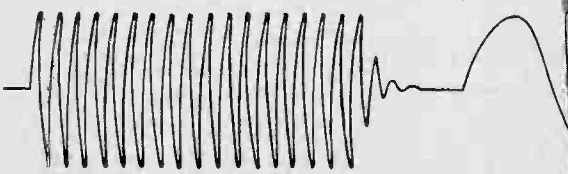

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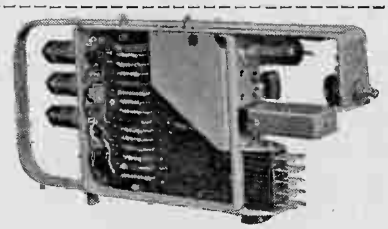

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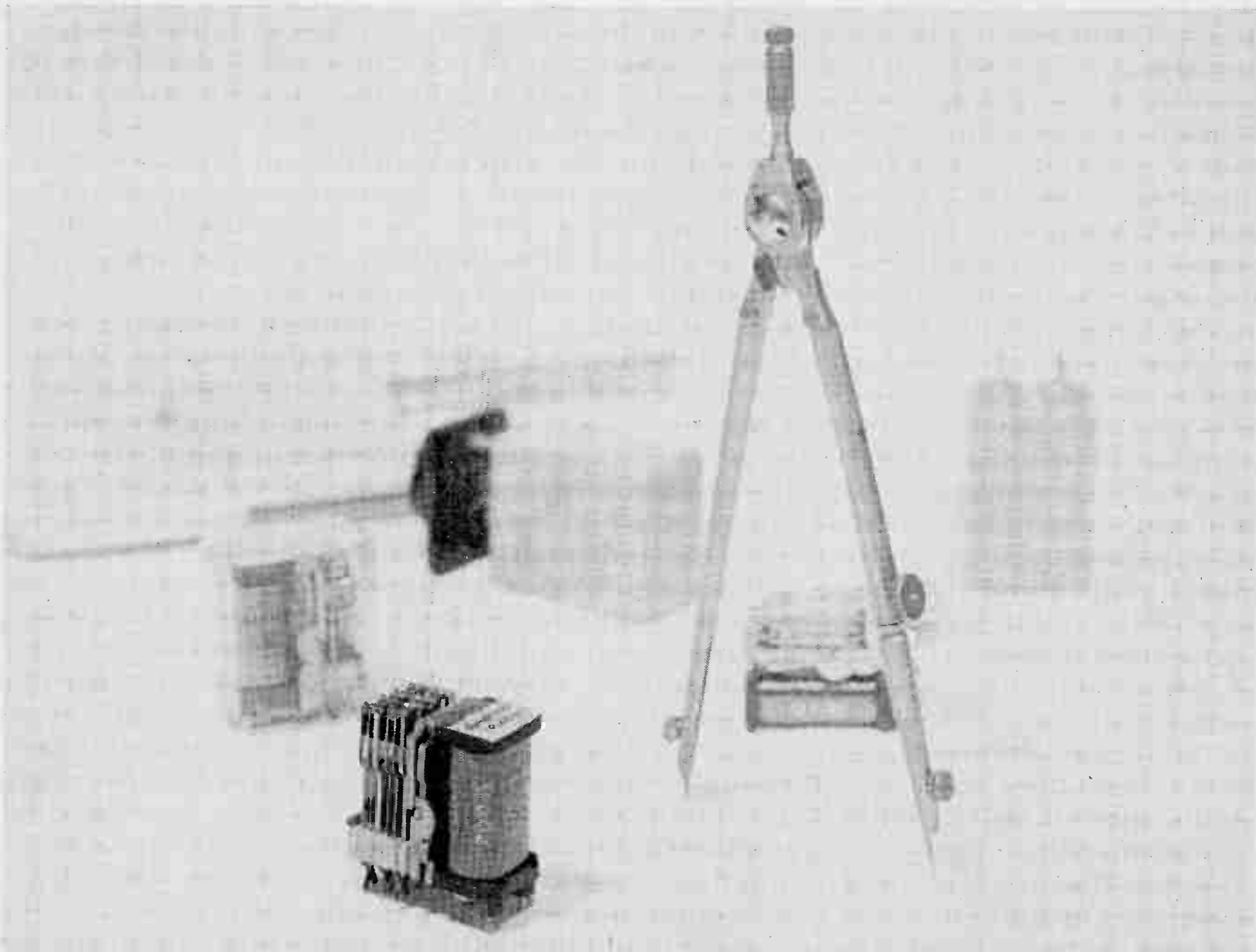

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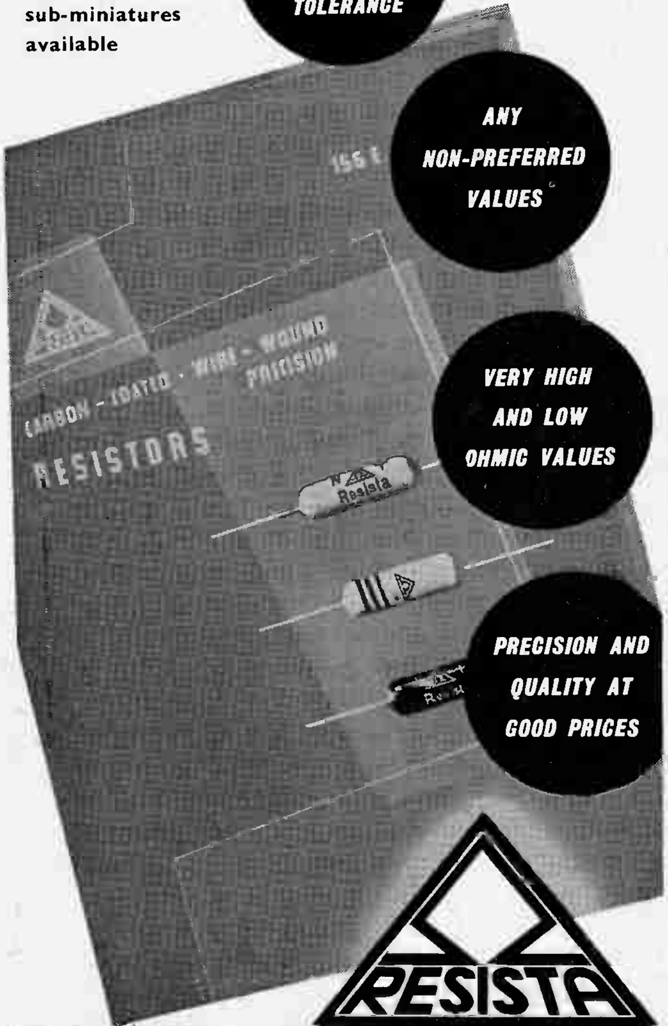

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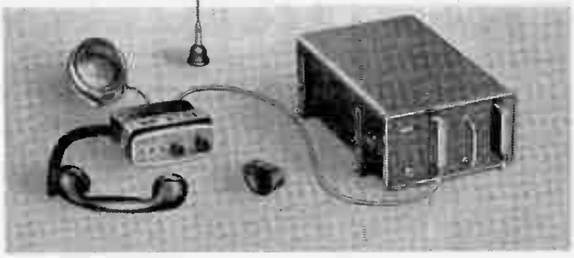

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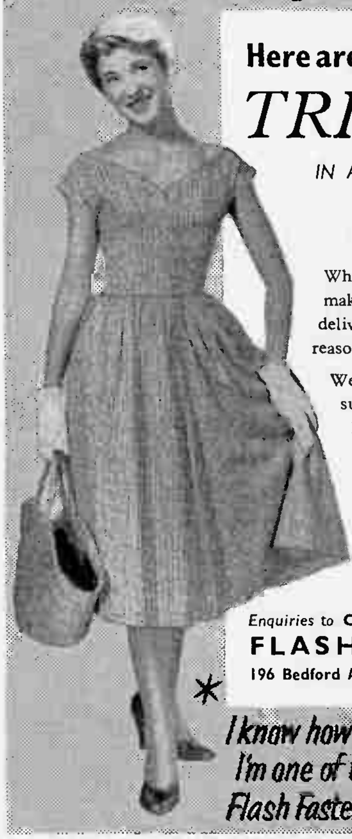

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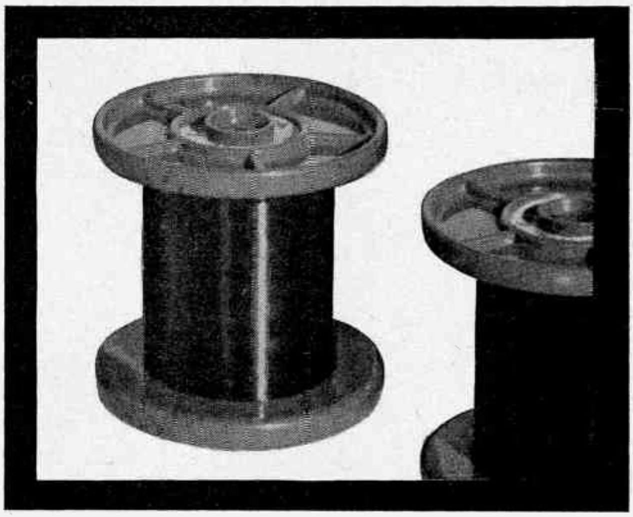

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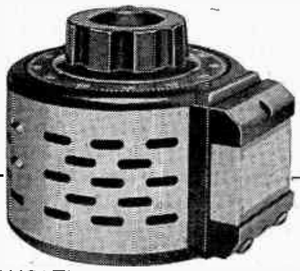

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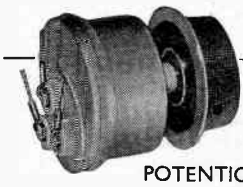

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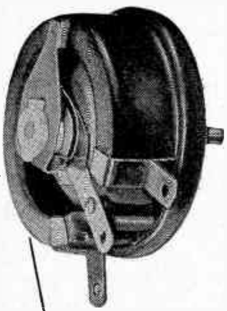

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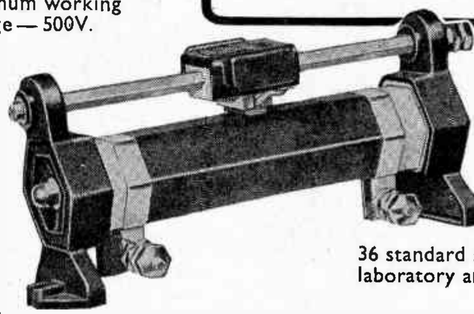

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DETAILS and application forms (stamped addressed foolscap envelope) from the Clerk to the Governors at the College. [1246

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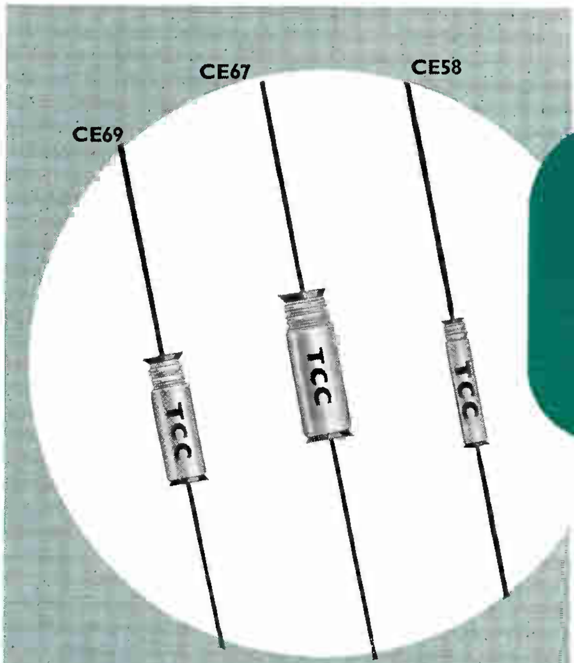

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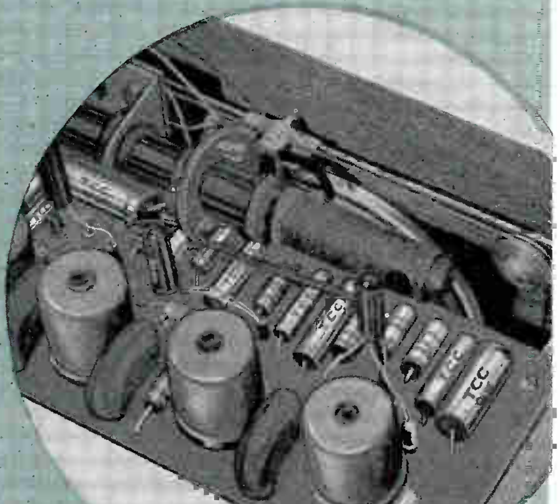

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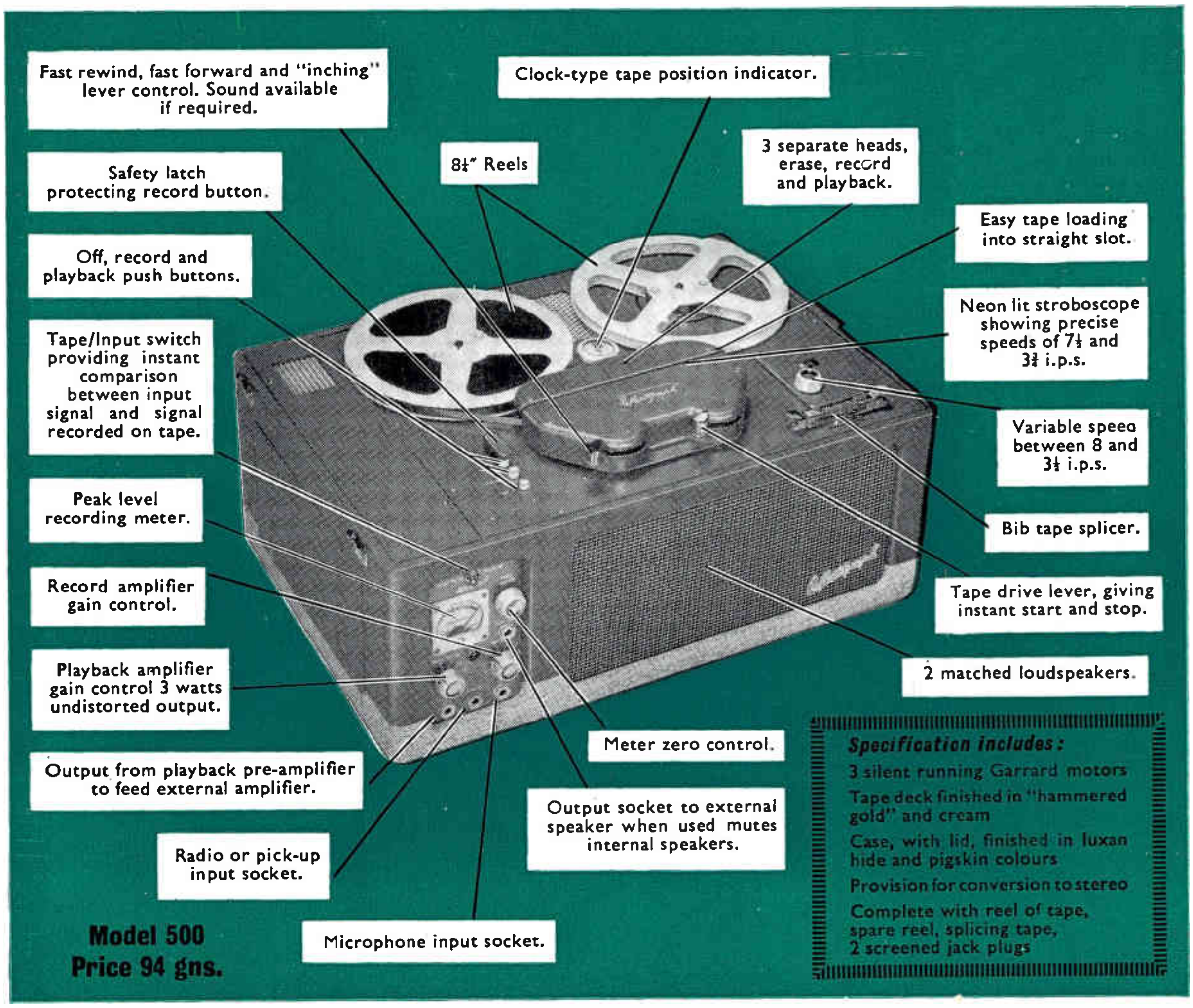

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