ELECTRONIC & RADIO ENGINEER

Incorporating **WIRELESS ENGINEER**

In this issue

Three shillings
and sixpence

NOVEMBER 1958 Vol 35 *new series* No 11

U.H.F. MEASURING EQUIPMENT

Trade Mark

Type 1602-B
U.H.F. Admittance Meter

No engineer concerned with impedance measurements from 41 Mc/s to 1500 Mc/s can afford to be without this *unique* Bridge.

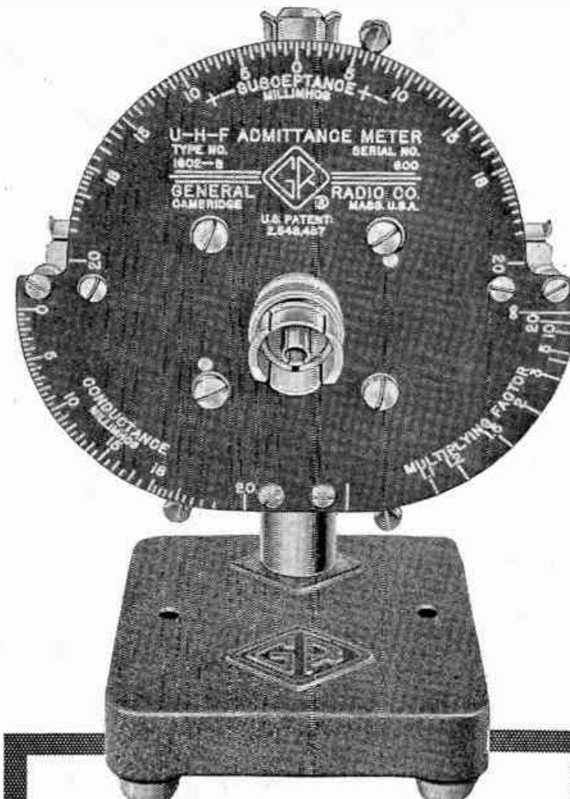
As a null instrument it can be used to measure the conductance and susceptance of an unknown impedance by direct reading of the scales. By connecting the unknown impedance through a 50 ohm line one or more odd quarter waves in length, the scales read directly in terms of resistance and reactance.

The Bridge can also be used as a comparator to indicate the degree of inequality between two admittances. In addition, as a direct reading device it can be used to determine the magnitude of the reflection coefficient of a coaxial feeder, or the magnitude of an unknown impedance, from the ratio of output voltages read on the detector meter. Balanced impedances can also be measured with the aid of the "G.R." Type 874-UB "Balun".

Owing to the *unique* coaxial form of the bridge arms and the use of the matched coaxial connectors "G.R." Type 874 throughout, any uncertainties regarding reflections (and thereby errors) at the vital points of connection are completely eliminated.

There are no sliding connections to cause intermittencies since the conductance, susceptance and multiplying arms merely control the rotation of small coupling loops within the coaxial arms of the bridge. A further *unique* feature is the independence with frequency of the susceptance readings.

Additional apparatus required consists of a suitable range Oscillator or a Signal Generator, and a sensitive, well shielded receiver as the detector. If the user does not already possess these, suitable instruments are available from the complete "GENERAL RADIO" range of measurement instruments, described in their 258-page current Catalogue "O", available on application.



BRIEF CHARACTERISTICS

FREQUENCY RANGE: 41 to 1500 Mc/s. This can be extended down to 10 Mc/s by the use of a correction factor, which is a function of frequency. (A Chart is provided).

ACCURACY: For both conductance and susceptance (up to 1000 Mc.): from 0 to 20 millimhos $\pm$ (3% + 0.2 millimho) from 20 to ∞ millimhos $\pm$ ($3\sqrt{M}$% + 0.2 millimhos) where M is the scale multiplying factor. Above 1000 Mc, errors increase slightly, and, at 1500 Mc, the basic figure of 3% in the expression above becomes 5%. For matching impedances to 50 ohms, the accuracy is 3% up to 1500 Mc.

DIMENSIONS: 7½" × 5½" × 5½".

NET WEIGHT: 8¼ lbs.

REASONABLY PRICED: £177.0.0. net, delivered (U.K. only), complete with all basic accessories, all duties paid.

Claude Lyons Ltd.

76 OLDHALL STREET · LIVERPOOL 3 · LANCS · TELEPHONE: CENTRAL 4641
VALLEY WORKS · HODDESDON · HERTS · TELEPHONE: HODdesdon 3007-8-9

CL42

WINSTON ELECTRONICS LIMITED

Sole Agents for BECKMAN-BERKELEY Division Beckman Helipots

BERKELEY DIVISION

Universal Eput Meters and Timers, Frequency Meters, Time Interval Meters; Analogue Computers, Data Reduction, Digital Readout, Transducers, Ferristors.

HELIPOT DIVISION

Some typical examples of Helical Potentiometers:

SERIES	A	AJ	AN	B	C	T	5300	5700
Number of turns	10	10	10	15	3	1	1	1
Diameter, inches	1-13/16	7/8	1-13/16	3-5/16	1-13/16	7/8	1-1/4	3
Length of case, inches	2	1-1/2	1-63/64	2-13/16	1-9/64	25/32	19/32	1
Shaft diameter, inches (nominal)	1/4	1/8	1/4	1/4	1/4	1/8	1/4	1/4
Coil length, inches (approx.)	46	18	45	140	14	1·9	3·1	8·2
	+4°	+10°	+1°	+4°	+4°			
Mechanical rotation	3,600°—0°	3,600°—0°	3,600°—0°	5,400°—0°	1,080°—0°	360° cont.	360° cont.	360° cont.
	+4°	+10°	+1°	+4°	+4°			
Electrical rotation	3,600°—0°	3,600°—0°	3,600°—0°	5,400°—0°	1,080°—0°	354° ± 2°	352° ± 2°	358° ± 1°
Resistance range, ohms	25 to 450K	25 to 100K	50 to 400K	40 to 1 meg	5 to 130K	1 to 100K	25 to 49K	50 to 163K
Best pract. resist. tol. (*a*)	±1%	±2·5%	±1%	±1%	±1%	±2%	±1%	±1%
Best prac. linearity tol. (*b*)	±0·05%	±0·05%	±0·025%	±0·01%	±0·1%	±0.2%	±0·25%	±0·1%
	1K and up	10K to 50K	5K and up	10K and up	5K and up		2K and up	5K and up
Max. noise millivolts (c)	250	250	100	250	250	100	100	100
	2K and up	1K and up		5K and up	500 and up			
Watts, at 25°C ambient (*d*)	6·9	2·8	6·9	13·8	4·1	1·5	2·8	6·9
Watts, at 40°C ambient	5	2	5	10	3	1·2	2	5
Weight, oz. (approx.)	4·4	1	4·5	13	2·5	0·6	2	5·9
Max. starting torque, oz. in.	2	0·7	1·3	2·7	1·8	0·05	0·7	1·3
Max. running torque, oz. in.	1·5	0·6	0·9	2	1·3	0·05	0·5	0·5
Moment of inertia, gm. cm.^{2}	18	0·3	22	200	7	0·12	2·8	8·6
Max. taps	28	32	28	80(e)	14	9	9	33
Min. distance between taps	20° ± 1°	45° ± 2°	20° ± 1/2°	15° ± 1°	20° ± 1°	30° ± 1°	30° ± 1°	10° ± 1°
Max. ganged sections	3	consult factory	2	3	3	5	no ganging	8
Life expectancy, shaft revs.	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000

HELIDELS · DUODIALS · DIGIDIALS

Winston Electronics also manufacture

VOLTMETERS · OSCILLATORS

TELECOMMUNICATIONS · TEST GEAR

Sub-Contract Facilities A.I.D. and A.R.B. Approved

GOVETT AVENUE SHEPPERTON, MIDDLESEX

WINSTON ELECTRONICS LIMITED

Telephone Walton-on-Thames 6321

REMEMBER POPPY DAY

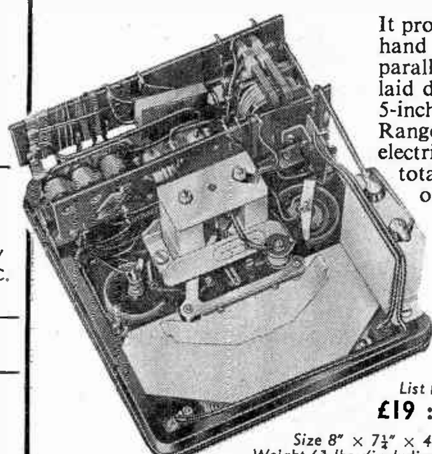
MODEL 7 Universal AVOMETER 50 RANGE

Fifty ranges...

in one instrument

THE wide scope of this multi-range AC/DC measuring instrument, coupled with its unfailing reliability, simplicity of use and high degree of accuracy, renders it invaluable wherever electrical equipment has to be maintained in constant, trouble-free operation.

It provides 50 ranges of readings on a 5-inch hand calibrated scale fitted with an anti-parallax mirror. Accuracy is within the limits laid down in Section 6 of B.S.S. 89/1954 for 5-inch scale industrial portable instruments. Range selection is effected by means of two electrically interlocked rotary switches. The total resistance of the meter is 500,000 ohms.



The instrument is self-contained, compact and portable, simple to operate, and is protected by an automatic cut-out against damage through inadvertent overload.

Power and Power Factor can be measured in A.C. circuits by means of an external accessory, the Universal AvoMeter Power Factor & Wattage Unit.

List Price
£19 : 10s.

Size 8" × 7½" × 4½"
Weight 6¾ lbs. (including leads)

CURRENT	VOLTAGE
1mA D.C. only	50mV D.C. only
2 ,, ,, ,,	100 ,, ,, ,,
5 ,, A.C. & D.C.	500 ,, ,, ,,
10 ,, ,, ,,	1V ,, ,,
50 ,, ,, ,,	5 ,, A.C. & D.C.
100 ,, ,, ,,	10 ,, ,, ,,
500 ,, ,, ,,	50 ,, ,, ,,
1 A ,, ,,	100 ,, ,, ,,
5 ,, ,, ,,	200 ,, ,, ,,
10 ,, ,, ,,	400 ,, ,, ,,
	500 ,, ,, ,,
	1,000 ,, ,, ,,

RESISTANCE

10,000 ohms 100,000 ,,	using internal 1½ volt cell
1 Megohm	using internal 9 volt battery
10 Megohms 40 ,,	using external source of A.C. or D.C. voltage

CAPACITY 0·01—20 mFds

POWER AND DECIBELS

Impedance	Power	Decibels 0=50mW
500 ohms	200 mW	—25 to + 6
5,000 ohms	2W	—15 to + 16
50,000 ohms	200 mW	—25 to + 6

Various accessories are available for extending the wide range of measurements.

...you can depend on AVO

Illustrated Brochure available on request.

Sole Proprietors and Manufacturers:—

AVO LTD

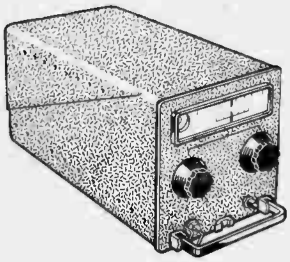
AVOCET HOUSE · 92-96 VAUXHALL BRIDGE ROAD · LONDON · S.W.1. *Telephone: VICtoria 3404 (9 lines)*

A7/9


NEW Industrial Cathode Ray Tubes
12" RADAR TUBE
Electrostatic Focus, High Brightness with helical acceleration to 25 kV screen potential.
5" OSCILLOSCOPE TUBE.
Very high plate sensitivity—2·5 v/cm with 10kV screen potential.
8" RECTANGULAR DISPLAY TUBE
Electrostatic Focus. Neck reduced to 23 mm dia. Less weight, more compact, easier scanning.
The Electronics Dept. of Ferranti Ltd., manufactures a wide range of cathode ray tubes and valves for many industrial applications.
FERRANTI

A.W.A ELECTRONICS

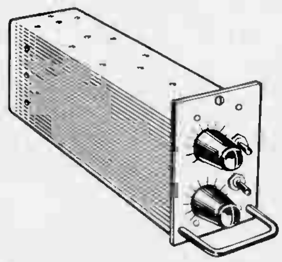
New concepts in electronics have been developed at AWA, as a result of experience with missile systems. Now they have a wider application. Here are some of the new AWA devices now available to industry.



U.H.F. WIDEBAND RECEIVER

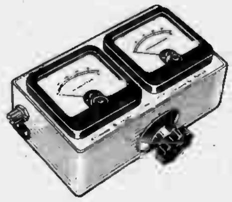
Basic arrangement consists of R.F. amplifier, mixer, local oscillator, I.F. amplifier (A.G.C. controlled), cathode follower output stage. Tuning indicator (EM 34) is also fitted to receiver. The standard forms: one for airborne racking with special separate power supply unit, the other on larger chassis including power supply unit (conventional 19" front panel). *Standard specification: 420-470 M/cs frequency range; 4 M/cs overall bandwidth, approximately 10 db noise factor; approximately 70 ohms input impedance. 200-250 V and 50-60 c/s input supply. Input is unbalanced, output is via low impedance (cathode follower) stage.*

TRANSISTOR GALVANOMETER AMPLIFIER

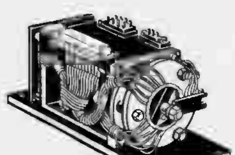


This Amplifier has been designed to drive viscous damped recording galvanometers which normally have a resistance of 50 ohms and a working range of D.C. to 2 Kc/s in frequency. The amplifier has a switched attenuator at its input and will accept single ended or push pull signals from ± 1 Millivolt to ± 500 volts and will feed a maximum of ± 50 Milliamps to the galvanometer. There is also a range of ancillary units available for use with this Amplifier as part of a comprehensive instrumentation system. *Standard specification: Dimensions: 4¼ in. x 3¾ in. x 10 in.; Frequency response: Flat from DC to 2 Kc/s, 5% down at 3 Kc/s, 3db down at 6 Kc/s; Noise level: 10 Microvolts at either input; Input impedance: 40,000 ohms on range 5, 110,000 ohms all other ranges; Gain: Maximum 5 Milliamps/Millivolt, minimum 0.04 Milliamps/Volt; Power requirements: ± 6 Volts D.C. 220 Milliamps each line.*

DIRECTIONAL COUPLER



Of the 'Loop' type, suitable for measurements of RF power and Standing Wave Ratio in coaxial cables. Directional properties are largely unaffected by frequency changes, so coupler may be used to help obtain optimum termination of a 52 ohm coaxial system up to 600 M/cs. *Standard specification: Size 7" x 4" x 2½"; weighs 4 lbs. 3 ozs.; Power Measurement Range is Low range 1 w.cw.max. High range 5 w.cw.max.; less than 1% attenuation; better than 2% accuracy at frequency of calibration.*



ROTARY SWITCH FOR TELEMETRY

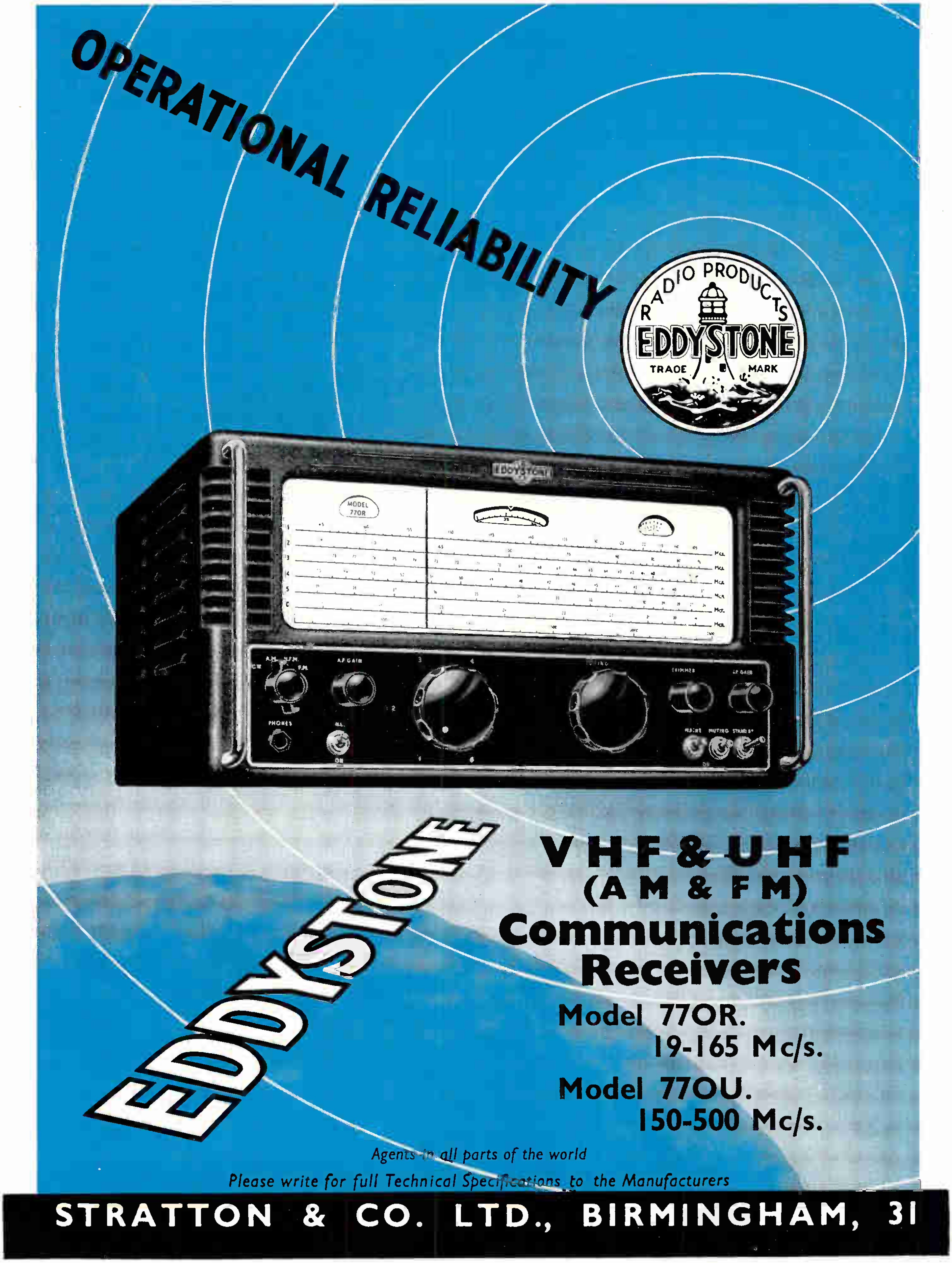
Based on a conception of British Ministry of Supply's Research and Development Establishment, gives facilities previously unobtainable from mechanical sampling devices. The Standard Model enables two 24 channel banks to be sampled at speeds up to 200 r.p.s.

All devices are adaptable to suit customers' own requirements. For further information consult:

A.W.A ELECTRONICS

SIR W. G. ARMSTRONG WHITWORTH AIRCRAFT LTD., Baginton, Coventry.

MEMBER OF THE HAWKER SIDDELEY GROUP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RADIO PRODUCTS
EDDYSTONE
TRADE MARK
EDDYSTONE
VHF & UHF
(A M & F M)
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

A*

ADCOLA
(Regd Trade Mark)

Soldering Instruments and Equipment

Comprehensive Range of Models

P.V.C. Cable Strippers

Solder Dipping Pots

Supplied in ALL VOLT RANGES

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FOR
PRODUCTION

RADIO, TV
RADAR
ELECTRONICS
TELECOMMUNICATIONS
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(Illustrated)
Protective Shield
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$\frac{3}{16}$" Detachable Bit Model
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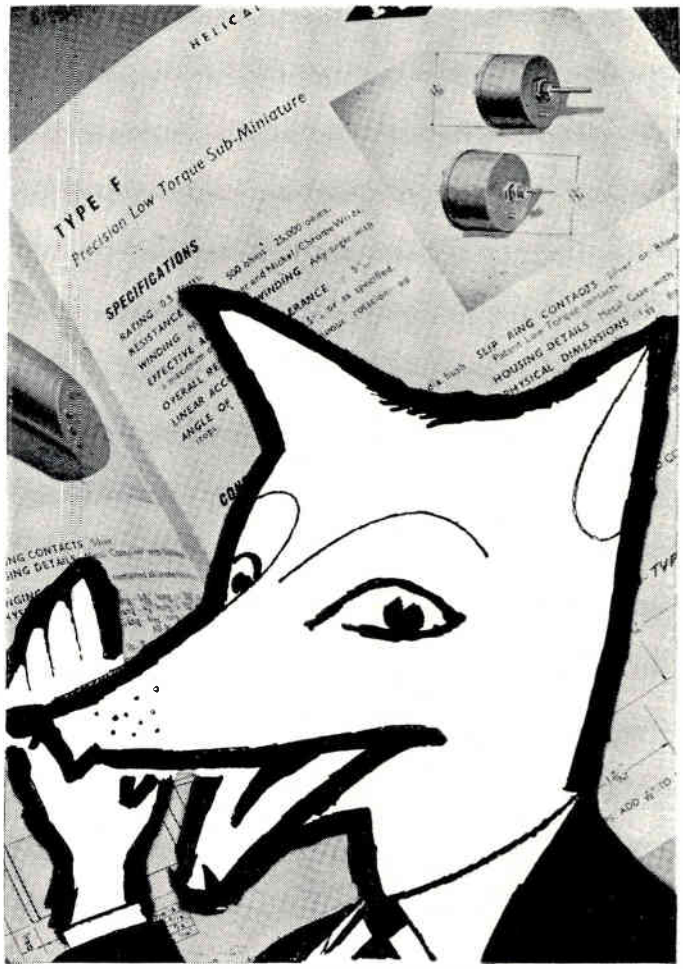


Potentiometry?...

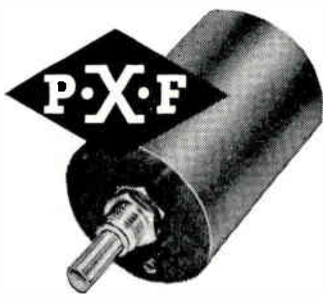
FOX-POTS to you!

Potentiometry, my dear Ponsonby, can mean "the measurement of potential".

But *I* say—and I invented the word—that it means "the art and craft of producing the best in potentiometers" or "pertaining to P. X. Fox".

Just tear out this advertisement, pin to your letterhead and post to P. X. Fox Limited at the address shown below. One of their invaluable catalogues will reach you by return post.

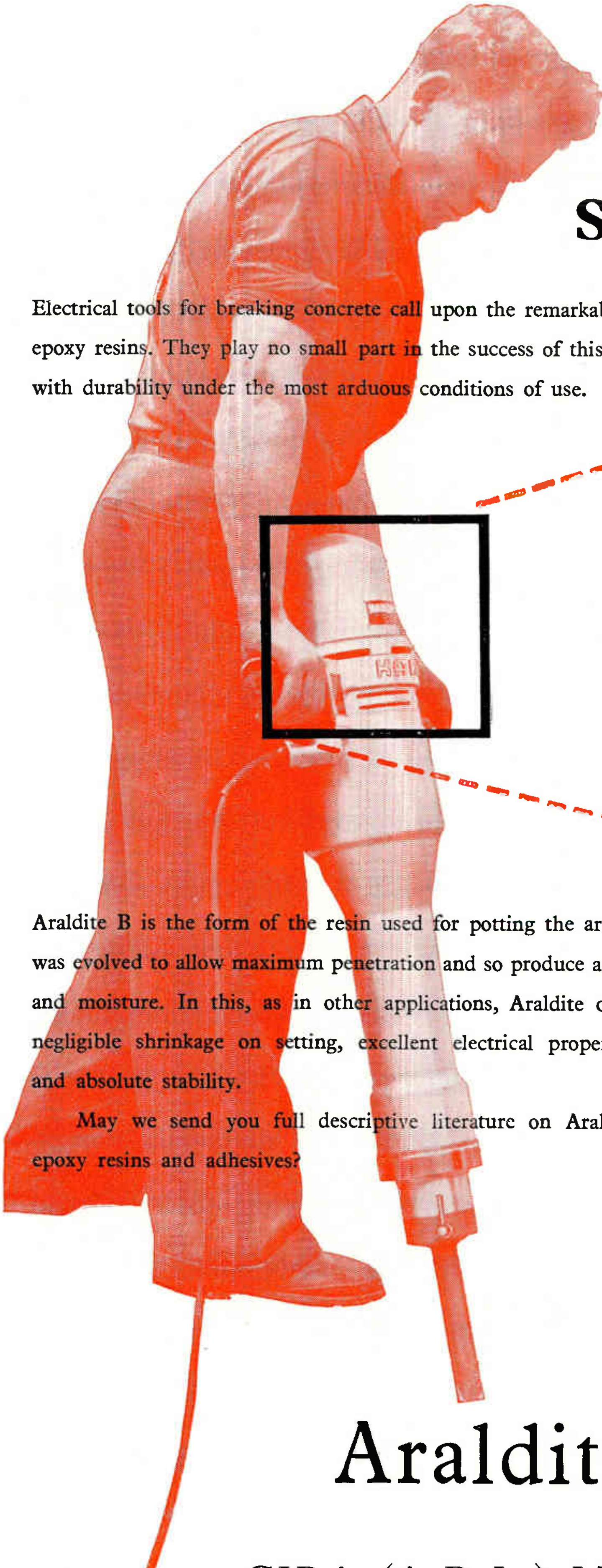
To give prompt and personal service we have opened a London office at 104 Chislehurst Road, Orpington, Kent. Telephone Orpington 21031.

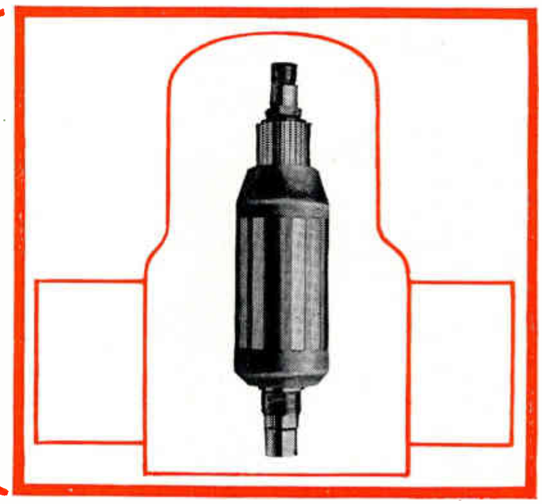


P. X. FOX LTD., DEPT. E.R.E., HAWKSWORTH ROAD
HORSFORTH, YORKSHIRE Telephone Horsforth 2831/2

Striking success

Electrical tools for breaking concrete call upon the remarkable mechanical as well as electrical properties of Araldite epoxy resins. They play no small part in the success of this Kango H Type Breaker which must combine toughness with durability under the most arduous conditions of use.





Araldite B is the form of the resin used for potting the armature of this breaker, and a special system of winding was evolved to allow maximum penetration and so produce an armature able to withstand vibration, high temperatures and moisture. In this, as in other applications, Araldite offers the advantages of outstanding adhesion to metals, negligible shrinkage on setting, excellent electrical properties and absolute stability.

May we send you full descriptive literature on Araldite epoxy resins and adhesives?

Araldite epoxy resins are used

* for bonding metals, ceramics etc.
* for casting high grade solid insulation
* for impregnating, potting or sealing electrical windings and components
* for producing glass fibre laminates
* for making patterns, models, jigs and tools
* as fillers for sheet metal work
* as protective coatings for metals, wood and ceramic surfaces

Araldite epoxy resins

Araldite is a registered trade name

CIBA (A.R.L.) LTD Duxford, Cambridge. Telephone: Sawston 2121

AP338

Audio Power Valves

TY7-6000A

TY3-250

for
Relay Services
Public Address Systems
Vibration Equipment

Mullard audio power valves are available both for new equipment designs and maintenance. Full data for these power valves and details of xenon and mercury vapour rectifiers for associated power supplies are readily obtainable from the address below.

AUDIO POWER AMPLIFIER VALVES

	Type No.	pa max. (watts)	Va max. (kilovolts)	Ik max. (amps)	Power Output (2 valves) (kW)
For Maintenance	*Triodes*				
	MZ2–200	275	2.4	0.4	1.2
	MY3–275	275	3.0	0.5	1.3
For New Equipment	TY2–125	135	2.5	0.25	0.7
	TY3–250	250	3.0	0.48	1.3
	TY4–500	450	4.0	0.7	2.4
	TY7–6000A	6000	7.2	2.8	20
	Tetrodes				
	QY3–65	65	3.0	0.22	0.27
	QY3–125	125	3.0	0.32	0.55
	QY4–250	250	4.0	0.45	1.2

POWER RECTIFIER VALVES

	Type No.	PIV max. (kilovolts)	Max d.c. output current (amps)	Typical heating up time (secs)
Mercury Vapour	RG1–240A	6.5	0.25	60
	RG3–250A/866A	10	0.25	60
	RG3–1250	13	1.25	60
Xenon	RR3–250/3B28	10	0.25	10
	RR3–1250/4B32	10	1.25	30

See Mullard valves and tubes on Stand 2 at the ELECTRONIC COMPUTER EXHIBITION Olympia, 28th November to 4th December.

Mullard Limited · Mullard House
Torrington Place · London · WC1 · Tel: LANgham 6633

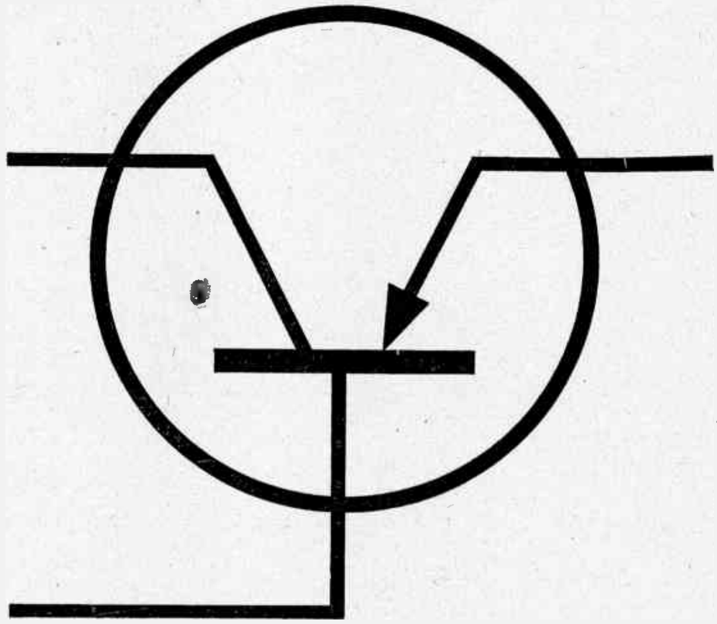
Mullard

GOVERNMENT AND INDUSTRIAL VALVE DIVISION

MVT 357

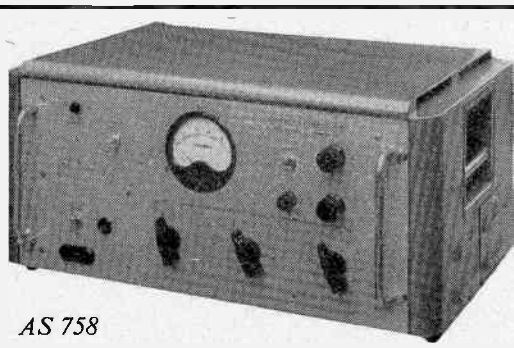
JUST THE TICKET

for any collector!

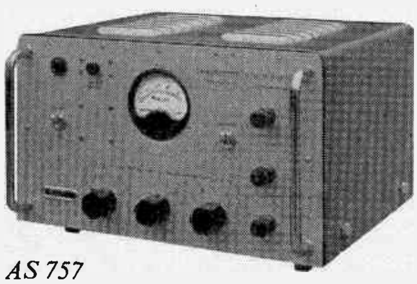


Transistors feel really secure fed from Solartron Transistor Power Supplies—precision rack, bench or sub-unit instruments built to the highest standards of craftsmanship in electronic engineering. Real 'collector's pieces' in fact!

With assured fast response to load transients and providing highly stable output voltages inside ± 7% mains input change, this new Solartron range of Power Supplies offers the right unit for any transistor research task—or sub-units for direct incorporation into production equipment. Just the choice too to replace batteries—no worries of unobserved voltage decay or finding an exact supply level.



AS 758



AS 757

All bench units have 3-dial decade switching, with its inherently simple resetting facilities, also automatic overload cut-out and load current metering. The sub-units together cover the voltage range zero to 50 volts, with 1.5 V coarse adjustment and ±1.5 V fine control. Each sub-unit has a subsidiary 5 V (nominal) stabilised output, giving 0—10 mA.

Semiconductor devices are used throughout for control and rectification and all other components have been selected to ensure satisfactory operation up to 35° Centigrade, even at maximum load current and with mains input 7% above nominal. Due to careful design of control circuitry, capacitative loading may be used throughout the whole range of Solartron Transistor Power Supplies, without danger of instability.

Summarised specifications

	AS 757	AS 758	AS 759	AS 852	AS 854	AS 855
	Bench	Bench or rack	Sub-Unit	Bench or rack	Sub-Unit	Sub-Unit
Output voltage :	± 0 – 50	± 0 – 30	± 1·5 – 13·5	± 30 – 50	± 11·5 – 32·5	± 32·5 – 50
Output current :	0 – 1A	0 – 10A	0 – 1A	0 – 10A	0 – 1A	0 – 1A
Output resistance :	0·01 Ω	0·01 Ω	0·01 Ω	0·01 Ω	0·01 Ω	0.01 Ω
Output Z to 100 Kc/s :	0·2 Ω	0·2 Ω	0·2 Ω	0·2 Ω	0·2 Ω	0·2 Ω
Stability factor greater than :	200 : 1	150 : 1	200 : 1	150 : 1	200 : 1	200 : 1
Ripple and noise (peak to peak):	1 mV	1 mV	1 mV	1 mV	1 mV	1 mV
Mains input :	90/130 Volts, 200/240 Volts. Permissible deviation ± 7%					
Dimensions :	12¾" × 8" × 13" (33 × 21 × 33 cm.)	22" × 10¾" × 16" (56 × 27 × 41 cm.)	7¼" × 5¾" × 5½" (18 × 15 × 14 cm.)	22" × 10¾" × 16" (56 × 27 × 41 cm.)	Appx. 8" × 6" × 6" (20 × 15 × 15 cm.)	Appx. 8" × 6" × 6" (20 × 15 × 15 cm
Appx. weight :	25 lbs. (11·5 kg.)	55 lbs. (25 kg.)	7¾ lbs. (3·5 kg.)	60 lbs. (27 kg.)	8 lbs. (3·8 kg.)	8 lbs. (3·8 kg.)
Price :	£95	£195	£55	£165	£60	£65

SOLARTRON

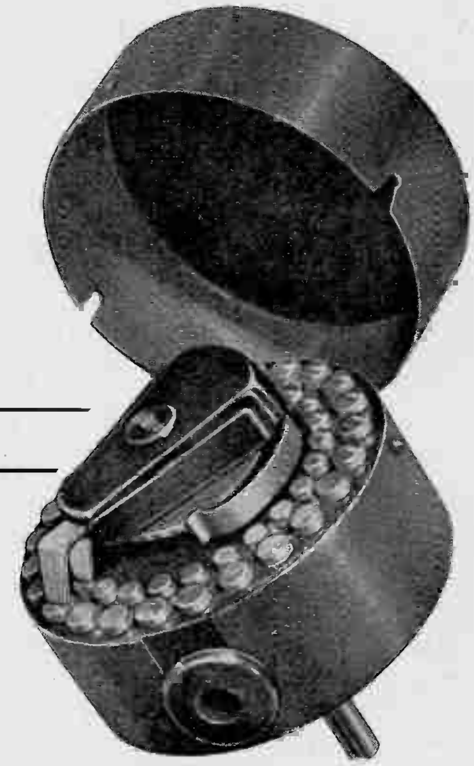
THE SOLARTRON ELECTRONIC GROUP LIMITED
THAMES DITTON · SURREY · ENGLAND · *Telephone :* EMBerbrook 5522

ELCOM

SWITCHES

FOR AUTOMATION

ELCOM have considerable experience in the design and production of rotary stud switches which have proved their efficiency in a wide range of applications including continuous thermocouple scanning, programme temperature controllers and many aspects of automation.



★ 2 pole 25 position switch suitable for continuous motor driven rotation.

ELCOM are always ready to discuss special purpose switching.

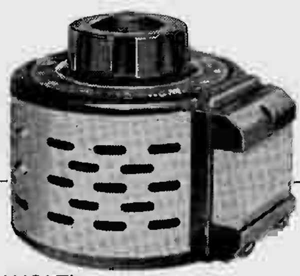
For details of **Faders and Attenuators, Plugs and Sockets, Precision Wire Wound Resistors** *write or phone*

ELECTRONIC COMPONENTS

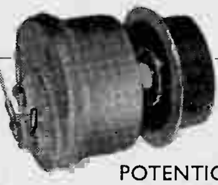
WEEDON ROAD INDUSTRIAL ESTATE, NORTHAMPTON

Telephone NORTHAMPTON 2467 and 1873   Grams 'ELCOM' NORTHAMPTON

Built to Laboratory Standards of *Accuracy* and *Quality*...



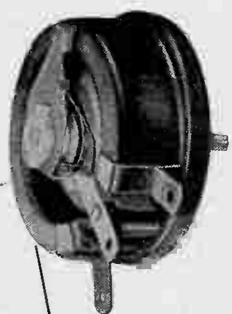
'REGAVOLT'
ROTARY VARIABLE TRANSFORMERS
Exact voltage control
6 standard models
250VA — 2.5 kVA



SEALED POTENTIOMETERS
— 1 and 5 watt models
Proofed against Dust, Fumes, Climate etc.
Maximum working voltage — 500V.

BERCO

VOLTAGE & CURRENT CONTROL EQUIPMENT



BERCOSTAT RHEOSTATS
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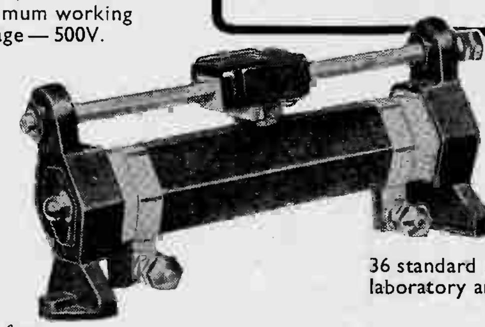

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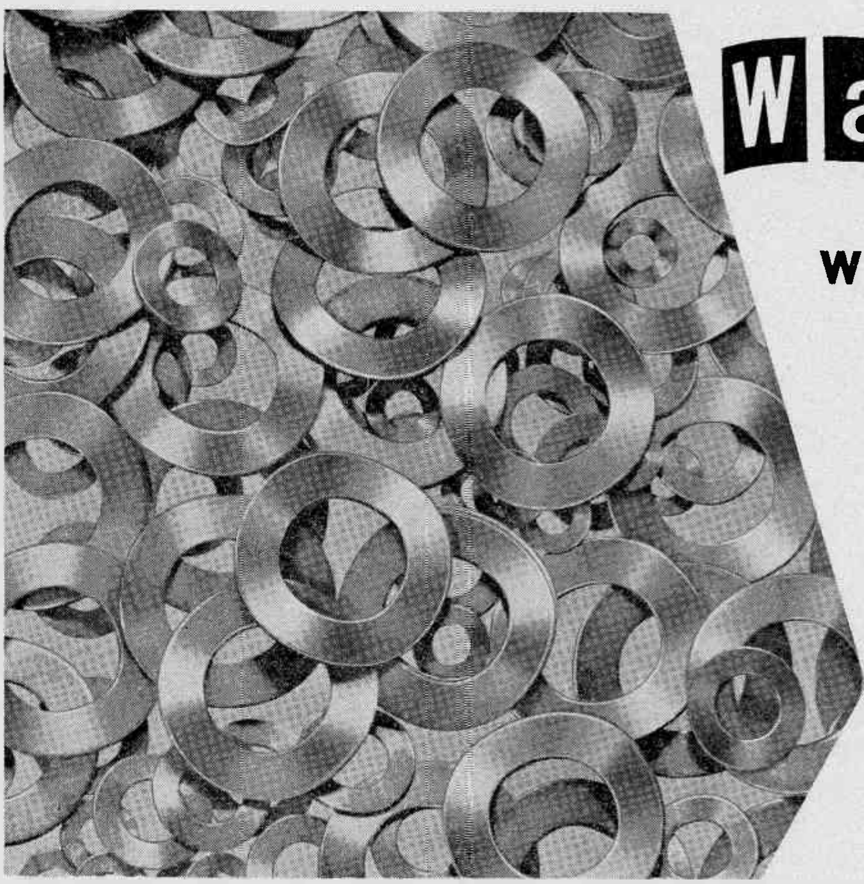

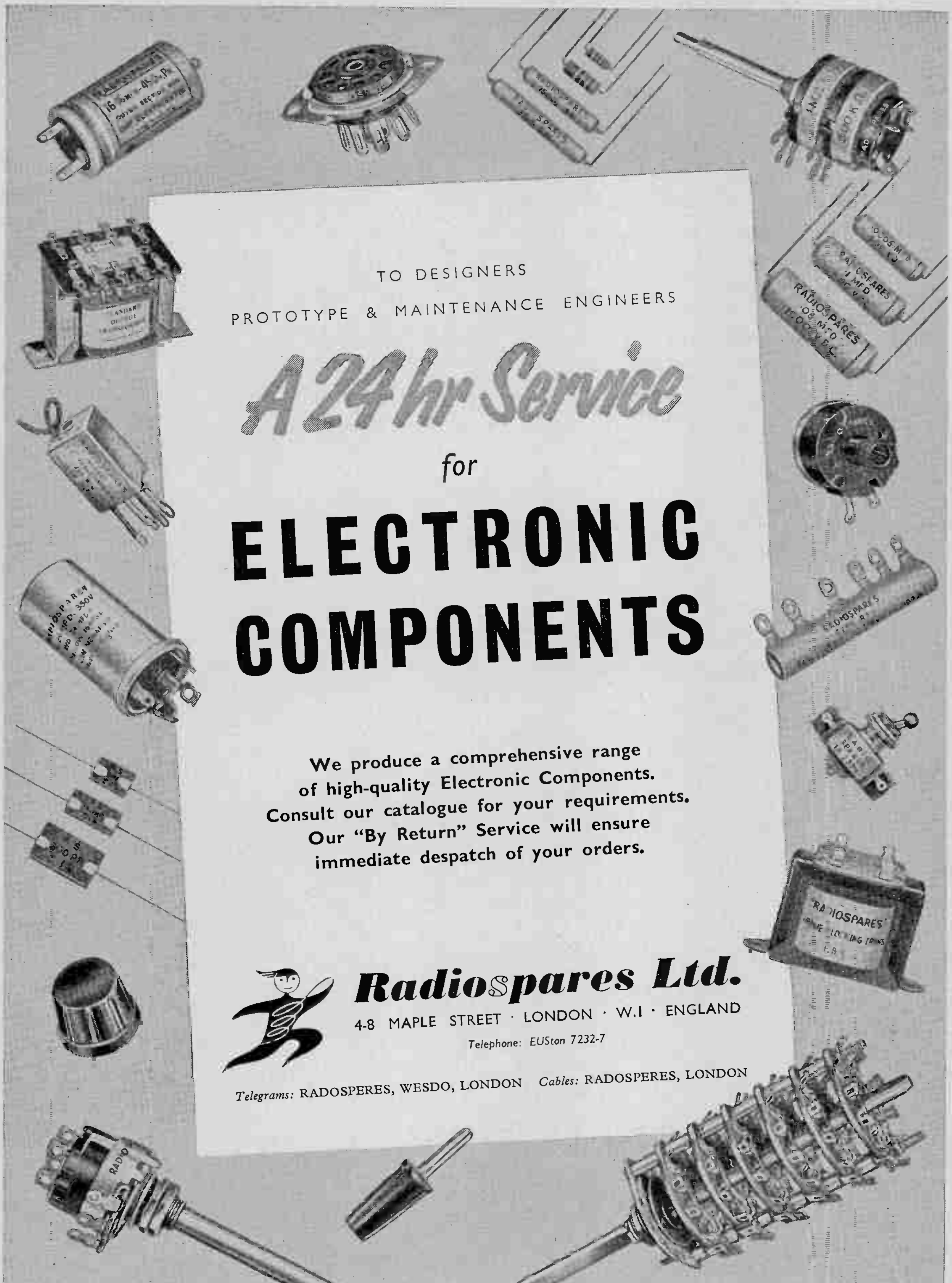
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Permanent Magnets | **Design Advisory Service**

No. 8

Demagnetisation

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.

There are two types of demagnetisation normally associated with permanent magnets. The first can be considered the controlled or precision reduction of the field for adjustment or stabilisation purposes. The second is the complete demagnetisation of the magnet to facilitate handling and assembly, and the avoidance of collecting magnetic particles.

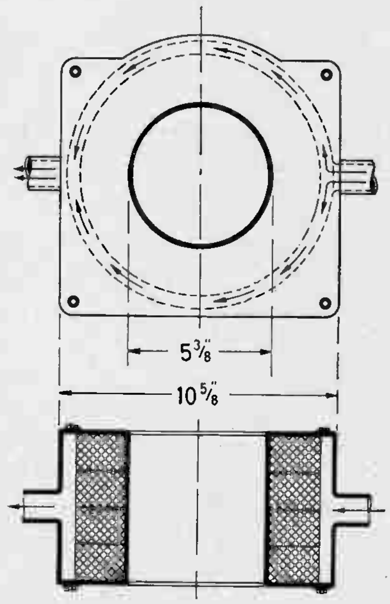
Providing the magnets are relatively small—that is—not exceeding about 2 lb. in weight, both methods of demagnetisation can conveniently be used with normal 50 c.p.s. power supply.

The first type of demagnetisation can be achieved in an accurately controllable a.c. field, usually by putting the magnet assembly into an air cored coil and controlling the a.c. supply by means of a variable transformer. If a very fine control is required for precision adjustment, a series choke with a movable iron core can be used to give infinitely fine adjustment of the field.

The second type of demagnetisation can be carried out in a similar manner, except that considerably more power is used. Generally it is found most convenient to connect the power supply direct to the coil and to move the magnetised magnets fairly slowly through the coil. Although theoretically, a field of 1,200 oersteds is sufficient for 'Ticonal' magnets, due to the screening effect of associated iron circuits the effectiveness of the field is considerably reduced, and the exact field requirements for this process cannot easily be calculated. The quickest method of finding the actual field requirements and current necessary, is by experimentation.

For 'Magnadur' magnets a demagnetising field in the region of 6,000 oersteds is necessary. An alternative method is to raise the temperature of the whole magnet past the curie point which is approximately 450°C., care should be taken to keep the temperature gradient small to avoid fracture of the magnet due to thermal expansion.

The demagnetisation of large magnets sometimes necessitates the use of lower frequency than 50 c.p.s. but as large magnets constitute unusual or special cases for which general instructions cannot easily be given, we would recommend engineers request assistance from our Design Advisory Service if they meet any unexpected difficulty.



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VOLUME 35 NUMBER 11

NOVEMBER 1958

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Transistors

An article with the formidable and forbidding title of "Analogous Transistor Systems Design and Nodal Methods of Construction with Applications to Research Equipment and Prototype Evaluation", by R. F. Treherne, appeared in the July 1958 issue of *Proc. Inst. Radio Engrs, Aust.* In spite of its title it is one of the best and most useful articles on transistors that we have seen. It is easy reading and should be of enormous help to anyone familiar with valves who is making his first tentative approach to the applications of transistors.

While pointing out that some transistor circuits have no valve equivalents, the author stresses the very close similarity between valves and transistors from the point of view of circuit design. He enunciates a set of principles of which the two most important are "Anything that a valve can do a transistor can do too, with a few exceptions" and "For every electronic circuit discipline intended to be executed with valves a similar discipline may be applied to transistor systems, with a few exceptions".

We draw attention to this article not merely because of its utility but because we feel that it is an important milestone in the history of the transistor. The first transistors were of the point-contact type and were truly but little like valves. It was not unreasonable at that time to stress the dissimilarities between the two. When the junction transistor came along it was, perhaps, natural to maintain this attitude but, as its similarities to the valve are greater that its dissimilarities, we feel that it hindered its application.

Early junction transistor circuit theory was founded on the earthed-base connection, a heritage from the point-contact transistor, in spite of the fact that a few simple calculations showed the earthed-emitted connection to be the better for most purposes. As time has gone on we have noticed more and more that the analogy between valve and transistor has become increasingly evident in both theory and practice. In few articles has this been explicitly stated; rather has it been implied in the treatment, almost as if the writers were unconscious of it.

Few have been as forthright as Mr. Treherne and we feel that his article marks a point in history; it brings the outlook on the junction transistor round to the point where, in our opinion, it should have started.

Narrow-Band Magnetostrictive Filters

By A. P. Thiele, B.Sc.*

SUMMARY. *Twenty filters, each with a 3-dB bandwidth of 7 c/s, were arranged with inputs in series and outputs isolated from one another. The design equations are stated, and construction described. The use of cobalt-substituted ferrite reduced temperature effects. Possible applications of both single resonators and arrays are considered.*

This article is about the design and construction of a bank of twenty narrow-band magnetostrictive ferrite filters with the frequency response shown in Fig. 1. The bandwidth of each filter is 7 c/s, the centre frequency 40 kc/s, each filter has a single-tuned-circuit response which overlaps that of its neighbours at the half-power points.

Banks of filters of this nature have applications in spectrum analysis, telemetry, and model control. Another possibility is to use the ringing effect of the high-Q elements as a means of storing information for short periods. The resonators lend themselves to incorporation into printed circuits. Although the present requirement was for a bank of filters, it is evident that single resonators have their uses (for example as alternatives to quartz crystals in high-stability oscillators) and some observations on this type of application are included.

Before describing in detail the construction and properties of the ferrite bank, the various types of filter which were evaluated are discussed and the broader initial target specification is stated.

Initial Specification

The following were the main requirements:

(1) The centre frequency was at our disposal within limits. Any frequency between 2 kc/s and 1 Mc/s would have been acceptable.

(2) Bandwidth to be about 7 c/s.

(3) Frequency response as shown in Fig. 1.

(4) Size to be as small as possible.

(5) Low cost (and therefore relative simplicity).

(6) The temperature coefficient of frequency was to be small, but as long as all the filters changed frequency together this was not too important.

Possible Types of Filter

Magnetostrictive Ferrite Filters

The basic material was cheap and readily available; a single element would give the required response; the circuitry appeared rather simple, and the insertion loss could be made fairly small (6 dB or so).

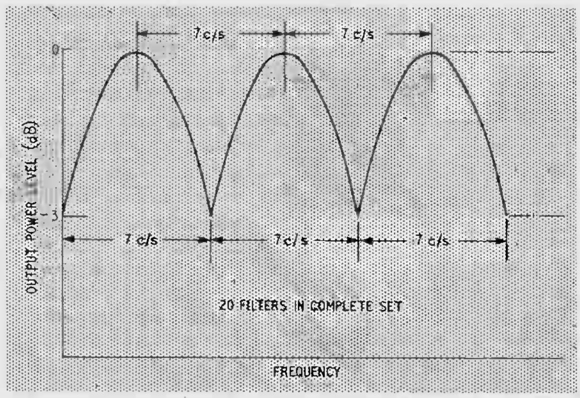


Fig. 1. *Frequency response of part of filter bank*

The completed bank showed promise of being neat and compact without much mechanical complexity.

Vibrating String Filters

The frequency-sensitive element is a short length (about 2 cm) of fine tungsten wire clamped at each end. A strong transverse d.c. magnetic field is produced at the centre of the wire. If now an alternating current of the same frequency as the mechanical resonant frequency of the wire when plucked at its centre is passed through the wire, it will vibrate with considerable amplitude. This vibration alters the impedance of the string and, since the mechanical Q is quite high, we have a suitable frequency-sensitive element.

This technique, although rather old (cf. vibration galvanometers),[1] appeared to be undeveloped and certainly very narrow bandwidths of 0·5 c/s–7 c/s at 2 kc/s could be achieved. The merits of such a device were that it could be made small, was relatively cheap and the associated input and output transformers, necessary because of the low impedance of the string, could be easily arranged on a printed-circuit board.

This device was developed but it is beyond the scope

* Cossor Radar and Electronics Ltd.

of this article to discuss it any further here. It is hoped that a paper on the device, which did prove suitable, will be published.

Quartz Filters

These appear to be an obvious choice. Filters of the required characteristics can be made. At the frequencies concerned the crystals will, however, be rather large and each individual filter will of necessity have quite a few components associated with it; e.g., a trimming capacitor to pull the crystal to the desired frequency, and other inductive and capacitive elements to produce the desired filter characteristics.

The result will almost certainly have superior characteristics (such as rejection level) with the disadvantage of increased complexity and cost. Quartz filters have already been made to similar specifications in which one filter element occupied about the same space as ten ferrite elements.

The only possible advantage for our purpose was the superior temperature characteristic. Our requirement was, however, that the frequency separations should remain constant and this could equally well be achieved with the ferrite resonators available at that time. The cobalt ferrites recently developed are comparable to quartz on this count and, if these are used, the above disadvantage is eliminated.

Recent developments[2], however, indicate an increasing interest in small quartz filter elements and with improved manufacturing and design techniques these may become competitive on a cost and size basis with, say, the ferrite elements, when they will be worth reconsidering.

Nuclear Resonance Filters

If we place a sample of a suitable substance (e.g., water) in a magnetic field and transfer radio-frequency energy to it via a small coil wound around it, then at a certain frequency the sample will absorb power. This absorption can be observed as a transfer of power into a detector coil placed at right angles to both the transmitter coil and the magnetic field. The frequency at which this phenomenon occurs is a function of the substance and the magnetic field.

This transfer of power in water is known as proton resonance. There is a direct relationship between the static d.c. magnetic field and the absorption frequency; viz., $f = \gamma H/2\pi$ where f is the Larmor frequency, γ the gyromagnetic ratio ($2{\cdot}74 \times 10^4$ for protons) and H the magnetic field. Thus for $H = 5000$, f would be about 22 Mc/s. If the magnetic field were perfectly homogeneous the bandwidth would be about 1 c/s. Any inhomogeneity over the sample will affect the bandwidth directly through the above equation; i.e., $df = \gamma/2\pi \, . \, dH$. For a seven-cycle bandwidth this means a field homogeneity of 3 parts in 10^7.

One method of making a bank could utilize water, with input and output coils placed in a graded magnetic field to give the slight frequency variations required over the bank. This, however, may not be compatible with the high homogeneity of magnetic field required for narrow bandwidths.

This type of filter appears to show most promise where narrow bandwidths at high frequencies are involved and thus, for the present application, is perhaps rather too sophisticated and elaborate. For further information about nuclear resonance in general the reader is referred to reference (3).

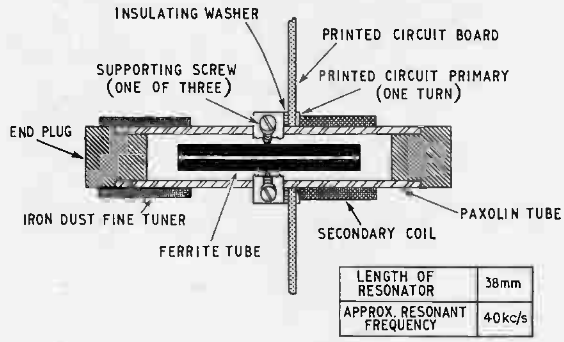


Fig. 3. *Construction of torsional filter element*

LC Filters

Any multi-element filter could certainly not compete on a cost basis for, of necessity, it would need to be made with temperature-compensated components. Even then the required bandwidth could never be practically achieved owing to the finite resistance of the inductors. We can definitely rule out this method.

Magnetostrictive Ferrite Filters

Mode of Vibration and Resonant Frequency

Single filter elements are shown in Figs. 2 and 3. Each consists of a tube of nickel zinc ferrite (Ferroxcube B4) supported at its centre by 3 screws symmetrically placed in a brass ring (split to prevent its being a shorted turn). The primary winding is a single turn round the centre of the tube. The output coil is also placed near the centre.

Mounted in such a fashion this tube can now vibrate mechanically in one of two fundamental modes, either longitudinally or torsionally, depending upon the type of magnetic polarization the tube has been given. Longitudinal vibration will occur with longitudinal polarization (as in Fig. 2) which can be provided by small permanent magnets at each end of the vibrator. The torsional mode may be excited by giving the tube a permanent circumferential magnetic polarization, by

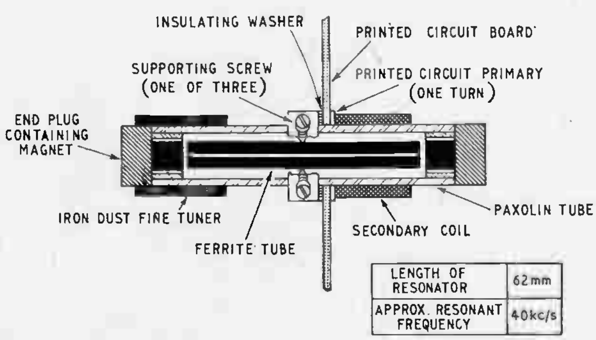


Fig. 2. *Construction of longitudinal filter element*

passing a large current through its centre. This polarization together with the alternating axial field produced by the input coil will produce a spiral alternating stress in the tube, which induces torsional vibrations.

This may be explained in the following manner. H is a static biasing field (Fig. 4) at any point A and $h \sin \omega t$ is the alternating axial field produced by the current in the input coil. The maximum resultant field $H_{max.\ res.}$ will be at a small angle to the direction of axis and have a value $H_{max.\ res.} = \sqrt{(H^2 + h^2)}$. The maximum stress will be along the direction of this magnetic field.

All these spiral stresses will combine and the result will be an alternating couple acting on the ferrite tube causing it to vibrate torsionally.

The resonant frequency f_r is given by the formula

$$f_r = \frac{1}{2l}\sqrt{\frac{E}{\rho}}$$

E = appropriate modulus
(Young's modulus for longitudinal vibrations, rigidity modulus for torsional vibrations)
ρ = density
l = length of resonator.

It is impossible to make an exact calculation of the resonant frequency from the physical characteristics of a resonator because small density variations (due to air pockets) considerably affect the resonant frequency. Variation in density can occur even with samples from the same batch. An extensive statistical investigation was made, the results showing almost complete correlation of frequency with density.

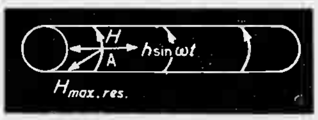


Fig. 4. *Method of inducing torsional vibrations*

It is of interest to note that a longitudinal filter will be almost twice as long as a torsional one operating at the same frequency. Since a short resonator is more easily supported, a torsional resonator is thus generally more stable mechanically than a longitudinal one for the same frequency. Against this, however, is the fact that the torsional resonator requires self-magnetic biasing. Since the B4 material (Fig. 5) is comparatively soft magnetically, long-term instability may result. The lines of flux in the ferrites are, however, closed and we have no evidence of any such instability over periods up to a year.

To obtain the maximum electromechanical coupling to the filter the magnetostrictive constant (λ) must be a maximum. λ varies with the intensity of magnetization and is in fact a maximum at 0·6 saturation intensity. It is very fortunate that this value coincides with the remanent flux-density produced when the resonator is polarized.

A convenient method of explaining the behaviour of a ferrite filter element is to utilize the equivalent circuit.

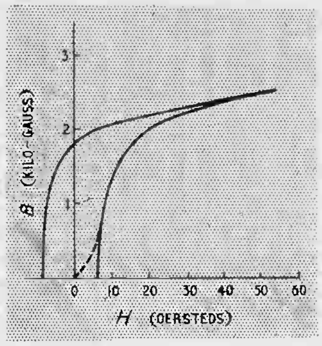


Fig. 5. *B–H curve for Ferroxcube B4*

The equivalent circuit parameters can then be related to the magnetostrictive and magnetomechanical properties of the ferrite, so that optimum values can be determined for various applications. Different ferrites will, in general, be required for transducers as opposed to filter elements.

It has been shown[4] that a magnetostrictive resonator can be represented by the equivalent circuit shown in Fig. 6, where

R_c = clamped resistance of secondary
L_c = clamped inductance of secondary
(or at some frequency far removed from resonance).
$Z_c = R_c + j\omega L_c$ = clamped impedance
R_m = motional resistance
L_m = motional inductance
C_m = motional capacitance
Z = total impedance.

A complete circuit would include the primary and introduce its mutual inductance with the secondary. This complication is, however, unnecessary for an understanding of the device as a filter.

It can be shown that

$$|Z| = \sqrt{\left\{R_c + \frac{1/R_m}{(1/R_m)^2 + (\omega C_m - 1/\omega L_m)^2}\right\}^2 + \omega^2 L_c{}^2 \left\{\frac{(1/R_m)^2 + (\omega C_m - 1/\omega L_m)[\omega C_m - (L_c + L_m)/(\omega L_m L_c)]}{(1/R_m)^2 + (\omega C_m - 1/\omega L_m)^2}\right\}} \quad \ldots \quad (1)$$

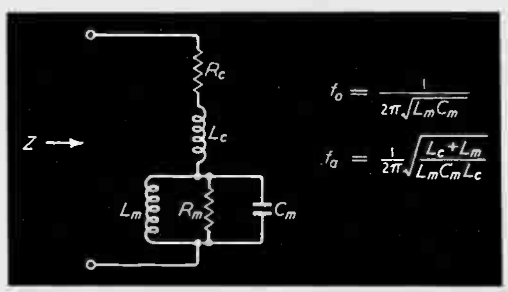
It can also be shown that Z has turning points where

$$\omega C_m = 1/\omega L_m \quad \ldots \quad (2)$$

$$\omega C_m = (L_c + L_m)/\omega L_m L_c \quad \ldots \quad (3)$$

Solving (2) and (3) for ω will yield two resonant frequencies f_r and f_a known as the resonant and anti-resonant frequencies, respectively (Fig. 7).

Fig. 6. *Equivalent circuit of magnetostrictive resonator*



$$f_r = 1/2\pi(L_m C_m)^{\frac{1}{2}}$$

$$f_a = \frac{1}{2\pi}\left\{\frac{L_c + L_m}{C_m L_m L_c}\right\}^{\frac{1}{2}}$$

The impedance at resonance Z_{fr} is found by substituting for ω from (2) into (1) when one obtains

$$|Z_{fr}| = [(R_c + R_m)^2 + \omega^2 L_c^2]^{\frac{1}{2}}$$

Since in general $R_c + R_m > \omega L_c$ we can write

$$|Z_{fr}| = R_c + R_m \qquad \ldots \qquad (4)$$

To obtain $|Z_{fa}|$ the impedance corresponding to the antiresonant frequency we substitute for ω from (3) putting $\omega_a = \omega_r\ (1 + \delta)$ when it can be shown that

$$|Z_{fa}| = \left[\left(R_c + \frac{R_m}{1 + 4\delta^2 Q_m^2}\right)^2 + \omega^2 L_c^2 \left(\frac{1}{1 + 4\delta^2 Q_m^2}\right)^2\right]^{\frac{1}{2}}$$

where Q_m, the mechanical quality factor is defined as

$$Q_m = R_m/\omega_r L_m$$

The ratio $|Z_{fr}|/|Z_c|$ is important for filter operation since it determines the ratio of the resonant to the off-resonant output signal assuming a constant-current source; i.e., the rejection level outside the pass-band of the filter.

$$\frac{|Z_{fr}|}{|Z_c|} = \frac{R_c + R_m}{(R_c^2 + \omega^2 L_c^2)^{\frac{1}{2}}}$$

Since $R_c \ll R_m$ and $R_c \ll \omega L_c$

$$\frac{|Z_{fr}|}{|Z_c|} = \frac{R_m}{\omega L_c} = Q_m \frac{L_m}{L_c} = Q_m k^2 \qquad \ldots \qquad (5)$$

where we define $k^2 = \dfrac{L_m}{L_c} = \dfrac{\text{converted stored energy}}{\text{input stored energy}}$

k is commonly called the electromechanical coupling coefficient and is often used in evaluation of transducer properties. It can be determined from the difference between the resonant and antiresonant frequencies as shown below:

From (3) we have

$$\omega_a = \left[\frac{1}{L_m C_m}\left(1 + \frac{L_m}{L_c}\right)\right]^{\frac{1}{2}}$$

$$= \omega_r\left(1 + \frac{1}{2}\frac{L_m}{L_c}\right)$$

from (2) and since $L_m/L_c \ll 1$,

$$\omega_a = \omega_r(1 + \tfrac{1}{2}k^2)$$

Again, putting

$$\omega_a = \omega_r(1 + \delta)$$

$$k = (2\delta)^{\frac{1}{2}}$$

k is also related to the magnetostriction constant λ permeability μ and Young's modulus E of the resonator by the formula

$$k = (4\pi\lambda^2\mu/E)^{\frac{1}{2}} \qquad \ldots \qquad (6)$$

For our application μ/E is approximately constant, so that k is directly proportional to λ. This means for optimum performance we require λ to be a maximum; this generally occurs as we have discussed before at 0·6 saturation intensity. This means in turn that $k^2 Q_m$ will be optimized for maximum off-resonance rejection.

Values of k and Q_m are quoted[5, 6] for various materials. For longitudinal vibrations B1 is apparently better while for torsional vibrations B4 is to be preferred.

Typical values of these equivalent circuit parameters

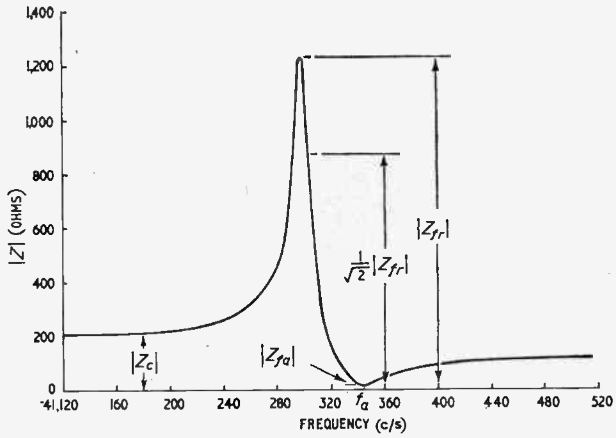


Fig. 7. *Typical frequency response of torsional resonator*

for a torsional resonator at a centre frequency of 40 kc/s using B4 material would be

$$R_c = 1{\cdot}8\ \Omega, \quad L_c = 590\ \text{H}, \quad R_m = 1220\ \Omega,$$
$$L_m = 1{\cdot}3\ \mu\text{H}, \quad C_m = 11{\cdot}6\ \mu\text{F}, \quad Q_m = 3750.$$

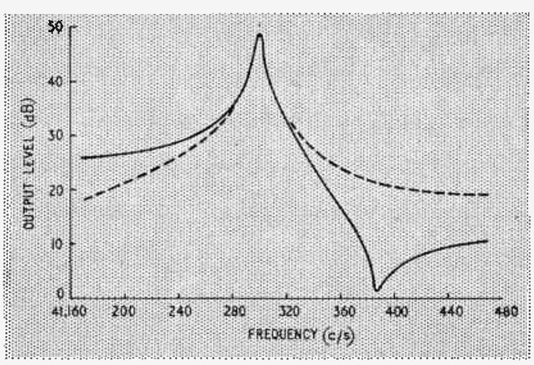
The frequency response of such a circuit is shown in Fig. 8. The dotted curve in Fig. 8 is obtained utilizing a bucking coil to eliminate the antiresonance. This is a conventional transformer whose secondary voltage of suitable amplitude is applied out of phase in series with the output of the filter (see Fig. 22).

Characteristics of a Single-Filter Element

The mount used experimentally was basically the same as that described earlier. The description was, however, rather brief and further details are given here. The brass supporting the ferrite resonator was a spring fit over the synthetic-resin-bonded paper tube which had an outer diameter of ½ in. and a wall thickness of $\frac{1}{16}$ in. The support screws were 8 B.A. with 60°-taper machined points. Imperfections of the points could cause an increase in bandwidth and a decrease in output. The resonator was jig-mounted into the centre of the tube.

In the test jig the primary was a single turn of wire wound around the paxolin tube while the secondary was generally a 200-turn coil of 36 s.w.g. enamelled cotton-

Fig. 8. *Frequency response of resonator with bucking coil (dotted line) and without bucking coil (full line)*



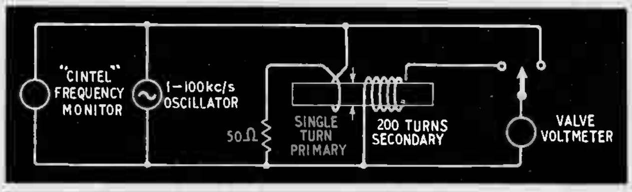


Fig. 9. *Circuit for obtaining resonator characteristics*

covered wire $\frac{3}{8}$-in. long, mounted adjacent to the brass support.

The ferrites were given their d.c. polarization by means of an ignitron magnetizer which could pass up to 200 A through a wire through the centre of the ferrite. This was of course greatly in excess of that required to saturate the ferrite, but the ignitron did give repeatable results.

The experimental apparatus used is shown in Fig. 9. The oscillator was specially designed for the project and has nine approximately equal ranges between 1 and 100 kc/s. With it the frequency can be adjusted to better than one cycle. It is of the Wien bridge type and its short-term stability is better than 1 part in 10^5. Frequency measurement is made with a 20-Mc/s 'Cintel' counter Type 2821 with an accuracy better than $\pm$ 0·1 cycle on this range.

The valve voltmeter can either be switched to monitor the input across the 50-Ω generator-terminating impedance from which the input current can be calculated, or to the output across the 200-turn secondary.

Torsional Resonators

A typical response curve is shown in Fig. 8. Its characteristics have already been discussed. On the same graph is shown the effect of using a bucking coil. The level of the skirts can be moved by tuning the bucking coil. In general, as the level of the skirt is decreased on one side of resonance it will increase on the other side. The construction of the bucking coil is similar to that of a filter element except that the magnetostrictive resonator is replaced by a non-magnetostrictive slug of grade A ferrite. An additional secondary coil is also added. The position of the slug can then be adjusted

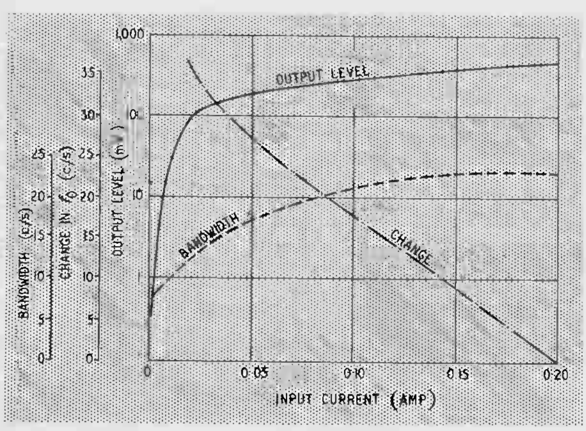


Fig. 10. *Torsional resonator characteristics for wide range of input currents*

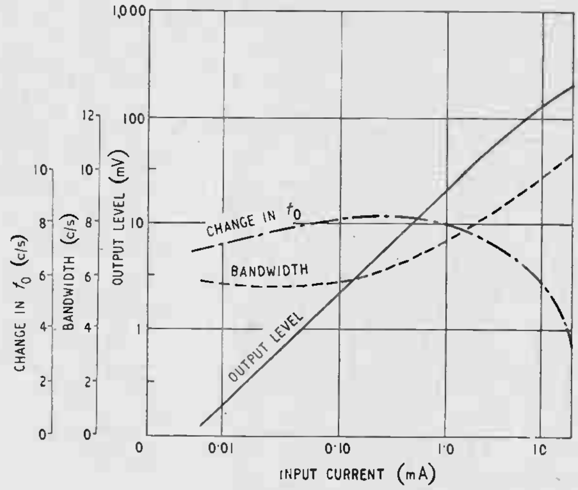


Fig. 11. *Torsional resonator characteristics for small range of input currents*

in the normal manner until the desired output characteristic is obtained.

Fig. 10 shows variation of output level, bandwidth and frequency f_r for a wide range of input levels. It is clear that if we require linear operation with a constant bandwidth we shall have to restrict the operating range. Fig. 11 shows the same results for much lower input levels, indicating that if we restrict our input level between 0·01–2 mA we shall have a reasonably constant bandwidth and linear operation and a resonant frequency sensibly independent of input level.

These changes of frequency, bandwidth and output are caused by an effect known as magnetomechanical hysteresis[7]. This can be expressed as a dependence of Young's modulus on magnetic field. It can be shown that there is a direct relationship between frequency and bandwidth. For fairly large inputs the bandwidth increases and the resonant frequency decreases when the input current is increased, whereas at low levels the reverse is true. These changes are consistent with the theory given in reference (7).

The method utilized for coarse tuning of the resonators was to decrease their length by grinding. Fig. 12 (a) shows, as we expect from the relationship $f_r = (1/2l)\sqrt{E/\rho}$, that the frequency is inversely proportional to the length. Since the frequency increases 26 cycles for every 0·001-in. decrease in length, the method is unsuitable for fine tuning. The frequency can, however, be pulled about 4 c/s using an iron dust tube o.d. = 0·68 in., i.d. = 0·50 in., length = 0·75 in., as shown in Fig. 12 (b).

With reference to Fig. 12 (c) it can be seen that the maximum output is obtained with the secondary coil as near the centre as possible. This is because the maximum mechanical strain is here, and hence the maximum change of susceptibility. Moving the coil is, however, a useful technique for equalizing the outputs of individual filters in a bank.

The natural bandwidths of individual filters will vary by about $\pm$ 1 c/s unless special effort is made to equalize them. The bandwidth can, of course, only be increased and this is done by placing suitable resistors across their output coils. Fig. 13 shows this. Fig. 14 shows the effect on bandwidth and output of two values of damping resistor.

Quite spectacular increases in bandwidth can be achieved by this means with, of course, a corresponding decrease in output. It is interesting to note that the saturation level remains unaltered.

If larger bandwidths are required a better way would be to increase the centre frequency since Q_m is constant for any given material, whatever the size of resonator.

Longitudinal Resonators

The characteristics of this type are very similar to the torsional variety. Fig. 15 shows the output and bandwidth characteristics. Saturation is observed to set in at a lower level for these examples. This is presumably due to the fact that we were using samples of smaller cross-sectional area and hence the total saturation flux density output would be proportionally smaller.

In this case we had the opportunity to vary the biasing flux. A long solenoid was wound on the resonator support tube (Fig. 16). Varying the current through this coil varied the biasing field and hence the filter characteristics.

The results of these experiments are shown in Fig. 17. All the properties have turning points at $H = 35$ gauss. This corresponds to 0·6 saturation magnetization. This is the value of field at which one would also expect the maximum magnetostrictive constant. Since all the properties of the filter have turning points here it is a very satisfactory value since their variation with the alternating signal field strength will be a minimum here.

In the practical filter utilizing a small permanent magnet, the optimum biasing field could not be achieved. Fig. 18 shows the filter characteristics with the permanent magnet biasing field. A stable operating point can, however, be achieved.

Fine tuning is accomplished in a similar manner to the torsional filter, using the iron-dust slugs. Its effect depends on the biasing field of the magnet, being greater for larger biasing fields (Fig. 19). The effect of these slugs is through the dependence of Young's modulus on magnetic flux. Their presence will affect the leakage flux just outside the specimen and hence the flux within the specimen. This in turn will directly

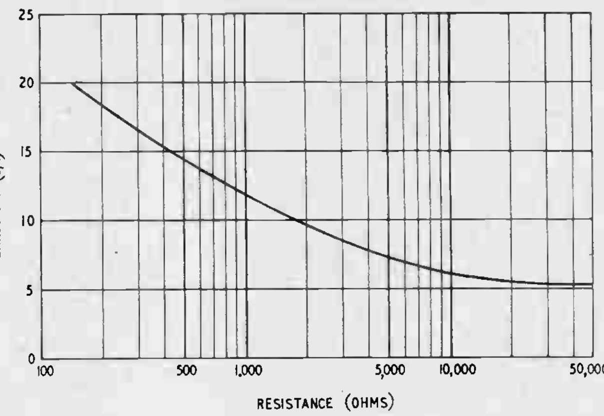
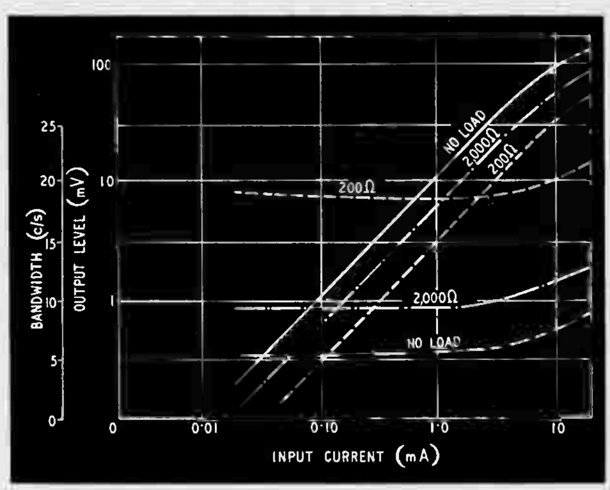


Fig. 13. *Effect of load resistance on bandwidth*

Fig. 14. *Effect of loading on output and bandwidth for torsional resonator*



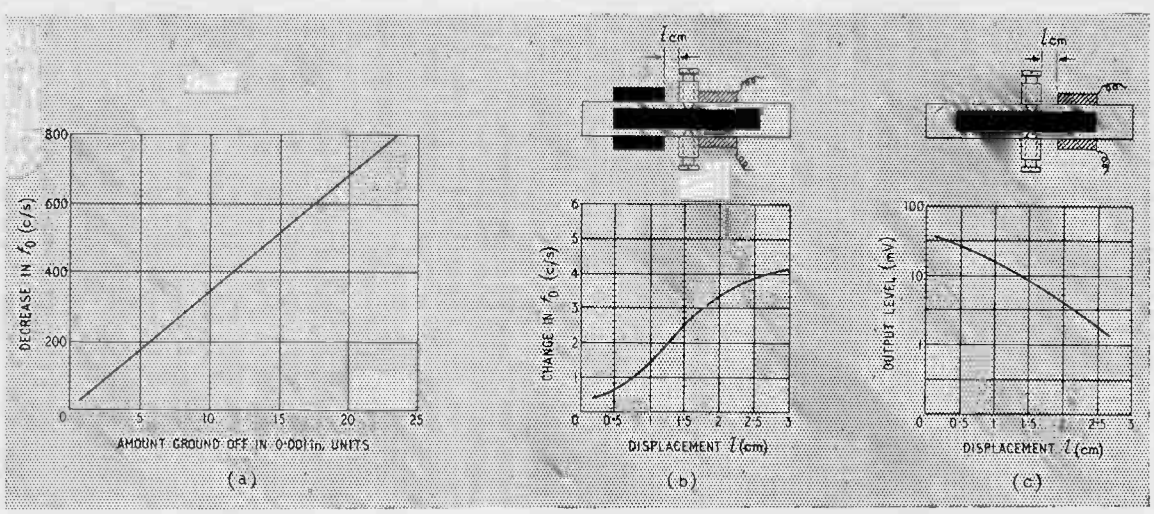


Fig. 12. *Effect of varying resonator length* (*a*), *position of tuning slug* (*b*) *and position of output coil* (*c*)

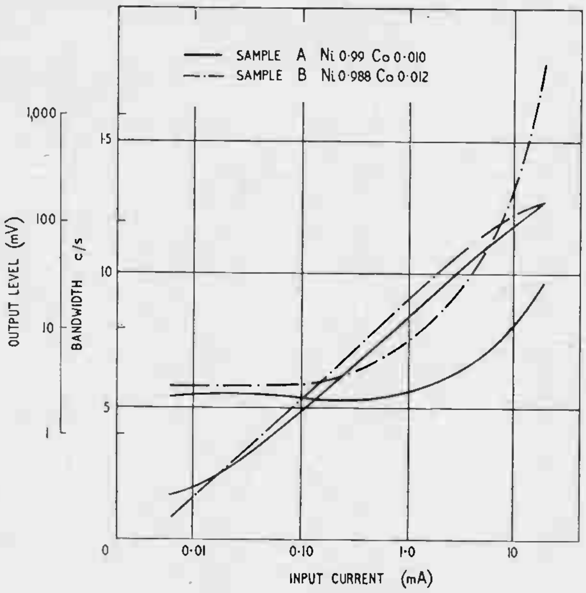


Fig. 15. *Longitudinal resonator characteristics for two compositions of ferrite*

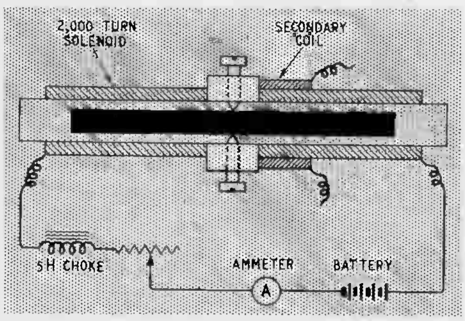


Fig. 16. *Experimental circuit for longitudinal resonator*

affect the resonant frequency, which is proportional to the square root of Young's modulus.

The effect of temperature on the resonant frequency is shown in Fig. 20 (a) for various types of ferrite. The B4 material has quite a high temperature coefficient (2·8 cycles/°C at 40 kc/s) but a cobalt-substituted material developed in Holland[8, 13] is an order better than this and wherever possible it is preferable to use this material. The published results for this material are shown for comparison in Fig. 20 (b). The cobalt substitution can be controlled to give a turning point at any particular temperature and then the temperature change over any given temperature range can be minimized.

Construction of Bank of 20 Filters (Torsional)

The simplest way of mounting the filter support tubes appeared to be through holes in an insulated board. Further, since there would be a large number of connections to be made it seemed obvious that this board should be a printed-circuit one.

The single-turn primaries were printed in series on one side, the connections from the output coils being made on the reverse side. Since 21 elements were to be disposed of, a convenient arrangement was three rows of seven (20 filters, 1 bucking coil). The damping resistors are also mounted on this board.

Particular care was needed in laying out the primaries as any unbalance caused unequal coupling to the filters. For example, connection must be made to the point A via the route BA making in effect a non-inductive lead, Fig. 21.

It was expected that with the very high mechanical Q associated with the resonators that frequency-adjacent elements would react on each other. To reduce this effect to a minimum, the elements were arranged so that no frequency-adjacent elements were physically next to each other, in either a horizontal or vertical direction. This layout is shown in Fig. 21, where adjacent elements have the maximum frequency separation possible (minimum of 28 cycles away).

The bucking coil is also mounted on the board, its

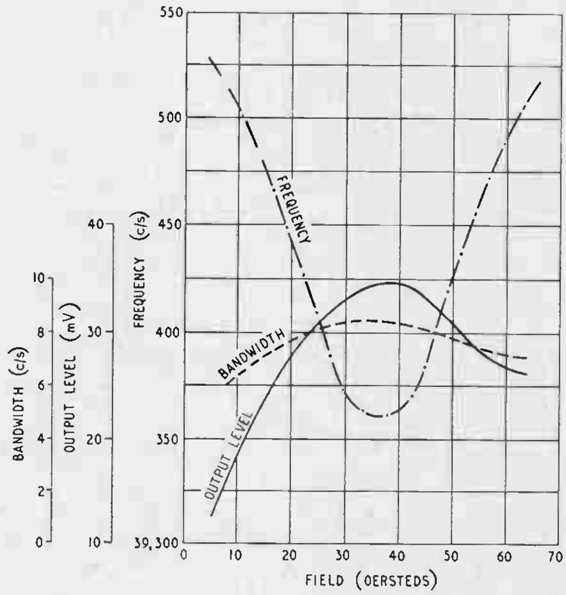


Fig. 17. *Effect of polarizing flux on longitudinal resonator*

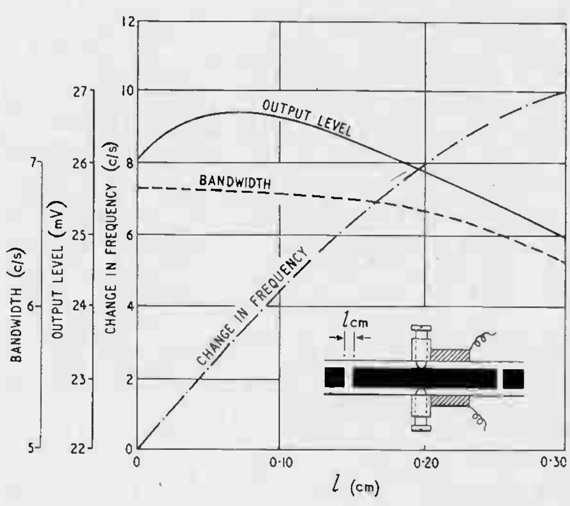


Fig. 18. *Effect of magnet position on longitudinal resonator*

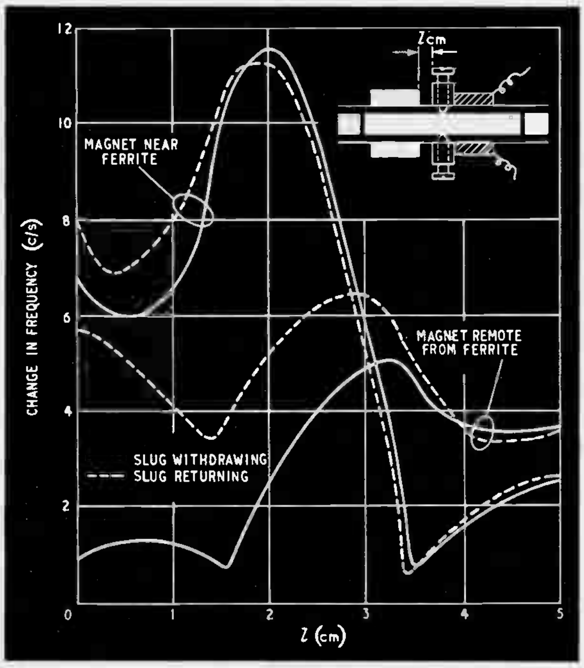
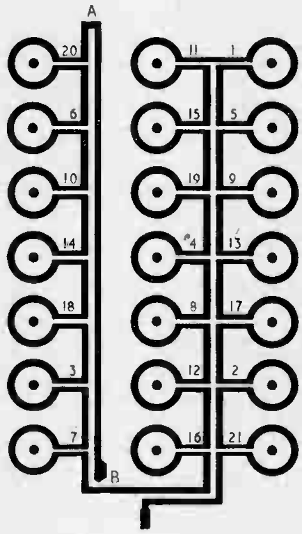


Fig. 19. *Effect of slug position on resonant frequency of longitudinal element for two positions of magnet*



FILTER No.	FREQUENCY AT 20°C
1	41700 c/s
2	41707
3	41714
4	41721
5	41728
6	41735
7	41742
8	41749
9	41756
10	41763
11	41770
12	41777
13	41784
14	41791
15	41798
16	41805
17	41812
18	41819
19	41826
20	41833
21	BUCKING COIL

Fig. 21. *Layout of printed-circuit primaries showing positions of filter elements*

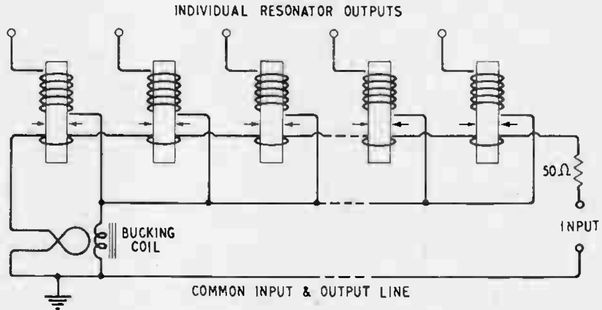


Fig. 22. *Circuit of filter showing bucking coil*

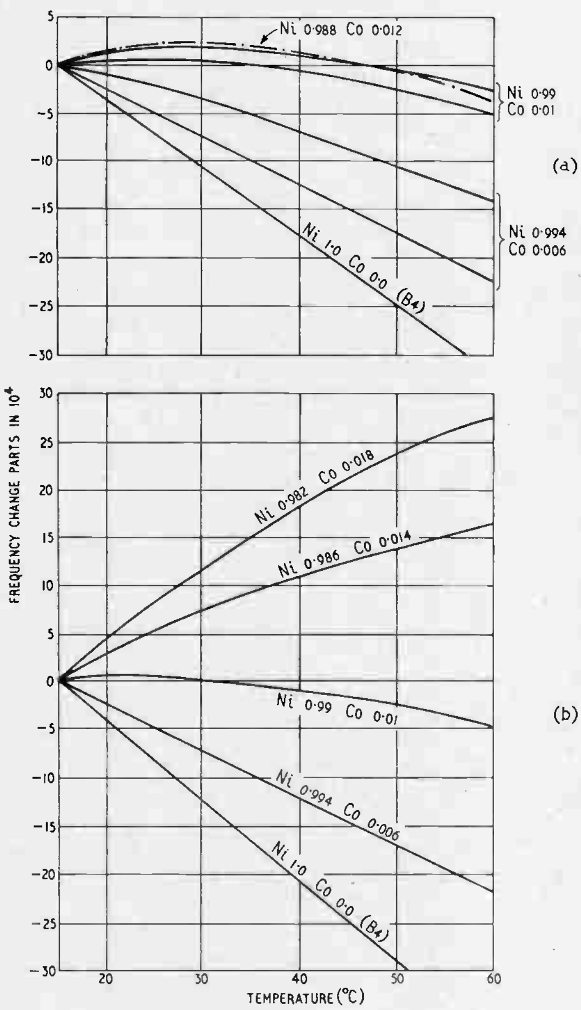


Fig. 20. *Temperature characteristics of cobalt substituted ferrites (a) experimental results (b) from Ref.* 13

output being joined to earth and the common secondary connection as in Fig. 22. The output of this coil is adjusted for minimum skirts on either side of the pass-band of the bank.

Dimensions of the mounting board are 4 in. by 7½ in. The bank is finally enclosed in a box 2½ in. by 4¾ in. by 8½ in. The resonator mount used was very similar to that shown in Fig. 3 and has been fully described earlier.

It was expected that the main problem in making the bank would be the selection and coarse tuning of the ferrite resonators.

A preliminary statistical investigation of a small group of samples indicated that quite large frequency spreads could be expected [Fig. 23 (a)]. We knew that the distribution could be improved by grinding small amounts off the length of the resonators. This is shown in Fig. 23 (b).

On the basis of these measurements 500 samples were thought to be a generous number of samples from which two identical banks could be made. Fortunately, however, the frequency distribution of the 500 samples was as shown in Fig. 23 (c) and very little bulk grinding was needed before selection of individual resonators could begin.

Most of the elements could then be immediately

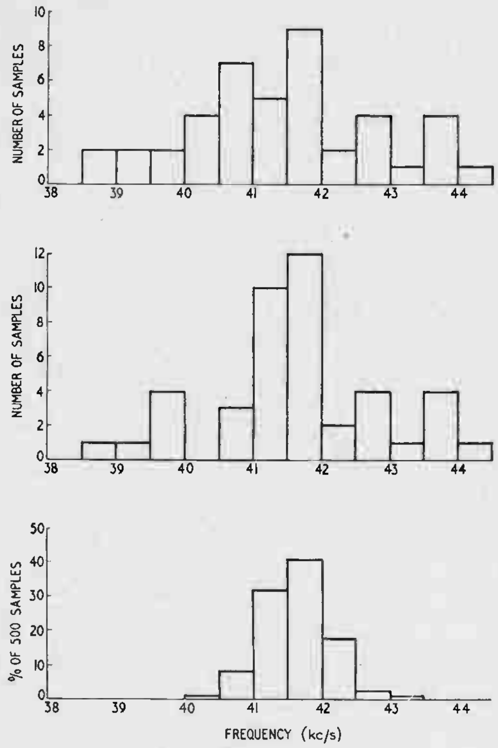


Fig. 23. *Histograms showing frequency distributions of ferrite samples: (a) for 43 raw samples; (b) for 43 samples after grinding and (c) for 500 samples*

selected and finally tuned with the iron dust slugs, individual grinding being required in only a few cases to fill in the inevitable gaps. When this grinding was done, however, it did cause some difficulty since the grinding produced heat which affected the frequency of the elements. This meant that sufficient time had to elapse to allow them to stabilize before remeasuring them.

The target bandwidth for each filter was 7 c/s. Since, in general, the bandwidths were less than this, it was necessary to put resistors across the output coils. In addition, the outputs of the elements had to be equalized.

TABLE 1

Characteristics of Bank of Torsional Filters

Number of filters in bank	20
Centre frequency	41,770 c/s
Bandwidth	7 c/s ± 0·25 c/s
Insertion loss	6 dB
Input, current fed	2 mA max.
Output	23 mV max.
Relative outputs matched to better than 0·1 dB.	
Temperature coefficients of frequency, — 2·8 cycles/°C at 41 kc/s.	
Long-term electrical stability: over a period of one year no detectable change of resonant frequency, bandwidth or output.	
Mechanical stability	4,000 bumps (K.114 clause 5)
	Resonators—Horizontal 2 c/s
	Vertical 2 c/s
	45° 10 c/s
	(There is no specification for this test and no attempts have been made to improve performance.)
Physical size	Overall $2\frac{1}{2}$ in. by $4\frac{3}{4}$ in. by $8\frac{1}{2}$ in.
Weight	2 lb.

This was achieved by moving the output coil away from the centre.

Unfortunately these two adjustments were not entirely orthogonal, the addition of the resistor decreasing the output, and moving the secondary coil decreasing its magnetic coupling and hence reducing the bandwidth. No real difficulty was experienced in practice in making these adjustments, however.

Performance of Bank

The performance of the individual filter elements having already been discussed, it remains to state the overall characteristics of the bank and interaction between physically adjacent elements.

The performance is shown in Table 1; most of the points have already been discussed. The bump test is that specified in K.114 clause 5; i.e., 4000 bumps.

The test was performed for 3 orientations of the resonators, vertical, horizontal and 45° to the vertical, all but the 45° test made very little change and suitable shock-mounting should remedy this.

There is interaction between elements similar to that shown in Fig. 24. The subsidiary peak is due to magnetic coupling with a filter 14 c/s away. The position of the two filters here was immediately adjacent. We are thus considering rather an unfair case but it does serve to show the form of the interference. In actual practice the physically-adjacent element would be 28 cycles away and the height of this peak above the main curve about 1 dB. The whole effect being about 15 dB below the main peak.

This effect can be eliminated by the use of magnetic screening. In the present application this was unnecessary.

Fig. 25 is a photograph of the completed bank.

Applications

These filters were developed mainly for use in banks where fairly large numbers of filters are required. The

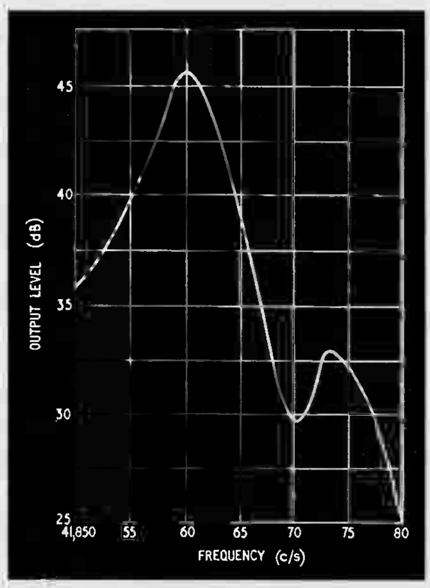
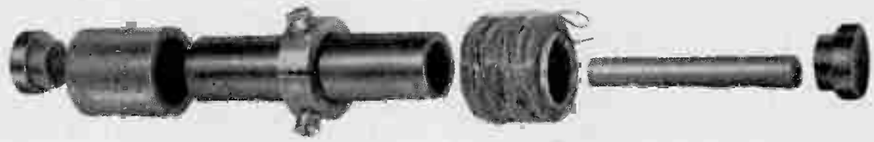
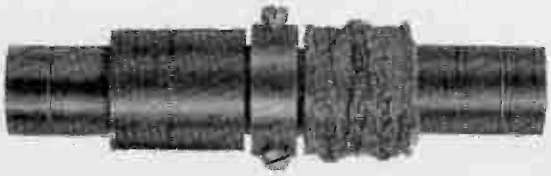
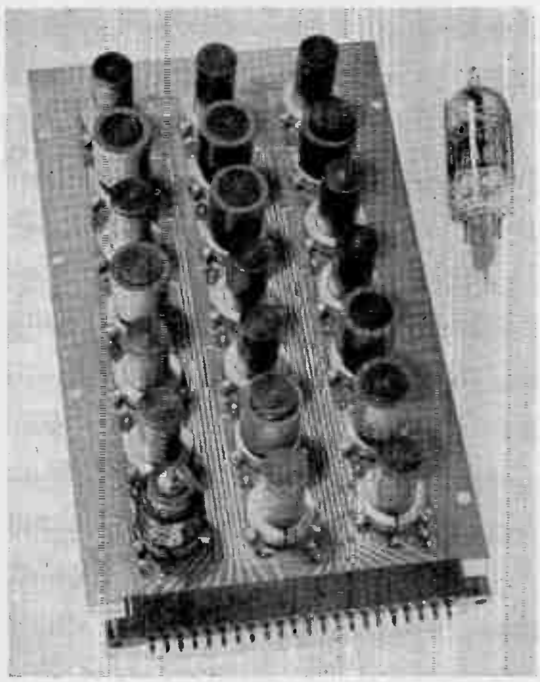


Fig. 24. *Effect of interaction between torsional filters*

Fig. 25. *Assembled filter unit and its component parts.* (*Below*) *Filter bank with miniature valve for size comparison*







initial application required that they should be fairly narrow-band and have a single-tuned-circuit response, and this was the type developed. A possible further development would have been bandpass filters with a similar bandwidth but in the event this was not necessary.

In view of this, the discussion on applications will be restricted to those with requirements similar to that described above. For completeness it might be mentioned that the bandwidths of filters using ferrite elements can be made as great as 2 kc/s at a centre frequency 100 kc/s[9], (single elements of the type discussed here would have a bandwidth of 15 c/s at this frequency), while others can be used as i.f. filters in radio receivers with a centre frequency of 465 kc/s[10].

The applications to be considered here thus fall into two rather simple groups. The first and perhaps the most important is where large banks of filters are required and the second is where the resonators form the frequency-controlling elements in oscillators.

We shall discuss the second type of application first. When considered as single elements the resonators come up for direct comparison against quartz crystals.

As developed they can be used over the range 20 kc/s–200 kc/s. Using the cobalt-substituted ferrites the frequency change over the temperature range 0–50°C can be made less than 0·02%. This compares well with quartz where a normal crystal would have almost the same frequency change. The quartz can be specially cut, when stabilities twice this can be achieved.

It is estimated that the cost of a single ferrite element should certainly be less than half the cost of a comparable quartz element. In addition, if the ferrite resonator is used in a stable oscillator circuit[11], the input and output windings can be arranged to form part of the oscillatory circuit, thus reducing the number of components required. The operating levels would have to be arranged to avoid magnetomechanical hysteresis but this should be possible in most cases.

The uses of banks of a narrow-band filters are many provided they are cheap and compact. Most of their applications stem from their use as spectrum analysers or comb filters[12]. Spectrum analysers could be made, for example, to cover any or all of the band 20 kc/s–200 kc/s (with intrinsic bandwidth 3 c/s–30 c/s respectively). The input to the banks can be fairly easily arranged. If the primaries are series fed, the input current will be the same for each filter, and under these conditions the outputs can be equalized to better than 0·1 dB.

Practical applications of these spectrum-analyser type banks would be telemetry, model control, Doppler radar, noise reduction in radar systems, and perhaps as short-term stores in electronic computers.

Acknowledgements

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REFERENCES

1 E. W. Golding, "Electrical Measurements and Measuring Instruments", 4th edition, p. 250. Pitman.

2 D. I. Kosowsky, "High Frequency Crystal Filter Design Techniques and Applications", *Proc. Inst. Radio Engrs*, Vol. 46, pp. 419–429.

3 'Quantum', "Proton Resonance and the Measurement of Magnetic Fields", *Electronic and Radio Engineer*, Vol. 34, June 1957, pp. 215–218.

4 Butterworth and Smith, "The Equivalent Circuit of the Magnetostriction Oscillator", *Proc. Phys. Soc.*, 1931, Vol. 43, pp. 166–185.

5 P. Popper, "The Magnetostriction of Ferrites". "Soft Magnetic Materials for Telecommunications". Pergamon Press, 1953, pp. 322–332.

6 C. M. van der Burgt, "Dynamical Physical Parameters of the Magnetostrictive Excitation of Extensional and Torsional Vibrations in Ferrites", *Philips Res. Rep.*, 1953, No. 8, pp. 91–132.

7 R. M. Bozorth, "Ferromagnetism", p. 707. D. Van Nostrand.

8 C. M. van der Burgt, "Ferroxcube Materials for Piezomagnetic Vibrators", *Philips Tech. Rev.*, 1956–57, No. 18, pp. 285–316.

9 R. W. George, "Electromechanical Filters for 100 kc Carrier and Sideband Selection", *Proc. Inst. Radio Engrs*, 1956, Vol. 44, pp. 14–18.

10 M. L. Doebz and J. C. Hathaway, "How to Use Mechanical I.F. Filters", *Electronics*, March 1953, pp. 138–142.

11 E. A. Roberts, "Magnetostriction Frequency Control Units and Oscillator Circuits", *Trans. Inst. Radio Engrs. on Ultrasonic Engineering*, PGUE–4, August 1956, pp. 23–41.

12 S. F. George and A. S. Zamanakas, "Comb Filters for Pulsed Radar Use", *Proc. Inst. Radio Engrs*, 1954, pp 1159–1165.

13 C. M. van der Burgt, "Ferrites for Magnetic and Piezomagnetic Filter Elements with Temperature-Independant Permeability and Elasticity", *Proc. Instn elect. Engrs*, 1957, Vol. 104, Part B, Supplement No. 7.

Wide-Range RC Oscillator

1,000:1 CONTINUOUS FREQUENCY COVERAGE

By C. G. Mayo, M.A., B.Sc., M.I.E.E.* and J. W. Head, M.A.*

SUMMARY. *A novel type of tone-source or oscillator is described; a frequency range of more than* 1000 : 1 *can be obtained in a single sweep. Elements are used which have continuously distributed series resistance and shunt capacitance, and behave like 'Kelvin cables'. These elements are easily made from standard high-stability resistors.*

The tone-source has a performance comparable with that of a beat-frequency tone-source, and also has the simplicity, cheapness, high frequency-stability and uniformity of scale associated with a resistance-capacitance oscillator.

The essentials of the conventional *RC* oscillator circuit are indicated in Fig. 1. We shall suppose for simplicity that the input voltage V_1 is supplied at zero impedance and is given. The voltage at the output (assumed unloaded) is V_2. Well-known methods are available for obtaining a practical equivalent of these assumed conditions. We then find that at a steady input frequency $\omega/2\pi$

$$\frac{V_2}{V_1} = \frac{Z_2}{Z_1 + Z_2} \quad \ldots \quad (1)$$

where Z_1 is the total series impedance and Z_2 is the total shunt impedance, so that

$$Z_1 = R_1 + 1/(j\omega C_1);\; 1/Z_2 = (1/R_2) + j\omega C_2 \quad (2)$$

Substituting from Equ. (2) into Equ. (1) and simplifying, we have

$$\frac{V_1}{V_2} = 1 + \frac{Z_1}{Z_2} = \left(1 + \frac{R_1}{R_2} + \frac{C_2}{C_1}\right) + j\left(\omega R_1 C_2 - \frac{1}{\omega R_2 C_1}\right) \quad \ldots \quad (3)$$

Assuming that there is no phase shift in the amplifier connecting V_2 back to V_1 with suitable gain, the oscillating frequency is that for which V_1/V_2 in Equ. (3) is real, so that we obtain the well-known result

$$\omega^2 = 1/(R_1 R_2 C_1 C_2) \quad \ldots \quad (4)$$

As it is much easier to obtain smooth, continuous control of C_1 and C_2 (with standard variable capacitors) than of R_1 and R_2, it is usually convenient to keep R_1 and R_2 constant and make C_1 and C_2 vary together to control the frequency. Now a variable capacitance can be conveniently made to vary by say 25 : 1, so that with the arrangement of Fig. 1, the maximum frequency range obtainable for a particular pair of values of R_1 and R_2 is also about 25 : 1.

There are great advantages in having a much wider frequency range obtained with a single sweep. The difficulties encountered are discussed by Kovalevski and Oliver,* who have obtained an ingenious solution at the cost of considerable complexity. The authors have found, however, that a satisfactory and simple solution can be obtained in a completely different manner.

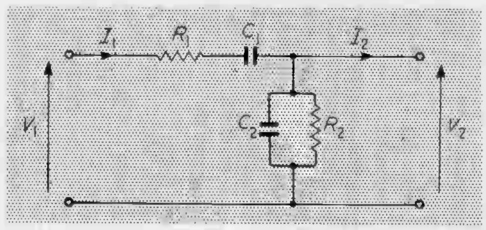


Fig. 1. *Essentials of a conventional RC oscillator circuit*

The basic principle underlying the new type of tone source to be described below† is to replace the resistances R_1 and R_2‡ in Fig. 1 by appropriate 'Kelvin cable' elements (having continuously-distributed series resistance and shunt capacitance) so that the maximum frequency range can be greatly increased. We must therefore next consider the basic properties of such elements. It is probable that there are also considerable advantages to be gained from replacing resistance elements in feedback amplifiers by Kelvin cables in certain circumstances. This possibility is being investigated but is at an early stage at present.

The Kelvin Cable

The Kelvin cable has uniformly-distributed series resistance and shunt capacitance. If the cable is of length l, resistance r_0 per unit length and capacitance

* *Research Department, B.B.C. Engineering Division.*

* Brief note "Very-Wide-Range Audio Oscillator," *Electronic & Radio Engineer*, July, 1957, Vol. 34, No. 7, p. 272; fuller details N. Kovalevski and B. M. Oliver, "An RC Oscillator that Covers the 20 cps–20 kc Range in a Single Sweep," *Hewlett Packard Journal*, January, 1957.
† Provisional Patent Application No. 4194/58.
‡ Alternatively, the capacitors C_1 and C_2 could be replaced by Kelvin cables.

C_0 per unit length, then at frequency $\omega/2\pi$ and at distance x along the cable, we have, in the notation of Fig. 2,

$$dV/dx = -r_0 I;\ dI/dx = -j\omega C_0 V \quad \ldots \quad (5)$$

with the added conditions that when $x = 0$ the voltage is the input voltage V_1, and when $x = l$, the ratio of the voltage V_l to the current I_l is the terminating impedance Z_T. From Equ. (5) it follows immediately that

$$V = V_1 \cosh kx + X \sinh kx \quad \ldots \quad (6)$$

where

$$k = (j\omega C_0 r_0)^{1/2} = (\tfrac{1}{2}\omega C_0 r_0)^{1/2}(1 + j);$$
$$Z_0^2 = r_0/(j\omega C_0) \quad \ldots \quad (7)$$

and the value of X is obtained from the condition that $V_l/I_l = Z_T$; it is

$$X = -\frac{V_1 (\cosh kl + \{Z_T/Z_0\} \sinh kl)}{\{Z_T/Z_0\} \cosh kl + \sinh kl} \quad \ldots \quad (8)$$

and we thus obtain

$$\left.\begin{aligned} V &= V_1\{Z_T \cosh k(l-x) + Z_0 \sinh k(l-x)\}/D \\ I &= V_1\{Z_0 \cosh k(l-x) + Z_T \sinh k(l-x)\}/(Z_0 D) \end{aligned}\right\} (9)$$

where

$$D = Z_T \cosh kl + Z_0 \sinh kl \quad \ldots \quad (10)$$

By putting $x = 0$ in Equs. (9), we obtain

$$\frac{V_1}{I_1} = Z_0 \frac{Z_T \cosh kl + Z_0 \sinh kl}{Z_0 \cosh kl + Z_T \sinh kl}$$
$$= Z_0 \frac{(Z_T/Z_0) \coth kl + 1}{\coth kl + (Z_T/Z_0)} \quad \ldots \quad (11)$$

If $\omega C_0 r_0 l^2$ is greater than about 4, coth kl in Equ. (11) will be a complex number very little different from unity, and Equ. (11) reduces to $V_1 = Z_0 I_1$, whatever the terminating impedance Z_T may be. The same is also true at any frequency or frequencies for which $Z_T = Z_0$. The impedance in these cases is therefore Z_0, which from Equ. (7) is peculiar in having a constant phase angle of $-\pi/4$ (half way between that of a capacitance and that of a pure resistance). Equ. (7) also shows that the magnitude of Z_0 is inversely proportional to the square root of the frequency.

At first sight, it appears from Equ. (11) that the termination is going to be of considerable importance, especially at very low frequencies, and we indicate below how suitable terminations may be designed if we are obliged the make the best possible use of a given cable for which $\omega C_0 r_0 l^2$ is appreciably less than 4 at the lowest frequency required. In practice, however, elements of the kind under consideration can be cheaply and easily made and, if necessary, the effective length of the cable can be doubled by connecting two such elements in cascade. Doubling the length of the cable divides by 4 the frequency at which $\omega C_0 r_0 l^2$ has any particular value (say 4), assuming that C_0 and r_0 are unchanged, and may therefore be easier than seeking any optimum termination.

As explained below, the cable element can conveniently be made from a standard high-stability resistor. It will only be necessary to pay attention to the termination at frequencies for which $\omega C_0 r_0 l^2$ is appreciably less than 4, if any. The simplest termination is a short-circuit, in which case the cable behaves as a pure resistance at very low frequencies. The effect of this is to contract the frequency scale. Alternatively, if the termination is an open-circuit, the cable behaves largely as a capacitance at very low frequencies, and the frequency scale is correspondingly widened.

We shall assume here that the output voltage obtained from the tone-source is applied to the grid of a valve, and therefore that it is convenient that direct current should be able to pass through the oscillator network. Alternative possibilities for which this restriction is not necessarily met will be mentioned from time to time in passing, but only those for which there is a d.c. path will be discussed in any detail. A termination as in Fig. 3 provides a d.c. path, and the impedance of this termination can be made equal to Z_0 at a single frequency $\omega_0/2\pi$ which is at our choice, as well as at frequencies for which $\omega C_0 r_0 l^2 > 4$. If ω_0 is so chosen that $\omega_0 C_0 r_0 l^2 = 2$, say, we shall find that the impedance in Equ. (11) does not differ seriously from Z_0 when $\omega C_0 r_0 l^2$ is between, say, 1 and 4, so that the cable becomes nearly as effective as if its length were doubled. If $\omega_0 C_0 r_0 l^2$ is made equal to 3, the impedance in Equ. (11) would remain closer to Z_0 than when $\omega_0 C_0 r_0 l^2 = 2$, but this closeness would be maintained over a shorter range, say, when $\omega C_0 r_0 l^2$ was between 2·3 and 4. An exact analysis of this is not required; it is sufficient to say that by proper choice of ω_0, we can substantially reduce the frequency above which the cable has effective impedance Z_0. Another possible way of achieving the same general result more effectively is to use the alternative termination of Fig. 4, which also permits the passage of direct current. If the impedance of the termination in Fig. 4 is to have phase angle $-\pi/4$ (without which condition it cannot equal Z_0) it can be shown that

$$\mu(1 + \omega^2 C_T^2 R_T^2) + 1 = \omega C_T R_T \quad \ldots \quad (12)$$

and if the impedance is to have the correct magnitude, we must also have

$$\frac{\omega C_T R^2}{1 + \omega^2 C_T^2 R_T^2} = \left(\frac{r_0}{2\omega C_0}\right)^{1/2} \quad \ldots \quad (13)$$

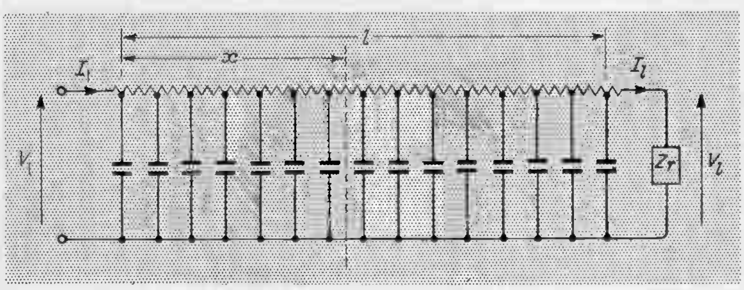


Fig. 2. *Kelvin cable with arbitrary terminating impedance*

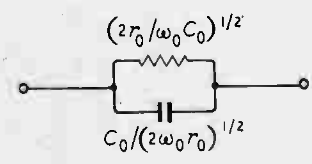


Fig. 3. *Termination matching a Kelvin cable at a single frequency* $\omega_0/2\pi$

Now given μ, and the product $C_T R_T$, Equ. (12) has two roots ω_1 and ω_2 in ω which are in general distinct; substituting into Equ. (13), we shall obtain a different value of R_T associated with ω_1 from that associated with ω_2. We shall thus only have one frequency at which the impedance of the termination is Z_0, and there will be no advantage over the simpler termination of Fig. 3. If, however, μ is so chosen that the quadratic Equ. (12) has equal roots in ω, we do appear to be able to obtain matching of a higher order at the frequency $\omega/2\pi$ given by Equ. (12). The condition for equal roots turns out to be $\mu = \frac{1}{2}(\sqrt{2} - 1)$ or 0·207107, and if this higher-order matching is to be at frequency $\omega_0/2\pi$,

$$R_T = 2\{r_0/\omega_0 C_0\}^{1/2}; C_T = \tfrac{1}{2}(\sqrt{2} + 1)\{C_0/\omega_0 r_0\}^{1/2} \qquad \text{.. .. .. (14)}$$

Again, we are at liberty to choose ω_0 in the light of practical considerations as to whether it is more important to keep the terminal impedance very close to Z_0 over a relatively short range below the frequency at which the terminating impedance ceases to matter, or whether it is better to have the terminal impedance only fairly close to Z_0 over a relatively long range. We shall not consider this question of termination further; we shall merely assume that the effective impedance of the Kelvin cable element is Z_0 at all frequencies of interest.

Effect of Replacing the Resistances of Fig. 1 by Kelvin Cables

If in the circuit of Fig. 1, the resistances R_1 and R_2 are both replaced by equal* Kelvin cables whose impedances will be taken as Z_0 given by Equ. (7), and if further $C_2 = C_1$, Equ. (3) becomes

$$\begin{aligned}\frac{V_1}{V_2} &= 1 + \left(Z_0 + \frac{1}{j\omega C_1}\right)\left(\frac{1}{Z_0} + j\omega C_1\right) \\ &= \left\{3 + C_1\left(\frac{\omega r_0}{2C_0}\right)^{1/2} + \frac{1}{C_1}\left(\frac{C_0}{2\omega r_0}\right)^{1/2}\right\} \\ &\quad + j\left\{C_1\left(\frac{\omega r_0}{2C_0}\right)^{1/2} - \frac{1}{C_1}\left(\frac{C_0}{2\omega r_0}\right)^{1/2}\right\} \qquad \text{.. (15)}\end{aligned}$$

since, from Equ. (7)

$$Z_0 = \left(\frac{r_0}{j\omega C_0}\right)^{1/2} = \left(\frac{r_0}{\omega C_0}\right)^{1/2} e^{-j\pi/4} = \left(\frac{r_0}{2\omega C_0}\right)^{1/2}\left\{1 - j\right\} \qquad \text{.. .. .. (16)}$$

The condition for resonance is that the imaginary part of V_1/V_2 in Equ. (15) shall be absent, namely

$$\omega = C_0/(r_0 C_1^2) \qquad \text{.. .. .. (17)}$$

Since in Equ. (17), ω varies inversely as C_1^2, we can now, by varying C_1 in the ratio 25 : 1 as before, obtain a 625 : 1 variation in ω. A minor modification, explained below, enables the range to be increased still further. At the oscillating frequency, from Equs. (15) and (17),

$$V_1/V_2 = 3 + \sqrt{2} \qquad \text{.. .. .. .. (18)}$$

so that the loss ratio of the network is independent of the frequency of oscillation. This is an important practical advantage.

* If the Kelvin cables are unequal, so that the cable replacing R_1 has impedance αZ_0 (where α is real and positive) while the cable replacing R_2 has impedance Z_0, Equ. (17) is replaced by

$$\omega = C_0/(\alpha r_0 C_1^2) \qquad \text{.. .. .. (17a)}$$

and Equ. (18) is replaced by

$$V_1/V_2 = 2 + \alpha + \sqrt{(2\alpha)} \qquad \text{.. .. .. (18a)}$$

so that the general nature of the results described here on the assumption that $\alpha = 1$ is not greatly affected.

Construction of the Cable Elements

A Kelvin cable can be made from a high-stability resistor. This resistor will generally be covered with paint or lacquer over the actual cracked-carbon helical element. Colloidal graphite (Aquadag) can then be used to make an electrode over the element. The lacquer as dielectric provides the required distributed capacitance between the resistor and the Aquadag. The Aquadag electrode may occupy one or more areas bounded by generators of the cylindrical resistor element; the width of these areas is determined by the capacitance required.

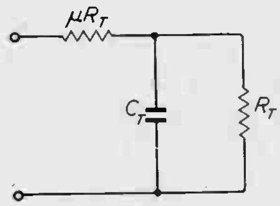


Fig. 4. *Termination having impedance phase angle $-\pi/4$ at two frequencies. These frequencies coincide if $\mu = (\sqrt{2} - 1)/2$*

Alternatively, the original lacquer can be removed and replaced by a suitable enamel whose thickness can be regulated by techniques well known for wire enamelling. The Aquadag has a resistance small compared with that of the element, so it is quite satisfactory as an electrode; it is merely thinned with water and brushed on with a small brush. The electrode must be carefully placed, as extra lumped shunt capacitance (or lumped series resistance) arises if the electrode extends beyond (or falls short of) the resistive helix. The element can easily be checked by bridge measurements. Sprayed-metal techniques have certain advantages over colloidal graphite.

Simple Variation to Extend the Range

Suppose now that a fixed capacitance C_s is added in parallel* with each of the two cable elements so that its total impedance becomes Z' where

$$\frac{1}{Z'} = \frac{1}{Z_0} + j\omega C_s \qquad \text{.. .. .. .. (19)}$$

Then we have to replace R_1 and R_2 in Equ. (2) by Z', substitute into Equ. (1) and find the condition for the imaginary part to be zero. This condition is found by straightforward algebra to be

$$\omega^2 C_1^2 = 1/|Z'|^2 \qquad \text{.. .. .. .. (20)}$$

But from Equs. (19) and (16)

$$\{1/|Z'|\}^2 = \left(\frac{\omega C_0}{2r_0}\right) + \left\{\left(\frac{\omega C_0}{2r_0}\right)^{1/2} + \omega C_s\right\}^2 \qquad \text{.. (21)}$$

so the condition of resonance reduces to $\omega = 0$ (irrelevant) or

* Similar results could be obtained if the capacitance C_s is in series with each cable element. The equation corresponding to Equ. (23) is now

$$\omega = \frac{C_0}{r_0 C_s^2}\left\{\left(\frac{C_s}{C_1}\right)^2 - \left(2\left[\frac{C_s}{C_1}\right]^2 - 1\right)^{1/2}\right\} \qquad \text{.. .. .. .. (23a)}$$

and C_s must always exceed C_1. ω becomes zero instead of infinite in Equ. (23a) if $C_s = C_1$. For a given maximum ratio of C_1/C_s and maximum-to-minimum range for C_1, curves similar to Figs. 5 (a), (b) and (c) can be constructed; they will have curvature in the opposite sense. If C_s is in series with the Kelvin cable element, there is of course no d.c. path.

$$\omega[C_1^2 - C_s^2] - (\sqrt{\omega C_s}) \cdot (2C_0/r_0)^{1/2} - (C_0/r_0) = 0 \quad \ldots \ldots \ldots (22)$$

Equ. (22) can be solved as a quadratic in $\sqrt{\omega}$, and the solution, after a little rearrangement and manipulation, can be written

$$\omega = \frac{C_0}{C_s^2 r_0 \left\{ \left(\frac{C_1}{C_s}\right)^2 - \left(2\left[\frac{C_1}{C_s}\right]^2 - 1\right)^{1/2} \right\}} \quad \ldots (23)$$

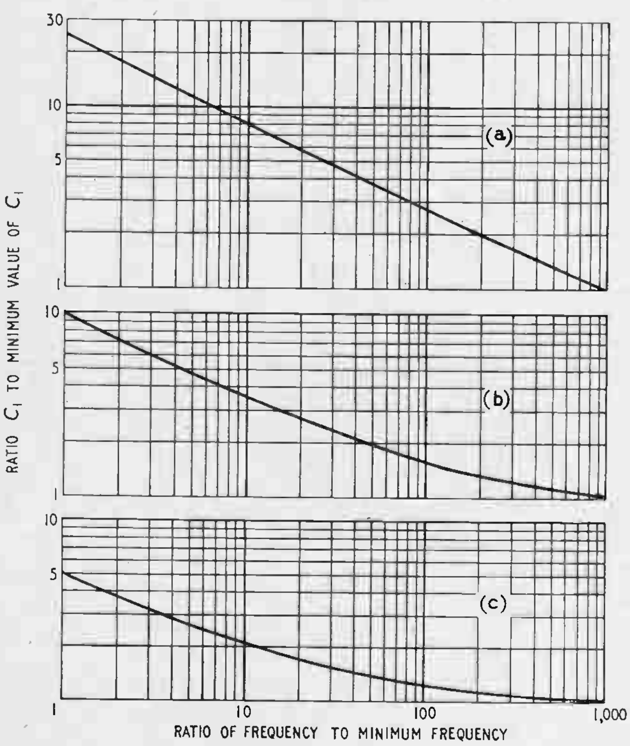
Equ. (23) reduces, as it should, to Equ. (17) if C_s is sufficiently small in comparison with C_1. If the lowest value of C_1 used is sufficiently large in relation to C_s, C_1 will have to be varied in the ratio $\sqrt{1000} : 1$ or 31·6 to 1 to make the corresponding variation in ω in the ratio 1000 : 1. At the other extreme, if the lowest value of C_1 used is equal to C_s, ω becomes infinite, and the ratio of the lowest frequency to the highest frequency is also infinite. We now determine the minimum value of C_1/C_s so that a variation of about 1000 : 1 in ω shall be covered by a variation of (a) 25 : 1, (b) 10 : 1, and (c) 5 : 1 in C_1. The ratio of C_1 to its minimum value is plotted on a logarithmic scale against the ratio of ω to its minimum value in these three cases in Fig. 5 (a), (b) and (c) respectively. If the minimum value of C_1/C_s is λ and the maximum $k\lambda$, we have to determine λ for given k by solving (approximately) the equation

$$k^2\lambda^2 - (2k^2\lambda^2 - 1)^{1/2} = 1000\,\{\lambda^2 - (2\lambda^2 - 1)^{1/2}\} \quad \ldots \ldots \ldots (24)$$

or

$$1000(2\lambda^2 - 1)^{1/2} - (1000 - k^2)\lambda^2 = (2k^2\lambda^2 - 1)^{1/2} \quad \ldots \ldots \ldots (25)$$

Fig. 5. *Relative variation of ω and C_1 from Equ.* (23) ; (*a*) *when the minimum C_1 is* 3.636 C_s ; (*b*) *when the minimum C_1 is* 1.3 C_s ; (*c*) *when the minimum C_1 is* 1.111 C_s



This can be done easily by trial and error, since the left-hand side of Equ. (25) varies much more rapidly than the right-hand side with λ. For $\lambda = 1$, $k > 1$, the left-hand side of Equ. (25) is k^2 and the right-hand side is $(2k^2 - 1)^{1/2}$ which is less, whereas for large λ the left-hand side of Equ. (25) is negative (unless $k^2 > 1000$, which is not of interest). In this way we find that for $k = 25$, $\lambda = 3{\cdot}636$ approx.; for $k = 10$, $\lambda = 1{\cdot}3$ approx. and for $k = 5$, $\lambda = 1{\cdot}111$ approx. It will be seen that the slope of Fig. 5 (a) changes very slowly, since the frequency varies approximately as the inverse square of the capacitance in this case. The last term in the denominator of Equ. (23) is relatively unimportant. However, the scale in octaves per degree must be 25 times more open at the lower end of the frequency range with a linear capacitor. With a normal capacitor law, the scale might in fact be only 5 times as open at the lower end. A capacitor having for minimum capacitance one twenty-fifth of the effective radius for maximum capacitance would be needed to give a uniform scale in octaves per degree. As this is a rather severe requirement, Fig. 5 (b) and (c) have been included; these figures are obtained with less severe requirements on the capacitors, but they have appreciable curvature. Thus curvature of the log C_1/log ω characteristic can be traded to any desired extent against a high value of the ratio of the maximum-capacitance radius to the minimum-capacitance radius for the capacitor.

Practical Requirements

For the practical construction of the tone source, it is important that the value of Z_0 or of $(r_0/\omega C_0)$ should suit the variable capacitance, which might conveniently have a maximum value of 1000 pF at the lowest required frequency. The modulus of Z_0 at the lowest required frequency should be about the same as the impedance of the tuning capacitance at that frequency. It is also important that each cable shall be long enough or the termination suitably adjusted to ensure that the impedance is effectively Z_0 at all required frequencies, but, as we have seen, this requirement is not difficult to meet.

If the variable capacitance has the maximum value 1000 pF and the lowest operating frequency is 40 c/s, the maximum impedance associated with the variable capacitance is, say, 4 MΩ, so the modulus of Z_0 must also be 4 MΩ at 40 c/s. It follows that

$$(r_0/80\pi C_0)^{1/2} = 4 \times 10^6 \quad \ldots \ldots \ldots (26)$$

If the cable element is made from a single 5-MΩ resistor of length l, $r_0 l$ is the total resistance and $C_0 l$ is the total element-to-electrode capacitance; this is found from Equ. (26) to be 1250 pF, and $\omega C_0 l$ is $3{\cdot}125 \times 10^{-7}$. This is perfectly practicable. The value of $|kl|$ in Equ. (11) is then $\{(5 \times 10^6) \times (3{\cdot}125 \times 10^{-7})\}^{1/2}$ which is 1·25. This is rather low unless the termination of Fig. 3 or Fig. 4 already discussed is used, but at higher frequencies the terminations rapidly diminish in importance.

It is perfectly possible to make the Kelvin-cable elements by connecting a number of smaller cable elements in cascade; indeed, it may be cheaper and easier to do this and increase the effective length of the cable rather than pay excessive attention to the termination. Equ. (17a) indicates that exact matching of the characteristic impedances of the various elements is not likely to have critical importance.

The most convenient method of measuring the impedance of one of the Kelvin-cable elements is to compare it with a resistance and a capacitance in parallel. At sufficiently high frequencies, as we have seen, the resistance and reactance of the cable are equal; whether the frequency of observation is sufficiently high can be checked by testing whether the same measured values are obtained with the cable first short-circuited and then open-circuited.

A simple rule of thumb for obtaining the lowest frequency f_{min} which could be developed by an oscillator incorporating such elements is given by

$$f_{min} = 5{\cdot}5 \times 10^{-5}\,(C_2/R)^2 \text{ c/s} \qquad \ldots \ldots (27)$$

where C_2 (pF) is the maximum capacitance of the tuning capacitor, and $R(\text{M}\Omega)$ is the parallel resistance, measured at 1 kc/s. Equ. (27) merely assumes that the phase angle of the cable impedance is still $-\pi/4$ at frequencies down to f_{min}; whether this is achieved by having a sufficiently long cable or a suitable termination is irrelevant.

Acknowledgement

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The Fringe of the Field ***by Quantum***

FURTHER OUTLOOK–WARMER

But probably still unsettled. This is the gist of the forecast for the immediate future of work in progress on Zeta at Harwell and Sceptre III at Aldermaston, as given in the Fourth Annual Report (1957–58) of the United Kingdom Atomic Energy Authority. No hint of the deep depression featured in the newspaper headlines. The account given in this Report and its predecessor, together with the symposium of authoritative articles on "Controlled Release of Thermonuclear Energy" that appeared in *Nature* of 25th January 1958, present a rather different picture from that implanted (if that is the appropriate word for a picture falling on stony ground) in the public mind.

You should read these *Nature* articles, which describe not only the work with Zeta and Sceptre III, but also the experiments at Los Alamos with Perhapsotron S–3 (a miniature Zeta) and the linear Columbus discharge tubes. The overall achievement to that date was the production of a pinch discharge held stable for millisecond durations; temperatures of the order of 4 million to 5 million degrees K and the development of techniques to measure them; and neutron emission, indicating the certain operation of a fusion reaction, which was greatly in excess of that anticipated. Whether there was indeed a true thermonuclear fusion or not was (and at present still is) uncertain. I think the workers were in the position of a man who presses button B and gets four *shillings* out; he is satisfied that the apparatus is operating in the sense intended, and is by no means disappointed—but he does wonder what is going on inside. What seems certain, however, is that higher temperatures would yield more definite information on this point, and here I hand you back to the Authority's Report. In this article I really want to examine two points—what is meant by a "true thermonuclear reaction", and what is to be expected of such an action at different temperatures. This involves going right back to the very beginnings, and discussing first the nuclear fusion reactions themselves.

Fusion as a Source of Energy

In every energy-yielding nuclear change, the total mass of the resulting products is less than the total mass of the original participants. If m grammes is the loss in mass (i.e., in rest-mass), E ergs the liberated energy, and c cm sec^{-1} the velocity of light, then $E = mc^2$. When masses are expressed in the atomic mass unit (a.m.u.), which is 1/16 the mass of the ^{16}O oxygen isotope, and energies in million-electron-volts (MeV), the equation becomes $E = 931{\cdot}1\, m$, since 1 a.m.u. is $1{\cdot}695 \times 10^{-24}$g, and 1 MeV is $1{\cdot}602 \times 10^{-6}$ erg.

The nuclei and particles involved are given in Table 1.

Without considering yet the conditions under which they may take place, various possible fusions and their energy releases can be written down from this table.

TABLE 1

Particle (nucleus)	Symbols	Structure	Mass in a.m.u.
neutron	n		1·00894
proton	p, H, ^{1}H		1·00758
deuteron	D, ^{2}H	p + n	2·01471
triton	T, ^{3}H	p + 2n	3·01700
helium-3	^{3}He	2p + n	3·01702
helium-4	α, ^{4}He	2p + 2n	4·00389

The masses of the electron e^- and positron e^+ are each about $5{\cdot}5 \times 10^{-4}$ a.m.u.

These will be referred to later by number.

(1) *Union of four protons to form one ^4He and liberate two positrons:*

Reaction	4H	$\rightarrow$ ^{4}He + $2e^+$ + E	
Masses	4·03032		4·00504
E	= 0·02528 a.m.u. =		23 MeV

(2) *Proton and deuteron uniting to form ^3He:*

Reaction	H + D	$\rightarrow$	^{3}He + E
Masses	3·02229		3·01702
E	= 0·0053 a.m.u. =		4·9 MeV

(3) *Two deuterons joining to form ^3He and liberating a neutron:*

Reaction	D + D	$\rightarrow$ ^{3}He + n + E	
Masses	4·02942		4·02596
E	= 0·00346 a.m.u. =		3·1 MeV

(4) *Two deuterons joining to form a triton and a proton:*

Reaction	D + D	$\rightarrow$	T + p + E
Masses	4·02942		4·02458
E	= 0·00484 a.m.u. =		4·4 MeV

(5) *Deuteron and triton joining to form ^4He and a neutron:*

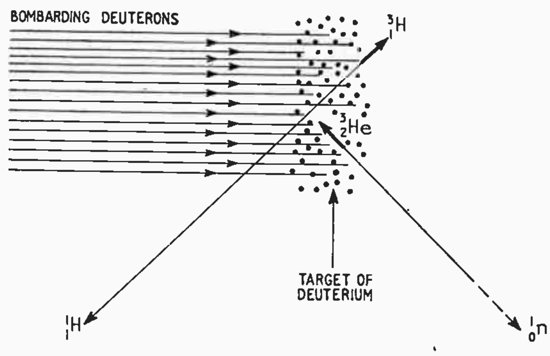
Reaction	D + T	$\rightarrow$ ^{4}He + n + E	
Masses	4·03171		4·01283
E	= 0·01868 a.m.u. =		17·4 MeV

Reactions (1) and (5) are the big fellows, and (3), (4) and (5) the ones relevant to the present discussion.

Conditions for Reaction

Interactions between charged particles cannot take place unless they approach one another so closely that the potential barrier of the Coulomb field on each side (or the inverse-square-law electrostatic repulsion between them) is overcome, and short-range nuclear forces can operate. This means that their relative velocity of approach must be high, but not too high. Given this, the collision must be favourable; a pretty deep knowledge of nuclear theory is needed to work out the probability of a favourable collision (in terms of the "reaction cross-section") for a given relative velocity, and I have to skip a few pages when they start talking about this. The point is, that mere violence is not enough to ensure reaction; and the most probable result of collision is simply an elastic billiard-ball-rebound scattering. The corollary to this, that there is a non-violent ingredient to the process as well, explains why it is possible to get reactions going (with a reduced yield, of course) at velocities far below the optimum.

The equation of (1) is an energy-balance rather than a reaction, for the simultaneous collision of four protons is a most unlikely sort of event. This is the net outcome of the carbon-cycle chain invoked by H. A. Bethe in 1939 to account for the heat generation in the interior of the sun and other stars, at a temperature of the order 30 million degrees K. Assuming thermal equilibrium and a Maxwell distribution, the most probable energy $W = kT$, where k is Boltzmann's constant; one degree corresponds to about $8{\cdot}6 \times 10^{-5}$ eV, so 3×10^7 degrees represents 250 eV. The cycle of operations, which begins with a ^{12}C nucleus collecting a proton, follows with five more steps (three proton-collecting, and two positron-emitting), and ends with a ^{12}C nucleus and a ^{4}He embodying the four protons, is described in all the books. It is a true self-sustaining thermonuclear reaction, for the energy emitted maintains the temperature required for its perpetuation, with a huge excess to spare. But it is leisurely and haphazard in the matter of power supply, since it takes about a million years to complete the chain of operations on a gram of hydrogen.



(*Courtesy Cambridge University Press*)

Fig. 1. *Illustrating the disintegration of deuterium by bombardment with deuterons. Approximately 2 million deuterons bombarding a target of pure deuterium at 100,000 volts will produce one each of the two reactions shown*

Equation (2) is mentioned here for its intrinsic interest and unexpected source—cryonuclear rather than thermonuclear if you like. The H and D are really a molecule of HD in the liquid hydrogen of a bubble chamber, and the energy to prime the action comes by the absorption of a μ-meson. This was reported by Alvarez and his team in 1957.

Equations (3), (4), and (5) are those observed directly in 1933–34 by bombarding a deuterium-containing target with a deuteron beam accelerated under a high voltage (Fig. 1). The process was followed down from several hundred kV down to a few kV, and the optimum energy for at least (3) and (4) was found to be 0·1 MeV; expressed as T for a Maxwell distribution this corresponds to $1{\cdot}2 \times 10^{10}$ degrees K. Bombardment would of course be hopelessly ineffective as a source of power; the deuteron beam itself is tenuous, and only about one particle in a million makes an effective collision (a hundred times as many being scattered elastically).

These experiments were among the many that followed the arrival of the first supply of heavy water at the Cavendish Laboratory, and are described in a paper by Oliphant, Harteck, and Rutherford, *Proc. Roy. Soc. A*, 1933, Vol. 144, p. 692. The deuterium target was a thin layer of ammonium salt, ND_4 Cl or $(N D_4)_2 SO_4$; the accelerator a modified Cockcroft-Walton machine; and the reaction products, after sorting in a magnetic field, were detected by a linear counter system operating an oscilloscope. Cloud chamber photographs were made by P. I. Dee, and Fig. 2 is reaction (4) caught in the act by him. I have seen the investigation of reaction (4) attributed to Dee and Walton; this is very possibly correct, but I haven't been able to trace the reference. The important things to notice, however, are the place and the date; fusion reactions were among the *first* genuine artificial transmutations studied!

The D,D and D,T Reactions

The reactions themselves have thus been known for nearly a quarter of a century. The triton (or, if you like, the hydrogen-3 isotope tritium) was discovered by

Oliphant and Harteck; they found the mass of the triton by working equation (5) in reverse, so to speak. The total energy of the triton and the proton was found from their ranges in air, and the energy of the incident deuteron subtracted from this to give E. The total number of a.m.u. available for the rest-masses of proton and triton together is thus known, and that of the proton subtracted. I am tempted to digress a little on to the subject of deuteron bombardment, for I looked all this up in Lord Rutherford's 1936 Sidgwick Lecture ("The Newer Alchemy", Cambridge University Press), which is quite thrilling in recalling the excitement of those days; but apart from mentioning one important point I must content myself with reproducing two figures (Figs. 1 and 2), with their original captions. The lower prefix (e.g., the 2 in $^3_2$He) on each symbol is the atomic number, the upper the mass-number used in the present article; and $^2_1$H is our D.

The important point is the binding energy of the deuteron itself. The mass of D is little less than the sum of the masses of n and p together, so their union to give a deuteron yields relatively little energy, about 2 MeV; the energy required to separate them again, the binding energy of the deuteron, is thus only 2 MeV. Consequently, the deuteron is a readily separable partnership, and extremely effective as a projectile. Cyclotron experiments showed that, in bombardment, the deuteron penetrates nuclear potential barriers much more readily than the theory of those days would have predicted. Quite apart, then, from being the most useful participant in a fusion reaction, the deuteron has just the properties that make it a very active one. Note that Rutherford calls fusion "disintegration of deuterium!" The ranges in air referred to were the usual way of expressing the energies of ionizing particles at that time.

After twenty-five years of general currency, or thereabouts, equations (3), (4), (5) recently acquired an aura of portentous secrecy. This made me wonder whether, with all the rocketry there is nowadays, they will start going all secretive about Newton's Third Law of Motion. A quite redundant precaution, as anyone who has vainly tried to disclose the Law to his students will testify! While I was simmering in my sarcasm, I realized that perhaps I'm not so bright on Newton III myself—for of course this is one of the reasons why a thermal collision must score over an impact between a projectile and a stationary target particle. *Momentum* is conserved, so that even with a perfectly inelastic collision only part of the projectile's kinetic energy is available for conversion—while with a head-on inelastic thermal collision between equal particles all the kinetic energy of the pair is made available. So 100,000 eV of *bombarding* energy (Rutherford mentions 20,000 eV as a figure at which the reaction could be detected) must really imply that the equivalent *thermal* energy for the same result could be much less. Most sums on collisions are worked in co-ordinates referred to the centre of mass of the particles, but whatever the reference frame the above conclusion holds.

Thermonuclear Reactions

This analogy is not perhaps a very good one, but the difference between bombardment and thermal-agitation as a means of getting nuclear reaction is not unlike the difference between two ways of causing the exothermic chemical reaction $2H_2 + O_2 \rightarrow 2H_2O$. You can store the hydrogen under pressure, let it out into the air in a fine jet intermittently, and keep on lighting the jet; or you can mix hydrogen and oxygen in the right proportions, start things with a spark or a light and, before you know where you are, the molecules throughout the mixture have seen to the matter themselves. You do not need to apply a light in several places, nor to repeat the action. In one case an elaborate sequence of operations, each dealing with a little gas at a time, is needed; in the other, merely the right mixture with a fraction of it raised initially to the right temperature. But in each case the reaction is the same.

Similarly, the reactions (3), (4), (5), observed when single deuterons are thrown at other deuterons (or tritons), occur equally well when huge numbers of them are present (or mixed), and given the chance to see to

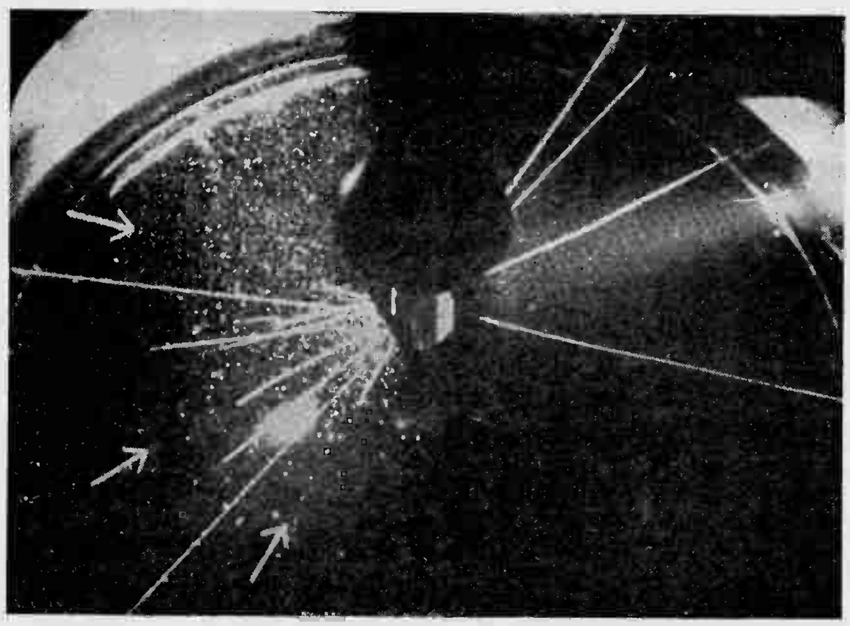
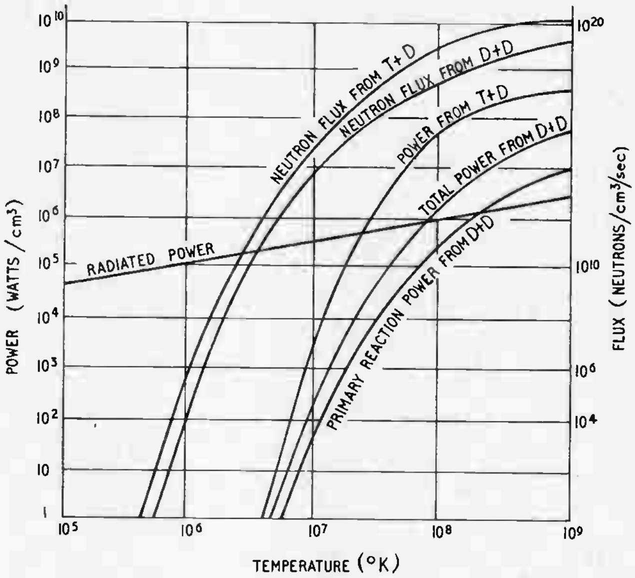


Fig. 2. *Three examples of the emission in opposite directions of ^1_1H and ^3_1H particles produced by the bombardment with artificially-accelerated deuterons of a thin target containing deuterium ($^2_1H + ^2_1H \rightarrow ^1_1H + ^3_1H$). The tracks of the ^3_1H particles seen on the left of the target tube had a range of 1·6 cm, while the proton tracks emerging on the opposite side had a range of 15 cm.*

(Courtesy Cambridge University Press)

things for themselves using their own thermal-agitation energy. In the first place, a completely ionized plasma of deuterons and electrons is needed, at a pressure of a thousandth of a millimetre of mercury or less, when the number of deuterons per cm^3 will be of the order of 10^{18}–10^{16} or so. Secondly, it must be remembered that, while kT gives the most probable kinetic energy at T, an appreciable fraction of the ions have kinetic energies greatly in excess of this. Taking this point up, it seems at first very mysterious that, if a "bombardment energy" of the order 0·1 MeV which is the kT for about 10^{10} °K is needed under Dee and Walton conditions, there can be any detectable effect at all at temperatures of the order of a few million degrees. If T_0 °K is the temperature for maximum probability of interaction on collision, then the fraction of particles in a Maxwell-distribution equilibrium at T °K possessing the necessary energy is $\exp\{-T_0/T\}$; you can work out e^{-2000} if you like—I make it about 10^{-873}. The key to the mystery is, of course, the way in which the probability of reaction depends on the energy of collision, and this puts things on an entirely different scale. I am quoting now from an article by Dr. W. B. Thompson in *Nature* for 4th May 1957, on "Thermonuclear Power—a Theoretical Introduction"—rather diffidently, as he seems to leave out a figure which would enable one to work through his numerical results, shown in Fig. 3. However, the argument is clear enough. First, the "reaction cross-section" for colliding light nuclei at low energies E (this symbol now standing for collision energy, relative to the centre of mass) is not directly proportional to E, but is given by the expression $AE^{-1}\exp(-BE^{1/2})$, where A is a constant for the reaction, and B another constant proportional to the product of the charges. The reaction probability P for the reaction to occur under thermal agitation collision at T °K is approximately $\exp\{-(T_0/T)^{1/3}\}$, which gives us 10^{-9} or so instead of the formidable 10^{-873}. Multiplied by the number of *pairs* of particles in a plasma at a fraction of a millimetre of mercury pressure—the figure he works from, an ion density of 10^{18} per cm^3 gives 5×10^{35} for the number of pairs—the number of reactions per cm^3 per sec. is calculated. Then, as the energy in MeV for a single reaction is known, the total energy released per cm^3 per sec is obtained; this is expressed in watts per cm^3. As the curves of Fig. 3 show, it should be possible even at relatively low temperatures between 10^6 and 10^7 °K to detect reactions which flourish at their best at more like 10^{10} °K (his T_0 was 7×10^{10} °K). Of these curves, the lowest refers to the two D,D reactions on their own; the next, with the secondary reaction (5) involving tritons included; and the highest, to a mixture of 10^{18} deuterons and 10^{18} tritons, that is reaction (5) on its own.

Finally, to the straight line on Fig. 3. Assuming that the plasma is kept away from the walls of the container, its only way of losing energy is by radiation. The agents of this are the electrons, equal in number in the plasma to the positive ions. The process is the deceleration of the electrons in the neighbourhood of positive ions (Bremsstrahlung or "braking radiation"), a classical electromagnetic effect like that responsible for the continuous background X-ray emission when electrons are arrested by a metal target. The power radiated in this way is proportional to $T^{1/2}$, rising with temperature much more slowly than the power generated. Ignoring the intersection of this line with the "neutron-flux" curves, which doesn't mean anything, its intersection with each of the power curves gives the temperature above which, if radiation were the only loss, the power generated would exceed the power lost, and the thermonuclear action could sustain itself.



(*Courtesy "Nature"*)

Fig. 3. *Results calculated by W. B. Thompson for reactions* (3), (4) *and* (5) *assuming T_0 to be 7×10^{10} degrees K, and the ion density to be 10^{18} per cm^3. Of the power curves, the lowest refers to the two (D,D) reactions on their own; the next to these with the secondary reaction* (5) *included; and the top one to a mixture of equal numbers of deuterons and tritons at the start, with reaction* (5) *only. The neutron flux is an indication of the number of reactions occurring per cm^3 per sec.; it should be noted that only two of the three reactions are neutron-emitting ones*

Conclusion

If I have interpreted the 1957–58 Report correctly the major subject of enquiry is the origin of the intense neutron flux observed. Collisions between ions accelerated by the electric field along the axis of the apparatus also initiate (3), (4), (5), giving a background of neutrons from which it is difficult to disentangle the randomly-directed neutrons given by thermal-agitation collisions. The work at higher temperatures mentioned in the Report, by increasing the proportion of true thermonuclear action, should give conditions more favourable for its positive detection. It looks, in short, as if things are steadily warming up.

I haven't got on to the difference between the electron temperature in the plasma, the ion temperature, and the temperature estimated experimentally; this is a long story, and we might go into it on some future occasion. Since this article was completed, I have read a report of the recent Geneva conference, and the 'magnetic mirror' machines, one of which (Scylla from Los Alamos) was actually demonstrated there. The *electron* temperature attainable is said to be of the order of ten million degrees K, though no figures are given for the ion temperature, which is indeed a sign of the upward trend proceeding.

Electronic Computers and the Engineer

By Mechanikos

In general, electronic engineers are apt to be more concerned with the development of computer circuitry than with the use of computers. In modern development work of all kinds, however, mathematical analysis is increasingly used and, as circuits become more complex and performance specifications more stringent, so the mathematics becomes more difficult. Sooner or later, general algebraic solutions become impracticable and it is necessary to resort to arithmetic solutions. The engineer is then involved in a vast amount of computional labour.

When only a numerical solution is practicable, it means that suitable values have to be assigned to all constants, and we must also choose a convenient series of values for the variable. New values for the constants are then taken and a fresh series of results obtained. It is easy to see that the arithmetical labour involved can become enormous. If there are only four constants and we solve for twenty different values of each and for twenty values of the variable, we have to perform $20^5 = 3{\cdot}2 \times 10^6$ calculations in all!

It is for just this kind of thing, involving repetitive work, that the electronic computer is fitted. It operates so rapidly that it can provide answers to problems of this kind in a time measured in minutes rather than in hours, as compared with the weeks, months or years needed for manual computation.

Computers are, of course, very expensive pieces of apparatus and comparatively few organizations can afford to buy one. Moreover, since they work so quickly, it is difficult for any but the largest firms to keep one fully occupied. Many owners of a computer thus find it has unoccupied time and are, consequently, willing to hire it out. Although the cost is of the order of £50 an hour, the computer works so quickly that it does an enormous amount of computation in this time. The use of a computer is thus a practicable proposition for most engineers.

It is not, unfortunately, possible to present the machine with an equation and tell it to solve it. The computer must be given precise instructions for every step of the way. The problem must be translated from the ordinary mathematical form into computer language, a process which is usually called programming.

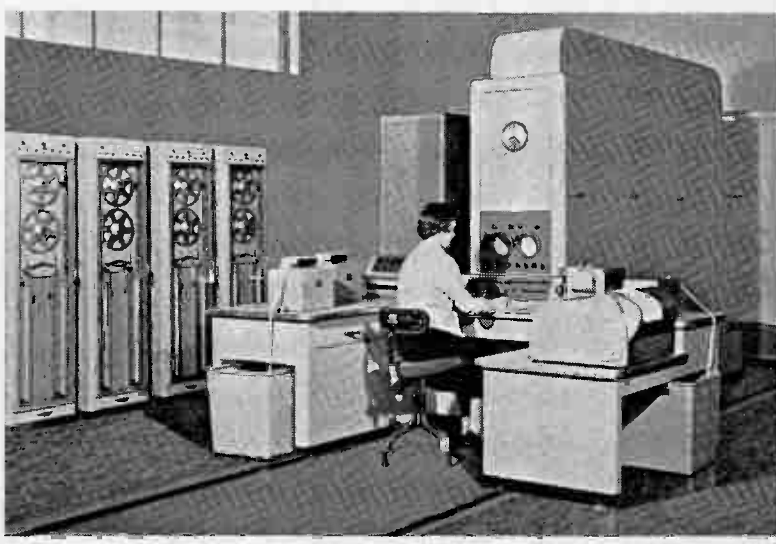
Some organizations hiring out 'machine time' insist on doing this 'programming' themselves; that is, they expect the engineer only to specify what has to be calculated, and for what values of the various constants involved. The staff of the hiring organization then 'translates' the problem into a series of operations which can be performed by the machine, and they eventually obtain results which are handed back to the engineer without any explanation of how the results were obtained.

Alternatively and, in the writer's opinion, preferably, courses are held at intervals on which engineers can learn the rudiments of the technique of 'programming' or translating problems from engineers' language into 'machine language' and re-translating the results back into engineers' language. If an engineer has attended such a course, he can at least appreciate what is being attempted to solve his problem, even if he may need the advice of experienced programmers from time to time. At best the engineer can become capable of preparing his own programmes with occasional help only.

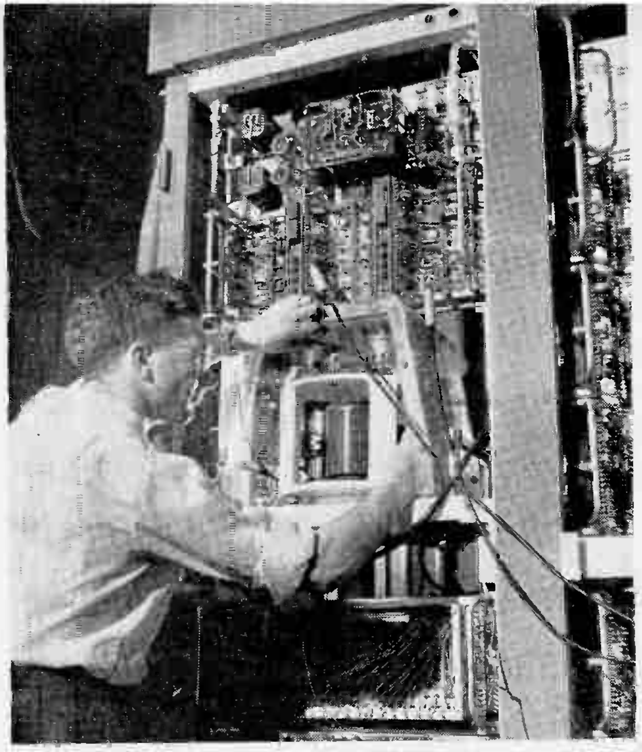
Essentially, what the machine can do is to store numbers (which may represent actual numbers associated with the problem, or may represent pairs of coded 'orders' controlling the action of the machine), to perform arithmetical operations (specified by these coded 'orders') on numbers previously placed in suitable parts of the machine, and to shift numbers from one part of the machine to another. Normally, it can be arranged that the machine will take its first 'order' from a specified 'address' or place in its store, and subsequent 'orders' will be taken from consecutively numbered 'addresses' thereafter. It is, however, normally necessary that sometimes the machine should be able to 'jump', and either omit some 'orders' or return to an order already obeyed and perhaps repeat some sequence of orders several times, continuing a different set of operations thereafter. The unit of time required for a fundamental operation like transferring a number from one location in the quick-access or 'computing store' to another is a fraction of a millisecond. Some 'orders' like multiplication and division, require several times as long as this unit, but still a time small compared with a second.

Unfortunately the 'computing store' is expensive to make and its capacity is relatively limited—in one particular machine, it will hold 48 'words' each consisting of either a single number or a pair of orders,

In the Ferranti Pegasus computer the information from punched cards or tape is transferred to magnetic tape before being fed into the computer



Plug-in units are used in the E.M.I. Emidec 2400 computer. Printed circuits and transistors are employed



Interior of part of the English Electric Deuce computer. The magnetic drum store is visible in the centre

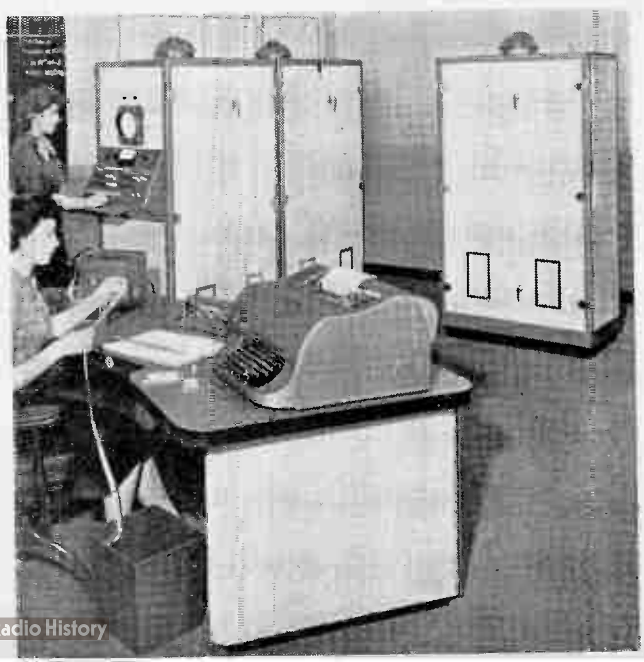
and there are also 8 'accumulators', each capable of holding one 'word', which are used for arithmetical operations. A further large 'main' store is provided by means of a magnetic drum, capable of holding several thousand 'words', but before any arithmetic can be done on words in the main store, the required word or groups of words must be transferred to the computing store. This is a relatively slow operation, because it is necessary to wait until the required part of the main store is in the position where it can be read, and this may require a complete revolution of the drum. In commercial applications, where it is often necessary to perform a simple operation (such as addition, or multiplication by a constant) on a very large amount of data, even the main store may be inadequate, and further storage space can be supplied by means of magnetic tape. The extent of this storage space is almost unlimited, but the time required to transfer data from the tape to the computing store can be very long unless great care is taken. In engineering applications, however, the main store is usually sufficient.

So far we have only considered operations within the machine, but before they can be useful to the engineer we have to have some way of getting data and orders into the machine, and of extracting results from it. Usually, the problem is first broken up into a series of instructions to the machine together with data, and these instructions are then written down in order, and subsequently punched on to paper tape. At the beginning, the paper tape is read into the machine, which has built-in 'initial orders' which cause a correct programme to be arranged so that the machine can carry it out. If the programme is not correct, the machine will usually either stop or produce obviously nonsensical results, and it is a virtual certainty that this is due to the programmer's human error. It is possible to make the machine print out the contents of various parts of the store so that the programmer can then find out what has gone wrong. Special 'registers' are provided which cause a number transferred to them to be printed (either as a number or as a letter as required).

Inside the machine only 'binary numbers' are used; a number consists of 38 binary digits each of which is either a 1 (pulse present) or zero (pulse absent). Preceding these digits is a 'sign digit', zero for positive numbers and 1 for negative. If the number is regarded as an integer, it can therefore be between -2^{38} and $+2^{38}$; if it is regarded as a fraction, between -1 and $+1$ by steps of 2^{-38} (2^{38} = 274, 877, 906, 944). Numbers must therefore be scaled down so as to be within these limits at all stages of the calculation; the simplest scaling is usually to divide by a suitable power of 2. If this is difficult to determine, 'floating-point arithmetic' may be used, and a number is expressed in the form $A{\cdot}2^a$ where a is an integer between -256 and $+256$, and A is numerically between $\frac{1}{4}$ and $\frac{1}{2}$. 'Floating-point' arithmetic unfortunately slows down the machine.

To exploit fully the speed of the machine, it is necessary

The Standard Telephones & Cables Zebra computer is designed for mathematicians. It has a flexible programming system and a large store



fully to translate the problem to be solved into the machine's language. Certain processes (such as input and output processes, finding square roots, etc.) are required so frequently that the necessary programming has already been done and recorded on the 'Library tape'. Any such programme ('subroutine') can be used as often as required in the programme to solve a particular problem—it is only necessary to provide a 'cue' at the appropriate point in a sequence of orders to switch over, so to speak, to the 'subroutine', and a 'link' by means of which to return from the 'subroutine' to the main or 'master' programme. Library-tape subroutines have been fully checked, so it is only the 'master programme' that need be checked when they are used.

To some extent, machine speed can be traded for simplification of programming by extensive use of subroutines. For example, one particular machine can be made to handle matrix multiplication and carry out the order, "Take the 24-row 17-column matrix stored (by columns) in consecutive addresses beginning at address No. 1, multiply it by the 17-row 9-column matrix stored (by columns) in consecutive addresses beginning at No. 500, and put the resulting 24-row 9-column matrix in consecutive addresses beginning at No. 1000." The time taken for multiplying two square matrices having 24 rows and columns each is about 5 minutes. An additional $3\frac{3}{4}$ minutes would be required for output printing of a 24×24-element square matrix.

Another possible simplification of programming at the expense of machine time is called (for this same machine) autocode. 'Floating-point' arithmetic is used, and the programmer merely has to write some such equation as

(i) $v1 = v2 + v3$

(ii) $v1 = \mathrm{SQRT}v2$

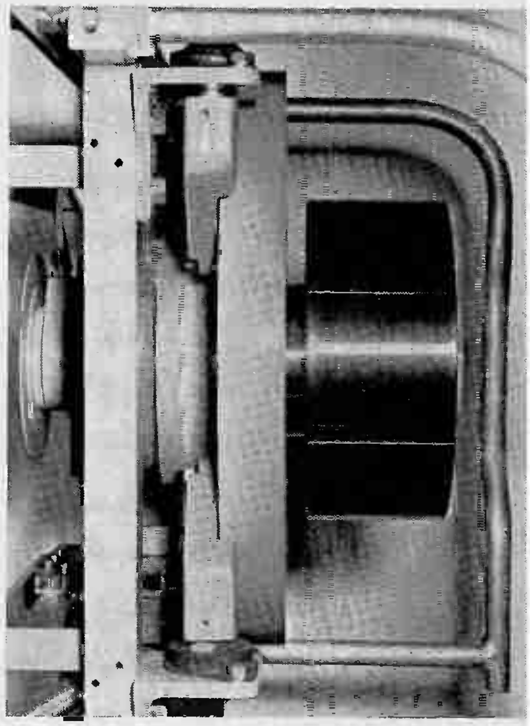
to indicate (i) that the number in position number 2 is to be added to the number in position number 3 and the sum placed in position number 1, destroying what was previously there, or (ii) that the square root of the number in position number 2 is to be placed in position number 1. Equations of this kind may involve a whole set of 'orders' (like those discussed below) inside the machine, which are carried out automatically if the 'autocode tape' has been fed in before the programme tape.

When taking full advantage of the speed of the machine is the prime consideration, however, the programme will consist of a series of 'orders' like those which follow. Two consecutive 'orders' form a 'word' and are stored together in the machine in the same way as numbers. Both positive and negative numbers must be preceded by a sign, otherwise they will be misinterpreted by the machine as order-pairs with disastrous results. A typical 'order' to the machine will be written:

(i) 3·2 7 01 (iii) 0·0 0 60

(ii) 2·3 5 20 (iv) 6 $\boxed{0}$ 72

The first of these orders means: take the number in position 3·2 of the computing store, add it to the number in 'accumulator' 7, and leave the result in accumulator 7; the fact that addition is required and the place to which the result is sent are specified by the third number 01. Order (ii) means: take the number in position 2·3 of the computing store, and multiply it by the number in accumulator 5. This time, the result is necessarily a 'double length' number occupying accumulators 6 and 7, and this fact has to be remembered in any subsequent operations. The fact that multiplication is required is specified by the last number 20. The third order is a 'jump' order; it means: "jump to the order in position 0·0 in the computing store (instead of obeying the next order in the sequence) if the number in accumulator 0 is zero [and accumulator 0 is a special one which always contains zero]. The fact that a jump is required is specified by the number 60, which really means: 'if the number in the accumulator specified [here accumulator 0] is zero, jump; if it is not zero, carry out the next order in the sequence. When this '60' order is applied to an accumulator, other than accumulator 0, which may or may not contain the number zero, the possibility of choice arises for the machine—it can automatically decide between two possible courses of action. This facility enormously increases the possible uses of the machine; it enables full advantage to be taken of the fact that the machine can repeat long sequences of operations without making a mistake or getting tired and with astonishing speed.



Magnetic drum forming the store in the Sperry Gyroscope instrument. Speed is regulated by an eddy-current brake visible on the left

The last order (iv) is needed when we require to transfer a 'block' of 8 words from the main store of the machine to the computing store; the block-transfer operation is specified by the number 72, and the order as written transfers the contents of block 6 of the main store to block 0 of the computing store; the square round the 0 is a convention designed to make it immediately obvious that the 0 is a block-number and not an accumulator number. This block-transfer order will destroy what was previously in block 0 of the computing store, but the contents of block 6 of the main store will remain unaltered. Sometimes, for example when a long sequence of numbers has to be added up, it is convenient to add a fourth single-figure digit, say D, to the orders; this process is called 'modification', and it causes the position of the number to be processed to be changed just before the order is obeyed, in a manner depending upon the contents of accumulator number D just before the order is obeyed. This procedure is too complicated to be explained in this article; it does, however, greatly reduce the storage space occupied by programmes in which similar sequences of operations are repeated several times.

Programmes for many common operations have already been worked out and fully tested, such as the solution of linear simultaneous equations, Fourier analysis, and so on.

Before any new problem is tackled, therefore, it is highly desirable to check that a programme, or at any rate a helpful subroutine, does not already exist. For once a programme or subroutine has been tested, it can be used over and over again, and an important part of the facilities provided with the programming course for users of one machine is that a programme developed by one user is listed and made freely available to all other users.

When an engineer decides that machine solution of a problem is desirable, it is first necessary to decide the values or ranges of values of all constants that appear in the relevant formulae. For a computer can do arithmetic speedily, but it cannot do algebra. It is then necessary to prepare a 'flow chart' specifying in outline the sequence of calculations required. This 'flow chart' can be in engineers' language, and it will usually at intervals require a choice of alternative courses of action to be specified. For instance, if we are considering a flow chart for a programme to factorize integers, and at some stage we are trying 31 as a divisor, different courses of action will be required according as there is or is not a remainder. It is essential first to have a satisfactory flow chart (the preparation of which takes a time small compared with that required for the programme itself). Once the flow chart is prepared, attention can be concentrated upon preparing the programmes for the various stages involved independently. Some of these stages may be partly or wholly covered by 'library subroutines', so that the principal requirement is a 'master programme' which will fit these subroutines together in their appropriate places. For a large-scale calculation, such as the tabulation of a function of two variables x and y each of which may have 100 different values, it may be advisable to determine a few values initially by autocode giving priority to simplification of programming at the expense of machine speed. Errors in the flow chart could thus be exposed without serious waste of machine time. Once a satisfactory simplified programme has been obtained, priority for the main programme can be given to saving machine time wherever possible, especially in sequences of operations repeated many times.

The cost of hiring 'machine time' is of the order of £50 an hour, which is not as much as it sounds when the fundamental machine operation takes a fraction of a millisecond. If the staff of the firm hiring the machine do the programming, the additional charge for this will naturally be heavy, because it is difficult to estimate in advance how long it will take to write a programme and to detect the 'blunders' in it which nobody can altogether escape. If, however, the engineer has even a rudimentary understanding of the principles of programming, collaboration becomes possible, both between him and the staff of the firm hiring the machine and between him and more experienced engineer-users of that machine. Only by adequate collaboration between the engineer (who alone fully understands the requirements of the calculation) and people who fully understand the machine can the immense possibilities of the machine be fully exploited.

ELECTRONIC COMPUTER SYMPOSIUM

A Business Symposium is being held in the Apex Restaurant at Olympia during the Electronic Computer exhibition. The opening address in the first session will be "Retrospect and Prospect", by the Earl of Halsbury, F.R.I.C., F.Inst.P. The papers and sessions are as follows:

1st December 2.15–4.30 *p.m.*

"Payroll Production and Sales Application", by N. C. Pollock (Stewarts & Lloyds Ltd.).

"The Computer as an Aid to Production Management", by J. Grant (British Tabulating Machine Co. Ltd.).

"Computer Services in the United Kingdom", by D. Wragge-Morley (*Financial Times*).

1st December 6.00–8.15 *p.m.*

"Large-scale File Maintenance", by D. G. Pedder (Radio Rentals Ltd.).

"Technical Planning of Steel Tube Manufacture", by R. G. Hitchcock (Tube Investments Ltd.).

"Public Utility Accounting", by G. Sherlock (South-West Gas Board).

"Electronic Data Processing in the Nationalised Industries", by D. W. Hooper (National Coal Board).

2nd December 10.15 *a.m.*–12.30 *p.m.*

"The Application of Linear Programming to the Design of Animal Feeding Stuffs", by A. Muir (J. Bibby & Sons Ltd.).

"Integrating the Procedures of an Insurance Office", by K.-E. Schang (Trygg-Fylgia Insurance Co.).

"The Approach to E.D.P. of a Large User", by S. G. Furniss (I.C.I. Ltd.).

"Electronics in Banking", by Clearing Bankers.

2nd December 2.15–4.30 *p.m.*

"Inventory Control, Accounting and Payroll", by A. Bradley (Ford Motor Co.).

"Production Control by Buying Computer Time", by R. B. Baggett (Job White & Sons Ltd.).

"Accounting for Farmers' Sugar Beet Production", (Irish Sugar Co. Ltd.).

3rd December 10.15 *a.m.*–12.30 *p.m.*

"Merchandise Accounting", by D. S. Greensmith (Boots Pure Drug Co. Ltd.).

"Stores Control and Control by Exception", by K. F. Turner, and "Computer for Research and Design", by L. Griffiths (Rolls-Royce Ltd.).

"Technique for Statistical Analysis of Family Expenditure", by M. A. Wright (National Physical Laboratory).

"Government Experience", by J. Merriman.

3rd December, 2.15–4.30 *p.m.*

"Analysis of Sales Statistics", by C. A. Wilkes (I.C.I. Ltd.).

"Wages Accounting", by W. H. Sargent (British Railways, Western Region).

"Industrial Mathematics", by D. G. Owen (United Steel Co. Ltd.).

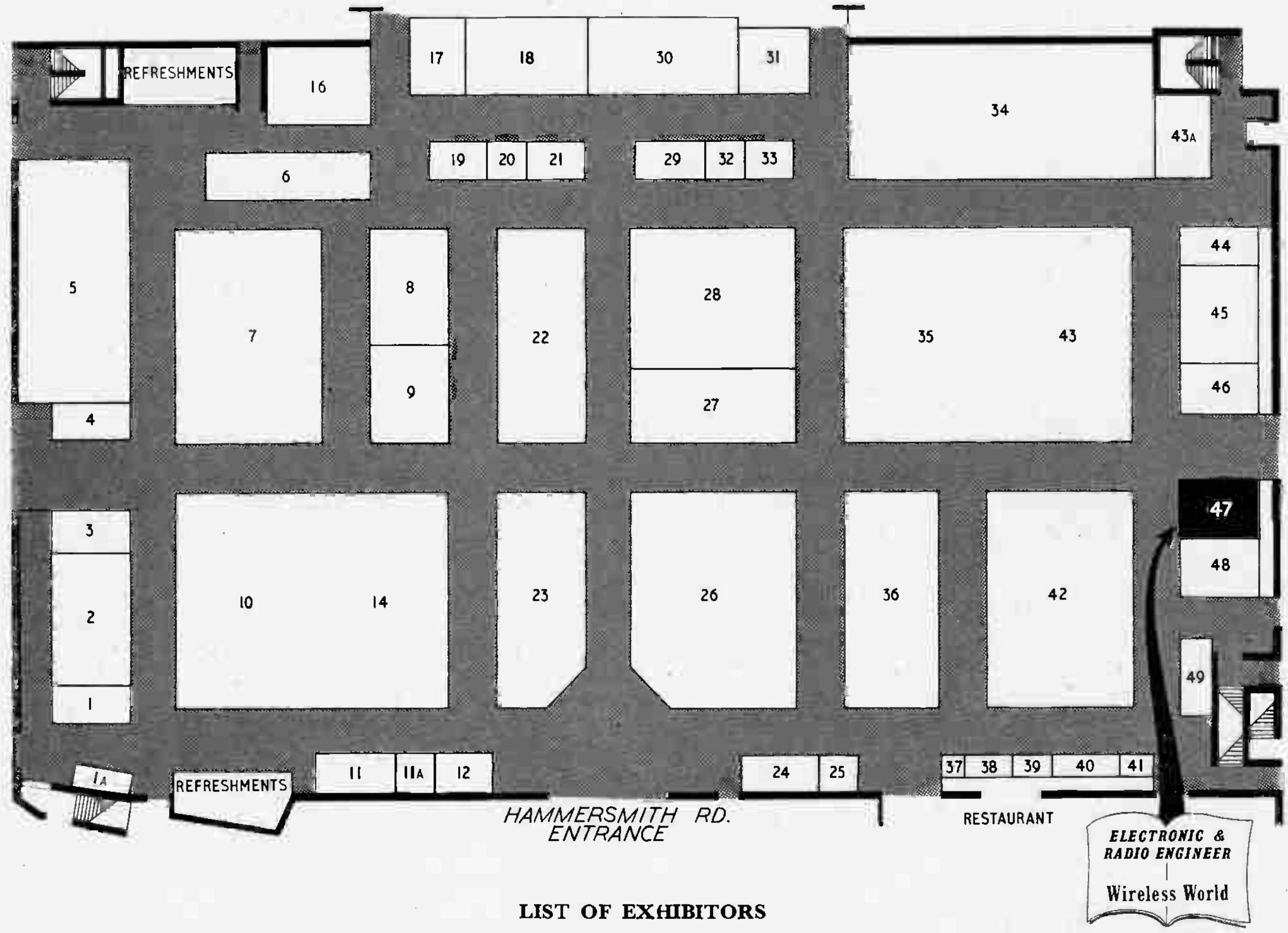
"Electronic Data Processing", by A. J. Brockbank (Glaxo Laboratories Ltd.).

The admission charge for the exhibition is 2s. 6d. For each session of the symposium it is £2 12s. 6d., or £15 15s. for all sessions.

Electronic Computer Exhibition

NATIONAL HALL, OLYMPIA, LONDON, W.8

From 28th November to 4th December. **Hours of opening, 10 a.m. to 8 p.m.** **Admission 2s. 6d.**



LIST OF EXHIBITORS

	Stand
Air Trainers Link Ltd.	1a
Benson-Lehner (G.B.) Ltd.	12
Percy Boyden & Co. Ltd.	1
British Computer Society Ltd.	41
British Tabulating Machine Co. Ltd.	5 & 7
British Thomson-Houston Co. Ltd.	8
Bulmer's (Calculators) Ltd.	45
Burroughs Adding Machine Ltd.	28
Business Publications Ltd.	38
Creed & Co. Ltd.	30
Current Affairs Ltd.	20
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Egry Ltd.	3
ELECTRONIC & RADIO ENGINEER	47
Elliott Bros. (London) Ltd.	35 & 43
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Punched Card Accessories Ltd.	29
Rank-Precision Industries Ltd.	48
Saunders-Roe Ltd.	19
Short Bros. & Harland Ltd.	4
Siemens Edison Swan Ltd.	16
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Latching Counters

PART 2—NON-BINARY COUNTERS AND TRANSISTOR CIRCUITS

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

There existed in the main counter chain two non-binary sections. The first consisted of four binary stages having a natural count of 16, reset at a count of 9, and the second of five binary stages having a natural count of 32 but reset at a count of 25.

The original decision to use this arrangement rather than two sections each consisting of two binary stages reset at a count of 3, followed by two sections each consisting of three binary stages reset at a count of 5, was based on the desirability of keeping down the size of the equipment. Not only does the first arrangement require one less unit in the main chain but also there is a considerable saving in the resetting circuits, as the amount of equipment required for resetting increases only slowly with the number of stages reset. In addition, there was some saving in the gating circuits fed from the counter, since the output waveforms obtained from the first arrangement were better suited for the generation of the gating pulses required.

It had been found in practice, however, that this saving in equipment was more than counterbalanced by the increased difficulty in fault-finding which resulted from the resetting loops encompassing up to five binary stages. Although it was expected that the double-pulse version would be very much more reliable, so that easy fault location would become less imperative, it was decided that on balance the advantage would still lie with the short sections. Development therefore proceeded on the basis that only scale-of-3 and scale-of-5 counting stages would be required.

The first possibility considered was a reset binary stage on the same lines as those used in the original single-pulse counter. Fig. 10 gives the input–output table and block diagram of a scale-of-3 counter working on this principle. It will be noted that specially-designed reset units are not required but that the amount of equipment used is excessive, 5½ units as against 2 for a binary stage. In addition, as the reset pulse resets the two binary stages to '0 0' at nominally the same instant

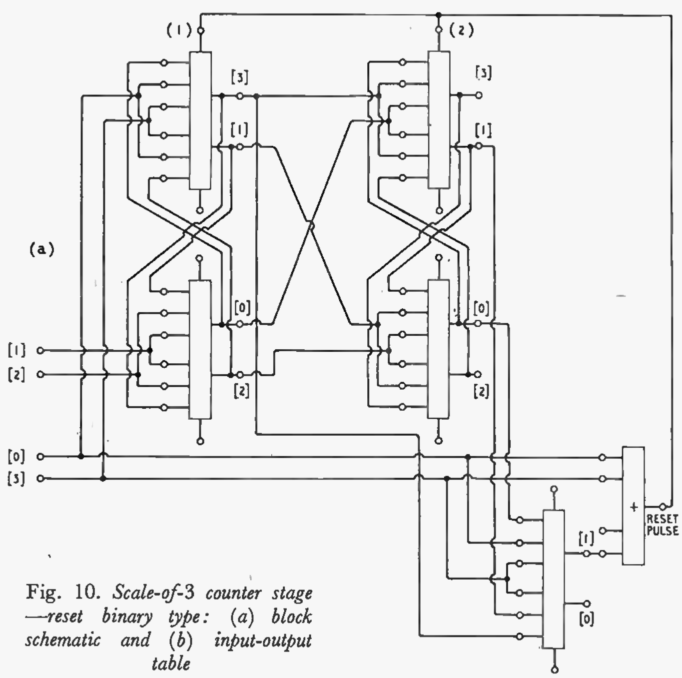
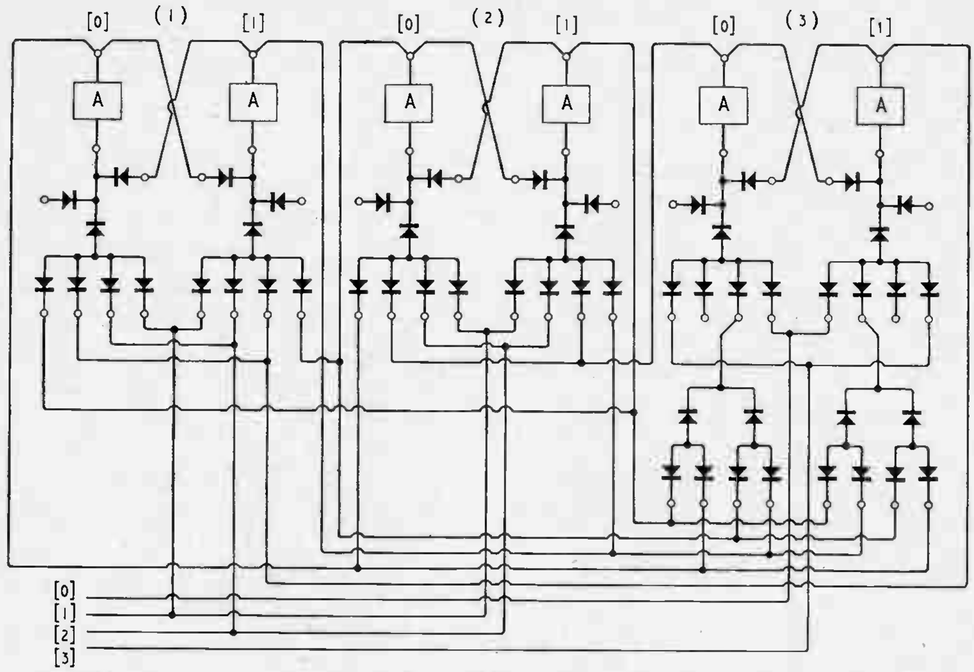


Fig. 10. *Scale-of-*3 *counter stage —reset binary type: (a) block schematic and (b) input-output table*

Inputs				Outputs (1)				Outputs (2)				Reset Register		Reset Pulse
[0]	[1]	[2]	[3]	[0]	[1]	[2]	[3]	[0]	[1]	[2]	[3]	[0]	[1]	—
0	1	1	0	0	1	1	0	0	1	1	0	1	0	1
0	0	1	1	0	1	1	0	0	1	1	0	1	0	0
1	0	0	1	0	0	1	1	0	1	1	0	0	1	0
1	1	0	0	0	0	1	1	0	1	1	0	0	1	0
0	1	1	0	1	0	0	1	0	0	1	1	0	1	0
0	0	1	1	1	0	0	1	0	0	1	1	0	1	0
1	0	0	1	1	1	0	0	0	0	1	1	0	1	0
1	1	0	0	1	1	0	0	0	0	1	1	0	1	0
0	1	1	0	0	1	1	0	1	0	0	1	0	1	0
0	0	1	1	0	1	1	0	1	0	0	1	0	1	0
1	0	0	1	0	0	1	1	1	0	0	1	1	0	0
1	1	0	0	0	0	1	1	1	0	0	1	1	0	0
0	1	1	0	0	1	1	0	0	1	1	0	1	0	1
0	0	1	1	0	1	1	0	0	1	1	0	1	0	0

(b)



(a)

Fig. 11. *Scale-of-4 counter stage—cyclic type:* (*a*) *block schematic. Units A are single-stage d.c. amplifiers. Biasing networks for the diodes are omitted;* (*b*) *input-output table*

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

(b)

States omitted in scale-of-3 stage

as the normal operate pulse sets these to '1 1', there is the possibility of a spurious pulse being produced.

Although this might be considered to be an improvement on the original arrangement in which the spurious pulse was certain to be produced as it was necessary to operate the monostable trigger circuit, in practice, the possibility of a spurious pulse caused as much trouble as the certainty and it was decided to make every effort to discover some other arrangement which would be free from this defect and would also, if possible, be more economical in equipment.

The problem was attacked by attempting to derive from the binary stage a more general form in which the count may be any integer.

As the latching counter is a double-pulse counter, a scale-of-n counter must have at least $2n$ stable states, since it must change state on the receipt of each pulse and it can be shown that all the states in an output cycle must be different. A scale-of-4 counter must therefore have at least eight states, which means that it must consist of at least three registers, each of which has two stable states. It is clear, therefore, that there is the possibility of constructing a scale-of-4 counter stage which will require one register less than the two binary stages normally used to give a count of 4.

The circuit and input-output table for such a scale-of-4 stage are given in Fig. 11. Each input pulse operates one register, the particular register being decided by the setting of the other two, so that, as in the case of the binary latching counter, no transient processes are involved in the operation. For the sake of greater clarity the d.c. biasing networks for the diodes have been omitted from the circuit diagram. The saving of one register is obtained at the expense of a considerable complication of the diode gates associated with the register and it would only be in exceptional circumstances, when the output waveforms of this counter happened to be well suited for the generation of the required gating waves, that it would be economical to employ it in preference to two binary stages in cascade. These circumstances did not exist in the case of the equipment under development but the use of this type of counter was, in any event, practically ruled out by the fact that it did not suit the unit system employed throughout the equipment.

Scale-of-4 counters of the type described above were not actually constructed, the reason for considering them in some detail being the hope that this would lead to a simple design of scale-of-3 counter. A scale-of-3 counter will still require three registers as two are just sufficient for a scale-of-2 counter stage. All that is necessary, therefore, is to rearrange the gating so that two of the eight possible stable states are omitted from the cycle. One way of doing this is indicated in Fig. 12, giving the input–output table and block diagram, the states omitted being shown on the scale-of-4 counter cycle diagram, Fig. 11.

The scale-of-3 stage proved to be very much simpler than the scale-of-4 stage from which it was derived. This was mainly owing to the fact that the register which, in the scale-of-4 case, made four transitions during an output cycle, now made only two. The arrangement of Fig. 12 is quite a practical one, requiring only the standard registers apart from the first, in which two diodes normally connected to a common terminal have to be separated. This involves, however, only a simple modification which could be made to all units, the commoning of the diode connections being effected externally when required. For the sake of uniformity, all the block and circuit diagrams from Fig. 8 on have been drawn on the basis of a four-terminal input, as described in Part 1. In fact, as explained there, it was not possible to provide a four-terminal input at that time. The separation of the two diodes required only one additional terminal, which was available.

Subject to the modification described above being acceptable, it appeared that this design of scale-of-3 counter stage met all the requirements for economy in equipment and circuit simplicity. It has one minor disadvantage, however, in that the output waveforms are not symmetrical. Although this does not prevent the generation of any desired gating pulses, it does add to the difficulty of understanding and illustrating the operation of the circuits.

As soon as it had become evident that symmetrical outputs were desirable, it was realized that there should be no difficulty in producing them and also that the resulting design of scale-of-3 counter stage was capable of simple extension to give scale-of-5, or indeed of any odd number. A generalized block diagram is shown in Fig. 13 together with cycle and waveform diagrams for this type of counter stage. All the registers now require split inputs, but this is not a disadvantage as it would still be necessary to modify all the units for the sake of uniformity, even if the design of Fig. 12 were to be adopted. It was accordingly decided to adopt the design shown in Fig. 13 for the scale-of-3 counter stage. For completeness, the corresponding design for a symmetrical counter stage dividing by an even number is given in Fig. 14. The normal binary latching counter is included in the scheme and it will be observed that a scale-of-4 counter stage operating on this principle requires the same number of registers as a two-stage binary counter having the same division factor.

Serious consideration of the scale-of-5 counter stage had been postponed until the design of the scale-of-3 stage had been determined. It followed automatically when the generalized version was finally derived. Fig. 13 indicates that a scale-of-5 counter stage of this type will require five registers of the same type as those used in the scale-of-3 stage. Although five registers are one more than the minimum number required for a scale-of-5 counter stage, the advantages of simplicity and uniformity were such that it was decided that the design of Fig. 13 would be used for the scale-of-5 as well as the scale-of-3 stage.

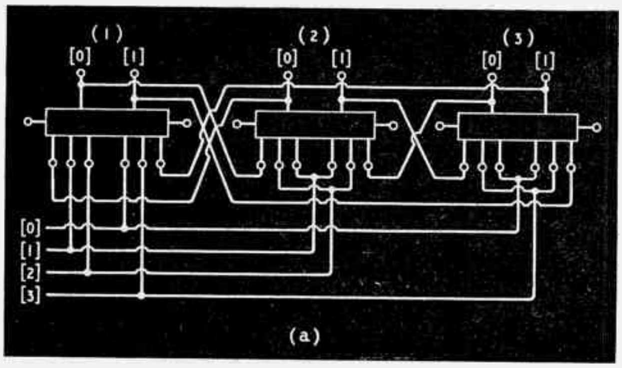
The non-binary stages of the main counter were accordingly modified to the new design and the necessary alterations made to the gate circuits. These modifications proved to be quite straightforward and the expected improvement in reliability was obtained. Fig. 15 shows a section of the main counter which includes both binary and non-binary stages.

With the conversion of the non-binary stages, the last of the conventional counters had been removed and this, as far as the particular equipment being developed was concerned, concluded the development of the latching counter.

Reset Feature

In many applications of counting chains it is necessary to reset some or all of the stages of a counter instantaneously to zero, or to an arbitrary count, at some

Fig. 12. *Scale-of-3 counter stage—cyclic type: (a) block schematic, (b) input-output table*



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

(b)

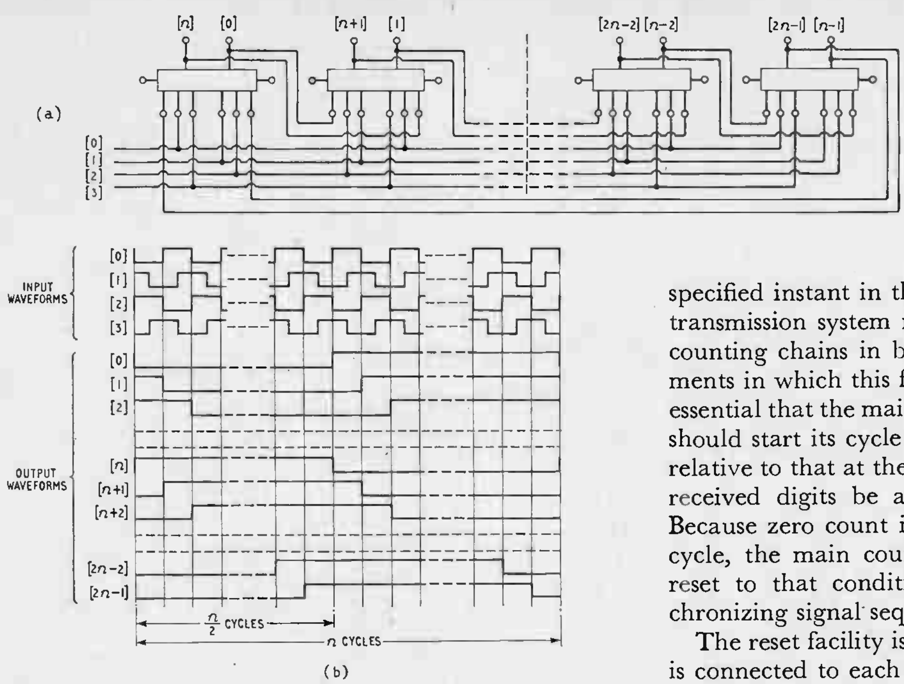


Fig. 13. Scale-of-n (odd) counter stage (4-phase drive): (a) block schematic, (b) waveforms and (c) input-output table

specified instant in the cycle of operations. In the data-transmission system mentioned earlier there are several counting chains in both encoding and decoding equipments in which this facility is needed. For example, it is essential that the main counter chain at the receiving end should start its cycle of operations at the proper instant relative to that at the transmitting end, in order that the received digits be accorded their proper significance. Because zero count is the most convenient point in the cycle, the main counter chain at the receiving end is reset to that condition on recognizing a special synchronizing signal sequence.

The reset facility is provided by an extra diode, which is connected to each grid circuit of a counter unit as in

n cycles; $n/2$ cycles

Inputs				Outputs											
[0]	[1]	[2]	[3]	[0]	[1]	[2]			[n]	[$n+1$]	[$n+2$]			[$2n-2$]	[$2n-1$]
0	1	1	0	0	1	1			1	0	0			0	0
0	0	1	1	0	1	1			1	0	0			0	0
1	0	0	1	0	0	1			1	1	0			0	0
1	1	0	0	0	0	1			1	1	0			0	0
0	1	1	0	0	0	0			1	1	1			0	0
0	0	1	1	0	0	0			1	1	1			0	0
1	0	0	1	0	0	0			1	1	1			1	0
1	1	0	0	0	0	0			1	1	1			1	0
0	1	1	0	0	0	0			1	1	1			1	1
0	0	1	1	0	0	0			1	1	1			1	1
1	0	0	1	1	0	0			0	1	1			1	1
1	1	0	0	1	0	0			0	1	1			1	1
0	1	1	0	1	1	0			0	0	1			1	1
0	0	1	1	1	1	0			0	0	1			1	1
1	0	0	1	1	1	1			0	0	0			1	1
1	1	0	0	1	1	1			0	0	0			1	1
1	1	0	0	1	1	1			0	0	0			1	1
0	1	1	0	1	1	1			0	0	0			0	1
0	0	1	1	1	1	1			0	0	0			0	1
1	0	0	1	1	1	1			0	0	0			0	0
1	1	0	0	1	1	1			0	0	0			0	0

(c)

(a)

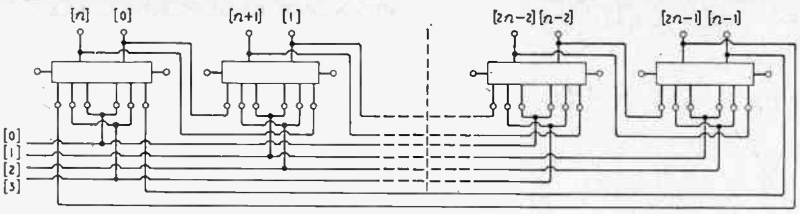
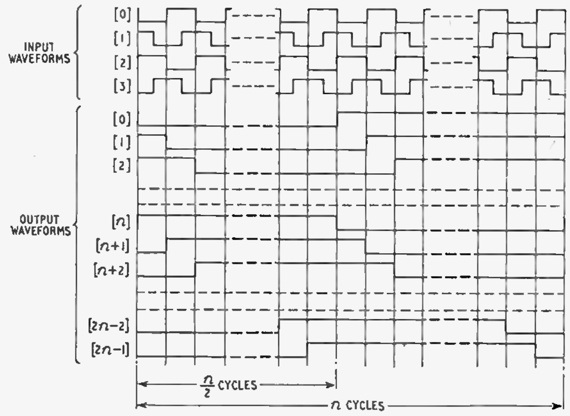


Fig. 14. *Scale-of-n (even) counter stage (4-phase drive): (a) block schematic (b) waveforms and (c) input-output table*



(b)

Fig. 8 (Part 1). Normally, the condition applied to the reset terminal is '0', which has no effect on the operation of the counter. However, when a '1' is applied, it overrides the effect produced by conditions existing at the other input terminals to the same grid and the valve on that side is made to conduct, if it is not already doing so. If the input to the grid of the opposite valve is in the inhibited state, owing to the presence of a '0' on any one or more of its normal input terminals, the resetting of the first valve to the conducting condition causes the second valve to be cut off.

When the reset condition is applied to a counter stage, the output state required must be consistent with conditions existing at the input. It is not possible, for

n cycles — $n/2$ cycles

Inputs				Outputs									
[0]	[1]	[2]	[3]	[0]	[1]	[2]		[n]	[$n+1$]	[$n+2$]		[$2n-2$]	[$2n-1$]
0	1	1	0	0	1	1		1	0	0		0	0
0	0	1	1	0	1	1		1	0	0		0	0
1	0	0	1	0	0	1		1	1	0		0	0
1	1	0	0	0	0	1		1	1	0		0	0
0	1	1	0	0	0	0		1	1	1		0	0
0	0	1	1	0	0	0		1	1	1		0	0
1	0	0	1	0	0	0		1	1	1		0	0
1	1	0	0	0	0	0		1	1	1		0	0
0	1	1	0	0	0	0		1	1	1		1	0
0	0	1	1	0	0	0		1	1	1		1	0
1	0	0	1	0	0	0		1	1	1		1	1
1	1	0	0	0	0	0		1	1	1		1	1
0	1	1	0	1	0	0		0	1	1		1	1
0	0	1	1	1	0	0		0	1	1		1	1
1	0	0	1	1	1	0		0	0	1		1	1
1	1	0	0	1	1	0		0	0	1		1	1
1	1	0	0	1	1	1		0	0	0		1	1
0	1	1	0	1	1	1		0	0	0		0	1
0	0	1	1	1	1	1		0	0	0		0	1
1	0	0	1	1	1	1		0	0	0		0	0
1	1	0	0	1	1	1		0	0	0		0	0

(c)

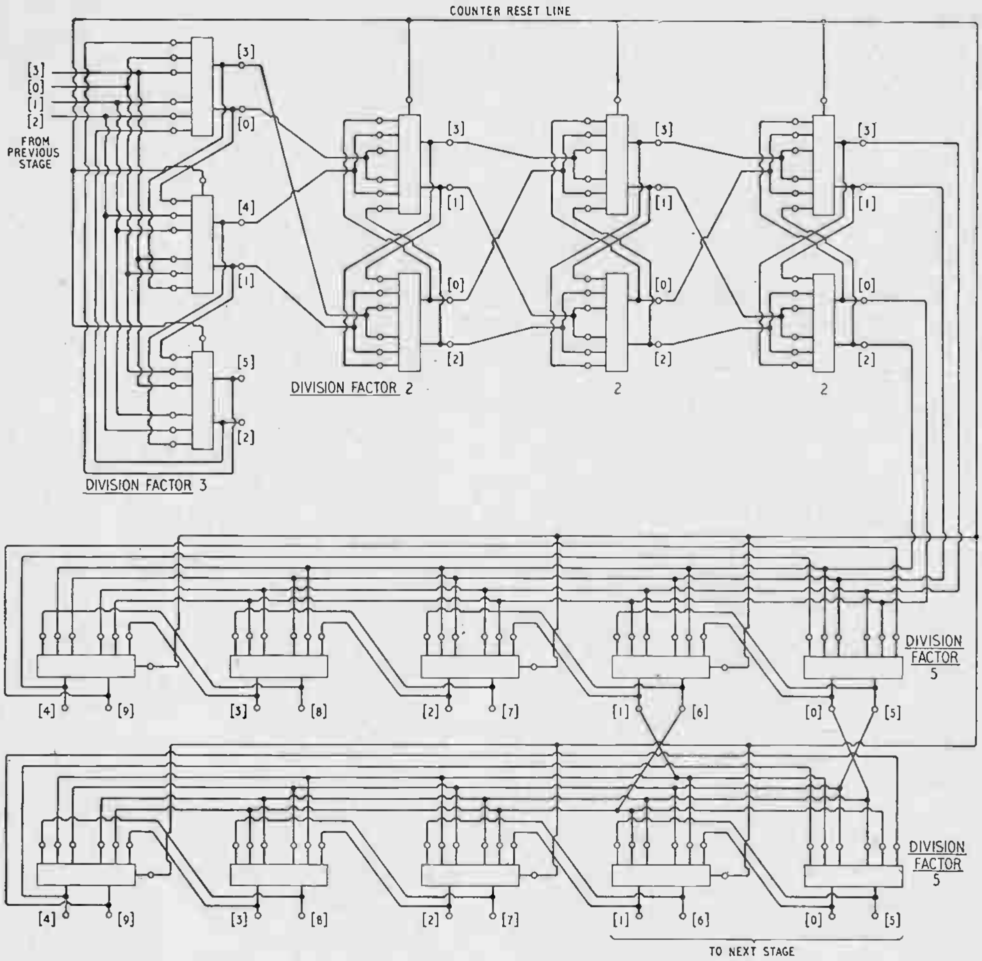


Fig. 15. *Latching-counter chain*

example, to reset the outputs of one half-section of a binary stage to '0' and '1' by the application of a '1' to the reset terminal on the side corresponding to the first output, if a '1' coincidence exists at the input terminals to the opposite side. In such an event both outputs would assume condition '0', since both valves would be made to conduct. This state would persist for as long as the reset condition was applied to one grid and the '1' coincidence existed at the other, after which either of the two possible states might result, depending on which condition was removed first.

When a counter is to be reset to a known condition, whether it is zero count or an arbitrary one, the states required from all the output terminals will be known for each stage. Each stage is consequently set to the required condition by applying reset pulses to the appropriate reset terminals, all stages generally being reset simultaneously. Where a 2-phase input to a stage is used, advantage may be taken of the fact that one input will be in condition '1', so that simply resetting the section of the stage inhibited by '0' will ensure that the other section is set automatically to the required condition, consistent with input polarities. In the 4-phase system, because both sections may be inhibited simultaneously, in the case of some stages, by input conditions '0, 0, 1, 1' or '1, 1, 0, 0' for the phase sequence [0], [1], [2], [3], in either case, it is necessary to reset both sections. This applies particularly to cases where the counter may be reset to an arbitrary count. When the count is zero or some other fixed count, all input conditions will be known and resetting need then only be applied to both sections of a stage when both sections are inhibited. The only minor disadvantage of this difference between the 2-phase counter and 4-phase counter is the increase in the loading of the resetting source.

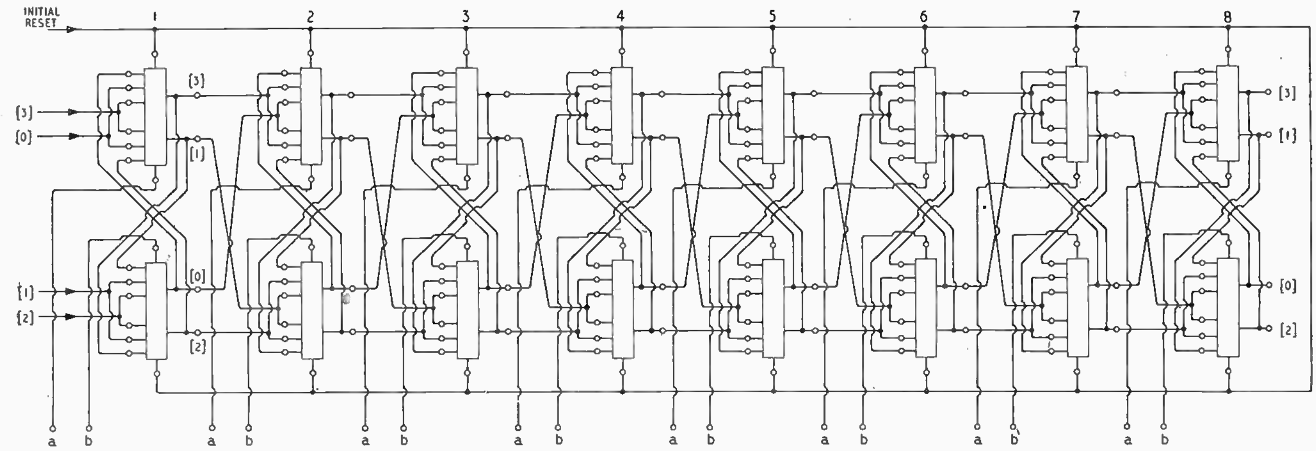
In the foregoing paragraphs only binary stages have been considered, but the same principles apply for non-binary counter stages. As in the case of a binary stage, so with non-binary stages, advantage may be taken of a '1' coincidence, during the resetting to a known count, to reset a section of a stage to the required state and thereby reduce the loading of the resetting source. Where this input condition does not exist, as may happen in the 4-phase system, all sections of the non-binary stage have to be reset.

In another application, the reset facility affords a means for injecting a signal sequence, representing a binary number, digit by digit into a binary counter, each digit being injected into the appropriate stage in accordance with its significance in the number. In this operation, each stage is reset to one of the two conditions '0, 1, 1, 0' or '1, 0, 0, 1' corresponding to digits '0' or '1' respectively. A counter of this type is employed in the data-transmission system being developed as a means for digital-to-analogue conversion. In such a circuit, because it is not known which half-section of a stage may be inhibited by the outputs from the previous stage, it is necessary to reset both for each stage and allow the input conditions to make any necessary change when the reset pulses are removed. In the case of a binary stage this change, if it occurs, will always involve a reversal of output polarities for phases [1] and [3]. In the 2-phase system, if a '1' exists in any one stage, the two conditions mentioned earlier, which normally correspond to digits '0' and '1', become modified for the following stage to '0, 0, 1, 1' or '1, 1, 0, 0', respectively, on removal of the reset pulses.

The case wherein both half-sections are inhibited during resetting, such as may happen in the 4-phase system, presents a difficulty, since it is not known whether the condition in which the stage is left, when the reset pulse is removed, is consistent with the input conditions. This ambiguity arises from the fact that two inhibit periods exist per cycle of the input waveforms. The output conditions of the stage which are consistent with the input conditions during the inhibit periods are those which are consistent during the active periods immediately preceding those periods. The difficulty could be overcome by providing a means for recognizing the input conditions during an inhibit period and resetting the sections of the counter stage accordingly.

The unavoidable circuit complications which would follow such a course would result in the 4-phase system being at a considerable disadvantage when compared with the 2-phase system, in which no simultaneous inhibit period exists and therefore no similar resetting difficulty.

An alternative solution, which involves no great increase in circuit complexity but demands that the sequence of digits be injected into the counter chain in descending order of significance, is illustrated in Fig. 16, together with a table showing the sequence of events which take place as each digit is injected into the eight-stage counter. Fig. 17 illustrates a similar operation in a 2-phase system. The only increase in circuit complexity for the 4-phase system is the means for resetting initially all stages so that their outputs inhibit the succeeding stages. In the 2-phase system, it is essential to inject the digits in ascending order of significance to avoid the possibility of two corrections being applied from one stage to the next, instead of a permissible one. This possibility does not exist in the 4-phase system owing to the inhibit condition which is made use of in the resetting operation. It should be noted that the output conditions shown in the two tables are those which exist after the removal of reset pulses and any changes which occur due to inconsistency with input conditions are accounted for in the results quoted.



a)

Stage	Conditions required (Stage read at [0] phase)
1	0
2	1
3	1
4	0
5	1
6	0
7	1
8	1

(b)

Fig. 16. *Decoding counter chain (4-phase drive): (a) block schematic, (b) input table and (c) output table. Note.* '1' *on terminal 'a' resets stage to* '1'; '1' *on terminal 'b' resets stage to* '0'

Operation	Inputs				Stage 1				Stage 2				Stage 3				Stage 4				Stage 5				Stage 6				Stage 7				Stage 8				Remarks
	[0]	[1]	[2]	[3]	[0]	[1]	[2]	[3]	[0]	[1]	[2]	[3]	[0]	[1]	[2]	[3]	[0]	[1]	[2]	[3]	[0]	[1]	[2]	[3]	[0]	[1]	[2]	[3]	[0]	[1]	[2]	[3]	[0]	[1]	[2]	[3]	
Initial reset to inhibit condition	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	—
Set 1 into stage 8	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	0	0	1	—
Set 1 into stage 7	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	0	0	1	1	1	0	0	Stage 7 resets stage 8
Set 0 into stage 6	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	0	1	1	0	1	0	0	1	1	1	0	0	—
Set 1 into stage 5	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	0	0	1	0	0	1	1	1	0	0	1	1	1	0	0	Stage 5 resets stage 6
Set 0 into stage 4	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	0	1	1	0	1	0	0	1	0	0	1	1	1	0	0	1	1	1	0	0	—
Set 1 into stage 3	1	1	0	0	1	1	0	0	1	1	0	0	1	0	0	1	0	0	1	1	1	0	0	1	0	0	1	1	1	0	0	1	1	1	0	0	Stage 3 resets stage 4
Set 1 into stage 2	1	1	0	0	1	1	0	0	1	0	0	1	1	1	0	0	0	0	1	1	1	0	0	1	0	0	1	1	1	0	0	1	1	1	0	0	Stage 2 resets stage 3
Set 0 into stage 1	1	1	0	0	0	1	1	0	1	0	0	1	1	1	0	0	0	0	1	1	1	0	0	1	0	0	1	1	1	0	0	1	1	1	0	0	—

(c)

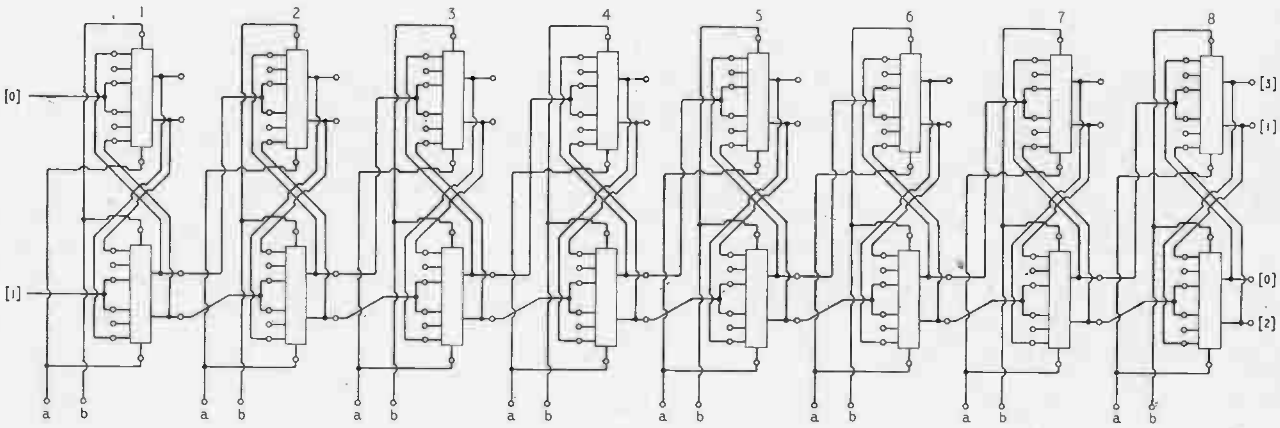
Transistors in Latching Counters

When work on a new equipment employing techniques similar to those described in Part 1 was initiated, it was decided that the development of the transistor had reached the stage at which it would be reasonably safe to use it. The designing of the equipment commenced on the basis that valves would only be used in situations where transistors would not meet the requirements. It was hoped that a considerable reduction in the size and power consumption of the equipment would be achieved and ultimately a significant improvement in reliability, as it was believed that by the time the equipment went into production transistors would have a very much lower catastrophic failure rate even than the 'reliable' series of valves.

After some consideration of the possibilities it was decided not to imitate the valve circuits used in the previous equipment but to employ instead current-switching techniques appropriate to the transistor, which is essentially a current amplifier.

Of the three possible transistor connections, the common-emitter is the only one which gives a phase reversal. Such a logical element is necessary and, in consequence, some common-emitter stages must be used. In addition, it can give both current and voltage gain so that it can be used alone in an extensive system working at constant levels maintained by limiting. As there did not appear to be any substantial advantage to be gained by the introduction of a proportion of common-base or common-collector stages, it was decided to use only the common-emitter connection in the digital section of the equipment.

The development of the basic current-switching circuits is illustrated in Fig. 18 in which, for the sake of clarity, component and supply voltage values appropriate to the currently available low-frequency transistors have been inserted. In Fig. 18 (a), the 47-kΩ resistor passes a current of about 200 μA which is substantially independent of the setting of the switch. If the switch is open, this current flows out of the transistor base connection and the transistor, which has a minimum gain of 30, will



(a)

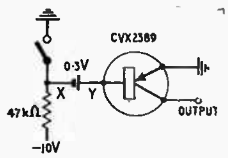
Stage	Initial Arbitrary Count	Final Required Count
1	1	0
2	0	1
3	1	1
4	1	0
5	0	1
6	0	0
7	1	1
8	0	1

(b)

Fig. 17. *Decoding counter chain (2-phase drive): (a) block schematic, (b) input table and (c) output table. Note.* '1' *on terminal 'a' resets stage to* '1'; '1' *on terminal 'b' resets stage to* '0'

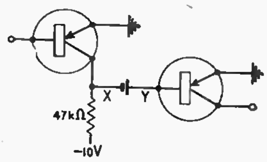
Operation	Inputs		Stage 1				Stage 2				Stage 3				Stage 4				Stage 5				Stage 6				Stage 7				Stage 8				Remarks
	[0]	[1]	[0]	[1]	[2]	[3]	[0]	[1]	[2]	]3]	[0]	[1]	[2]	[3]	[0]	[1]	[2]	[3]	[0]	[1]	[2]	[3]	[0]	[1]	[2]	[3]	[0]	[1]	[2]	[3]	[0]	[1]	[2]	[3]	
Initial Arbitrary Count	0	1	1	0	0	1	0	0	1	1	1	0	0	1	1	1	0	0	0	0	1	1	0	1	1	0	1	0	0	1	0	0	1	1	—
Set 0 into stage 1	0	1	0	1	1	0	1	0	0	1	1	1	0	0	1	1	0	0	0	0	1	1	0	1	1	0	1	0	0	1	0	0	1	1	Stage 1 resets stage 2 Stage 2 resets stage 3
Set 1 into stage 2	0	1	0	1	1	0	1	0	0	1	1	1	0	0	1	1	0	0	0	0	1	1	0	1	1	0	1	0	0	1	0	0	1	1	—
Set 1 into stage 3	0	1	0	1	1	0	1	0	0	1	1	1	0	0	1	1	0	0	0	0	1	1	0	1	1	0	1	0	0	1	0	0	1	1	Stage 2 resets stage 3 for the second time
Set 0 into stage 4	0	1	0	1	1	0	1	0	0	1	1	1	0	0	0	0	1	1	1	0	0	1	0	0	1	1	1	0	0	1	0	0	1	1	Stage 3 resets stage 4 Stage 4 resets stage 5 Stage 5 resets stage 6
Set 1 into stage 5	0	1	0	1	1	0	1	0	0	1	1	1	0	0	0	0	1	1	1	0	0	1	0	0	1	1	1	0	0	1	0	0	1	1	—
Set 0 into stage 6	0	1	0	1	1	0	1	0	0	1	1	1	0	0	0	0	1	1	1	0	0	1	0	0	1	1	1	0	0	1	0	0	1	1	Stage 5 resets stage 6
Set 1 into stage 7	0	1	0	1	1	0	1	0	0	1	1	1	0	0	0	0	1	1	1	0	0	1	0	0	1	1	1	0	0	1	0	0	1	1	—
Set 1 into stage 8	0	1	0	1	1	0	1	0	0	1	1	1	0	0	0	0	1	1	1	0	0	1	0	0	1	1	1	0	0	1	1	1	0	0	Stage 7 resets stage 8

(c)



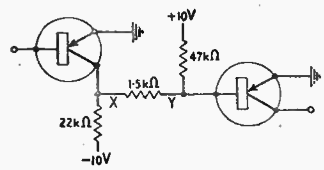
Switch	Voltage at	
	X	Y
Open	− 0·4	− 0·1
Closed	0	+ 0·3

(a)



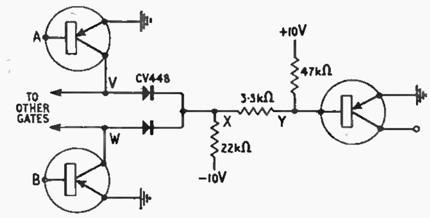
Driving Transistor	Voltage at	
	X	Y
Cut off	− 0·4	− 0·1
Bottomed	− 0·1	+ 0·2

(b)



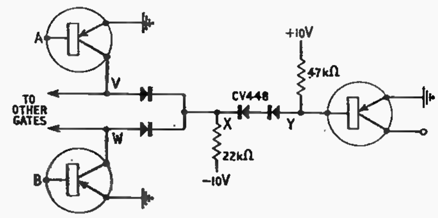
Driving Transistor	Voltage at	
	X	Y
Cut off	− 0·7	− 0·1
Bottomed	− 0·1	+ 0·2

(c)



Driving Transistors		Voltage at			
A	B	V	W	X	Y
Cut off	Cut off	− 1·3	− 1·3	− 1·3	− 0·1
Bottomed	Cut off	− 0·1	− 0·4	− 0·4	+ 0·2
Cut off	Bottomed	− 0·4	− 0·1	− 0·4	+ 0·2
Bottomed	Bottomed	− 0·1	− 0·3	− 0·4	+ 0·2

(d)



Driving Transistors		Voltage at			
A	B	V	W	X	Y
Cut off	Cut off	− 0·7	− 0·7	− 0·7	− 0·1
Bottomed	Cut off	− 0·1	− 0·4	− 0·4	+ 0·2
Cut off	Bottomed	− 0·4	− 0·1	− 0·4	+ 0·2
Bottomed	Bottomed	− 0·1	− 0·1	− 0·4	+ 0·2

(e)

Fig. 18. *Transistor switching circuits*

always bottom, provided that the current flowing into the output terminal does not exceed 7 mA. If the switch is closed, the current flows to earth and a potential of + 0·3 V is applied to the transistor base, cutting it off. The current required to cut off the transistor, which may amount to 10 μA at 25°C, is supplied by the battery.

Looking in at the output terminal, the device is seen to act as a switch which is open when the transistor is cut off and closed to earth or, more exactly, to the bottoming potential which is about 0·1 V negative, when the transistor is bottomed. If, therefore, the switch in Fig. 18 (a) is replaced by a transistor as in Fig. 18 (b), the operation is the same except for the effect of the finite bottoming potential of the driving transistor, which reduces the bias on the base to 0·2 V which, however, is still sufficient to ensure that cut-off will occur.

In a practical system the positive bias for all the transistors must be obtained from a common supply. In Fig. 18 (c) the battery is replaced by the voltage dropped across a series resistance fed with a constant current derived from a 10-volt positive supply. As the resistor from the negative line now has to accept the current flowing through the 47-kΩ resistor from the positive line as well as the current required to bottom the transistor, it is reduced to 22 kΩ, which means that the driving transistor has to accept twice the current when bottomed. In addition, its collector potential rises to 0·7 V instead of 0·4 V when it is cut off, owing to the additional voltage drop in the 1500-Ω resistor when it is carrying the current taken by the 22-kΩ resistor.

When operating as part of a complete digital system, the basic circuit of Fig. 18 (c) must be capable of accepting inputs from diode coincidence circuits and of feeding a number of such circuits from its output terminal. In Fig. 18 (d) is shown a 2-input gate circuit. In this circuit the forward voltage drop of the input diodes, about 0·3 V, makes it necessary to increase the value of the series bias resistor to 3300 Ω, which results in the driving transistors having a collector potential of about 1·3 V negative when they are both cut off.

Although the circuit of Fig. 18 (d) is quite satisfactory, it can be improved by substituting a non-linear resistance for the 3300-Ω bias resistor and thereby reducing the change in bias voltage which occurs on switching. The most readily available non-linear resistance having suitable characteristics is the CV448 point-contact germanium diode, which has a forward voltage drop of about 0·3 V at the current levels used. Two in series provide a bias of 0·6 V, which results in the driving transistors having a collector potential of about 0·7 V negative when both are cut off. With this arrangement, gate circuits having any number of inputs likely to be required can easily be constructed, as the low reverse voltages to which the diodes are subjected reduce greatly both the leakage currents and the effects of stray capacitance. As the switching current required at each input is about 450 μA, each output can be connected to fifteen inputs, which is considerably in excess of the probable requirements, so that it should never be necessary to provide an additional amplifier merely to increase the available output.

A register, or half latching counter, operating on the same principles as the gate circuit described above is illustrated in Fig. 19. It is the transistor equivalent of the latching counter half-section shown in Fig. 8. The operation is basically the same as that of the equivalent valve circuit and hence does not need detailed description. A few points are worth noting, however. The diodes D_1 and D_{10} correspond to the biasing diodes in the gate circuit of Fig. 18 (e) and carry current continuously. Only one is required in each base lead because the voltage drops across the diodes D_2, D_3, D_4, D_{11}, D_{12} and D_{13} are approximately cancelled by the drops across diodes D_5, D_6, D_7, D_8, D_{15}, D_{16}, D_{17} and D_{18}. The circuit also differs from the gate circuit in that the current into the base of the transistor may have a value equal to twice or three times the nominal bottoming current depending on the input conditions. This is a consequence of the more complex logical requirements of the circuit and cannot be avoided without a very considerable increase in complexity. As the additional current is well within the rating of the base and is insufficient to cause hole-storage trouble, it was not considered objectionable and the arrangement shown is accepted as the standard one where 'and' gates operating on cut-off inputs are required.

The registers described have been employed in a latching-counter chain counting down from 100 kc/s and also for other purposes. When constructed with low-frequency transistors they operate reliably up to an input frequency of about 50 kc/s and are perfectly satisfactory for simple counting. For frequencies above 50 kc/s, or if it is intended to use the counter to generate pulses having precise timing at lower frequencies, it is necessary to have high-frequency transistors. If these have a minimum current gain of 30, the performance of the high-frequency registers will be exactly the same as that of the low-frequency registers, apart from the scaling up in frequency. The low permissible collector voltage, which is a feature of the high-frequency transistor, is not objectionable as the collector potential is not likely under any circumstances to exceed 1 V. If, however, high-frequency transistors having a current gain of 10 are used, the output from a register will be insufficient to drive a scale-of-5 counter stage. This difficulty can be overcome by decreasing the 22-kΩ negative-feed resistors to, say, 10 kΩ, thus increasing the ratio of effective to total input current. However, it is probably better to standardize on 22 kΩ and use high-frequency transistors having a gain of 30, even though these are somewhat more expensive and difficult to obtain, as this means that the high-frequency units can be used in place of the low-frequency ones so that only one type of spare need be carried. In addition, the high-frequency stages of the counter will be able to supply the standard number of inputs.

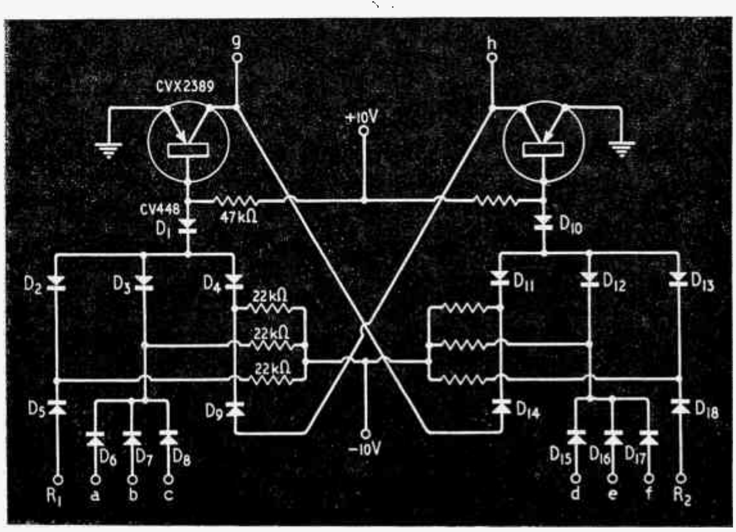
For ease of construction and compact assembly each register is constructed on a synthetic resin varnished paper card which is mounted vertically on a frame. As it was expected that the reliability obtained would be very high, it was decided that it was not worth while using plug-in units and all the cards in the experimental equipment are permanently wired. This in itself should further increase the reliability and it is hoped that failures will be sufficiently rare to justify the provision of only the simplest monitoring facilities.

General Observations

Although a considerable bibliography on counters had been accumulated, it was not until after the development of the latching counter had been completed that any reference to it was found in the literature. It was then discovered that there was a complete account of the principles on which it is based in "Annals of the Computation Laboratory of Harvard University"[5], Vol. 27. In this, the name 'double pulse counter' was used. The article quoted did not attract much attention at the time of publication, probably because it was written before germanium diodes suitable for use in switching circuits were generally available. The circuits described, therefore, made use of triode and pentode gates, which meant that the number of valves required was excessive.

There do not appear to have been any further publications on the latching counter itself but there have recently been published a number of papers dealing with

Fig. 19. *Transistor register*



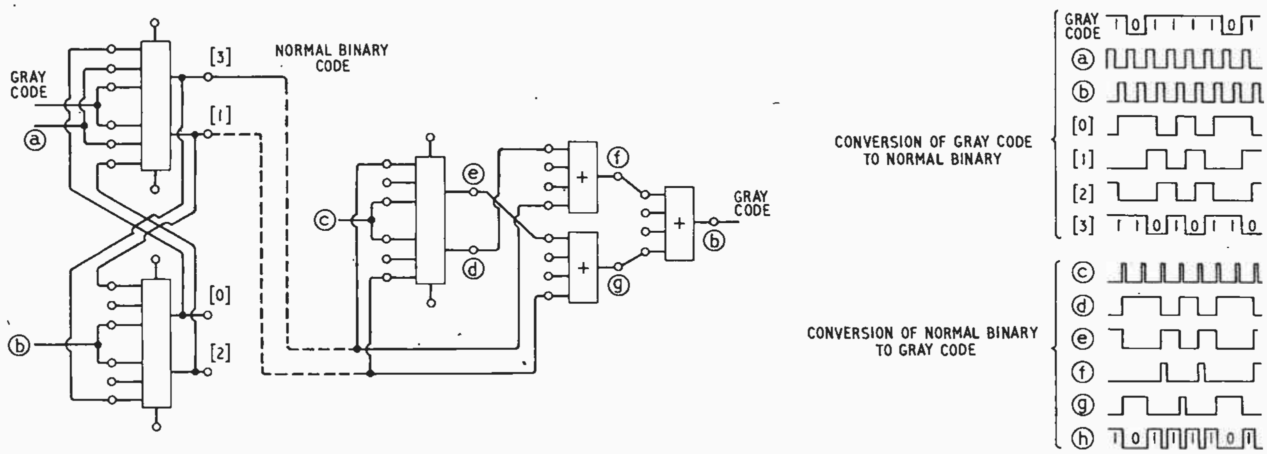


Fig. 20. *Cyclic binary code conversion*

switching circuits in which the idea of the latching counter is implicit. The most recent is "A Method for Synthesizing Sequential Circuits"[4] by G. M. Mealy in the *Bell System Technical Journal*, September 1955, which contains a short bibliography. An earlier paper, which was overlooked at the time and has only recently come to the notice of the authors, was published by W. H. Ware in the *Proc. Inst. Radio Engrs*, Computer Issue, October 1953, entitled "The Logical Principles of a New Kind of Binary Counter"[3]. The counter described therein bears a resemblance to a 2-phase operated latching counter and it is interesting to note that here again the author appears to have been unaware of the earlier work carried out by Harvard University Computation Laboratory.

Conclusions

The foregoing description of the latching counter has inevitably been coloured by the requirements of the equipment in which it is used, an equipment which was in an advanced stage of development before the need for a new design of counter stage became evident. It is probable, however, that even if the equipment and the counter had been developed together the result would not have been greatly different. The only radical change which could have been made without any appreciable change in the size or complexity of the counter would have been the replacement of pairs of binary stages by scale-of-4 stages. There is no reason to believe that any real advantage would have been obtained by such a change. It is just possible that the three additional registers required for a scale-of-9 stage, in place of the two scale-of-3 stages, would have been more than saved by a reduction in the size of the gating circuit equipment, but against this must be set the disadvantage of the longer loop in the main counting chain. A similar change to scale-of-25 in place of the two scale-of-5 stages would have been ruled out by the considerable increase in the number of registers required; i.e., twenty-five instead of ten.

The minimum-register counter stages, having counts of the form $N = 2^n$, where n is any integer, are of interest because they can by suitable choice of terminals be arranged to present their counts in the cyclic binary code. If this were required, they might be employed in preference to the normal system in which the straight binary scale is converted to cyclic binary by means of a set of diode reversing switches provided that no more than five or six digits were needed. It was because of this property that they were named 'cyclic counters' (see also Appendix).

The minimum-register counter stages having counts other than powers of two may be arranged to present their outputs in the truncated cyclic binary code which is sometimes used in shaft-position coding systems and, if this were a requirement, they might also be employed on a limited scale in such systems.

In view of its disadvantages the reset binary counter would not be seriously considered unless the count required were a large prime number. Even in this case, however, it is probable that some compromise between the cyclic and ring counter could be reached in which a considerable reduction in the number of registers could be achieved at the cost of only a moderate increase in complexity.

During the development of the remainder of the equipment considerable experience was gained with the latching counter circuits and ample opportunities arose for observing their behaviour. Towards the end of the development attempts were made, at the expense of some inconvenience, to record faults which occurred and the times required to locate and eradicate them. Records were kept for a period of some 1,800 hours during which average availability figures of 98% and 95% were obtained for the encoding and decoding equipments, in spite of continuous modifications to other circuits. The lower figure for the latter is due to its greater complexity and consequent longer fault-localizing time. The availability figure for the counter chains in both equipments taken over the 1,800-hour period was better than 99·5%.

The reliability and maintenance line records for the experimental equipment employing transistors should be of considerable interest in due course, as it is a disadvantage of the current-switching system that the voltage waveforms at the input and output terminals are not easy to interpret. It will therefore be a severe test for the supposition that reliability can be made sufficiently high that the provisioning of fault-locating and maintenance facilities becomes of secondary importance.

In conclusion, it is considered that the improved performance achieved by the use of the double-pulse counter, in spite of its increased complexity compared with that of the single-pulse counter, suggests that the use of the latter in clock-controlled complex digital systems should be restricted to applications where economy of space and equipment is of paramount importance.

Acknowledgements

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APPENDIX

Use as a Gray Code Counter

The latching counter may be used for generating the cyclic permuting, or Gray, code, which is sometimes used in shaft-position coding systems. This code is generated simultaneously with the normal binary code by a binary latching-counter chain. While the normal code is obtained by reading the phase [0] outputs, the Gray code may be obtained from the phase [3] outputs, with phase [0] for the last stage, which gives the most significant digit. This is illustrated by Fig. 16, which shows how a binary number 11010110 is injected into an eight-stage binary counter. Reading the phase [3] outputs, except that for the first stage, together with phase [0] for the last stage gives, in descending order of significance, 10111101, which may be verified as being the equivalent number in the Gray code.

The conversion of the Gray code to the normal binary code, when the digits are in serial form, may be effected by making use of a single binary latching-counter stage, the output being taken from phase [3]. The order of the digits must be with the most significant digit first. The circuit and conversion of the typical number quoted above are illustrated in Fig. 20, together with the reverse operation, which is achieved by making use of a latching-counter half-section as a shift register and three gating amplifiers of the type shown in Fig. 3. Since the pulse defining the amount of shift must occur before the end of a digit period, the '1' digits at the output are shortened but, for most applications, this is of little or no consequence.

REFERENCES

[1] R. H. Barker, "A Transducer for Digital Data Transmission Systems", *Proc. Instn Elect. Engrs*, Paper No. 1905M, January 1956, Vol. 103B, p. 42.
[2] R. M. Brown, "Some Notes on Logical Binary Counters", *Trans. Inst. Radio Engrs on Electronic Computers*, June 1955, EC4, No. 2, p. 67.
[3] W. H. Ware, "The Logical Principles of a New Kind of Binary Counter", *Proc. Inst. Radio Engrs*, Computer Issue, Paper No. 4713, October 1953, Vol. 41, No. 10, p. 1429.
[4] G. H. Mealy, "A Method of Synthesizing Sequential Circuits", *Bell Syst. Tech. J.*, September 1955, p. 1045.
[5] "The Synthesis of Electronic Switching Circuits", *The Annals of the Computation Laboratory of Harvard University*, 1951, Vol. 27.

Negatively-Biased Multivibrator

STABLE CIRCUIT WITH VOLTAGE CONTROL OF FREQUENCY

By A. Bar-Lev*

SUMMARY. *A multivibrator with its grid returned to a negative bias is described and its operation analysed. The effects of the bias on frequency and wave-shapes are discussed. It is shown that a linear relationship between the frequency and bias voltage, extending over a frequency ratio of more than five to one in the audio range, may be achieved.*

The frequency stability of a negatively-biased multivibrator is found to be high and so it may be used as a variable-frequency source, a source of special wave-shapes or be frequency-modulated.

The fixed-biased multivibrator (f.b.m.) circuit and its operation have been known for a long time and are described in many textbooks[1]. In such multivibrators the grid resistors are returned to a fixed positive voltage or, as is more usual, to the cathodes. The characteristics of a multivibrator with its grids returned to a variable positive voltage, the so-called positive bias multivibrator (p.b.m.) were described by Bertram[2], who showed that for certain values of the circuit parameters the p.b.m. has a nearly linear frequency versus bias-voltage relationship. The linearity was found to be dependent on the value of the unbypassed cathode resistors. In this paper the operation, wave-shapes and characteristics of a negatively-biased multivibrator (n.b.m.) are described and analysed. Such a multivibrator has been neglected up to now. Its operation and characteristics are very different from the f.b.m. or p.b.m. (both of which operate in the same way). Its frequency may be made to vary linearly, statically or dynamically, with the negative bias and it has almost constant amplitude. It also has special wave-shapes and operates with almost no grid current and so does not load the bias source, which may be of high impedance.

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Operation of the F.B. or P.B. Multivibrator

In these free-running multivibrators one of the valves, let us say V_1 in Fig. 1, conducts, while V_2 is cut-off. This state does not change till the grid voltage of V_2 [e_g in Fig. 2(b)] reaches the cut-off value—e_{g1}. V_2 now starts conducting, the potential of point 2,

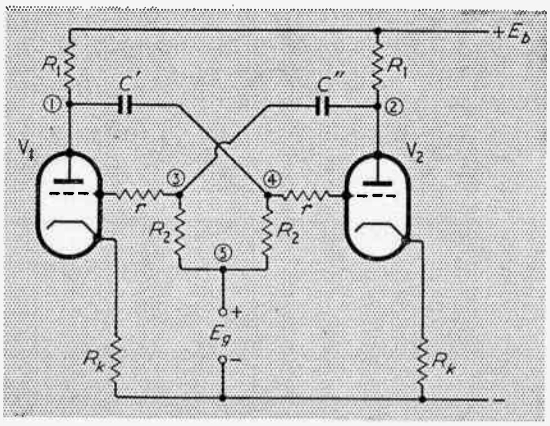


Fig. 1. *Positive-bias multivibrator (p.b.m.)*

Fig. 1, goes down and because of the coupling capacitor C'' the potential at point 3 goes down too which, in turn, makes point 1 more positive and point 2 still more negative, and very quickly this cumulative action brings about a flip-over in the circuit. V_2 is now fully conducting while V_1 is cut-off. Point 1 potential jumps from a low positive value, e_{b0} which corresponds to zero grid-voltage [Fig. 2(a)] towards E_b, corresponding to below cut-off grid-voltage. The sharp end of the jump is modified by an exponential arc due to the charging current of C' through R_1 and the grid–cathode resistance r (with the grid positive). The high-frequency case where this effect has special importance is not dealt with here and may be found in the literature.

The half-period of the f.b.m. and p.b.m. depends only upon the time taken by the coupling capacitor C to discharge through R_2 in series with R_1 and the valve anode resistance r_a in parallel. In the p.b.m. the voltage across C was E_b just before flip-over and the next flip-over would occur when C had discharged down to $e_{b0}-E_g$ (Fig. 2). The higher the positive bias $+E_g$ is, the less time it will take C to discharge and the shorter the period. Bertram[2] has shown that an almost linear frequency–positive bias relationship can be obtained when using cathode degeneration (R_k in Fig. 1).

It should be noted here that in the p.b.m. the conducting valve has almost no control whatsoever on the flip-over moment while, as will be seen later, it is the other way round in the n.b.m.

The Negatively-Biased Multivibrator

The operation of the n.b.m., which has its grids returned to a negative bias $-E_g$ (Fig. 3) will now be explained.*.

In Fig. 3 r' and r'' represent the grid–cathode resistances (with a positive grid). Let us start our examination at the moment V_1 is starting to conduct and investigate its grid voltage [Fig. 4(a), between the indicated times t_a to t_c].

At time t_a this grid has reached cut-off voltage $-e_{g1}$, V_1 starts conducting and the same commulative action as in the p.b.m. case causes V_2 to cease conduction, its anode voltage makes a positive jump towards $+E_b$ and because of C'' (Fig. 3) this jump is transferred to V_1 grid which becomes slightly positive. But in contrast to the p.b.m. it will not stay positive for long. Capacitor C'' starts to charge through R_1'' and the small grid–cathode resistance r' (which effectively shunts R_2'' as long as the grid stays positive†).

This charging of C'' does not stop as the voltage across C'' becomes $+E_b$ and V_1 grid voltage reaches zero but continues towards a value of $E_b + E_g$ across C'' and $-E_g$ for the grid potential (as is apparent from Fig. 3 when V_2 is cut-off). At time t_b, when the grid voltage passes through zero and becomes negative, r' will become infinite and C'' will continue to charge through R_1'' and R_2'' in series. This continues up to a time t_c, when conduction of V_1 ceases (on what t_c depends, we shall see later). Since C'' is charging towards a higher voltage ($E_b + E_g$) than in the p.b.m. case (then it is $E_b - E_g$) the grid will reach zero voltage quicker and

* R_1'; C'; R_2'; r' in Fig. 3 have the same values respectively as R_1''; C''; R_2''; r''. The distinction is made in order to facilitate reference to different circuits.

† Since $r' \ll R_1''$ the grid can become only slightly positive and most of the voltage drop, caused by the charging current of C'', is across R_1'' and modifies V_2 anode voltage jump towards $+E_b$ by an exponential arc. It is the same in a p.b.m. but, as will be shown later, this modification is much less pronounced in a n.b.m.

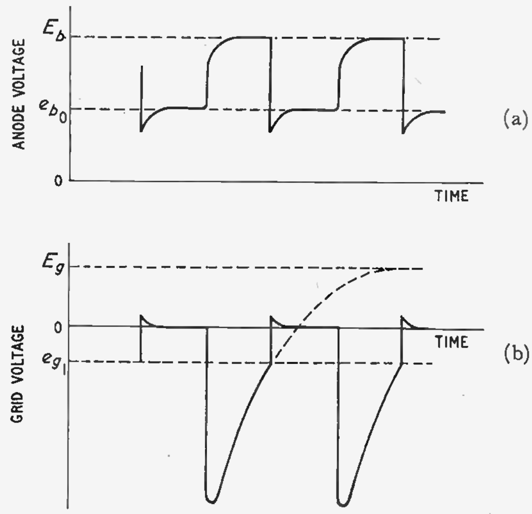


Fig. 2. *Wave-shapes for the p.b.m.*

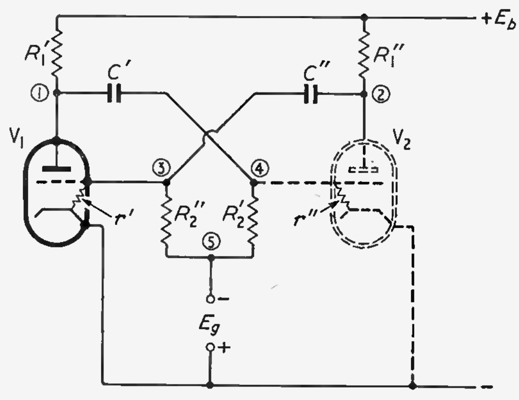


Fig. 3. *The negatively-biased multivibrator (n.b.m.) circuit with V_2 in a cut-off state*

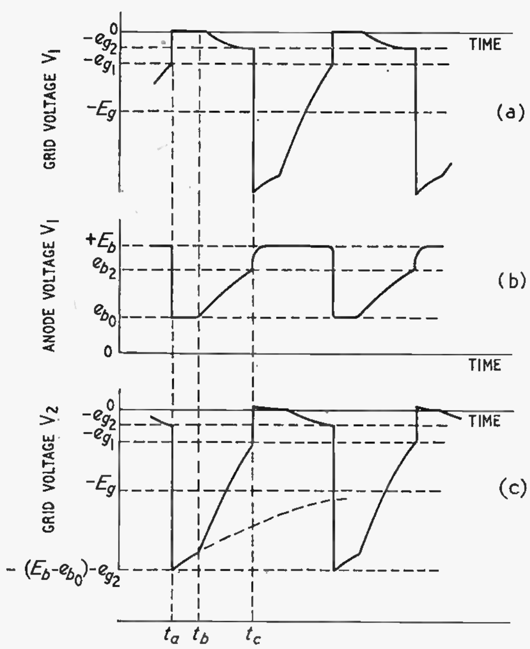


Fig. 4. *Wave-shapes for the n.b.m.*

then, since usually $R_1'' \ll R_2''$, most of the voltage drop due to the charging current will be across R_2''. The modification of V_2 anode voltage mentioned in the second footnote will therefore last for a shorter time and be much less pronounced than in p.b.m. where r' always shunts R_2'' during the conduction period (compare Figs. 6 and 7).

The anode voltage of V_1 during the same period t_a to t_c is shown in Fig. 4(b). Since $R_1' \ll R_2'$, C' and R_2' have almost no influence on this anode voltage which depends on R_1' alone. Between t_a and t_b V_1 grid voltage was very nearly zero and we may look upon its anode voltage as staying at a fixed value e_{b0} determined by E_b, R_1, and the appropriate anode characteristic. After t_b, the grid voltage becomes negative and is given by

$$e''_g = +E_g\left[1 - \exp.\left\{-\frac{t - t_b}{C''(R_1''+R_2'')}\right\}\right]$$

(See Appendix, Equ. 3.)

and causes the conducting anode voltage to become more positive according to a similar curve but amplified by the valve. This positive anode voltage change, acting through C' on the grid of the cut-off valve V_2, is one of the main factors determining the exact moment t_c when this grid will reach cut-off potential $-e_{g1}$ and cause a flip-over in the circuit. This is a major difference between a n.b.m. and other multivibrators where the flip-over moment is determined by the cut-off valve grid circuit alone.

Let us now examine in detail the cut-off grid voltage shown in Fig. 4(c). The negative jump at t_a is caused by the starting conduction of V_1, acting upon this grid through C', and is equal to $E_b - e_{b0}$ volts. Capacitor C' then starts to discharge through R_2' in series with the parallel combination of R_1' and the conducting valve resistance for zero grid voltage. The rate of discharge is slowed down by the presence of $-E_g$. Were $|E_g| > |e_{g1}|$, as in Fig. 4(c), the cut-off grid would never have reached $-e_{g1}$ [it would rise according to the broken line in Fig. 4(c)] but for the action of the conducting-anode voltage-rise which begins at t_b and is passed on to it through C'. The slope of the grid wave-shape becomes steeper and depends on $-E_g$, the time constant of discharge (which for a large R_2', is practically $C'R_2'$) and the anode-voltage wave-shape of the conducting valve. The cut-off grid voltage wave-shape is calculated in the Appendix, the results of which are shown in Fig. 4. At time t_c the cut-off grid reaches cut-off voltage $-e_{g1}$ and flip-over occurs. Oscillograms showing n.b.m. wave-shapes are given in Figs. 5 and 6, and the waveforms may be calculated from Equs (1) to (8) in the Appendix.

The anode voltage of the same multivibrator but with the polarity of E_g reversed (p.b.m.), adjusted to have the same frequency, is shown in Fig. 7.

Frequency Characteristics of the N.B.M.

As stated above, $-E_g$, in the discharge path of C', is of such a polarity as to impede the blocked-valve grid in reaching cut-off voltage. We may say that this direct influence of $-E_g$ on the cut-off period is to lengthen it and so lower the frequency while indirectly, by forcing the conducting-valve grid negative and its anode positive (which in turn makes the cut-off grid positive), $-E_g$ tends to shorten the cut-off period and raise the frequency.* By using valves giving higher amplification (e.g., pentodes instead of triodes) or by a combination of crystal rectifiers designed to increase

* This indirect influence is by far the stronger (owing to the valve amplification) and E_g therefore controls the frequency.

Fig. 5. *Oscillogram of a n.b.m. grid voltage with $-E_g = -40$ V and $f \doteq 78$ kc/s*

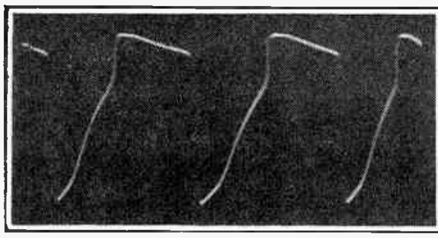


Fig. 6. *Oscillogram of a n.b.m. anode voltage with $-E_g = -40$ V and $f = 78$ kc/s*

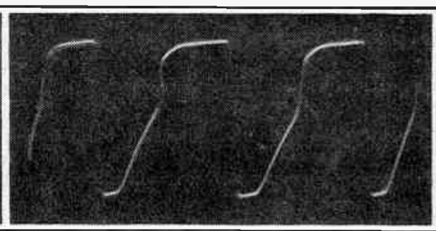
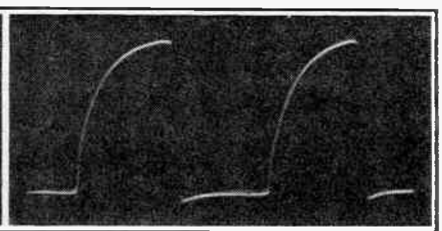


Fig. 7. *Oscillogram of a p.b.m. anode voltage with $+E_g = 60$ V and $f = 78$ kc/s*



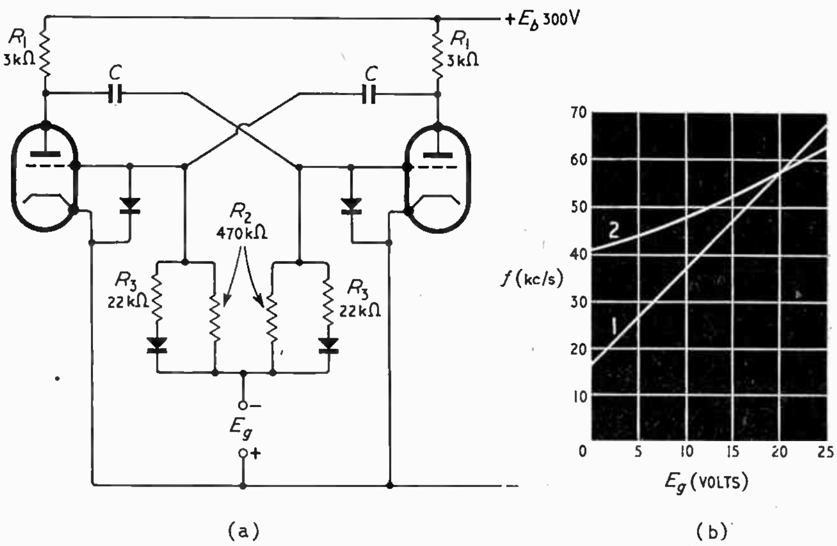


Fig. 8. *A modified n.b.m. for higher change of frequency with* E_g. *(a) The circuit. (b) Curve* 1, *frequency characteristic of n.b.m. shown in (a); Curve* 2, *characteristic of same n.b.m. with no modification;* $R_2 = 22\,k\Omega$, $R_3 = \infty$

the influence of $-E_g$ on the conducting grid but not on the cut-off grid (as in Fig. 8) we may obtain a higher change of frequency with E_g. It is interesting to note that oscillations will usually continue in the simple n.b.m. until $-E_g$ is about 4 times more negative than the cut-off value.

The half period (and from it the frequency) of the simple n.b.m. may be calculated from the simultaneous equations (7) and (8) of the Appendix:

$$(7)\quad \frac{T}{2} = CR_2 \log_e \frac{E_b + e_{g2} - e_{b0} - E_g}{e_{g1} - E_g + g_m R_{eq} e_{g2}}$$

$$(8)\quad \frac{T}{2} = CR_1 \log_e \frac{E_b - e_{b0} - e_{g1} - g_m R_{eq} e_{g2}}{\frac{R_1}{R_2} E_g} + C(R_1 + R_2) \log_e \frac{1}{1 - e_{g2}/E_g}$$

Where $-e_{g2}$ is defined in Fig. 4(b) as the voltage of the conducting grid just before it is cut-off at time t_c and $g_m R_{eq}$ is the valve amplification. Fig. 9 gives the results, calculated and measured, for f and e_{g2} as functions of E_g for a specific n.b.m. This n.b.m. was used as a frequency modulator for recording low-frequency transient phenomena on magnetic tape. It used a 6SN7 valve with $R_1 = 16\,k\Omega$, $R_2 = 316\,k\Omega$ $C = 600$ pF $E_b = 190$ V. The frequency change achieved was from about 1300 c/s to 7 kc/s with only a slight departure from linearity at the upper part.

Frequency Stability

Frequency stability of multivibrators is highly dependent on the slope of the blocked-grid voltage wave-shape where it traverses the cut-off voltage $-e_{g1}$ [Fig. 4(c) at time t_c]. The steeper the slope the more well-defined is the time at which it will reach this voltage and start flip-over action independently of small changes of $-e_{g1}$ caused by anode supply-voltage change. The slope may be found by differentiating Equ. (6) in the Appendix and making $t = T/2$. Then, with the help of Equs (4) and (7), we find for the n.b.m.

$$\left.\frac{de_g}{dt}\right|_{t=T/2} = \frac{1}{CR_2}\left[e_{g1} - E_g + g_m R_{eq}(E_g - e_{g2})\frac{1}{1 + R_1/R_2}\right]$$

and for the zero-biased multivibrator whose frequency is given by (9) we find

$$\left.\frac{de_g}{dt}\right|_{t=T/2} = \frac{e_{g1}}{CR_2}$$

while for the p.b.m. we get

$$\left.\frac{de_g}{dt}\right|_{t=T/2} = \frac{+E_g + e_{g1}}{CR_2}$$

using the values for the n.b.m. which were calculated for Fig. 9 we find for biases -20, 0, and $+20$ V respectively the results 905 V/msec for the n.b.m.,

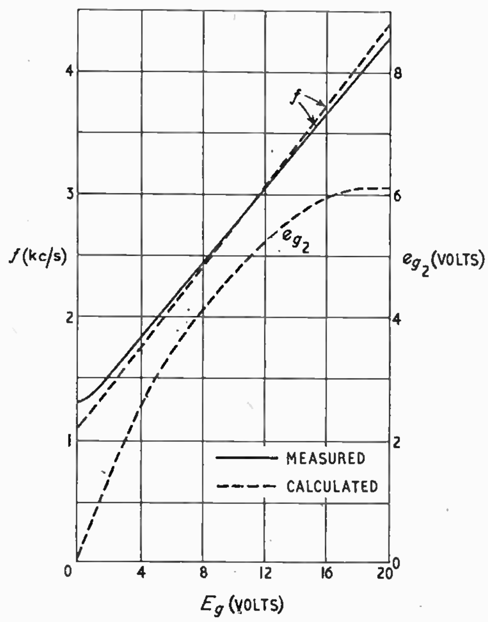


Fig. 9. *Frequency characteristic and* e_{g2} *versus negative bias* $-E_g$ *for a typical case*

63 V/msec for zero bias and 169 V/msec for the p.b.m. This means that the n.b.m. is by far the most stable of the three.

Conclusion

The n.b.m. circuit has been found to have possibilities as a frequency modulator or variable-frequency oscillator over a very wide range of audio frequencies. If wave-shape is not important, or where variable-frequency pulses are needed, it may be used as a source of its special wave-shapes and has a good frequency stability.

Acknowledgement

The author is indebted to Ing. J. Karfunkel, Head of the Electronics and Communication Department, Israel Institute of Technology, for encouragement and advice.

APPENDIX

Calculations of frequency and wave-shapes of a n.b.m. are based on Fig. 3. The definitions of the voltage symbols are given in Fig. 4 and all voltages are referred to the cathode.

(a) *Conduction Period* [*Fig.* 4 (*a*)]

In Fig. 10 the grid circuit of V_1 for the conduction period is

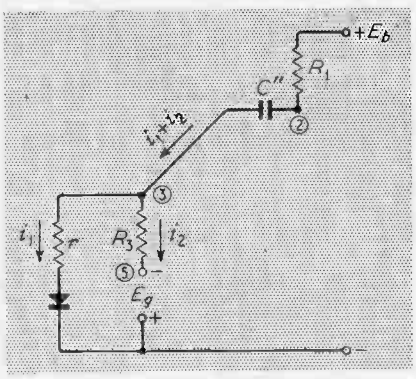


Fig. 10. *Grid circuit of V_1 during conduction period*

reproduced. The rectifier represents the grid–cathode rectifying action and r is its small forward resistance.

The initial voltage across C'' at the beginning of conduction is $e_{b2} + e_{g1}$ and, so long as point 3, Fig. 10, is positive we have

$$\begin{cases} E_b = (i_1 + i_2)R_1 + Q/C + i_1 r \\ i_1 r = i_2 R_2 - E_g \end{cases}$$

where Q is the charge on C''. Since $r \ll R_2$,

$$\frac{dQ}{dt} = i_1 + i_2 = i_1 + i_1 \frac{r}{R_2} + \frac{E_g}{R_2} \approx i_1 + \frac{E_g}{R_2}$$

from which, by substituting i_1, and the initial conditions, we get Q. At time t_b (if time is measured from t_a as the zero point) i_1 becomes zero and we have

$$E_b = \frac{dQ}{dt} R_1 + \frac{Q}{C}$$

from which we can calculate $t_b = \tau_1$, the length of time during which the grid stays positive,

$$\tau_1 = C(R_1+r)\log_e \frac{E_b - e_{b2} - e_{g1} + \frac{r}{R_2}E_g}{(R_1+r)/R_2 \cdot E_g} \approx CR_1 \log_e \frac{E_b - e_{b2} - e_{g1}}{R_1/R_2 \cdot E_g} \quad (1)$$

For small r, compared with R_1 or R_2. The grid potential during this time is designated e'_g and is given by*

$$e'_g = i_1 r \approx \frac{r}{R_1 + r}[E_b - e_{b2} - e_{g1}]e^{-\frac{t}{C(R_1+r)}} - \frac{r}{R_2}E_g \approx 0 \quad (2)$$

At t_b the grid becomes negative and for the conduction period the grid potential is given by

$$e_g'' = E_g\left[1 - e^{-\frac{t-\tau_1}{C(R_1+R_2)}}\right] \quad \ldots \quad (3)$$

At time $t = t_c$, $e_g'' = e_{g2}$ [Fig. 4 (a)] from which we get

$$\tau_2 = t_c - \tau_1 = C(R_1 + R_2)\log_e \frac{1}{1 - e_{g2}/E_g} \quad \ldots \quad (4)$$

(b) *The Cut-Off Period* [*Fig.* 4 (*c*)]

Initial conditions: voltage across C' at the beginning is $E_b + e_{g2}$. We may approximate the anode voltage of the conducting valve [shown in Fig. 4 (b)] by

$$e_b = e_{b0} \quad [\text{for } 0 = t_a \leqslant t \leqslant t_b = \tau_1$$

$$e_b = e_{b0} + \frac{\mu R_1}{r_a + R_1}e_g'' = e_{b0} + g_m R_{eq} e_g'' \text{ for } \tau_1 = t_b \leqslant t \leqslant t_c = \tau_1 + \tau_2$$

where $R_{eq} = R_1 r_a/R_1 + r_a$, r_a is the anode resistance and e_g'' is given by (3) ($g_m R_{eq}$ is the amplification when R_2 is high compared with R_1). With these approximations we find for the cut-off period

$$e_g''' = -(e_{b0} + E_g - E_b - e_{g2})e^{-\frac{t}{CR_2}} + E_g \quad \text{for } 0 \leqslant t \leqslant \tau_1 \quad (5)$$

$$e_g^{(4)} = e_g''' + g_m R_{eq}\frac{R_2}{R_1}E_g\left[-e^{-\frac{t-\tau_1}{C(R_1+R_2)}} + e^{-\frac{t-\tau_1}{CR_2}}\right] \text{ for}$$

$$\tau_1 \leqslant t \leqslant \tau_1 + \tau_2 \quad \ldots \quad (6)$$

Flip-over occurs when $e_g^{(4)}$ equals e_{g1} (the cut-off voltage) and then $t = \tau_1 + \tau_2 = T/2$ (where T is the period of oscillation). For this moment we get [from (6)]

$$\frac{T}{2} = CR_2 \log_e \frac{E_b + e_{g2} - e_{b0} - E_g}{e_{g1} - E_g + g_m R_{eq}\frac{R_2}{R_1}E_g\left(1 - \frac{e_{g2}}{E_g}\right)\left[1 - \left(1 - \frac{e_{g2}}{E_g}\right)^{R_1/R_2}\right]}$$

This may be brought into a simpler form, since usually $R_1 \ll R_2$ and always $e_{g2} < E_g$. We have, with the help of the binomial theorem,

$$e_{g1} - E_g + g_m R_{eq}\frac{R_2}{R_1}E_g\left(1 - \frac{e_{g2}}{E_g}\right)\left[1 - \left(1 - \frac{e_{g2}}{E_g}\right)^{R_1/R_2}\right]$$

$$\approx e_{g1} - E_g + g_m R_{eq} e_{g2}$$

from which

$$\frac{T}{2} \approx CR_2 \log_e \frac{E_b + e_{g2} - e_{b0} - E_g}{e_{g1} - E_g + g_m R_{eq} e_{g2}} \quad \ldots \quad (7)$$

also from (1) and (4)

$$\frac{T}{2} = CR_1 \log_e \frac{E_b - e_{b0} - e_{g1} - g_m R_{eq} e_{g2}}{R_1/R_2 \cdot E_g} + C(R_1 + R_2)\log_e \frac{1}{1 - e_{g2}/E_g} \quad \ldots \quad (8)$$

where we have put $e_{b2} = e_{b0} + g_m R_{eq} e_{g2}$. Equs (7) and (8) are simultaneous equations for the unknowns e_{g2} and T. For the special case $E_g = 0$ (and then of course $e_{g2} = 0$ and the ratio e_{g2}/E_g can never be greater than 1 from physical reasoning) we get from (7) the well-known formula[1]

$$\left.\frac{T}{2}\right|_{E_g = 0} = CR_2 \log_e \frac{E_b - e_{b0}}{e_{g1}} \quad \ldots \quad (9)$$

which gives the frequency of the zero-biased multivibrator.

* e_g'' and later e_g''' and $e_g^{(4)}$ and the rest of the voltages in the equations are always the absolute values and does not include the polarity which is negative for e_g'', e_g''', $e_g^{(4)}$ and positive for e_g'.

REFERENCES

1 Boone, "Circuit Theory of Electron Devices", Wiley.
2 Bertram, "The Degenerative Positive-Bias Multivibrator", *Proc. Inst. Radio Engrs*, February 1948.

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 contoin.

Brune's Theorem

SIR,—In his review of D. F. Tuttle's new book "Network Synthesis", which appeared in your September issue, your reviewer seems to have misunderstood the fundamental theorem in the theory of two-terminal network synthesis. He expresses surprise because the author considers the result that a physically realizable driving-point immittance function must have a "positive real-part" to be remarkable. The requirement is not merely that the function must have a positive real part but that it must be *positive real*. This term was coined by Dr. Otto Brune in his celebrated M.I.T. Thesis[1] in 1931 to describe a function of the complex frequency variable p which is real when p is real and which has a real part that is positive over the entire right-half of the complex p-plane.

Brune demonstrated that positive reality is a necessary and sufficient condition for a given rational function to represent the driving-point immittance of a finite passive discrete-parameter network. This contribution is surely the most significant ever made to the theory of two-terminal network synthesis and is truly remarkable.

Dept. of Aircraft Elect. Eng., S. R. DEARDS.
The College of Aeronautics, Cranfield.
17th September 1958.

REFERENCE

[1] O. Brune, "Synthesis of a Finite Two-Terminal Network whose Driving Point Impedance is a Prescribed Function of Frequency," *Journal of Mathematics and Physics*, Vol. 10, No. 3, pp. 191–236 (1931).

New Books

The Heenan Multiform Manual

By T. HANSON. Pp. 267. Published by Heenan & Fronde Ltd., Worcester. Available from Wickman Ltd., Post Office Box No. 44, Banner Lane, Tile Hill, Coventry. Price 75s.

A technical reference book containing information on the use of four-slide automatic wire and strip-forming machines.

Illustrated with perspective drawings and photographs, the book includes sections on the design of tools, the various techniques available, and the selection or adaptation of economical and efficient tooling layouts. A chapter is included which lists a mass of factors, conversion tables, useful dimensions and other technical data.

The machines covered by the manual were designed by the author.

High Fidelity: A Bibliography of Sound Reproduction

Compiled by K. J. SPENCER, A.L.A. Pp. 325. Iota Services Ltd., 38 Farringdon Street, London, E.C.4. Price 30s.

There are four main sections in this book in which are grouped the references to articles in periodicals, books, trade literature and, finally, to other bibliographies. Most references are to material published in the period 1947-57.

Each reference gives the title of the original article, the author's name, journal title, volume and page numbers, and date of publication. In some cases, a few lines descriptive of the content of the article are added; they are hardly adequate to rank as abstracts, however.

There is little evidence of selection in the references and the compiler admits in his preface that "it has not been practicable to read every reference cited".

Subject and author indexes are included. The latter gives the page number on which the reference appears. The subject index, however, gives merely the section. This is in spite of the fact that each periodical reference carries a serial number, of which no use seems to be made. If one turns up, for example, "ultra-linear amplifier" in the index, one finds merely "2". Trying first serial 2 and then page 2, without success, one turns to the contents and sees that 'amplifiers' are the second section under periodical references. They are not actually numbered either in the contents or in the sections themselves.

Turning to the amplifier section, one finds that it is necessary to search some 44 pages containing 432 references. The subject index is thus of no help in finding references; all that it does tell one is that there is indeed a reference to the subject in the book if one can find it! W.T.C.

Radio Astronomy: Special Subject List No. 26

Compiled by F. R. TAYLOR, F.L.A. Pp. 15. Issued by The Library Association, Chaucer House, Malet Street, London, W.C.1. Price 2s. 6d.

This is not a book, but a duplicated bibliography of 204 items, with a short introduction. The bibliography is described as highly selective, and concentrates mainly on material published since 1950. It was compiled in July 1958 and contains items published in 1958.

Russian-English, English-Russian Electronics Dictionary

By the Department of the Army, Washington, D.C., U.S.A. Pp. 943. McGraw-Hill Publishing Co. Ltd., 95 Farringdon Street, London, E.C.4. Price 62s.

A comprehensive dictionary for the engineer, scientist and author who has occasion to use technical Russian publications on electronics and telecommunications.

About 22,000 Russian and 25,000 English terms from antennae to X-rays are included and an extensive cross-reference system to alternative words, spellings and connected terms is provided.

Television Engineering

By S. W. AMOS, B.Sc.(Hons.), A.M.I.E.E., and D. C. BIRKINSHAW, M.B.E., M.A., M.I.E.E. Pp. 268. Published for *Wireless World* by Iliffe & Sons Ltd., Dorset House, Stamford Street, London, S.E.1. Price 35s.

"The fourth, and final, volume of a comprehensive textbook on the fundamentals of television theory and practice." It contains sections on counter circuits, frequency dividers, principles and practice of d.c. restorer and clamping, gamma-control amplifiers, delay lines, fixed and variable equalizers, scanning coils, field and line output stages, shunt-regulated amplifiers and cathode followers.

Translated Contents Lists of Russian Periodicals

Pp. 8. August 1958 supplement. D.S.I.R. (C.T.S.), Charles House, 5-11 Regent Street, London, S.W.1.

B.B.C. Television—A British Engineering Achievement

Pp. 64. B.B.C. Publications, 35 Marylebone High Street, London W.1. Price 2s. 6d.

An account of the development of B.B.C. television for non-specialists.

Single Sideband for the Radio Amateur. 2nd Edition

Pp. 210. Published by the American Radio Relay League Inc., West Hartford 7. Connecticut, U.S.A. Price $1.75.

A revised and enlarged edition.

Theorie der Spulen und Ubertrager. 3rd Edition

By RICHARD FELDTKELLER, Dr. rer. nat., Dr.-Ing.E.h. Pp. 186. S. Hirzel Verlag, Birkenwaldstrasse 185, Stuttgart, N., Germany. Price DM24.

An informative textbook on coil and transformer design.

Electronic Components Handbook. Volume 2

Edited by KEITH HENNEY and CRAIG WALSH. Pp. 357. McGraw-Hill Publishing Co. Ltd., 95 Farringdon Street, London, E.C.4. Price 97s.

Like Volume 1, which was reviewed in the July 1957 issue of *Electronic & Radio Engineer*, this volume is intended to provide the designer with factual information on certain components used in U.S. military electronic equipment. Whereas resistors, capacitors, relays and switches were included in the first volume, the components covered in this volume are power sources and convertors, fuses and circuit breakers, electrical indicating instruments, printed wiring boards, solder and fluxes, choppers, blowers, r.f. transmission lines and waveguides.

It is most unfortunate that many of the JAN and MIL component specifications listed in the text may not have British equivalents but, nevertheless, the specifications are bound to be of immense interest to firms engaged in the manufacture of N.A.T.O. equipment.

A chapter on the comparatively new technique of printed wiring should interest most electronic designers but, as the printed wiring board is still in its infancy, "rigid performance limits cannot yet be set down because their ultimate effects on durability are not sufficiently known". Some notes on printed-circuit soldering are included in the chapter on Solders and Fluxes.

As mentioned in the previous review of Vol. 1, the book appears to have been photographically produced from the original typescript. It is, however, a neat, lucid and presentable publication, being well illustrated with drawings, photographs, functional and circuit diagrams.

B.J.M.

Selected Abstracts from the "J.Brit.I.R.E." 1946-1958

Pp. 72. Published by the British Institution of Radio Engineers, 9 Bedford Square, London, W.C.1. Price 3s. 6d.

This edition is confined mainly to the principal papers and reports which have been published in the Institution's Journal since the end of the war. The abstracts are classified by subject according to the Universal Decimal Classification, and the entries are fully cross-referenced.

The range of subjects covered extends from astronomy to automatic computers, and it is interesting to note that 19 papers on this latter section are listed.

NEL Reliability Bibliography. Supplement 1

Pp. 172. United States Department of Commerce, Washington 25, D.C., U.S.A. Price $3.00.

Scientific Manpower, 1957

Pp. 46. National Science Foundation, Washington 25, D.C., U.S.A. Available on request to the Public Information Office.

NATIONAL BUREAU OF STANDARDS

Table of Natural Logarithms for Arguments between Five and Ten to Sixteen Decimal Places

N.B.S. Applied Mathematics Series 53. Supersedes Mathematical Table 12. Price $5.00, post paid.

Integrals of Airy Functions

N.B.S. Applied Mathematics Series 52. Pp. 28. Price 32 cents, post paid.

Supplementary List of Publications of the National Bureau of Standards: 1st July 1947 to 30th June 1957

Supplement to N.B.S. Circular 460 and supersedes supplement to Circular 460, 30th December 1952. Pp. 373. Price $1.88, post paid.

The above are published by U.S. Department of Commerce, National Bureau of Standards, Washington 25, D.C., U.S.A.

BRITISH STANDARDS

Rationalized and Unrationalized Formulae in Electrical Engineering

B.S.2990: 1958. Pp. 16. Includes tables and explanatory notes on m.k.s. and c.g.s. systems of units. Price 4s. 6d.

Glossary of Terms used in Vibration and Shock Testing

B.S.3015: 1958. Contains 72 definitions with mathematical appendices on line spectra, continuous spectra and spectra of experimentally determined quantities. Price 5s.

Electronic-Valve Bases, Caps and Holders

B.S.448: 1953. Four new sections and one new replacement section (for B5E: 1953) are now available; they are, B5E, B7G/F, B8D, B8D/F and B9A/F. Price 2s. each section.

Machine Screws and Machine Screw Nuts

B.S.450: 1958. Up-to-date standard for machine screws with B.S.W. and B.S.F. threads. Price 12s. 6d.

Engineering Drawing Practice: Students' Edition

B.S.308A: 1958. Pp. 40. A specially abridged version of B.S.308: 1953. Price 4s. 6d., less one-third students' discount.

Pure-Tone Audiometers

B.S.2980: 1958. Deals primarily with audiometers which provide for the measurement of the threshold of hearing for pure tones and at a number of selected frequencies. Price 4s. 6d.

These Standards are obtainable from British Standards Institution, Sales Branch, 2 Park Street, London, W.1.

MANUFACTURERS' LITERATURE

Electronic Glass/Metal Seals and Components. Leaflet describing well over 50 different glass-metal seals. (In English, French and German.)
The Roditi International Corporation Ltd., 12a Golden Square, London, W.1

Claw-Type Cable Cleating System. Pp. 8. Describes the cleating system and gives data on the range of cleating assemblies.
British Insulated Callender's Cables Ltd., 21 Bloomsbury Street, London, W.C.1.

Technical Careers in the Medical Research Council. Pp. 30. Information for entry into the technical officer and technician categories.
Medical Research Council, 38 Old Queen Street, London, S.W.1.

A.T.E. Quartz Oscillator Crystals. Pp. 40. Consists principally of a guide to the specification and use of quartz crystal oscillators. Also includes data on A.T.E. crystals.
Automatic Telephone & Electric Co. Ltd., Strowger Works, Liverpool 7.

M.S.4. Silicone Compound. Leaflet on an insulating and waterproofing compound.
Holiday & Hemmerdinger Ltd., 71 Ardwick Green North, Manchester 12.

Transformers. Pp. 48. A pictorial publication (No. 127) on the design and construction of transformers, chokes, coils and other windings. Includes design charts for small transformers and chokes.
Haynes Radio Ltd., Queensway, Enfield, Middx.

Radiospares Ltd. announce that their October/December catalogue is now available.
Radiospares Ltd., 4-8 Maple Street, London, W.1.

High-Precision Deposited Carbon Resistors. Pp. 16. Technical data on carbon-film resistors, 1 Ω to 100,000 MΩ, 0·05 to 6 W, tolerance from 0·1%, up to 3,000 Mc/s. Separate price list available.
Aveley Electric Ltd., Ayron Road, South Ockendon, Essex.

RADIO RESEARCH, 1957

A recommendation that the programme of the Radio Research Station, D.S.I.R., should be generally broadened in scope to meet present and future demands is made by the Radio Research Board in their annual report*.

Their proposals include further development of measuring techniques of secondary-standard calibre up to the highest radio frequencies, new investigations into the properties and applications of molecular amplifiers and oscillators, and basic research on the

* "Radio Research 1957", the Annual Report of the Radio Research Station at Ditton Park, Slough, is published for D.S.I.R. by H.M.S.O., Kingsway, London, W.C.2, price 3s. 6d. (63 cents U.S.A.).

design and properties of microwave aerials and ways of transmitting information to achieve economy in the use of the radio-frequency spectrum.

The Board advise that any subjects chosen for future study should be generic in scope and aimed at practical applications.

The Radio Research Station at Slough is one of the four I.G.Y. World Data Centres dealing with the ionosphere and exchanges information with over a hundred observing points. Observations have been carried out on the radio transmissions from the first artificial earth satellites. These signals have been particularly interesting, as they come from sources travelling within and sometimes above the main regions of the ionosphere.

Experiments have been carried out on ionospheric forward-scatter over large distances to find the angular distribution of the radiation arriving at the receiver. Corresponding investigations have been made at shorter wavelengths into the forward-scattering of signals by way of the lower part of the atmosphere.

Investigations are in progress at the Radio Research Station and at Cambridge University of the propagation characteristics of radio waves at very low frequencies. Further knowledge of the phase and amplitude characteristics of the waves as reflected from the ionosphere is necessary in order to develop precise navigational aids for use over long distances.

EXHIBITIONS

Electrical Engineers

Next year's Show will be held, once again, at Earls Court, London, from Tuesday, 17th March, to Saturday, 21st March, inclusive.

Further information may be obtained from the Exhibition Manager, 6 Museum House, Museum Street, London, W.C.1.

Radio Hobbies

The 1958 International Radio Hobbies Exhibition will be held at the Royal Horticultural Old Hall, Vincent Square, London, S.W.1, from Wednesday, 26th November, to Saturday, 29th November.

The Show will be open from 11 a.m. until 9 p.m. each day; admission 2s.

Physical Society's Exhibition 1959

The Physical Society's annual exhibition of scientific instruments and apparatus will be held from Monday, 19th January to Thursday, 22nd January inclusive, in the Old and New Halls of the Royal Horticultural Society, off Victoria Street, Westminster, London, S.W.1.

Further information may be obtained from the Honorary Exhibition Secretary, A. G. Peacock, B.Sc., 1 Lowther Gardens, Prince Consort Road, London, S.W.7.

FARADAY LECTURE AT ROYAL FESTIVAL HALL

The Institution of Electrical Engineers announces that the 1958/59 Faraday Lecture on "Automation" will be delivered by Dr. H. A. Thomas, M.Sc., at the Royal Festival Hall on Monday, 26th January, at 6 p.m.

Admission to the lecture will be free and tickets may be obtained from the Secretary, The Institution of Electrical Engineers, Savoy Place, London, W.C.2, during the month of December. It is requested that a stamped, addressed envelope should be enclosed with the application for tickets.

MEETINGS

I.E.E.

6th November. "The Recognition of Moving Vehicles by Electronic Means", by T. S. Pick and A. Readman.

18th November. "Ferro-Electrics", discussion to be opened by L. A. Thomas.

19th November. "Television Recording: A Survey of the Problems and the Methods Currently in Use", by J. Redmond.

20th November. "What is a Cultured Engineer?", discussion to be opened by K. R. Sturley, Ph.D., B.Sc., at 6 o'clock.

24th November. "The Use of Dispersive Dielectrics in a Beam-Scanning Prism", by J. S. Seeley, B.Sc.(Eng.), Ph.D., and J. Brown, M.A., Ph.D.; "The Quarter-Wave Matching of Dispersive Materials", by J. S. Seeley; and "Theory of Reflections from the Rodded-Type Artificial Dielectric", by A. Carne and J. Brown, M.A., Ph.D.

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

Brit. I.R.E.

26th November. Annual General Meeting (for members only) at 6 o'clock to be followed at 7.15 by the Presidential Address of Professor E. E. Zepler, Ph.D., at the London School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, London, W.C.1.

The Television Society

21st November. "The European Television Network—Some Operational Problems", by J. Treeby Dickinson.

4th December. "A New Development in Flying Spot Film Scanners", by E. H. Traub.

These meetings will be held at 7 o'clock at the Cinematograph Exhibitors' Association, 164 Shaftesbury Avenue, London, W.C.2.

The Institution of Electronics

20th November. "The Applications of Transistors in Communications and Control Equipment", by E. Wolfendale, B.Sc., at 7 p.m. in the Assembly Hall, University of London Institute of Education, Malet Street, London, W.C.1.

The Society of Instrument Technology

12th November. "Some Applications of Control Technique in Astronomy", by P. Fellgett, M.A., Ph.D., at 6 o'clock at Manson House, Portland Place, London, W.1.

STANDARD-FREQUENCY TRANSMISSIONS

(Communication from the National Physical Laboratory)

Deviations from nominal frequency for September* 1958

Date 1958 September	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	N.M.	+ 4
2	+ 1	+ 4
3	+ 1	+ 4
4	+ 2	+ 4
5	+ 2	+ 4
6	+ 2	N.M.
7	+ 2	N.M.
8	+ 2	− 2
9	+ 2	− 4
10	+ 2	− 2
11	N.M.	− 3
12	+ 2	− 3
13	+ 2	N.M.
14	+ 2	N.M.
15	+ 2	− 3
16	+ 3	− 3
17	+ 3	− 3
18	+ 3	− 2
19	+ 3	− 3
20	+ 3	N.M.
21	+ 3	N.M.
22	+ 3	− 4
23	+ 3	− 4
24	+ 3	− 4
25	+ 4	− 3
26	+ 4	− 3
27	N.M.	N.M.
28	+ 4	N.M.
29	+ 4	− 3
30	N.M.	− 2

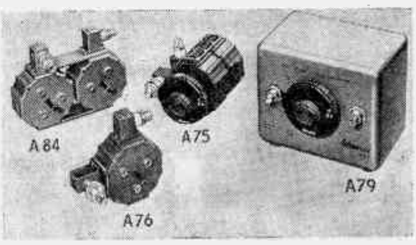
* *Nominal frequency is defined to be that frequency corresponding to a value of* 9 192 631 830 *c/s for the N.P.L. caesium resonator. N.M. = Not Measured.*

New Products

Wide-Band Attenuator Pads

Advance Components Ltd. have added four new wide-band models to their range of coaxial attenuators. They are said to be capable of handling up to 0·5 W of sine-wave power, and their standard sockets accept Plessey minor coaxial plugs.

Types A.75 and A.84 consist of two ten-position resistive ladder networks providing an attenuation range of 99 dB in 1-dB steps. In the type A.75, the two sections are



mounted with concentric spindles and the attenuation setting appears in a window on the control knobs. In the type A.84, the two sections are mounted side by side. Each type has an input/output impedance of 75 Ω, an attenuation accuracy of ± 1 dB up to 100 Mc/s and ± 3 dB at 300 Mc/s, and a v.s.w.r. of 1·5 maximum at 250 Mc/s.

Type A.76 consists of one ten-position network providing an attenuation range of 90 dB in 10-dB steps. It has an attenuation accuracy of ± 0·5 dB up to 100 Mc/s and ± 2 dB at 300 Mc/s, input/output impedance of 70 Ω at zero setting and 75 Ω at 10 to 90-dB settings, and a v.s.w.r. of up to 1·4 at 300 Mc/s.

Type A.79 consists of the type A.75 mounted in a metal case and is said to be suitable for use or applications where a separate screened coaxial attenuator is required.

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

Multimeters

Two new portable multi-range meters have been produced by Taylor Electrical Instruments Ltd.

Model 100A has dimensions of 8½ in. × 7½ in. × 4½ in. and it weighs 4½ lb. The sensitivity is 100,000 Ω/V, and the switched ranges cover 0·5–2,500 V d.c., 10–2,500 V a.c., 10 μA–10 A d.c., −10 dB–+15 dB, 2 kΩ–200 MΩ, and output ranges of 10–1,000 V. The accuracy is quoted as 2% d.c., 3% a.c.

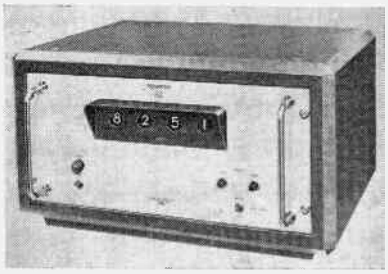
The model 127A, illustrated, is a pocket-sized instrument with dimensions of 5¾ in. × 3¾ in. × 1⅞ in. and it weighs 14 oz. It has a sensitivity of 20,000 Ω/V, and the 20 ranges cover 0·3–1,000 V d.c., 10–1,000 V a.c., 50 μA–1 A, and 2 kΩ–20 MΩ. The accuracy is quoted as 3% d.c., 4% a.c.

Taylor Electrical Instruments Ltd.,
Montrose Avenue, Slough, Bucks.

Digital Counter

J. Langham Thompson Ltd. have introduced a new digital counter which is available either as a tachometer (as illustrated) or as a counter for random pulses up to 10 kc/s.

The counter is stated to have an overall accuracy of ± 1 count, and incorporates a crystal-controlled cyclic timer with an accuracy of ± 0·005%. The in-line neon



readout is said to be clearly readable at 30 feet.

Provision is made for the connection of two remote indicators.

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

Flameproof Terminating Glands

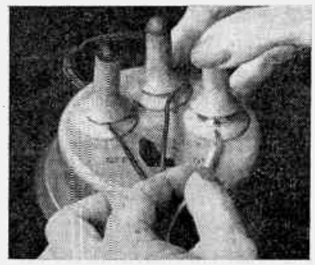
These glands have been designed for use with flameproof equipment and may be used in conjunction with either plastic or rubber-insulated and sheathed steel-wire armoured cables.

The design incorporates an internal flame-proof path for gases, and provision is made to prevent the ingress of moisture.

The Telegraph Construction and Maintenance Co. Ltd.,
Mercury House, Theobalds Road, London, W.C.1.

Test-Bench Connector

A mains connector for use in the workshop or factory has been produced by Mycalex



and T.I.M. Ltd. It consists of three fully-insulated spring-loaded terminals and an on/off switch mounted on a stove-enamelled metal base. Provision is made for fixing the connector to the workshop bench. The unit is fitted with a mains connecting cable.

The manufacturers claim that, by dispensing with the usual plug and screw terminal connections, a safe and positive contact can be effected quickly.

Mycalex and T.I.M. Ltd.,
Ashcroft Road, Cirencester, Glos.

Direct-Viewing Storage Tube

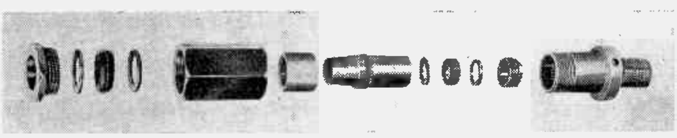
The type E702 is a direct-viewing storage tube having a useful screen diameter of 4 in. and employing electrostatic deflection.

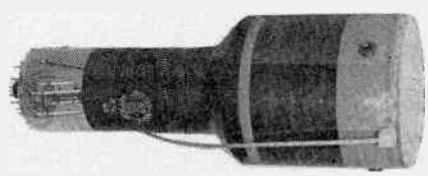
Information is claimed to persist without deterioration for one to two minutes, and still to be visible for periods up to 10 minutes. Erasure can be completed in 30 milliseconds by application of a 10-V pulse, or can be spread over a period of time by applying a train of shorter-duration pulses giving, in effect, a variable persistence.

The high brightness of the tube permits its use in daylight without a viewing hood.

The writing gun requires a 2-kV negative supply while 250 V at a few milliamps is sufficient for the viewing gun. A phosphor-screen supply of 5 kV to 10 kV at 0·5 to 1 mA is also needed.

English Electric Valve Co. Ltd.,
Chelmsford, Essex.





Abstracts and References

COMPILED BY THE RADIO RESEARCH ORGANIZATION OF THE DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH AND PUBLISHED BY ARRANGEMENT WITH THAT DEPARTMENT

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 : 061.3 **3308**

Symposium on Unsolved Problems in Acoustics.—(*J. acoust. Soc. Amer.*, May 1958, Vol. 30, No. 5, pp. 375–398.) The text is given of papers read at the 54th meeting of the Acoustical Society of America held at Michigan, U.S., 24th–26th October 1957, including the following:

(*a*) Electroacoustics and Transducers.—F. V. Hunt (pp. 375–377).

(*b*) Speech and Communication.—G. A. Miller (pp. 397–398).

534.1-8 : 538.222 **3309**

Paramagnetic Centres as Detectors of Ultrasonic Radiation at Microwave Frequencies.—Kittel. (See 3416.)

534.13-8-16 : 538.69 **3310**

A Proposal for Determining the Fermi Surface by Magnetoacoustic Resonance.—A. B. Pippard. (*Phil. Mag.*, Sept. 1957, Vol. 2, No. 21, pp. 1147–1148.)

534.22.08-16 **3311**

The Velocity of Sound in Metals at High Temperatures.—J. F. W. Bell. (*Phil. Mag.*, Sept. 1957, Vol. 2, No. 21, pp. 1113–1120.) A pulse method of measuring the sound velocity in thin rods over a wide temperature range is described.

534.75 **3312**

Effect of the Transmission Characteristic of the Ear on the Threshold of Audibility.—J. Zwislocki. (*J. acoust. Soc. Amer.*, May 1958, Vol. 30, No. 5, pp. 430–432.) Sensitivity/frequency curves are given based on v. Békésy's results (e.g. 2121 of 1949).

534.75 **3313**

Creation of Pitch through Binaural Interaction.—E. M. Cramer & W. H. Huggins. (*J. acoust. Soc. Amer.*, May 1958, Vol. 30, No. 5, pp. 413–417.) A faint pitch quality is detected when white noise presented at one ear is shifted in phase and presented to the other ear. An investigation of this phenomenon shows that phase information is of importance in pitch perception at frequencies up to 1·6 kc/s.

534.75 : 621.391 **3314**

Information Transmission with Elementary Auditory Displays.—W. H. Sumby, D. Chambliss & I. Pollack. (*J. acoust. Soc. Amer.*, May 1958, Vol. 30, No. 5, pp. 425–429.) The transmission of the letters of the alphabet by tone-coded signals is investigated using codes with two, three or five alternatives per letter and varying each of the four tonal variables. The highest reception rate was obtained with a three-alternative, frequency-coded display.

534.75 : 621.391 **3315**

Confidence Ratings and Message Reception for Filtered Speech.—L. Decker & I. Pollack. (*J. acoust. Soc. Amer.*, May 1958, Vol. 30, No. 5, pp. 432–434.)

534.771 : 534.78 **3316**

Fundamentals of Testing the Hearing of Speech.—F. J. Meister. (*Arch. tech. Messen*, Jan. 1958, No. 264, pp. 7–8.) The problems are outlined of selecting suitable speech material and of evaluating test results in physiological measurements of hearing ability. For details of normal measurement technique see *ibid.*, Feb. 1958, No. 265, pp. 21–24.

534.79 **3317**

Proposal for an Explanation of Limens of Loudness.—J. R. Pierce. (*J. acoust. Soc. Amer.*, May 1958, Vol. 30, No. 5, pp. 418–420.) The root-mean-square deviation in the number of pulses produced in a given time is suggested as a measure of the limen of loudness.

AERIALS AND TRANSMISSION LINES

621.315.212.3 **3318**

Transmission Characteristics of a Three-Conductor Coaxial Transmission Line with Transpositions.—G. Raisbeck & J. M. Manley. (*Bell Syst. tech. J.*, July 1958, Vol. 37, No. 4, pp. 835–876.) The design, manufacture and some experimental results are described. The effective cross-section of the centre conductor is increased by using a solid central member and a thin concentric shell. The reduction of skin-effect losses, compared with a two-conductor cable of the same diameter, gives lower attenuation from 1 to 10 Mc/s with a reduction of 17 % at 4 Mc/s.

621.315.616 **3319**

Plastics in Cables.—E. E. L. Winterborn. (*P.O. elect. Engrs' J.*, April 1958, Vol. 51, Part 1, pp. 33–39.) The application to telephone exchanges, underground and aerial telephone cables, and to the protection of cables from corrosion, is discussed.

621.372 **3320**

Group and Phase Velocity.—(*Wireless World*, Sept. 1958, Vol. 64, No. 9, pp. 445–449.) A simplified explanation of the terms is given and is applied to line and waveguide transmission.

621.372.2 **3321**

Calculation of Transmission Line Equations with New System Parameters.—W. Doebke. (*Arch. elekt. Übertragung*, Dec. 1957, Vol. 11, No. 12, pp. 495–503.) Mathematical difficulties in the solution of line equations can be reduced by adopting the parameters on which the scattering-matrix concept is based. See e.g. 1660 of June (Carlin).

621.372.2.029.6 : 621.317.74 **3322**

High-Frequency Measuring Lines.—Moerder. (See 3577.)

621.372.22 **3323**

The Nonuniform Transmission Line as a Broadband Termination.—I. Jacobs. (*Bell Syst. tech. J.*, July 1958, Vol. 37, No. 4, pp. 913–924.) The transmission-line equations are solved for a line in which the fractional change in shunt admittance/wavelength is constant. It is shown that a fixed length of line can be made to have as large an effective length as desired, and complete absorption of all energy will occur if the line has a small loss term.

621.372.8 + 621.396.677.7 **3324**

Some Aspects of Waveguide Technique.—J. C. Parr. (*J. Telev. Soc.*, April/June 1958, Vol. 8, No. 10, pp. 413–422.) Fundamental properties of electromagnetic waves and the generation of various modes of propagation inside a waveguide are discussed. Modes in resonant cavities are also considered, and three devices, the cavity wavemeter, the hybrid T junction, and the slotted-waveguide array are described.

621.372.8 **3325**

Determination of Higher-Order Propagating Modes in Waveguide Systems.—M. P. Forrer & K. Tomiyasu. (*J. appl. Phys.*, July 1958, Vol. 29, No. 7, pp. 1040–1045.) A theoretical analysis and an experimental method are given for determining the power level and relative phase of all propagating modes in a rectangular waveguide. Practical details are quoted for a 5-MW, S-band magnetron.

621.372.8 **3326**

Local Reflections in Waveguides of Variable Cross-Section.—V. Pokrovskiĭ, F. Ulinich & S. Savvinykh. (*Dokl. Ak. Nauk S.S.S.R.*, 21st May 1958, Vol. 120, No. 3, pp. 504–506.) Mathematical analysis of the reflection and scattering produced by discontinuities.

621.372.823 : 621.317.7 : 538.566 **3327**

Double-Probe Polarimetric Analyser for the 1 000-Mc/s Band.—Picherit. (See 3574.)

621.372.823 : 621.372.83 **3328**

Circular-Waveguide Taper of Improved Design.—H. G. Unger. (*Bell Syst. tech. J.*, July 1958, Vol. 37, No. 4, pp. 899–912.) Conical tapers with gradual change of cone angle transform cylindrical waves into spherical waves in the transition region. Optimal and almost optimal tapers are found for which the power conversion from TE_{01} transmission to spurious modes is small for frequencies up to 75 kMc/s.

621.372.826 : 537.226 **3329**

Surface Waveguide.—S. K. Chatterjee & R. Chatterjee. (*J. Instn Telecommun. Engrs, India*, March 1958, Vol. 4, No. 2, pp. 90–95.) Characteristic equations are given for surface-wave propagation along a solid conductor embedded in three coaxial dielectrics. See also 1017 of April.

621.372.85 : 621.318.134 **3330**

Use of Microwave Ferrite Toroids to Eliminate External Magnets and Reduce Switching Power.—M. A. Treuhaft & L. M. Silber. (*Proc. Inst. Radio Engrs*, Aug. 1958, Vol. 46, No. 8, p. 1538.) Experiments show that toroids may replace slabs in some microwave devices, eliminating the need for external magnetizing currents and permitting higher switching rates.

621.372.852.22 **3331**

X-Band Phase Shifter without Moving Parts.—W. H. Hewitt, Jr, & W. H. von Aulock. (*Electronics*, 4th July 1958, Vol. 31, No. 27, pp. 56–58.) The unit comprises two transversely magnetized ferrite slabs in the narrow walls of a rectangular waveguide. Continuous phase variation from 0 to 360° is obtainable for up to 15 kW peak power. Maximum insertion loss is 0·75 dB, and voltage s.w.r. 1·08.

621.372.852.3 : 621.372.823 **3332**

The Frequency Response of Waveguide Potential Dividers with Coaxial Launching and Pick-Up.—A. Sander. (*Nachrichtentech. Z.*, Jan. 1958, Vol. 11, No. 1, pp. 1–5.) Two types of piston attenuator are discussed, with reference to theory presented earlier (2292 of 1956). 40 references.

621.372.852.323 : 621.318.134 : 621.317.74 **3333**

High-Power Testing of Ferrite Isolators.—Wantuch. (See 3578.)

621.396.67 : 517.512.2 (083.5) **3334**

A New Table of the Amplitude Functions of the Iterated Sine and Cosine Integrals and Some Comments on the Aperiodic Functions in Hallén's Antenna Theory.—P. O. Brundell. (*Acta polyt., Stockholm*, 1957, No. 217, 14 pp.; *Kungl. tek. Högsk. Handl., Stockholm*, 1957, No. 108.) See also 1873 of 1955 (Hallén).

621.396.673.029.4 **3335**

A Study of Earth Currents near a V.L.F. Monopole Antenna with a Radial Wire Ground System.—J. R. Wait. (*Proc. Inst. Radio Engrs*, Aug. 1958, Vol. 46, No. 8, pp. 1539–1541.) The results of experimental studies are briefly reported and confirm the author's earlier theoretical work. See also 334 of 1955 (Wait & Pope).

621.396.677 **3336**

Suppression of Undesired Radiation of Directional H.F. Antennas and Associated Feed Lines.—H. Brueckmann. (*Proc. Inst. Radio Engrs*, Aug. 1958, Vol. 46, No. 8, pp. 1510–1516.) Practical measurements of rhombic aerials show large side lobes which may contribute to interference in the h.f. band. Aerial arrays using nonuniform amplitude distributions and a tapered-aperture horn are briefly described, in which the side lobes are substantially reduced. Coaxial feeders coupled to wideband transformers are suggested in place of open-wire lines which are difficult to balance accurately.

621.396.677.001.57 **3337**

Use of Scale Model Techniques in the Design of V.H.F. and U.H.F. Aerials.—F. J. H. Charman, J. Thraves & E. F. Walker. (*Electronic Engng*, Aug. 1958, Vol. 30, No. 366, pp. 498–501.)

621.396.677.3 : 523.164 **3338**

Optimum Arrays for Direction Finding.—N. F. Barber. (*N.Z. J. Sci.*, March 1958, Vol. 1, No. 1, pp. 35–51.) The design of an array of receivers suitable for exploring the distribution of wave power with wave direction is discussed. Examples of practical arrays, including the Mills Cross, for the determination of power distribution with the minimum mean square error are examined.

621.396.677.3 : 523.164 **3339**

Gain Measurements of Large Aerials used in Interferometer and Cross-Type Radio Telescopes.—A. G. Little. (*Aust. J. Phys.*, March 1958, Vol. 2, No. 1, pp. 70–78.) A method is described using strong, discrete radio sources whose intensity need not be known. The method is applied to the 3·5-m Mills Cross radio telescope at Sydney [1126*g* of April (Mills et al.)].

621.396.677.73 **3340**

A New Ultra-Wide-Band Microwave Antenna.—T. Sakurai. (*Rep. elect. Commun. Lab., Japan*, Feb. 1958, Vol. 6, No. 2, pp. 40–45.) The aerial described is matched over the frequency band 4 000–9 400 Mc/s with a voltage s.w.r. better than 1·12. The gains are 32 and 40 dB at the ends of the band.

621.396.677.8.029.6 **3341**

Polarization-Transforming Plane Reflector for Microwaves.—J. Aagesen. (*Acta polyt., Stockholm*, 1957, No. 239, 27 pp.) The infinite reflector investigated consists of a perfectly conducting surface in front of which is a parallel, anisotropically conducting surface. The intervening space is filled with a perfect dielectric. By a suitable choice of the thickness of the dielectric and the plane of polarization of the incident wave it is always possible to obtain a circularly polarized reflected wave.

621.396.677.833 **3342**

A 360° Scanning Microwave Reflector.—J. A. C. Jackson & E. G. A. Goodall. (*Marconi Rev.*, 1st Quarter 1958, Vol. 21, No. 128, pp. 30–38.) The design and construction are described for a parabolic-torus reflector in the form of a radome with a wire grating inserted in its surface. A beam width of 3·5° for −6 dB with side lobes at −25 dB is possible for X-band frequencies using a 6-ft diameter reflector.

AUTOMATIC COMPUTERS

681.142 3343
Electronic Computer Research.—(*Tech. News Bull. nat. Bur. Stand.*, April 1958, Vol. 42, No. 4, pp. 57–79.) A note on the research program of the National Bureau of Standards followed by ten short papers with titles as under.
(*a*) A High-Speed Multiplier for Electronic Digital Computers.—(pp. 58–59).
(*b*) Processing Pictorial Information on Digital Computers.—(pp. 60–63).
(*c*) Low-Power Plug-In Packages for Electronic Computer Circuitry.—(pp. 63–65).
(*d*) SEAC Converted to Applications Research Facility.—(pp. 65–66).
(*e*) A Function Generator for Two Independent Variables.—(p. 67).
(*f*) Man-Machine Simulation System.—(pp. 68–70).
(*g*) Problem Solving on the High-Speed Computer.—(pp. 71–75).
(*h*) Chemical Structure Searching with Automatic Computers.—(pp. 75–76).
(*i*) Magnetic Amplifiers for Digital Computers.—(pp. 77–78).
(*j*) Diode Amplifier Shift Register.—(pp. 78–79).

681.142 3344
Electronic Computers 1957.—K. Prause. (*VDI Z.*, 1st June 1958, Vol. 100, No. 16, pp. 701–708.) A survey with tabulated data on German equipment. 94 references.

681.142 3345
Accuracy Control in Electronic Business Data Processing Systems.—J. C. Hammerton. (*Electronic Engng*, Aug. 1958, Vol. 30, No. 366, pp. 483–486.)

681.142 3346
Digital Codes in Data-Processing Systems.—M. P. Atkinson. (*Trans. Soc. Instrum. Technol.*, June 1958, Vol. 10, No. 2, pp. 87–90.) Discussion on 1981 of July.

681.142 3347
Simple Digital Correlator.—C. Collins. (*Rev. sci. Instrum.*, June 1958, Vol. 29, No. 6, pp. 487–490.) "A description is given of a simple electronic correlator which employs punched-tape input and visual digital readout. Cold-cathode counting tubes are used in the arithmetic unit. Several basic design considerations are briefly discussed, and an outline is given of the recent application of the correlator to a problem in meteor physics."

681.142 3348
An Improved Technique for Fast Multiplication on Serial Digital Computers.—M. Shimshoni. (*Electronic Engng*, Aug. 1958, Vol. 30, No. 366, pp. 504–505.)

681.142 3349
Half-Adders Drive Simultaneous Computer.—F. B. Maynard. (*Electronics*, 18th July 1958, Vol. 31, No. 29, pp. 80–82.) A combination of transistorized half and full adders, emitter followers, output amplifiers and multiplier gates provides simultaneous binary addition of digital inputs.

681.142 3350
Relay-Scanning-Design Technique Generates High Accuracy and Speed in Analogue-to-Digital Transducer Measurements.—A. F. Kay. (*Commun. & Electronics*, May 1958, No. 36, pp. 248–250.) The converter is designed to handle three decades of binary decimal pulses; each decimal unit is equivalent to 20 μV input. The converter scans an internal voltage until it becomes equal to the unamplified input voltage, and supplies a serial pulse output.

681.142 3351
The Design of Function Generators using Short-Time Memory Devices and Nonlinear Elements.—A. W. Revay & D. J. Ford. (*Commun. & Electronics*, May 1958, No. 36, pp. 143–152.) The various types of function generator discussed have easily controllable output waveforms which can be made to approximate to any desired shape with a high degree of accuracy.

681.142 3352
An Electronic Differential Analyser.—A. K. Choudhury & B. R. Nag. (*Indian J. Phys.*, Feb. 1958, Vol. 32, No. 2, pp. 91–108.) Equations are derived to show the effect of errors due to circuit elements, and some experimentally obtained solutions are compared with calculated values.

681.142 : 512.3 3353
On the Application of an Electronic Differential Analyser for Finding the Roots of a Polynomial.—B. R. Nag. (*Indian J. Phys.*, May 1958, Vol. 32, No. 5, pp. 212–217.) A transfer function is used with the polynomial as numerator and another suitable function as denominator. The roots are given by the zeros of the output of the system.

681.142 : 517.9 3354
Digital Field Computers.—B. Meltzer & I. F. Brown. (*Nature, Lond.*, 17th May 1958, Vol. 181, No. 4620, pp. 1384–1385.) To eliminate the speed limitation of conventional digital techniques for field computations, a nonuniversal unitary system is proposed, based on the analogy between electron flow through a resistance network and the flow of pulses through a network of computer units. An integral number N is represented by N pulses, and a basic unit generates a train of $\frac{1}{2}(N_1+N_2)$ synchronized pulses from two input pulse trains of N_1 and N_2 pulses. The interconnection of a lattice of basic units gives a finite-difference representation of the general field equation.

681.142 : 518.4 3355
An Automatic Graph Plotter.—J. J. Morrison. (*Trans. Soc. Instrum. Technol.*, June 1958, Vol. 10, No. 2, pp. 55–66.) The adaptation of an analogue plotting table for accepting input data in digital form is described.

681.142 : 621.039 3356
The Application of Digital Computers to Nuclear-Reactor Design.—J. Howlett. (*Proc. Instn elect. Engrs*, Part B, July 1958, Vol. 105, No. 22, pp. 331–336. Discussion, pp. 365–369.) The main computational problems are reviewed, together with examples of the treatment of neutron transport problems. An assessment is made of the performance requirements of future computers.

681.142 : 621.372.5 3357
Use of Laguerre Filters for Realization of Time Functions and Delay.—A. K. Choudhury & N. B. Chakrabarti. (*Indian J. Phys.*, May 1958, Vol. 32, No. 5, pp. 205–211.)

681.142 : 621.385.832 3358
Analogue Multiplier and Function Generator with Cathode-Ray Tube.—A. K. Choudhury & B. R. Nag. (*Indian J. Phys.*, March 1958, Vol. 32, No. 3, pp. 141–148.) A capacitive pick-up device is mounted outside the c.r. tube in front of the screen; it is easily replaced so that the same tube can be used as multiplier or for generating different types of functions.

681.142 : 621.396.11 3359
An Electronic Computer for Statistical Analysis of Radio Propagation Data.—M. Grønlund & C. O. Lund. (*Acta polyt., Stockholm*, 1957, No. 222, 26 pp., 18 plates.)

CIRCUITS AND CIRCUIT ELEMENTS

621.3.049.75 3360
Printed Circuits.—A. Roos. (*Metal Ind., Lond.*, 6th June 1958, Vol. 92, No. 23, pp. 467–470.) Review of materials and manufacturing processes.

621.318.4.045 3361
Coils for Magnetic Fields.—G. M. Clarke. (*Electronic Radio Engr*, Aug. & Sept. 1958, Vol. 35, Nos. 8 & 9, pp. 298–306 & 340–344.) A comparison between wire-wound, foil-wound and coaxial-cable-wound solenoids, considering the limitations of temperature-rise and weight. Equations relating field, power and internal temperature difference are obtained from which the performance of any coil can be calculated. The relative advantages of Al or Cu windings are considered.

621.319.4 3362
A Note on the Self-Resonance of Ceramic Capacitors.—J. Bork. (*Proc. Instn Radio Engrs, Aust.*, May 1957, Vol. 18, No. 5, pp. 159–162.) Details of changes in self-resonant frequency with capacitor type, length of connecting leads and method of mounting are given. Practical applications of the self-resonance of these components in v.h.f. circuits are suggested.

621.372 : 512.831 3363
Certain Applications of Matrices to Circuit Theory.—L. A. Pipes. (*Commun. & Electronics*, May 1958, No. 36, pp. 251–256.) Matrices can be constructed for circuits so that their eigenvalues and vectors relate to

E

the circuit parameters. Propagation constants, characteristic impedances and symmetrical components in polyphase systems are considered from this point of view.

621.372.2 : 621.318.5 **3364**

Synthesis of Series-Parallel Network Switching Functions.—W. Semon. (*Bell Syst. tech. J.*, July 1958, Vol. 37, No. 4, pp. 877–898.) "From the switching functions of *n* variables, those which correspond to networks are abstracted and called network functions. Properties of those network functions corresponding to series-parallel networks are studied and a method for synthesis is developed."

621.372.414 **3365**

High-Power Radio-Frequency Broad-Band Transformers.—E. R. Broad. (*P.O. elect. Engrs' J.*, April 1958, Vol. 51, Part 1, pp. 8–13.) "The design of wide-band transformers composed of simple transmission line elements and capable of handling radio-frequency power of the order of 20 kW is discussed. Examples are given of devices matching 75-ohm coaxial cable to balanced-pair transmission lines with a standing-wave ratio of less than 1·3 over the band 4–28 Mc/s."

621.372.51 **3366**

Complex Matching.—D. Steffen. (*Elektronische Rundschau*, Jan. 1958, Vol. 12, No. 1, pp. 3–9.) The conditions are investigated for obtaining maximum real power at the input of a complex load matched to a generator with complex internal impedance.

621.372.54 : 621.396.96 **3367**

Analysis and Synthesis of Delay-Line Periodic Filters.—H. Urkowitz. (*Trans. Inst. Radio Engrs*, June 1957, Vol. CT-4, No. 2, pp. 41–53. Abstract, *Proc. Inst. Radio Engrs*, Oct. 1957, Vol. 45, No. 10, p. 1432.)

621.372.543.2 **3368**

Pulse Distortion by Band Filters.—K. Emden. (*Arch. elekt. Übertragung*, Dec. 1957, Vol. 11, No. 12, pp. 509–512.) The roots of the homogeneous differential equations for image-parameter (Zobel) band-pass filters with one to four stages are tabulated. The integration constants are determined for the case of a square-wave-modulated carrier equal to the mid-band frequency of the filter.

621.372.543.2 **3369**

Design of Unsymmetrical Band-Pass Filters.—R. F. Baum. (*Trans. Inst. Radio Engrs*, June 1957, Vol. CT-4, No. 2, pp. 33–40. Abstract, *Proc. Inst. Radio Engrs*, Oct. 1957, Vol. 45, No. 10, pp. 1431–1432.)

621.372.553 **3370**

Simplifying Phase Equalizer Design.—W. J. Judge. (*Electronic Ind.*, April 1958, Vol. 17, No. 4, pp. 76–77.) A graphical method using bridged-T and all-pass lattice networks.

621.372.57 : 621.314.7 **3371**

Power Amplification × Bandwidth Figure of Merit for Transducers including Transistors.—L. J. Giacoletto. (*J. Electronics Control*, June 1958, Vol. 4, No. 6, pp. 515–522.) A figure of merit based on spot-frequency maximum power amplification × bandwidth is derived for a transducer which is unilateralized and conjugately matched, the result being simplified by assuming a bell-shaped frequency response. Specific formulae are given for valve and transistor circuits. See e.g. 2238 of 1953.

621.372.6 **3372**

On the Synthesis of Three-Terminal Networks Composed of Two Kinds of Elements.—K. M. Adams. (*Philips Res. Rep.*, June 1958, Vol. 13, No. 3, pp. 201–264.) "A set of necessary and sufficient conditions and a method of realization of all sets of series-parallel *LC* three-terminal network functions from the zeroth to the sixth degree are given."

621.372.632 : 621.396.621 **3373**

A Low-Noise Crystal-Controlled Converter for 144 Mc/s.—G. R. Jessop. (*R.S.G.B. Bull.*, May 1958, Vol. 33, No. 11, pp. 510–512.) Construction details of a converter providing satisfactory reception of signals of about 3 dB above noise level.

621.373.1.018.756 **3374**

Millimicrosecond Pulse Generator.—O. H. Davie. (*Electronic Radio Engr*, Sept. 1958, Vol. 35, No. 9, pp. 332–335.) The generator uses a length of high-frequency cable which is charged from a known d.c. potential. The cable is then discharged into the load by a magnetically operated mercury switch at pulse repetition frequencies up to 120 c/s for pulses of 1-mμs rise time.

621.373.1.029.4 **3375**

Calculations for a Capacitor with Rotating Armatures Piloting a Very-Low-Frequency Generator.—P. Dupin, R. Lacoste & H. Martinot. (*C. R. Acad. Sci., Paris*, 24th Feb., 1958, Vol. 246, No. 8, pp. 1172–1175.) See 1699 of 1957 (Dupin).

621.373.421.13 **3376**

Fluctuations in Quartz Crystal Oscillators.—M. E. Zhabotinskiĭ & P. E. Zil'berman. (*Dokl. Ak. Nauk S.S.S.R.*, 11th April 1958, Vol. 119, No. 5, pp. 918–921.) Results of an analysis using symbolic differential equations show that the noise and thermal fluctuations are not determining factors for stability. See also 1996 of 1956 (Rytov).

621.373.421.13 **3377**

Thermally Compensated Crystal Oscillator.—(*Wireless World*, Sept. 1958, Vol. 64, No. 9, p. 441.) Frequency stabilization without the use of a temperature-controlled oven is obtained by varying the effective shunt load of the crystal, a thermistor bead being the temperature-sensitive element.

621.373.52.072.6 **3378**

Transistor Circuit Varies Reactance.—F. F. Radcliffe. (*Electronics*, 4th July 1958, Vol. 31, No. 27, pp. 76 . . 80.) Frequency control of a 2·5-kc/s oscillator to within 0·1 c/s is achieved by means of a variable-reactance circuit which produces an effective capacitance change of up to 3 500 pF for a change in emitter current from zero to 700 μA

621.374.3 : 681.142 **3379**

A Neon Pulser for the Computer Laboratory.—R. L. Ives. (*Electronic Ind.*, April 1958, Vol. 17, No. 4, pp. 98–100.) An output of 70 V peak, positive or negative, at pulse repetition frequencies from less than 1 c/s to 2·5 kc/s is obtained.

621.374.32 **3380**

High-Speed Pulse Amplitude Discriminator.—F. J. M. Farley. (*Rev. sci. Instrum.*, July 1958, Vol. 29, No. 7, pp. 595–596.) A circuit is described for use in fast counting systems. It handles pulses of amplitude 1–21 V generating a positive output pulse of constant amplitude whose length is determined by the length of the input pulse. Dead time is about 20 mμs and peaks 40 mμs apart are separated.

621.375.012 : 621.396.822 **3381**

Optimum Noise Performance of Linear Amplifiers.—H. A. Haus & R. B. Adler. (*Proc. Inst. Radio Engrs*, Aug. 1958, Vol. 46, No. 8, pp. 1517–1533.) A single quantitative measure of amplifier 'spot noise' performance $(M_e)_{opt}$ is established which removes difficulties associated with the effect of feedback on the noise figure, as it is a function only of the amplifier noise and circuit parameters. It determines the lowest noise figure obtainable at high gain with a given amplifier used alone, or passively connected to other amplifiers of the same $(M_e)_{opt}$, and it provides an index of the absolute quality of noise performance.

621.375.024 **3382**

Performance Calculations for D.C. Chopper Amplifiers.—I. C. Hutcheon. (*Electronic Engng*, Aug. 1958, Vol. 30, No. 366, pp. 476–480.) Switched chopping and demodulating circuits are analysed, and methods of calculating the essential parameters are described.

621.375.024 : [621.317.725 : 621.385 **3383**

D.C. Amplifier Expands Input Voltage Range.—V. D. Schurr. (*Electronics*, 6th June 1958, Vol. 31, No. 23, pp. 87–89.) A direct-coupled d.c. amplifier with infinite input-voltage range and infinite input impedance is described, and details are given of its application in a differential valve-voltmeter without input voltage dividers for measurements at mean levels between − 150 and + 300 V.

621.375 + 621.385].029.65 **3384**

The Generation and Amplification of Millimetre Waves.—W. Kleen & K. Pöschl. (*Nachrichtentech. Z.*, Jan. & Feb. 1958, Vol. 11, Nos. 1 & 2, pp. 8–19 & 77–84.) A detailed survey of techniques and devices including the maser and the harmotron. 88 references.

621.375.126 : 621.396.96 **3385**

The Design of Primary and Secondary Radar I.F. Amplifiers.—N. N. Patla. (*J. Instn Telecommun. Engrs, India*, March 1958, Vol. 4, No. 2, pp. 102–111.) The features of synchronous- and stagger-tuned circuit arrangements are discussed and design procedures outlined. Practical considerations such as feedback, coil design and heat dissipation, and the design of amplifiers having logarithmic characteristics are also covered.

621.375.2 : 621.317.755 **3386**

Direct or A.C. Coupling for Deflexion Amplifiers.—H. L. Mansford. (*Electronic Engng*, Aug. 1958, Vol. 30, No. 366, pp. 473–475.) A quasi-d.c. coupling system using a vertical-deflection amplifier input switch providing d.c. reference pulses for level clamping is described. It is suitable for the range d.c.–100 Mc/s, and the range of d.c. shift can be extended indefinitely as far as insulation permits.

621.375.2.132.3 **3387**

A Direct-Coupled Phase-Splitter.—C. Billington. (*Electronic Engng*, Aug. 1958, Vol. 30, No. 366, pp. 480–482.) A precision cathode-follower and inverter are described having an output resistance of about 3 Ω and a frequency response from d.c. to beyond 100 kc/s.

621.375.226 : 621.396.96 **3388**

Ringing Amplifier.—S. Rozenstein & E. Gross. (*Electronic Radio Engr*, Sept. 1958, Vol. 35, No. 9, pp. 327–332.) A circuit for amplifying 0·2-μs pulses by 110 dB in a radar transponder is described. Damped oscillations, produced by the transient response of a tuned circuit, are amplified, and the second half-cycle selected to trigger the transponder. The unit is of small size and has a low power consumption and a fixed internal delay of 0·4 μs.

621.375.23 **3389**

Bootstrap Circuit Technique.—A. W. Keen. (*Electronic Radio Engr*, Sept. 1958, Vol. 35, No. 9, pp. 345–354.) "The normal amplifier, the bootstrapped amplifier, the cathode-follower and the anode-follower are shown to comprise a set of four circuits related to one another by simple circuit transformations. Three methods of excitation are distinguished. Each circuit may be put into feedback form, and the four basic feedback configurations applicable to bootstrap amplifiers are given. A number of practical examples are described."

621.375.3 **3390**

Magnetic Amplifiers.—D. Katz. (*Bell Lab. Rec.*, Aug. 1958, Vol. 36, No. 8, pp. 294–297.) The use of magnetic amplifiers as static switching devices is discussed. Switching action is obtained by biasing to saturated or unsaturated states. A binary to quaternary decoder using this principle is described.

621.375.3 **3391**

Magnetic-Amplifier Design.—R. E. Anderson. (*Commun. & Electronics*, May 1958, No. 36, pp. 160–175.) Commencing with the basic information of power supply frequency, desired gain and time constant, charts are developed to determine the core design, with reference to load voltage and current. With a specified core, additional charts are presented to determine the design of the winding layout.

621.375.3 : 537.312.62 **3392**

Superconducting Rectifier and Amplifier.—J. L. Olsen. (*Rev. sci. Instrum.*, June 1958, Vol. 29, No. 6, pp. 537–538.) To avoid heat losses due to heavy-current leads in apparatus at liquid-helium temperatures, a high-voltage a.c. supply is applied to a transformer which is coupled to the load through a coil of superconducting material. By applying a magnetic field parallel to the axis of the coil a d.c. component is produced in the load. A current amplification factor of 10 is obtained at 4·2°K using coils of 0·6-mm wire drawn from lead-tin solder. See also 2675 of September (De Vroomen & Van Baarle).

621.375.4 **3393**

Collector Bias, the Transistor Equivalent of Cathode Bias, and some Applications.—R. F. Treharne. (*Proc. Instn Radio Engrs, Aust.*, May 1957, Vol. 18, No. 5, pp. 149–159.) "A self-bias circuit for stabilizing the operating point of a transistor amplifier without unduly decreasing the gain at very low frequencies is discussed. Expressions for the frequency response, stability and input impedance are derived and the application of the circuit to amplifiers, oscillators and active filters is considered."

621.375.4 **3394**

Diode cuts Transistor Cut-off-Current Drift.—H. H. Hoge. (*Electronics*, 18th July 1958, Vol. 31, No. 29, p. 83.) Amplified thermal variations of cut-off current in grounded-emitter amplifiers can be compensated by connecting a diode, experiencing the same thermal changes and having similar collector/base junction saturation current characteristics, across the transistor base/emitter junction.

621.375.4.024 **3395**

A Stabilized D.C. Differential Transistor Amplifier.—L. Depian & R. E. Smith. (*Commun. & Electronics*, May 1958, No. 36, pp. 157–159.) Design details and performance characteristics of a circuit which is insensitive to temperature changes. The method employed eliminates feedback and compensating circuits with their attendant complications and disadvantages.

621.375.43 **3396**

Designing Multiple Feedback Loops.—F. H. Blecher. (*Electronic Ind.*, April & May 1958, Vol. 17, Nos. 4 & 5, pp. 78–82 & 64–68.) Design considerations applicable to transistors in the common-cathode, common-base or common-emitter connections are discussed. Theorems for determining the gain of any multiple-loop circuit and a stability criterion are given.

621.375.9 : 538.569.4.029.6 **3397**

The Saturation Effect in a System with Three Energy Levels.—Fain. (See 3420.)

621.375.9 : 538.569.4.029.64 **3398**

A Three-Level Solid-State Maser.—H. E. D. Scovil. (*Bell Lab. Rec.*, July 1958, Vol. 36, No. 7, pp. 243–246.) Non-mathematical description of three-level maser operation, including a mechanical analogy. Some constructional details and operating characteristics of a particular model amplifying at 6 kMc/s are given.

621.375.9.029.64 : 621.3.011.23 : 621.314.63 **3399**

Low-Noise Amplifier.—(*Bell Lab. Rec.*, July 1958, Vol. 36, No. 7, pp. 250–251.) Description of a 6-kMc/s parametric amplifier using a variable capacitance in the form of a diffused-base Si diode with an active area 0·002 in. in diameter. Advantages and applications of such amplifiers are discussed.

621.376.22 : 621.314.63 **3400**

Ring Modulator Reads Low-Level D.C.—E. J. Keonjian & J. D. Schmidt. (*Electronic Ind.*, April 1958, Vol. 17, No. 4, pp. 86–89.) D.c. signals in the range 10^{-10}–10^{-3}A are fed via a logarithmic Si-diode attenuator to a ring modulator and converted to a.c., which is amplified and serves as a measure of the d.c. input. See also 1663 of 1956 (Moody).

GENERAL PHYSICS

535.33-1 **3401**

The Forty-Eighth Kelvin Lecture: 'Infrared Radiation'.—G. B. B. M. Sutherland. (*Proc. Instn elect. Engrs*, Part B, July 1958, Vol. 105, No. 22, pp. 306–316.) Historical survey with details of applications in the field of infrared spectroscopy. 33 references.

537.122 : 53.08 **3402**

Importance of the Faraday to Elemental Constants and Electricity Standards.—A. G. McNish & R. D. Huntoon. (*Nature, Lond.*, 26th April 1958, Vol. 181, No. 4617, p. 1194.) The ratio *e*/*m* can be determined with high accuracy and without uncertainties due to electrical standards and the acceleration of gravity, using the value of the gyromagnetic ratio of the proton determined from precision measurements (see *Nuovo Cim.*, 1957, Vol. 6, No. 1, pp. 146–184), the cyclotron frequency of the proton, and the faraday determined electrochemically.

537.226 : 621.396.677.8 **3403**

Anisotropic Effects in Geometrically Isotropic Lattices.—Z. A. Kaprielian. (*J. appl. Phys.*, July 1958, Vol. 29, No. 7, pp. 1052–1063.) An analysis of the anisotropy produced by an arbitrary ratio of element spacing to wavelength in an artificial lattice dielectric. The 'granularity' which is important at high frequencies is considered in detail. See also 1671 of 1956.

537.226.31 **3404**

The Electric Properties of a Dielectric with a Variable Number of Relaxation Centres.—N. P. Bogoroditskiĭ, Yu. M. Volokobinskiĭ & I. D. Fridberg. (*Dokl. Ak. Nauk S.S.S.R.*, 21st May 1958, Vol. 120, No. 3, pp. 487–490.) Expressions are derived for permittivity and of dielectric loss tangent. It is shown that the number of ions and dipoles which give rise to relaxation polarization increases with temperature, leading to an increase of permittivity.

537.311.31 **3405**

Plasma Approach to Metallic Conduction.—L. Gold. (*Nature, Lond.*, 10th May 1958, Vol. 181, No. 4619, pp. 1316–

1317.) Normal and superconductive response in metals may be construed as limiting modes of metallic conduction using a theory of plasma interaction.

537.311.33 : 539.2 : 061.3 **3406**

Report on the 5th Course of the International School of Physics of the Italian Physical Society, Varenna, 14th July-3rd August 1957.—(*Nuovo Cim.*, 1958, Vol. 7, Supplement No. 2, pp. 165–736.) Report of the proceedings of the course on solid-state physics held at the Villa Monastero, Varenna The text is given of lectures and discussions, including the following:

(*a*) Optical Properties of Solids.—D. L. Dexter (pp. 245–286, in English). 53 references.

(*b*) The Transition from the Metallic to the Nonmetallic State.—N. F. Mott (pp. 312–328, in English).

(*c*) Electrons and Plasmons.—D. Pines (pp. 329–352, in English).

(*d*) Transport Properties of Solids.—J. M. Ziman (pp. 353–376, in English).

(*e*) Point Imperfections in Solids.—F. Seitz (pp. 414–443, in English).

(*f*) Dislocations in Germanium and Silicon.—H. G. van Bueren, J. Hornstra & P. Penning (pp. 646–660, in English).

(*g*) Properties of Semiconductors.—H. Y. Fan (pp. 661–695, in English).

(*h*) Semiconducting Compounds.—G. A. Busch (pp. 696–712, in English).

(*i*) Shallow Impurity States in Semiconductors.—W. Kohn (pp. 713–723, in English).

(*j*) Recombination Processes in Semiconductors.—P. Aigrain (pp. 724–729, in English).

(*k*) Semiconductors with Charge Carriers of Low Apparent Mass.—O. Madelung (pp. 730–736, in German).

537.311.62 **3407**

The Theory of the Anomalous Skin Effect in Metals.—V. P. Silin. (*Zh. eksp. teor. Fiz.*, Nov. 1957, Vol. 33, No. 5 (11), pp. 1282–1286.) Information concerning the Fermi surface obtained from measurements of surface impedance in the region of the anomalous skin effect does not depend on whether the conduction electrons are considered as a gas or as a degenerate fluid.

537.311.62 **3408**

Skin Effect with Shock Waves.—L. Castagnetto. (*C. R. Acad. Sci., Paris*, 10th Feb. 1958, Vol. 246, No. 6, pp. 916–918.) Approximate formulae are given for the skin effect in a cylindrical conductor traversed by a shock wave.

537.523 **3409**

The Impulse Breakdown Characteristic of a Point/Plane Gap in Air.—J. J. Kritzinger & G. R. Bozzoli. (*Nature, Lond.*, 3rd May 1958, Vol. 181, No. 4618, p. 1259.) The influence of the duration of the impulse wave on the breakdown characteristics for both polarities was investigated for air at a pressure of 62·5 cm Hg and temperature 25°C.

537.533 : 621.385.029.6 **3410**

The Complex Formulation of the Equations for Two-Dimensional Space-Charge Flow.—P. T. Kirstein. (*J. Electronics Control*, May 1958, Vol. 4, No. 5, pp. 425–433.) The equations satisfied by an electron for cóngruent space-charge flow are solved using a complex-variable formulation, for a constant magnetic field normal to the flow. Solutions are also obtained in the presence of space charge but with absence of magnetic fields, and for flow along the level lines of a harmonic function.

537.56 : 538.56 **3411**

Containment of a Fully Ionized Plasma by Radio-Frequency Fields.—H. A. H. Boot, S. A. Self & R. B. R. Shersby-Harvie. (*J. Electronics Control*, May 1958, Vol. 4, No. 5, pp. 434–453.) A fully ionized plasma is treated as a compressible loss-free dielectric in a r.f. field. It is shown that there are steady forces which may be used to confine a body of dense plasma in a conducting cavity resonant in a suitable mode. A particular solution, the E_0 cut-off mode, for which extensive numerical calculations have been made is discussed in some detail and interpreted in terms of possible physical experiments.

537.56 : 538.6 : 538.56.029.53 **3412**

Investigations on the Occurrence of High-Frequency Oscillations in an Ion Source with Magnetic Guiding Field.—H. Kühn. (*Z. Phys.*, 19th Oct. 1957, Vol. 149, No. 3, pp. 267–275.) Oscillations at about 1 Mc/s were observed in H_2 and A, and their amplitude and frequency were measured under various conditions. The effect is interpreted as an acoustic type of plasma oscillation.

537.56 : 538.63 **3413**

Oscillations in a Plasma with Oriented (D.C.) Magnetic Field.—L. Gold. (*J. Electronics Control*, May 1958, Vol. 4, No. 5, pp. 409–416.) The angular dependence of the double resonances representing coupling of a low-energy plasma and cyclotron oscillations is studied for all orientations of the d.c. electric and magnetic fields, using a nonlinear phenomenological approach. Conditions favourable for manifestation of these modes are indicated.

538.221 **3414**

Statistics of the Ising Ferromagnet.—A. Levitas & M. Lax. (*Phys. Rev.*, 1st June 1958, Vol. 110, No. 5, pp. 1016–1027.) The Ising model is treated by synthesizing a cluster treatment with the spherical model which is used to determine approximately the molecular field acting on the cluster, and the effective interactions between dipoles of the cluster. The method is applied to the square net and to the cubic lattice and the critical temperatures are obtained.

538.221 : 537.228.4 **3415**

The Use of the Kerr Effect for Studying the Magnetization of a Reflecting Surface.—E. W. Lee, D. R. Callaby & A. C. Lynch. (*Proc. phys. Soc.*, 1st Aug. 1958, Vol. 72, No. 464, pp. 233–243.) If a domain wall moving in an alternating field crosses a small area illuminated with plane-polarized light, the change in intensity of the reflected light passing through a nearly crossed analyser can be detected by use of a photomultiplier cell and by amplification of the alternating component of its output signal. Experimental results agree well with theoretical predictions. See also 2441 of 1954 (Fowler & Fryer).

538.222 : 534.1-8 **3416**

Paramagnetic Centres as Detectors of Ultrasonic Radiation at Microwave Frequencies.—C. Kittel. (*Phys. Rev. Lett.*, 1st July 1958, Vol. 1, No. 1, pp. 5–6.) It may be possible to detect microwave phonons generated by an electromechanical or magnetomechanical transducer by observing their effect on the saturation of an electron-spin resonance line. The quantitative aspects of this are estimated.

538.3 : 535.13 **3417**

The Equations of Electromagnetic Induction.—Pham Mau Quan. (*C. R. Acad. Sci., Paris*, 3rd Feb. 1958, Vol. 246, No. 5, pp. 707–710.) The association of Maxwell's electromagnetic equations with Einstein's space-time equations is considered.

538.569.4 : 535.34 : 621.372.413 **3418**

Stark-Effect, Resonant-Cavity Microwave Spectrograph.—P. H. Verdier. (*Rev. sci. Instrum.*, July 1958, Vol. 29, No. 7, pp. 646–647.) The construction and use of a cavity for a K-band Stark modulated spectrograph are described. The cavity is a circular cylinder of variable length operating in the TE_{01p} modes. See also 1632 of 1955 (Collier).

538.569.4.029.6 : 535.33 **3419**

Improvement in Millimetre-Wave Detection.—W. E. Tolberg, W. D. Henderson & A. W. Jache. (*Rev. sci. Instrum.*, July 1958, Vol. 29, No. 7, pp. 660–661.) A modification of the detector used in mm-λ spectroscopy [2079 of 1954 (King & Gordy)] is described which facilitates the adjustment of the cat's whisker.

538.569.4.029.6 : 621.375.9 **3420**

The Saturation Effect in a System with Three Energy Levels.—V. M. Fain. (*Zh. eksp. teor. Fiz.*, Nov. 1957, Vol. 33, No. 5(11), pp. 1290–1294.) Mathematical analysis of the effect of a high-frequency alternating field with given harmonics on a system with three energy levels. Expressions are derived for dielectric constant or permeability applicable to maser operation.

539.2 : 538.56 **3421**

Spin-Lattice Relaxation Resonances in Solids.—H. S. Gutowsky and D. E. Woessner. (*Phys. Rev. Lett.*, 1st July 1958, Vol. 1, No. 1, pp. 6–8.) Preliminary experiments suggest the importance of a spin-lattice relaxation mechanism in certain cases. Possible applications to spin-echo storage devices and to masers are outlined.

539.2 : 548.0 **3422**

Some Features of the Motion of Rapid Current Carriers in Polar Crystals.—Yu. I. Gorkun & K. B. Tolpygo. (*Dokl. Ak. Nauk S.S.S.R.*, 21st May 1958, Vol. 120, No. 3, pp. 491–495.) Investigation of the behaviour of polarons (majority current carriers in ionic crystals) with increase of energy.

GEOPHYSICAL AND EXTRATERRESTRIAL PHENOMENA

523.164 : 621.396.677.3 **3423**

Gain Measurements of Large Aerials used in Interferometer and Cross-Type Radio Telescopes.—Little. (See 3339.)

523.164 : 621.396.677.833 **3424**

Radio Telescope Sees 2 Billion Light Years.—C. N. Kington. (*Electronics*, 6th June 1958, Vol. 31, No. 23, pp. 70–75.) Details are given of the drive control system associated with the Jodrell Bank radio telescope. See also 108 of January.

523.164 : 621.396.677.833 **3425**

The Computer and Control for the Telescope at Jodrell Bank.—(*Electronic Engng*, Aug. 1958, Vol. 30, No. 366, pp. 466–472.) The analogue computer and the drive and correction systems which it controls are described.

523.164.3 : 523.4 **3426**

Further Observations of Radio Emission from the Planet Jupiter.—F. F. Gardner & C. A. Shain. (*Aust. J. Phys.*, March 1958, Vol. 2, No. 1, pp. 55–69.) Characteristics of radiation at 19·6 Mc/s are described in detail. The radiation appears to be random noise varying rapidly in intensity and its short-term characteristics can be affected markedly by the terrestrial ionosphere. Three main sources of noise are apparent but none can be identified with visual features. The great variability and spectral concentration of the radiation suggests an origin in some form of plasma oscillation in an ionized region having a critical frequency of about 20 Mc/s. See also 406 of 1956 (Shain).

523.164.32 : 523.74 **3427**

The Variation of Decimetre-Wave Radiation with Solar Activity.—C. W. Allen. (*Mon. Not. R. astr. Soc.*, July 1957, Vol. 117, No. 2, pp. 174–188.) "A statistical method is used to segregate the quiet component from the slowly varying component of solar decimetre-wave radiation in the period 1947–54. For this purpose the radiations at frequencies 2 800, 1 200, and 600 Mc/s have been correlated with sunspot numbers, sunspot areas, and faculae. The mean lives of the various radiations and activities have been estimated and compared. There is an increase of life with decreasing radio frequency. The life of 2 800 Mc/s radiation is about the same as sunspots but measurements of the latter show some anomalies. The slowly varying radiation flux is proportional to frequency in the range studied. The quiet sun flux has a small but significant variation with solar activity, the relative change being greater for smaller frequencies. The possibility that this variation may be associated with uncorrelated local sources, such as prominences, is not entirely excluded."

523.165 : 523.745 **3428**

Changes in Amplitude of the 27-Day Variation in Cosmic-Ray Intensity during the Solar Cycle of Activity.—D. Venkatesan. (*Tellus*, Feb. 1958, Vol. 10, No. 1, pp. 117–125.) The amplitude variation is in general agreement with the changes in solar activity, assessed by the sunspot number, only for the years 1937–1946 and 1952–1955. The poor correlation for the years 1946–1952 may be explained by the changes in the electromagnetic conditions in interplanetary space during the solar cycle.

523.165 : 523.75 **3429**

On the Increase in Cosmic-Ray Intensity and the Electromagnetic State in Interplanetary Space during the Solar Flare of Feb. 23, 1956.—D. Eckhartt. (*Tellus*, Feb. 1958, Vol. 10, No. 1, pp. 126–136.) A detailed analysis of the onset times of the increase in intensity is used in the study of the electromagnetic state. The existence of deflecting magnetic fields between the sun and the earth is demonstrated. A probable mechanism is discussed whereby flare low-energy cosmic-ray particles could be trapped and guided by a solar beam, which could also have caused the large magnetic storm observed two days after the flare.

523.165 : 550.385 **3430**

Geomagnetic Latitude Effect of the Cosmic-Ray Nucleon and Meson Components at Sea Level from Japan to the Antarctic.—M. Kodama & Y. Miyazaki. (*Rep. Ionosphere Res. Japan*, Sept. 1957, Vol. 11, No. 3, pp. 99–115.) Preliminary report on results of measurements made on board the ice-breaker 'Soya' from November 1956 to April 1957. The effects of a cosmic-ray storm in the Antarctic are described.

523.5 : 621.396 11.029.62 **3431**

A Theoretical Rate-Amplitude Relation in Meteoric Forward Scattering.—Hines. (See 3608.)

523.5 : 621.396.11.029.62 **3432**

Observations of Angle of Arrival of Meteor Echoes in V.H.F. Forward-Scatter Propagation.—Endresen, Hagfors, Landmark & Rödsrud. (See 3609.)

523.5 : 621.396.11.029.62 **3433**

The Fading of Long-Duration Meteor Bursts in Forward Scatter Propagation.—Landmark. (See 3610.)

523.53 **3434**

The 1956 Phoenicid Meteor Shower.—A. A. Weiss. (*Aust. J. Phys.*, March 1958, Vol. 2, No. 1, pp. 113–117.) From radio observations at Adelaide six hours before peak activity, the radiant coordinates are estimated to be 15 ± 2, -55 ± 3. The radio rate of 30/h measured on high-sensitivity equipment is much lower than that expected from visual rates of 20 to 100/h reported 1 to 9 h later. See also 771 of March.

523.75 : 550.386 : 621.396.11 **3435**

Sunspot and Magnetic Activity.—A. M. Humby. (*Wireless World*, Sept. 1958, Vol. 64, No. 9, pp. 435–438.) Unusual features of sunspot and magnetic activity in the years 1950–1957 and their effects on the performance and frequency usage of some h.f. radio-teletype circuits are examined.

523.78 **3436**

The Swedish Radio-Scientific Solar Eclipse Expedition to Italy, 1952.—S. I. Svensson, G. Hellgren & O. Perers. (*Acta polyt., Stockholm*, 1957, No. 212, 30 pp.; *Chalmers tek. Högsk. Handl.*, 1956, No. 181.) Preliminary report on observations of the solar eclipse of 25th February 1952. See e.g. 3378 of 1956 (Minnis).

523.78 : 551.510.535 **3437**

Nonuniformity in the Brightness of the Sun's Disk during the Eclipse of 30 June 1954.—C. M. Minnis. (*J. atmos. terr. Phys.*, July 1958, Vol. 12, No. 4, pp. 266–271.) The brightness distributions derived from British and Norwegian ionospheric measurements are presented so as to show their underlying similarity. Quantitative data for the most probable distribution are given and a comparison is made with radio noise measurements at 10·7 cm λ during the eclipse. See also 442 of 1957.

550.372 (481) **3438**

A Survey of Ground Conductivity and Dielectric Constant in Norway within the Frequency Range of 0·2–10 Mc/s.—K. E. Eliassen. (*Geofys. Publ.*, 1957, Vol. 19, No. 11, pp. 1–30.) Measurements were made using the wave tilt method, and a ground conductivity map of Southern Norway has been prepared.

550.385 + 551.594.5 **3439**

On the Theory of Magnetic Storms and Aurorae.—H. Alfvén. (*Tellus*, Feb. 1958, Vol. 10, No. 1, pp. 104–116.) It is shown that the nonmagnetic beam of ionized gas assumed in the Chapman-Ferraro theory is inconsistent with cosmic-ray observations, and that the main phase of the storm cannot be explained in terms of a nonmagnetic beam. The arguments of Chapman (1356 of 1953) and Cowling (13 of 1943) against the electric field theory are discussed and shown to be invalid.

550.385 **3440**

Statistical Investigation of Magnetic Crochets at Tamanrasset.—F. Duclaux & B. Leprêtre. (*C. R. Acad. Sci., Paris*, 24th Feb. 1958, Vol. 246, No. 8, pp. 1243–1245.)

550.385 **3441**

Sub-audible Geomagnetic Fluctuations.—H. J. Duffus, P. W. Nasmyth, J. A. Shand & C. Wright. (*Nature, Lond.*, 3rd May 1958, Vol. 181, No. 4618, pp. 1258–1259.) The observations of Duffus & Shand (3076 of October) have been extended to cover the frequency range 0·1–30 c/s. Records obtained at a portable subsidiary station about 200 miles from the main station near Victoria, B.C., in the same magnetic latitude, showed no phase shift of the normal daytime oscillations.

550.385 **3442**

Large-Amplitude Hydromagnetic Waves above the Ionosphere.—A. J. Dessler. (*Phys. Rev. Lett.*, 15th July 1958, Vol. 1, No. 2, pp. 68–69.) The hydromagnetic-wave velocity is calculated as a function of altitude. There are two regions where the wave velocity changes very rapidly with altitude and it is concluded that hydromagnetic waves above the ionosphere have an amplitude greater than the geomagnetic fluctuations they produce at the surface of the earth. See also 3077 of October.

550.385.1 : 523.75 **3443**

Method of Magnetic-Storm Forecasting from the Activities of Flares accompanied by Solar Radio Noise Outbursts.—K. Sinno. (*Rep. Ionosphere Res. Japan*, Dec. 1957, Vol. 11, No. 4, pp. 195–204.) A statistical study indicates that solar flares accompanied by 200-Mc/s radio noise bursts have a close correlation with terrestrial magnetic storms. See also 446 of February.

550.385.4 : 523.165 **3444**

On the Magnetic Clouds responsible for Variations of Cosmic-Ray and Geomagnetic Field.—H. Hirono. (*Rep. Ionosphere Res. Japan*, Dec. 1957, Vol. 11, No. 4, pp. 205–228.) Discussion of the mechanism suggested by Morrison (*Phys. Rev.*, 15th Feb. 1956, Vol. 101, No. 4, pp. 1397–1404), by which large ionized gas clouds carrying tangled magnetic fields are emitted from the sun and modulate the galactic cosmic rays reaching the earth. It is shown to be more probable that smaller magnetic clouds are intermittently ejected from the sun and slowed down by the interplanetary gas. The velocity of accompanying unmagnetized streams is unaffected, and the different velocities account for the observed initial and main phases of terrestrial magnetic storms; the model also explains some solar cosmic ray phenomena. 39 references.

550.389.2 : 621.396.11 **3445**

Radio Studies during the International Geophysical Year 1957–8.—W. J. G. Beynon. (*J. Brit. Instn Radio Engrs*, July 1958, Vol. 18, No. 7, pp. 401–412. Discussion, pp. 412–416.) Studies are discussed under five headings: (*a*) Vertical soundings, (*b*) ionospheric drift measurements, (*c*) backscatter, (*d*) radio noise and atmospheric studies, and (*e*) rockets and satellites. The history, program and organization of the I.G.Y. are briefly outlined.

550.389.2 : 629.19 **3446**

Theoretical Analysis of Doppler Radio Signals from Earth Satellites.—W. H. Guier & G. C. Weiffenbach. (*Nature, Lond.*, 31st May 1958, Vol. 181, No. 4622, pp. 1525–1526.) The analysis is briefly described and its application to the calculation of the orbits of two satellites (Sputnik I and Explorer I) from isolated observations made at one station is given.

550.389.2 : 629.19 **3447**

Observations of the U.S. Satellites Explorers I and III by C.W. Reflection.—J. D. Kraus, R. C. Higgy & J. S. Albus. (*Proc. Inst. Radio Engrs*, Aug. 1958, Vol. 46, No. 8, p. 1534.) The passage of satellites Explorer I and III may be detected by the increased signal strength of WWV as a result of ionization from the satellite paths. See also 1724 of June (Kraus).

550.389.2 : 629.19 **3448**

Continuous Phase-Difference Measurements of Earth Satellites.—J. W. Herbstreit & M. C. Thompson, Jr. (*Proc. Inst. Radio Engrs*, Aug. 1958, Vol. 46, No. 8, p. 1535.) Two similar receivers are used, operated from a common local oscillator. The phase-meter compares the a.f. tones from the two receivers. See also 234 of 1956.

550.389.2 : 629.19 **3449**

On the Interpretation of the Doppler Effect from Senders in an Artificial Satellite.—K. Weekes. (*J. atmos. terr. Phys.*, July 1958, Vol. 12, No. 4, pp. 335–338.) The Doppler effect is simply related to the angle of incidence of the transmitted signal if the geomagnetic field is ignored, otherwise the relationship is complex, and an investigation of the actual ray-paths is necessary even for the deduction of approximate numerical values.

550.389.2 : 629.19 : 551.510.535 **3450**

The Effect of the Ionosphere on the Doppler Shift of Radio Signals from an Artificial Satellite.—F. H. Hibberd. (*J. atmos. terr. Phys.*, July 1958, Vol. 12, No. 4, pp. 338–340.) Application of Snell's law to a ray passing through a spherically stratified ionosphere to a receiver on the ground, leads to a relation between Doppler shift and angle of incidence at the ground.

551.510.3 **3451**

High-Atmosphere Densities.—M. Nicolet. (*Science*, 6th June 1958, Vol. 127, No. 3310, pp. 1317–1320.) Models of the upper atmosphere are modified to allow for diffusion and other factors in order to conform to the results obtained from satellite observations.

551.510.53 : 550.38 : 523.165 **3452**

Distortion of the Magnetic Field in the Outer Atmosphere due to the Rotation of the Earth.—K. Maeda. (*Rep. Ionosphere Res. Japan*, Sept. 1957, Vol. 11, No. 3, pp. 116–129.) Assuming a cavity surrounding the earth, caused by the earth's revolution, the equations of the fields inside and outside this cavity imply a westward shift of the dip equator in the outer atmosphere, in agreement with cosmic-ray evidence. See e.g. 3721 of 1956 (Simpson et al.).

551.510.535 **3453**

Anomalies in Ionosonde Records due to Travelling Ionospheric Disturbances.—L. H. Heisler. (*Aust. J. Phys.*, March 1958, Vol. 2, No. 1, pp. 79–90.) Anomalies in ionosonde records of the F region during the passage of travelling disturbances are classified into four main types. The diurnal and seasonal variation of their occurrence is discussed and it is suggested that the ion distribution at a height of 200 km governs the type of anomaly observed. See also 1434 of 1957 (Munro & Heisler).

551.510.535 **3454**

Travelling Ionospheric Disturbances in the F Region.—G. H. Munro. (*Aust. J. Phys.*, March 1958, Vol. 2, No. 1, pp. 91–112.) Data obtained from April 1948 to March 1957 on the horizontal movements of the disturbances are analysed for a single radio frequency. The monthly means of direction show a seasonal change from 30° in winter to 120° in summer with a small change in mean speed from 8 km/min to 7 km/min respectively.

551.510.535 : 523.3 **3455**

Measurement of the Ionospheric Faraday Effect by Radio Waves Reflected from the Moon.—F. B. Daniels & S. J. Bauer. (*Nature, Lond.*, 17th May 1958, Vol. 181, No. 4620, pp. 1392–1393.) Continuous waves at 151·11 Mc/s were transmitted from Belmar, N.J., and received at Urbana, Ill., after reflection from the moon. From 2333 to 0600 C.S.T. the change in total electron content deduced from measurements made during the night of January 8th-9th 1958, was about 2·2 times the change computed for a parabolic layer from vertical-incidence recordings at the transmitter site.

551.510.535 : 523.72 **3456**

The Effect of Certain Solar Radiations on the Lower Ionosphere.—R. E. Houston, Jr. (*J. atmos. terr. Phys.*, July 1958, Vol. 12, No. 4, pp. 225–235.) "An electron density distribution in the D and E regions of the ionosphere is computed. Lyman alpha, Lyman beta, the Lyman continuum and X-radiations are considered. The resulting electron distribution is used to compute parameters which may then be compared with data from rocket and long-wave radio experiments. In general, there is good agreement between experimental results and the values predicted by the model."

551.510.535 : 523.75 **3457**

On the Ionospheric Current System of the Geomagnetic Solar Flare Effect (S.F.E.).—H. Volland & J. Taubenheim. (*J. atmos. terr. Phys.*, July 1958, Vol. 12, No. 4, pp. 258–265.) The analysis of 16 magnetograms obtained at Niemegk (near Berlin) between 1951 and 1957 shows that the s.f.e. current system is independent of the S_q system and situated at a lower level. Contributions to the geomagnetic s.f.e. apparently come from both the D and E regions. See also 3866 of 1957 (Taubenheim).

551.510.535 : 523.78 **3458**

The Interpretation of Changes in the E and F_1 Layers during Solar Eclipses.—C. M. Minnis. (*J. atmos. terr. Phys.*, July 1958, Vol. 12, No. 4, pp. 272–282.) Results obtained during a series of eclipses support an interpretation of ionospheric changes in terms of the response of a Chapman layer to the obscuration of a solar disk where localized sources of ionizing radiation are superposed on a uniformly bright background. An alternative hypothesis of a uniform disk and a complex layer with two different species of ion does not adequately explain observed characteristics. Experimental results indicate that errors due to layer tilts are probably not important. See also 3437 above.

551.510.535 : 551.557 **3459**

Method of Measuring Ionospheric Winds by Fading at Spaced Receivers.—R. B. Banerji. (*J. atmos. terr. Phys.*, July 1958, Vol. 12, No. 4, pp. 248–257.) Current statistical methods of measurement are critically reviewed and compared. As a result a method is suggested that may be less laborious than the autocorrelation methods but of comparable accuracy. See e.g. 3216 of 1954 (Ratcliffe).

551.510.535 : 621.396.11 **3460**

On the Bearing of Ionospheric Radio Waves.—K. Miya, M. Ishikawa & S. Kanaya. (*Rep. Ionosphere Res. Japan*, Sept. 1957, Vol. 11, No. 3, pp. 130–144.) Systematic measurements of bearings obtained by means of special d.f. equipment [465 of February (Miya et al.)] are analysed, and fluctuations are interpreted with regard to propagation modes and distance. When the great-circle m.u.f. exceeds the signal frequency the mean bearing coincides with the direction of the main beam of the transmitter aerial, but deviates considerably when the great-circle m.u.f. falls below the signal frequency. The changes are attributed to a major deviation from the great-circle path combined with a final scatter hop from continental land masses. Deviation of antipodal signal bearings are explained assuming that the signals follow paths of low absorption ('night zones').

551.510.535 : 621.396.11 : 621.317.799 **3461**

An Automatic Recorder For Measuring Ionospheric Absorption.—S. C. Mazumdar. (*J. Instn Telecommun. Engrs, India*, March 1958, Vol. 4, No. 2, pp. 81–86.) Ionospheric absorption is deduced from the ratio of the amplitudes of singly and doubly reflected vertical-incidence pulses. The two pulses are separated by adjustable gates and applied to two logarithmic amplifiers followed by a difference circuit operating a chart recorder. In the absence of a second reflection a local reference pulse can be used, the system being calibrated subsequently. See 1444 of 1957 (Mitra & Mazumdar).

551.510.535 : 621.396.11.029.45/.5 **3462**

Low Frequency Reflection in the Ionosphere.—Poeverlein. (See 3604.)

551.510.536 **3463**

The Transition from the Ionosphere to Interplanetary Space.—D. E. Blackwell. (*Nature, Lond.*, 3rd May 1958, Vol. 181, No. 4618, pp. 1237–1238.) Report of a discussion held by the Royal Astronomical Society in London, 21st February 1958, including five short talks concerning the solar corona, zodiacal light, radio echoes from the moon, earth-satellite observations, and a.f. atmospherics.

551.551 : 551.508.822 **3464**

Free Air Turbulence.—A. D. Anderson. (*J. Met.*, Dec. 1957, Vol. 14, No. 6, pp. 477–494.) Measurements of the altitude distribution between 3 000 and 18 300 m of layers of turbulence, made by means of a 'gustsonde' incorporating a v.h.f. transmitter, are analysed.

551.594.21 **3465**

Thunderstorm Charge Separation.—S. E. Reynolds, M. Brook & M. F. Gourley. (*J. Met.*, Oct. 1957, Vol. 14, No. 5, pp. 426–436.) Laboratory experiments show that charge separation may arise from the collision between graupel pellets and ice crystals, from friction between ice formations at different temperatures or with different amounts of contamination, and from the re-solidification of a liquid layer in contact with ice.

551.594.5 : 621.396.11.029.6 **3466**

Low-Latitude Reflections from the Aurora Australis.—T. J. Seed & C. D. Ellyett. (*Aust. J. Phys.*, March 1958, Vol. 2, No. 1, pp. 126–129.) Observations of radar reflections for the period March–June 1957 are reported. Records of radar, visual and geomagnetic observations for one day are compared.

551.594.6 : 621.396.11.029.45 **3467**

Velocity of Propagation of Electromagnetic Waves at Audio Frequencies.—Al'pert & Borodina. (See 3605.)

LOCATION AND AIDS TO NAVIGATION

621.396.93 **3468**

Methods and Installations for Long-Distance Radio Navigation.—W. Stanner. (*Elektrotech. Z., Edn A*, 1st May 1958, Vol. 79, No. 9, pp. 322–329.) A review of the principal present-day systems including Loran, Consol and Dectra.

621.396.93 **3469**

Improvements in H.F. Direction Finding by Automatic Time Averaging.—J. F. Hatch & D. W. G. Byatt. (*Marconi Rev.*, 1st Quarter 1958, Vol. 21, No. 128, pp. 16–29.) Equipment is described for use with c.w. or i.c.w. signals which gives automatically the mean bearing averaged over a range of time intervals. The improvement is assessed by comparison with simultaneous bearings observed on twin-channel c.r.d.f. equipment.

621.396.93(94) **3470**

The Australian D.M.E. System.—E. Stern. (*Proc. Instn Radio Engrs, Aust.*, Sept. 1957, Vol. 18, No. 9, pp. 318–327.) Description of the development and operation of the system. See 3471 below.

621.396.93.029.62 **3471**

Echo Interference in a 200-Mc/s Double-Pulse D.M.E. System.—B. R. Johnson. (*Proc. Instn Radio Engrs, Aust.*, Sept. 1957, Vol. 18, No. 9, pp. 309–317.) In d.m.e. systems such as the Australian system using double-pulse interrogation coding as a means of channel selection, echo interference may cause (*a*) interrogation of off-channel beacons, (*b*) incorrect range indication, (*c*) masking of beacon identification code. Theoretical analysis and experimental work indicate what type of reflectors may be troublesome, and how echo interference can be minimized.

621.396.933 **3472**

Factors in the Design of Airborne Doppler Navigation Equipment.—E. G. Walker. (*J. Brit. Instn Radio Engrs*, July 1958, Vol. 18, No. 7, pp. 425–442. Discussion, pp. 442–444.) "The paper describes the use of a Doppler-sensor of aircraft component-velocities as an input for self-contained dead-reckoning navigation. Choice of radio frequencies, beam configuration, radiated power and other system parameters is discussed and some basic quantitative expressions derived. Design features of the individual units of the sensor are given and requirements of computer and heading-reference outlined. System accuracy is discussed and the heading information is shown to be the factor presently limiting system performance."

621.396.933.1 : 621.396.824 **3473**

Sudden Changes in Bearing Indication on Medium-Wave Four-Course Radio Ranges using Cathode-Ray Direction-Finders.—A. R. Wendlinger. (*Elektronische Rundschau*, Jan. 1958, Vol. 12, No. 1, pp. 10–12.) Experimental investigations of the Stavanger effect show that it is due to interference at the receiver between signals emitted by two different radio beacons operating at almost identical frequencies.

621.396.96 **3474**

The Influence of Atmospheric Conditions on Radar Performance.—J. A. Saxton. (*J. Inst. Nav.*, July 1958, Vol. 11, No. 3, pp. 290–303.) The effects of gaseous absorption and of various forms of precipitation upon the performance of radars at 3 cm λ are reviewed. Heavy widespread rain can cause serious reduction in range. The effects of superrefraction are discussed, and it is shown how skip effects can occur.

621.396.96 **3475**

A 3-cm Airport Control Radar System.—F. W. Garrett. (*Marconi Rev.*, 1st Quarter 1958, Vol. 21, No. 128, pp. 3–15.)

621.396.96 **3476**

Four Ways to Simulate Radar Targets.—J. I. Leskinen. (*Electronics*, 6th June 1958, Vol. 31, No. 23, pp. 82–86.) Pulses are generated to simulate azimuth, elevation and range of targets moving at speeds up to 2 400 knots. Land and sea clutter effects are also produced.

621.396.96 : 621.375.226 **3477**

Ringing Amplifier.—Rozenstein & Gross. (See 3388.)

621.396.969.33 **3478**

The Planning of Shore-Based Radar Installations for Marine Navigation.—H. Bürkle. (*Telefunken Ztg*, Dec. 1957, Vol. 30, No. 118, pp. 236–245. English summary, p. 287.) Factors governing the choice of site and coverage and transmitter and aerial characteristics are examined. Avoidance of interference from neighbouring stations, and systems of transmitter control are also considered.

MATERIALS AND SUBSIDIARY TECHNIQUES

535.215 **3479**

Photoconductivity of Zinc Selenide Crystals and a Correlation of Donor and Acceptor Levels in II-VI Photoconductors.—R. H. Rube & E. L. Lind.

(*Phys. Rev.*, 1st June 1958, Vol. 110, No. 5, pp. 1040–1049.) Photosensitive crystals of ZnSe were prepared by incorporating suitable proportions of group-VII donors and either group-I or group-V acceptors in crystals prepared from the vapour phase. Photoconductivity phenomena characteristic of other group II-VI photoconductors were also found for ZnSe.

535.215 **3480**

Photo-effects with Anodic Oxide Layers on Tantalum and Aluminium.—W. C. van Geel, C. A. Pistorius & P. Winkel. (*Philips Res. Rep.*, June 1958, Vol. 13, No. 3, pp. 265–276.) The photoelectric properties of the system $Ta/Ta_2O_5/$ electrolyte during irradiation with ultraviolet light are investigated, and an attempt is made to explain the observed phenomena by assuming that the work function for Ta/Ta_2O_5 is smaller than that for electrolyte/Ta_2O_5.

535.37 **3481**

Phosphorescence and Fluorescence Quantum Yield Ratios as related to the Position of the Fluorescence Spectrum.—V. V. Zelinskiĭ & V. P. Kolobkov. (*Dokl. Ak. Nauk S.S.S.R.*, 11th April 1958, Vol. 119, No. 5, pp. 922–925.)

535.37 **3482**

Investigations in the $CuGaS_2$-ZnS and $AgGaS_2$-ZnS Systems.—E. F. Apple. (*J. electrochem. Soc.*, May 1958, Vol. 105, No. 5, pp. 251–255.)

535.37 : 546.472.21 **3483**

Some Remarks on the 'Self-Activation' of ZnS.—E. A. Schwager & A. Fischer. (*Z. Phys.*, 19th Oct. 1957, Vol. 149, No. 3, pp. 345–346.) The effect is interpreted as a shift of Schottky-type defect equilibrium according to the conditions of phosphor preparation.

535.37 : 546.472.21 **3484**

A Sensitive Method of Detecting Lead, and the Inclusion of Lead in Zinc Sulphide.—E. A. Schwager & A. Fischer. (*Z. Phys.*, 19th Oct. 1957, Vol. 149, No. 3, pp. 347–352.) Activation of ZnS by Pb is discussed.

535.376 **3485**

The Effect of Electric Fields on Scintillations in Crystalline Zinc Sulphide.—G. F. Alfrey & K. N. R. Taylor. (*J. Electronics Control*, May 1958, Vol. 4, No. 5, pp. 417–424.) In electroluminescent crystals brightness is reduced when α particles are incident on the negative electrode. Observations have been interpreted in terms of a cathode barrier in ZnS which changes in thickness with frequency, the variation being considered to be a change in dielectric constant. Results agree with earlier work [782 of 1956 (Ince & Oatley)] and are supported by observation of the electroluminescence threshold voltage.

535.376 : 621.385.832 **3486**

Electron Excitation of Bilayer Screens.—L. R. Koller & H. D. Coghill. (*J. appl. Phys.*, July 1958, Vol. 29, No. 7, pp. 1064–1066.) "The control of the colour of the luminescence of thin transparent superimposed phosphor films when excited by electron beams of varying voltage is discussed. The quantitative relations are found to be in agreement with a theory based on the laws of electron penetration and scattering."

537.226/.228.1 : 546.431.824-31 **3487**

Some Studies on the Ternary System $(Ba\text{-}Pb\text{-}Ca)TiO_3$.—T. Ikeda. (*J. phys. Soc. Japan*, April 1958, Vol. 13, No. 4, pp. 335–340.) The phase diagram for the system is investigated while the Ca concentration is increased, and it is shown that the ferroelectric and tetragonal phase changes to the orthorhombic structure of $CaTiO_3$, passing through cubic and pseudo-cubic phases. The dielectric, piezoelectric and mechanical properties of the system are also examined.

537.226/.227 : 546.431.824-31 **3488**

Barkhausen Pulses in Barium Titanate.—A. G. Chynoweth. (*Phys. Rev.*, 15th June 1958, Vol. 110, No. 6, pp. 1316–1332.) An investigation of the Barkhausen pulses that occur during polarization reversal. The pulse shapes and in particular their heights and rise times have been studied as a function of the crystal thickness and the applied field strength. The observations are not consistent with the usual jerky domain-wall motion models for the generation of Barkhausen pulses. It is suggested that the pulses could represent the nucleation and initial stages of growth of new spike-shaped domains extending along the *c* axis, and that the fixed numbers of pulses given by a crystal would then indicate a definite number of nucleating sites on the crystal surfaces.

537.226/.227 : 546.431.824-31 **3489**

Decay Effects in Barium Titanate Ceramics.—H. L. Allsopp. (*Phil. Mag.*, Sept. 1957, Vol. 2, No. 21, pp. 1100–1102.) Variations of dielectric and electromechanical properties following the application and removal of a strong alternating field are described.

537.226/.227 : 546.431.824-31 **3490**

Electron Spin Resonance in Single Crystals of $BaTiO_3$.—W. Low & D. Shaltiel. (*Phys. Rev. Lett.*, 15th July 1958, Vol. 1, No. 2, pp. 51–52.) The very intense spectrum observed at 3 cm λ is attributed to the ferroelectric state of $BaTiO_3$ and not to any paramagnetic impurity.

537.226 : 546.824-31 **3491**

Dielectric Losses in TiO_2 Single Crystals.—J. Van Keymeulen. (*Naturwissenschaften*, Feb. 1958, Vol. 45, No. 3, p. 56. In English.)

537.227 **3492**

The Polarization Reversal Process in Ferroelectric Single Crystals.—M. Prutton. (*Proc. phys. Soc.*, 1st Aug. 1958, Vol. 72, No. 464, pp. 307–308.)

537.227 **3493**

New Room-Temperature Ferroelectric.—R. Pepinsky, K. Vedam & Y. Okaya. (*Phys. Rev.*, 15th June 1958, Vol. 110, No. 6, pp. 1309–1311.) The neutral-salt complex with glycine, $(NH_2CH_2COOH)_2$-$MnCl_2.2H_2O$ is found to be ferroelectric from low temperatures to +55°C. Details of measurements on this salt are given.

537.227 **3494**

Ferroelectric and Optical Properties of Na(K-NH_4)-Tartrate Mixed Crystals.—Y. Makita & Y. Takagi. (*J. phys. Soc. Japan*, April 1958, Vol. 13, No. 4, pp. 367–377.) In 90·5% $NaNH_4$ tartrate crystals three kinds of polymorphic modification have been found: (*a*) a ferroelectric phase with spontaneous polarization along the *a* axis; (*b*) a ferroelectric phase with polarization along the *b* axis; (*c*) a paraelectric phase. The complete phase diagram of the system is examined.

537.311.3 : 539.23 **3495**

Remarks on some Electrical Properties of Very Thin Films of Silver.—C. Uny & N. Nifontoff. (*C. R. Acad. Sci., Paris*, 10th Feb. 1958, Vol. 246, No. 6, pp. 906–909.) Techniques used in the preparation of regular and stable thin films are noted, and measurements of resistance variation with time and with current are reported. See also 2167 of 1957.

537.311.33 **3496**

Statistics of Compensated Divalent Impurities in Semiconductors.—W. Mercouroff. (*C. R. Acad. Sci., Paris*, 24th Feb. 1958, Vol. 246, No. 8, pp. 1175–1177.) The introduction of compensating monovalent impurity centres considerably modifies the variation in the number of free carriers as a function of temperature. Analytical results have been confirmed by experiments on Zn-doped Ge compensated by Sb.

537.311.33 **3497**

Theory of an Experiment for Measuring the Mobility and Density of Carriers in the Space-Charge Region of a Semiconductor Surface.—R. L. Petritz. (*Phys. Rev.*, 15th June 1958, Vol. 110, No. 6, pp. 1254–1262.) Two models are considered: (*a*) a single crystal composed of two regions, a surface region of thickness of the order of a Debye length and a bulk region, and (*b*) a single crystal with continuous variation of the potential in the direction perpendicular to the surface. Rigorous expressions are derived for the Hall coefficient and magnetoresistance.

537.311.33 **3498**

Oxides of the 3*d* Transition Metals.—F. J. Morin. (*Bell Syst. tech. J.*, July 1958, Vol. 37, No. 4, pp. 1047–1084.) An examination of the magnetic, electrical and optical properties leads to a tentative energy-band scheme for the oxides of scandium, titanium and vanadium. The remaining 3*d* metal oxides do not have a conduction band, and an energy level scheme for these is calculated from electrostatics. 47 references.

537.311.33 **3499**

Compound Semiconductors.—H. P. R. Frederikse. (*J. Metals, N.Y.*, May 1958, Vol. 10, No. 5, pp. 346–350.) "A survey of the characteristics of compound semiconductors as deduced from measurements of their mechanical, optical, electrical, magnetic, and thermal properties."

537.311.33 3500

Solid Solution in $A^{III}B^{V}$ Compounds.—J. C. Woolley & B. A. Smith. (*Proc. phys. Soc.*, 1st Aug. 1958, Vol. 72, No. 464, pp. 214–223.) Investigations show that in most of the compounds considered, complete solid solution can be obtained throughout the whole range of composition under special conditions of temperature and annealing time.

537.311.33 3501

Adsorption and Charge Transfer on Semiconductor Surfaces.—H. J. Krusemeyer & D. G. Thomas. (*Phys. Chem. Solids*, 1958, Vol. 4, Nos. 1/2, pp. 78–90.) A theoretical evaluation of the concentration of ions and neutral atoms adsorbed on a semiconductor surface, from a mixture of two gases, one giving positive, the other negative, adions. Numerical results are calculated for semiconductors such as ZnO with a large forbidden gap at temperatures below the intrinsic range.

537.311.33 3502

Space-Charge Calculations for Semiconductors.—R. Seiwatz & M. Green. (*J. appl. Phys.*, July 1958, Vol. 29, No. 7, pp. 1034–1040.) A derivation of the general equation relating the electric field at the semiconductor surface to the electrostatic potential difference across the space charge region. The treatment considers degenerate free carrier distributions and partial ionization of impurities.

537.311.33 3503

Sweep-Out Effects in the Phase-Shift Method of Carrier-Lifetime Measurements.—N. B. Grover & E. Harnick. (*Proc. phys. Soc.*, 1st Aug. 1958, Vol. 72, No. 464, pp. 267–269.) The particular case of thin rectangular filaments with ohmic contacts and low-level sinusoidally modulated illumination is considered with a view to determining an upper limit for the value of the applied field consistent with negligible sweep-out effects.

537.311.33 3504

Infrared and Microwave Modulation using Free Carriers in Semiconductors.—A. F. Gibson. (*J. sci. Instrum.*, Aug. 1958, Vol. 35, No. 8, pp. 273–278.) The failures and successes of the classical Drude-Zener theory in relation to experimental results are discussed. Methods are described for modulating the conductivity of a semiconductor and for applying these techniques to the study of its optical and microwave properties.

537.311.33 : 061.3 3505

Report on the Second Symposium on the Physics of Semiconductors.—F. Herman. (*Phys. Chem. Solids*, March 1957, Vol. 2, No. 1, pp. 72–82.) Summary of papers presented at a symposium in Washington, D.C., 24th–26th October 1956, covering work on conduction mechanisms, the effect of magnetic fields, and investigations of paramagnetic resonance.

537.311.33 : 538.569.4 3506

Observation of Microwave Cyclotron Resonance by Cross Modulation.—H. J. Zeiger, C. J. Rauch & M. E. Behrndt. (*Phys. Rev. Lett.*, 15th July 1958, Vol. 1, No. 2, pp. 59–60.) The sample was placed in the high E-field region of a microwave cavity, the resonance peaks being observed by detecting changes in d.c. resistance of the sample. The microwave power applied was amplitude-modulated at 260 c/s and cross-modulation was observed on samples of pure Ge and *p*-type InSb.

537.311.33 : 538.63 3507

Variation of Hall Mobility of Carriers in Nondegenerate Semiconductors with Electric Field.—M. S. Sodha & P. C. Eastman. (*Phys. Rev.*, 15th June 1958, Vol. 110, No. 6, pp. 1314–1316.) An expression is obtained for the Hall mobility applicable in a large range of fields and non-Maxwellian distribution of velocities of carriers.

537.311.33 : 538.63 3508

Hall and Transverse Magnetoresistance Effects for Warped Bands and Mixed Scattering.—A. C. Beer & R. K. Willardson. (*Phys. Rev.*, 15th June 1958, Vol. 110, No. 6, pp. 1286–1294.) The transport integrals for warped bands were evaluated for relaxation times determined by mixed scattering from acoustic phonons and ionized impurities. Hall and transverse magnetoresistance coefficients were calculated for parameters characteristic of the degenerate valence bands in Ge and Si, the results being consistent with experimental observations.

537.311.33 : 538.63 3509

The Change of Carrier Concentration in the Simple Semiconductors with Static Magnetic Field.—Y. Uemura & M. Inoue. (*J. phys. Soc. Japan*, April 1958, Vol. 13, No. 4, pp. 377–381.) Three solutions are considered depending on the trapping-centre concentration: (*a*) with distinct trapping levels the carrier concentration n decreases with the magnetic field H; (*b*) with sufficient levels to form an impurity band whose width is less than kT, n increases or decreases depending on the effective carrier mass; (*c*) n increases with H for large effective carrier mass when the width of the impurity band is greater than kT.

537.311.33 : [546.28 + 546.289 3510

The Magnetic Susceptibility and Effective Mass of Charge Carriers in Silicon and Germanium.—D. Geist. (*Naturwissenschaften*, Jan. 1958, Vol. 45, No. 2, pp. 33–34.) Preliminary report on measurements of susceptibility at constant temperatures, from which any temperature dependence of the effective mass can be determined.

537.311.33 : 546.28 3511

Ion Pairing in Silicon.—J. P. Maita. (*Phys. Chem. Solids*, 1958, Vol. 4, Nos. 1/2, pp. 68–70.) "The occurrence of ion pairing in Si is demonstrated. The pairing process is used to determine the diffusivity of Li in Si at low temperatures and the distance of closest approach between the ions forming the pair."

537.311.33 : 546.28 3512

Lifetime in *p*-Type Silicon.—J. S. Blakemore. (*Phys. Rev.*, 15th June 1958, Vol. 110, No. 6, pp. 1301–1308.) Lifetime is measured as a function of excess electron density in the temperature range 200–400°K. A stronger dependence is found at electron densities $< 10^{12}$ cm^{-3} than at larger densities. The data are discussed in terms of two separate recombinative levels.

537.311.33 : 546.28 3513

Magnetic Properties of *N*-Type Silicon.—E. Sonder & D. K. Stevens. (*Phys. Rev.*, 1st June 1958, Vol. 110, No. 5, pp. 1027–1034.) The magnetic susceptibility of *n*-type Si samples with a wide range of donor concentrations has been measured as a function of temperature from 3°K to 300°K. By utilizing conduction-electron concentrations obtained from Hall-coefficient measurements on comparison specimens over the range 50°K–400°K, the contributions to the susceptibility arising from the conduction electrons and electrons trapped on donor atoms have been analysed. In the upper range of temperature the diamagnetic contribution of conduction electrons is dominant and is consistent with the model of six energy minima in the conduction band. However, comparison of the squared reciprocal mass ratio with that obtained from cyclotron-resonance experiments reveals that the former is appreciably smaller than the latter.

537.311.33 : 546.28 3514

Effect of Dislocations on Breakdown in Silicon *p-n* Junctions.—A. G. Chynoweth & G. L. Pearson. (*J. appl. Phys.*, July 1958, Vol. 29, No. 7, pp. 1103–1110.) A description of experiments providing definite correlations between the light-emission patterns at breakdown and dislocations, the latter being revealed by etching. The possible explanations of this effect are discussed. See e.g. 3527 of 1957 (Chynoweth & Pearson).

537.311.33 : 546.28 3515

Electron-Bombardment Damage in Silicon.—G. K. Wertheim. (*Phys. Rev.*, 15th June 1958, Vol. 110, No. 6, pp. 1272–1279.) It is shown that the bombardment imperfections consist of sites containing at least two electrically active point defects. The relation between these sites and the energy levels in the forbidden gap found in an earlier investigation is established. See also 2807 of 1957.

537.311.33 : 546.28 3516

Method for the Detection of Dislocations in Silicon by X-Ray Extinction Contrast.—J. B. Newkirk. (*Phys. Rev.*, 15th June 1958, Vol. 110, No. 6, pp. 1465–1466.)

537.311.33 : 546.28 3517

Sintering Method for Semiconductor Material.—G. K. Gaulé, J. T. Breslin & J. R. Pastore. (*Rev. sci. Instrum.*, July 1958, Vol. 29, No. 7, pp. 565–567.) A sintering process is described for forming small grains of pure Si into rods suitable for feeding a crystal-growing apparatus [see e.g. 3255 of 1954 (Keck et al.)]. The rods are sintered by application of pressure, alternating current and a r.f. field without using a binder.

537.311.33 : 546.28 **3518**

Control of Surface Concentration in the Diffusion of Phosphorus in Silicon.—M. J. Coupland. (*Nature, Lond.*, 10th May 1958, Vol. 181, No. 4619, pp. 1331–1332.) Desired values of surface concentration over the range $5 \times 10^{16} - 5 \times 10^{18}$ atoms/cm³ are obtained by controlling the phosphorus vapour pressure in a closed evacuated tube, one end of which, containing Si slices, is held in a diffusion furnace, while the other, containing yellow phosphorus, is maintained at temperatures in the range -30°C to $+35$°C.

537.311.33 : 546.28 **3519**

The Interaction of Oxygen with Clean Silicon Surfaces.—J. T. Law. (*Phys. Chem. Solids*, 1958, Vol. 4, Nos. 1/2, pp. 91–100.)

537.311.33 : 546.28 : 538.632 **3520**

The Electrical Conductivity and Hall Effect of Silicon.—E. H. Putley & W. H. Mitchell. (*Proc. phys. Soc.*, 1st Aug. 1958, Vol. 72, No. 464, pp. 193–200.) Measurements have been made in the temperature range 20°–500°K on single crystals of Si with extrinsic carrier concentrations between 2 and 5×10^{12} cm^{-3} to estimate the purity of the material and to study the Hall mobility. Mobilities of electrons and holes are greater than previously observed [e.g. 2184 of 1957 (Cronemeyer)].

537.311.33 : 546.289 **3521**

Predicted Intervalley Scattering Effects in Germanium.—W. Shockley. (*Phys. Rev.*, 1st June 1958, Vol. 110, No. 5, pp. 1207–1208.) Two methods for studying intervalley scattering effects are described. One is the study of the admittance of an *n-p* junction at high frequencies ; the other method uses an *n-p-n* transistor with suitable properties.

537.311.33 : 546.289 **3522**

Impact Ionization of Impurities in Germanium.—N. Sclar & E. Burstein. (*Phys. Chem. Solids*, March 1957, Vol. 2, No. 1, pp. 1–23.) The low-temperature electrical breakdown effect is investigated experimentally as a function of temperature, magnetic field, background radiation, type and concentration of impurities, geometry, surface effects, orientation of the specimens and time dependence. The effect is attributed to the impact ionization of impurities by free charge carriers, and a mean-value theory is developed for the critical breakdown field. See also 1796 of 1957 (Sclar).

537.311.33 : 546.289 **3523**

Effect of the Impurity Band in Germanium Doped with Zinc, at Very Low Temperatures.—W. Mercouroff. (*C. R. Acad. Sci., Paris*, 17th Feb. 1958, Vol. 246, No. 7, pp. 1013–1015.) At low temperatures, Hall effect and conductivity in samples of Ge, heavily doped with Zn and compensated with Sb, were found to vary with the applied electric field.

537.311.33 : 546.289 **3524**

The Effect of Ion Pair and Ion Triplet Formation on the Solubility of Lithium in Germanium—Effect of Gallium and Zinc.—H. Reiss & C. S. Fuller. (*Phys. Chem. Solids*, 1958, Vol. 4, Nos. 1/2, pp. 58–67.) Theoretical predictions of the effect of ion pairing or association on solubility are confirmed. By taking account of ion association effects a more accurate curve for the solubility of Li in undoped Ge is obtained.

537.311.33 : 546.289 **3525**

Preparation and Regeneration of Clean Germanium Surfaces.—S. P. Wolsky. (*J. appl. Phys.*, July 1958, Vol. 29, No. 7, pp. 1132–1133.) A summary of (*a*) a modified method designed to improve the cleaning efficiency of the ion bombardment process, and (*b*) thermal restoration effects in Ge surfaces exposed to oxygen.

537.311.33 : 546.289 **3526**

Temperature Dependence of Point-Contact Injection Ratio in Germanium.—D. Gerlich. (*Proc. phys. Soc.*, 1st Aug. 1958, Vol. 72, No. 464, pp. 264–267.) A method is described for the measurement of point-contact injection ratio by direct compensation. Results are given for *n*- and *p*-type material for the temperature range 150°–350°K. See also 1821 of 1957.

537.311.33 : 546.289 : 538.63 **3527**

Magneto-surface Experiments on Germanium.—J. N. Zemel & R. L. Petritz. (*Phys. Rev.*, 15th June 1958, Vol. 110, No. 6, pp. 1263–1271.) Ambient-induced changes in the conductivity, Hall coefficient, and magnetoresistance of thin samples of intrinsic Ge have been studied. The data are analysed using the theory of Petritz (3497 above). The results indicate that light holes play an important role in the transport process in the surface. There is a reduction of the mobility of surface electrons in qualitative agreement with the predictions of Schrieffer (2322 of 1955).

537.311.33 : 546.289 : 538.63 **3528**

Magnetoresistance Symmetry Relation in *n*-Germanium.—C. Goldberg & W. E. Howard. (*Phys. Rev.*, 1st June 1958, Vol. 110, No. 5, pp. 1035–1039.) Careful measurement of the weak-field magnetoresistance coefficients of *n*-type Ge indicates that the magnetoresistance symmetry relation is obeyed for samples with carrier concentrations as high as 6×10^{15} cm^{-3}. For a 3×10^{16} sample, the deviation, if any, is still quite small. For samples with larger concentrations there is definite evidence of some deviation.

537.311.33 : 546.289 : 538.63 : 535.376 **3529**

The Electromagnetoluminescence Effect in Germanium.—M. Bernard & J. Loudette. (*C. R. Acad. Sci., Paris*, 24th Feb. 1958, Vol. 246, No. 8, pp. 1177–1180.) The emission of infrared radiation by a sample of Ge placed in an electric field at right angles to a magnetic field is due to the recombination of electrons and holes. This has been studied experimentally.

537.311.33 : 546.289 : 541.135 **3530**

The Rectifying Effect of Germanium/Electrolyte Contacts.—G. Déjardin, G. Mesnard & A. Dolce. (*C. R. Acad. Sci., Paris*, 17th Feb. 1958, Vol. 246, No. 7, pp. 1016–1018.) Measurements have been made of the *I/V* characteristics of single-crystal *n*-type Ge in contact with a 0·1 N solution of HCl, using 12-V pulses of duration several microseconds, with and without a superimposed polarizing voltage of about 1 V.

537.311.33 : 546.289 : 621.314.63 **3531**

On the Backward Leakage Current in the Alloyed Germanium *p-n* Junction.—M. Kikuchi. (*J. phys. Soc. Japan*, April 1958, Vol. 13, No. 4, pp. 350–362.) Experimental procedure and results are described for the observation of 'creep' phenomena (i.e. variation of current with a fixed applied voltage). Creep is observed in the leakage current component and it is also found that, in some alloy-junction transistors, the creep in the emitter junction influences the characteristics of the collector junction. Some theoretical considerations are suggested which partially explain the experimental results.

537.311.33 : 546.57.24 **3532**

Electrical Properties of Ag_2Te.—S. Miyatani. (*J. phys. Soc. Japan*, April 1958, Vol. 13, No. 4, pp. 341–350.) Measurements of electronic conductivity, Hall constant and thermoelectric power have been made, for varying ratios of Ag/Te, using a galvanic cell $Ag/AgI/Ag_2Te/Pt$. The e.m.f. of the cell represents the position of the Fermi level relative to Ag-saturated Ag_2Te.

537.311.33 : 546.682.86 **3533**

High-Electric-Field Effects in *n*-Indium Antimonide.—M. Glicksman & M. C. Steele. (*Phys. Rev.*, 1st June 1958, Vol. 110, No. 5, pp. 1204–1205.) Pulsed current/voltage measurements have been made at 77°K on a single crystal of *n*-type InSb up to a current density of 10^4A/cm². Beyond about 2×10^3 A/cm² the current increased rapidly for small further increases in voltage. The mechanism of electron-hole pair creation is used to explain the results. See also 2148 of July (Prior).

537.311.33 : 546.682.86 **3534**

Theory of Cyclotron Resonance Absorption by Conduction Electrons in Indium Antimonide.—R. F. Wallis. (*Phys. Chem. Solids*, 1958, Vol. 4, Nos. 1/2, pp. 101–110.) A semi-classical treatment, assuming a simple conduction band with a minimum at $k = 0$, and neglecting spin interactions.

537.311.33 : 546.682.86 **3535**

Influence of Crystal Orientation on the Surface Behaviour of InSb.—M. C. Lavine, A. J. Rosenberg & H. C. Gatos. (*J. appl. Phys.*, July 1958, Vol. 29, No. 7, pp. 1131–1132.)

537.311.33 : [546.682.86 + 546.289] **3536**
: 535.33-1

The Infrared Emissivities of Indium Antimonide and Germanium.—T. S. Moss & T. D. H. Hawkins. (*Proc. phys. Soc.*, 1st Aug. 1958, Vol. 72, No. 464, pp. 270–273.)

537.311.33 : 546.682.86 : 538.63 **3537**

Magnetoresistance and Field Dependence of the Hall Effect in Indium Antimonide.—G. Fischer & D. K. C. MacDonald. (*Canad. J. Phys.*, May 1958, Vol. 36, No. 5, pp. 527–538.) Measurements of resistance and Hall effect show both to be highly dependent on magnetic field. The classical two-band model, often proposed to account for the behaviour of metals, is found to account quite well for the observed results up to the highest fields used. The underlying assumptions of this theory are reviewed and simple formulae are derived, allowing the concentration and mobilities of both types of carrier to be calculated from the magnetic-field dependence of the resistivity and Hall effect.

537.311.33 : 621.314.63 : 537.52 **3538**

The Avalanche Breakdown Voltage of Narrow $p^+\nu n^+$ Diodes.—J. Shields. (*J. Electronics Control*, June 1958, Vol. 4, No. 6, pp. 544–548.) Considerable reduction in breakdown voltage can occur when the width of the junction is reduced below a limiting value, the effect becoming more pronounced as the net impurity concentration in the ν region is decreased. The breakdown voltage is much higher than the voltage at which penetration of the space-charge region occurs. See also 2152 of July.

537.311.33 : 621.315.61 **3539**

Simplified Theory of One-Carrier Currents with Field-Dependent Mobilities.—M. A. Lampert. (*J. appl. Phys.*, July 1958, Vol. 29, No. 7, pp. 1082–1090.) A general method is presented for the calculation of steady-state, one-carrier currents in nonmetallic solids where the mobility is field-dependent. See also 832 of 1957.

537.312.62 : 534.23-8 **3540**

Ultrasonic Attenuation in Superconductors.—H. E. Bömmel & W. P. Mason. (*Bell Lab. Rec.*, July 1958, Vol. 36, No. 7, pp. 253–256.) Metals in the normal resistivity state give large attenuation for ultrasonic waves of sufficiently high frequency, but in the superconducting state the attenuation drops to zero as the temperature approaches 0°K. Results for lead and for very pure tin are given and the effect of an applied magnetic field is discussed.

538.22 **3541**

Magnetic Structures of MnO, FeO, CoO, and NiO.—W. L. Roth. (*Phys. Rev.*, 15th June 1958, Vol. 110, No. 6, pp. 1333–1341.)

538.22 : 538.569.4 **3542**

Quantitative Theory of Faraday Rotation at Centimetre Wavelengths in Chrome Alum, and its Experimental Verification.—B. C. Unal, A. Chevalier & T. Kahan. (*C. R. Acad. Sci., Paris*, 10th Feb. 1958, Vol. 246, No. 6, pp. 901–903.) The theory is valid for the region of parametric transparency where the spin-spin interaction does not occur.

538.22 : 546.65/.66 **3543**

Magnetic Properties of the Gd-La and Gd-Y Alloys.—W. C. Thoburn, S. Legvold & F. H. Spedding. (*Phys. Rev.*, 15th June 1958, Vol. 110, No. 6, pp. 1298–1301.)

538.221 **3544**

Excitation of Spin Waves in a Ferromagnet by a Uniform R.F. Field.—C. Kittel. (*Phys. Rev.*, 15th June 1958, Vol. 110, No. 6, pp. 1295–1297.) It is possible to excite exchange and magnetostatic spin waves in a ferromagnet by a uniform r.f. field, provided that spins on the surface of the specimen experience anisotropy interactions different from those acting on spins in the interior.

538.221 **3545**

Theory of the Curvature of Bloch Walls under the Influence of Stray Fields.—H. D. Dietze. (*Z. Phys.*, 19th Oct. 1957, Vol. 149, No. 3, pp. 276–298.) The influence of stray fields on the initial permeability is investigated with reference to Kersten's theory (see e.g. 1825 of 1957).

538.221 **3546**

Experimental Investigation of the Kinetics of Magnetic Moments in Iron above the Curie Point.—M. Ericson & B. Jacrot. (*C. R. Acad. Sci., Paris*, 17th Feb. 1958, Vol. 246, No. 7, pp. 1018–1020.)

538.221 : 538.652 **3547**

Magnetostriction Curves of Polycrystalline Ferromagnetics.—E. W. Lee. (*Proc. phys. Soc.*, 1st Aug. 1958, Vol. 72, No. 464, pp. 249–258.)

538.221 : 539.23 **3548**

Thin Ferromagnetic Layers. Electrical Properties of Thin Films of Nickel.—G. Goureaux & A. Colombani. (*C. R. Acad. Sci., Paris*, 3rd Feb. 1958, Vol. 246, No. 5, pp. 741–744.)

538.221 : 621.318.122 **3549**

Hysteresis Loops associated with a Simple Domain Structure.—A. Hart. (*Proc. phys. Soc.*, 1st Aug. 1958, Vol. 72, No. 464, pp. 244–248.)

538.221 : 621.318.124 **3550**

Origin of Magnetic Anisotropy in Cobalt-Substituted Magnetite.—J. C. Slonczewski. (*Phys. Rev.*, 15th June 1958, Vol. 110, No. 6, pp. 1341–1348.)

538.221 : 621.318.124.029.65 **3551**

Magnetic Materials for Use at High Microwave Frequencies (50–90 kMc/s).—F. K. du Pré, D. J. De Bitetto & F. G. Brockman. (*J. appl. Phys.*, July 1958, Vol. 29, No. 7, pp. 1127–1128.) Experimental results show that the no-field resonance line in oriented ferroxdure ($BaO.6Fe_2O_3$) can be placed at any frequency in the 50–90-kMc/s range by partial substitution of Fe_2O_3 by Al_2O_3. Similar effects occur in $SrO.6Fe_2O_3$. See also Guillaud & Villers (3451 of 1956).

538.221 : 621.318.134 **3552**

Switching in Rectangular-Loop Ferrites containing Air Gaps.—U. F. Gianola. (*J. appl. Phys.*, July 1958, Vol. 29, No. 7, pp. 1122–1124.) Switching waveforms produced by ferrite magnetic cores with or without air gaps are given and discussed with reference to predicted characteristics.

538.221 : 621.318.134 **3553**

Magnetization Processes in a Polycrystalline Manganese Zinc Ferrite.—L. F. Bates, H. Clow, D. J. Craik & P. M. Griffiths. (*Proc. phys. Soc.*, 1st Aug. 1958, Vol. 72, No. 464, pp. 224–232.) A description is given of Bitter-figure, magnetothermal and Barkhausen-effect studies which indicate that the processes of magnetization are entirely rotational.

538.221 : 621.318.134 : 538.569.4 **3554**

Ferromagnetic Resonance Line Width in Yttrium Iron Garnet Single Crystals.—R. C. LeCraw, E. G. Spencer & C. S. Porter. (*Phys. Rev.*, 15th June 1958, Vol. 110, No. 6, pp. 1311–1313.) Waveguide cavity perturbation techniques are used with samples of diameter 0·013–0·020 in. An extremely narrow line width of 520 milli-oersteds (the full width) is observed at 9 300 Mc/s along the hard axis [100]. The approximate invariance of the line width with frequency is compared with theoretical predictions. See also 2156 (*i*) of July.

538.221 : 621.318.134 : 621.372.8 **3555**

Investigation of the Dependence of Certain Properties of Ferrites on Temperature in the Centimetre-Wave Range.—V. A. Kuseleva & E. I. Kondorskiĭ. (*Dokl. Ak. Nauk S.S.S.R.*, 11th April 1958, Vol. 119, No. 5, pp. 926–928.) Experiments carried out on samples of $Ni_{0.7}Mg_{0.3}Fe_2O_4$ in circular and rectangular waveguides showed that with rise of temperature resonance occurs at reduced field strength. This seems to be related to the variation of the field anisotropy. The rotation of the plane of polarization due to a magnetic field for different temperatures, and the temperature dependence of the resonance field are shown. Ellipticity and attenuation ratios for temperatures between −196° and +220°C and different magnetic field strengths are tabulated.

549.514.51 : 537.228.1 **3556**

Elastic and Piezoelectric Constants of Alpha-Quartz.—R. Bechmann. (*Phys. Rev.*, 1st June 1958, Vol. 110, No. 5, pp. 1060–1061.) Results obtained by the resonance method (2116 of July) are tabulated.

621.315.612 : 537.311.3 **3557**

The Effect of Temperature and Thickness on the Electrical Resistivity of Ceramic Coatings.—W. H. Fischer. (*J. electrochem. Soc.*, April 1958, Vol. 105, No. 4, pp. 201–203.)

MATHEMATICS

517.566 : 621.396.822 **3558**

The Axis-Crossing Intervals of Random Functions.—J. A. McFadden. (*Trans. Inst. Radio Engrs*, Dec. 1956, Vol. IT-2, No. 4, pp. 146–150. Abstract, *Proc. Inst. Radio Engrs*, April 1957, Vol. 45, No. 4, p. 575.)

517.9 : 512.831 **3559**

Differential Equations, Difference Equations and Matrix Theory.—P. D. Lax. (*Commun. pure appl. Math.*, May 1958, Vol. 11, No. 2, pp. 175–194.) For comments by H. F. Weinberger see *ibid.*, pp. 195–196.

517.9 : 534.1 **3560**
On the Periodic Solutions of the Forced Oscillator Equation.—R. M. Rosenberg. (*Quart. appl. Math.*, Jan. 1958, Vol. 15, No. 4, pp. 341–354.)

519.2 : 621.391 **3561**
Some General Aspects of the Sampling Theorem.—D. L. Jagerman & L. J. Fogel. (*Trans. Inst. Radio Engrs*, Dec. 1956, Vol. IT-2, No. 4, pp. 139–146. Abstract, *Proc. Inst. Radio Engrs*, April 1957, Vol. 45, No. 4, p. 575.)

MEASUREMENTS AND TEST GEAR

529.78 : 621.374 **3562**
The Accurate Measurement of a Time Interval.—A. E. Cawkell & H. Ristlaid. (*Electronic Engng*, Aug. 1958, Vol. 30, No. 366, pp. 502–503.) A method is described for measuring the time interval between trigger pulse and output pulse in a delay unit. Measurements accurate to within $\pm 0\cdot 02\%$ can be made of a time interval in the ms range.

529.786 : 621.317.7.087.6 **3563**
A System for the Electrical Recording of Time Intervals.—G. Becker. (*Elektrotech. Z., Edn A*, 11th May 1958, Vol. 79, No. 10, pp. 358–361.) Equipment is described for the continuous comparison of the frequencies of two quartz clocks. A mechanism similar to a synchronous stop-watch, and a magnetic counting system are used to derive a recorder voltage proportional to the time interval being measured.

53.087.64 **3564**
Automatic Calibrator for Chart Recorders.—J. L. Durand. (*Rev. sci. Instrum.*, June 1958, Vol. 29, No. 6, pp. 534–535.) A circuit is outlined which produces calibration pips on a magnetic-resonance spectrometer chart.

621.3.018.41 (083.74) : 621.396.712 **3565**
WWV Standard-Frequency Transmissions.—W. D. George. (*Proc. Inst. Radio Engrs*, Aug. 1958, Vol. 46, No. 8, pp. 1534–1535.) A note on the accuracy of WWV and WWVH transmissions during May 1958.

621.3.082 + 621.3.078 **3566**
How Transducers Measure and Control.—R. K. Jurgen. (*Electronics*, 4th July 1958, Vol. 31, No. 27, pp. 59–70.) A general survey of the transducer field, together with applications.

621.317.332.6.029.6 **3567**
Measurement of Low Reflection Coefficients at High Frequencies in Terms of Magnitude and Phase.—A. Linnebach. (*Arch. elekt. Übertragung*, Dec. 1957, Vol. 11, No. 12, pp. 471–477.) The conventional reflectometer method is extended to cover the measurement of phase angle by the insertion of a quadripole with variable stub lines.

621.317.35 : 621.396.84 **3568**
Errors of Selectivity Measurement.—W. Rotkiewicz. (*NachrTech.*, Jan. 1958, Vol. 8, No. 1, pp. 22–24.) The causes of errors and their elimination in receiver selectivity measurements are discussed.

621.317.411.029.6 : 538.221 **3569**
Measurement of Permeability at V.H.F. using Transmission-Line Technique.—J. C. Anderson. (*J. Brit. Instn Radio Engrs*, July 1958, Vol. 18, No. 7, pp. 417–424.) Accurate measurements may be made without the aid of calibrated instruments or standing-wave detectors. These measurements are sufficiently precise to show detailed structure in the permeability/frequency curves. Results are given for strips of permalloy B and C, mumetal, and for pure nickel wire.

621.317.42 : 621.375.13 **3570**
The Control of Flux Waveforms in Iron Testing by the Application of Feedback Amplifier Techniques.—J. McFarlane & M. J. Harris. (*Proc. Instn. elect. Engrs*, Part A, Aug. 1958, Vol. 105, No. 22, pp. 395–402. Discussion, pp. 402–405.)

621.317.42 : 621.383 **3571**
The Construction of a Photoelectric Electronic Fluxmeter.—M. Sauzade. (*C.R. Acad. Sci., Paris*, 3rd Feb. 1958, Vol. 246, No. 5, pp. 727–730.) Description of the design of an integrating system comprising a galvanometer, photocell and amplifier, with capacitive feedback, of the type described by Edgar [see 2163 of 1956 (Kapitsa)]. See also 435 of 1949 (Dicke).

621.317.44 **3572**
A Ferrometer for the Determination of the A.C. Magnetization Curve and the Iron Losses of Small Ferromagnetic Sheet Samples.—H. Blomberg & P. J. Karttunen. (*Proc. Instn elect. Engrs*, Part A, Aug. 1958, Vol. 105, No. 22, pp. 375–384. Discussion, pp. 402–405.)

621.317.44 **3573**
Direct-Reading Iron-Loss Testing Equipment for Single Sheets, Single Strips and Test Squares.—J. McFarlane, P. Milne & J. K. Darby. (*Proc. Instn elect. Engrs*, Part A, Aug. 1958, Vol. 105, No. 22, pp. 385–394. Discussion, pp. 402–405.)

621.317.7 : 538.566 : 621.372.823 **3574**
Double-Probe Polarimetric Analyser for the 1 000-Mc/s Band.—F. Picherit. (*C. R. Acad. Sci., Paris*, 10th Feb. 1958, Vol. 246, No. 6, pp. 911–913.) Description of apparatus for accurate measurement of wave rotation in a circular waveguide, using a graduated rotatable section provided with two probes with a fixed angular separation of 90°.

621.317.73 : 537.312.9.082.73 **3575**
Apparatus for Piezoresistance Measurement.—M. Pollack. (*Rev. sci. Instrum.*, July 1958, Vol. 29, No. 7, pp. 639–641.) The piezoresistance effect in semiconductors is measured using a 29-c/s alternating stress. The method is sensitive and suitable for low-resistivity materials; the measurements are adiabatic. See also 1192 of April (Potter).

621.317.733 : 621.317.4 : 538.221 **3576**
Improved Bridge Method for the Measurement of Core Losses in Ferromagnetic Materials at High Flux Densities.—W. P. Harris & I. L. Cooter. (*J. Res. nat. Bur. Stand.*, May 1958, Vol. 60, No. 5, RP 2865, pp. 509–516.) An amplifier having negative output resistance was devised and is used in a manner that automatically allows accurate compensation for the harmonic components of the excitation current. See also 530 of 1957 (Cooter & Harris).

621.317.74 : 621.372.2.029.6 **3577**
High-Frequency Measuring Lines.—C. Moerder. (*Arch. tech. Messen*, Feb. 1958, No. 265, pp. 37–40.) The use of calibrated transmission lines for the measurement of circuit and line characteristics is described. Particular reference is made to the Smith chart and to commercial test equipment incorporating an artificial line with a c.r.o. display of the measured parameters on a Smith-chart graticule.

621.317.74 : 621.372.852.323 : 621.318.134 **3578**
High-Power Testing of Ferrite Isolators.—E. Wantuch. (*Electronic Ind.*, April 1958, Vol. 17, No. 4, pp. 83–85.) Description of methods for determining insertion loss, input s.w.r. under matched-load, and isolation under mismatched-load conditions.

621.317.74 : 621.374 **3579**
An Electronic Pulse-Duration Analyser.—E. Newell & A. A. Makemson. (*P.O. elect. Engrs' J.*, April 1958, Vol. 51, Part 1, pp. 64–69.) Description of apparatus for determining the duration and frequency of occurrence of transient irregularities on h.f. trunk telephone routes. Irregularities longer than 2 ms are recorded on cold-cathode counters, simultaneous recordings being made of durations exceeding four predetermined values in the range 2–50 ms.

621.317.75 : 621.376.3 **3580**
Testing the Linearity of Modulators and Demodulators in Multichannel F.M. Transmitters and Receivers.—G. C. Davey. (*Electronic Engng*, Aug. 1958, Vol. 30, No. 366, pp. 487–489.) Design principles are described of equipment which displays the slope of a demodulator characteristic and discriminates changes in slope of 1%. Modulators can be tested indirectly and the equipment may be used for conventional sweep tests in aligning i.f. amplifiers.

621.317.755 **3581**
A New Eight-Channel Oscillograph.—H. H. Feldmann. (*Elektrotech. Z., Edn B*, 21st May 1958, Vol. 10, No. 5, pp. 206–209.) A single-tube c.r.o. is described which provides facilities for the simultaneous display of four functions. The 2×4 variables are applied to the vertical and horizontal amplifiers, via an electronic switching circuit.

621.317.755 : 621.385.029.6 **3582**
Fractional-Millimicrosecond Oscilloscope System utilizing Commercially Available Components.—C. N. Winning-

stad. (*Rev. sci. Instrum.*, July 1958, Vol. 29, No. 7, pp. 578–584.) The oscilloscope described uses a travelling-wave c.r. tube with a synchronizing system which does not appreciably distort the applied pulse.

621.317.755.087.6 **3583**

Electronic Tracing of Oscilloscope Displays.—C. H. Hertz & E. Möller. (*Rev. sci. Instrum.*, July 1958, Vol. 29, No. 7, pp. 611–613.) A gated charging circuit is described for sampling the waveform applied to a c.r.o. and driving a pen recorder. Frequencies up to 10 kc/s can be recorded.

621.317.789 **3584**

Ergmeter measures Bursts of Energy.—L. A. Rosenthal. (*Electronics*, 6th June 1958, Vol. 31, No. 23, pp. 79–81.) Energy surges unbalance a bolometer bridge whose output is amplified and applied to a peak-holding voltmeter; the instrument is calibrated by using an internally generated pulse of known energy content.

621.317.799 : 551.510.535 : 621.396.11 **3585**

An Automatic Recorder for Measuring Ionospheric Absorption.—Mazumdar. (See 3461.)

621.317.799 : 621.316.82 **3586**

Potentiometer Tester.—S. Morleigh. (*Wireless World*, Sept. 1958, Vol. 64, No. 9, pp. 450–452.) Description of circuits for locating bad contacts and for measuring contact resistance in precision variable resistors and inductive potentiometers.

621.317.799 : 621.396.61/.62 **3587**

Recent Developments in Communications Measuring Instruments.—E. Garthwaite & A. G. Wray. (*J. Brit. Instn Radio Engrs*, July 1958, Vol. 18, No. 7, pp. 387–397.) Improvements in design and advances in measuring techniques are illustrated by reference to specific instruments. Future trends are briefly discussed.

621.317.799 : 621.396.933.029.6 **3588**

A Standing-Wave-Ratio Measuring Instrument for Use in the Maintenance of Aircraft Installations.—A. G. Hancock & T. S. Kepner. (*A.W.A. tech. Rev.*, Oct. 1957, Vol. 10, No. 2, pp. 90–99.) A portable instrument for measuring s.w.r. on transmission lines in v.h.f. aircraft installations is described. The battery-operated equipment includes bridges for 50-Ω and 70-Ω installations, and fixed and variable oscillators.

OTHER APPLICATIONS OF RADIO AND ELECTRONICS

53.087.5 **3589**

Digital and Pictorial Photographic Electronic Recorder.—R. G. McPherson & I. A. Sonderby. (*Commun. & Electronics*, May 1958, No. 36, pp. 194–196.) Digital recording is achieved by photographing square spots or bits in rows on the film. With a bit size of 10 mils and 40 bits/row, 4 000 bits/in. may be stored on 16-mm film. Playback is effected by mechanical or electrical scanning.

53.087.9 : 621.395.625.3 **3590**

Magnetic Tape for Data Recording.—C. D. Mee. (*Proc. Instn elect. Engrs*, Part B, July 1958, Vol. 105, No. 22, pp. 373–380, Discussion, pp. 380–382.) The occurrence of 'drop-outs' in both the recording and reproduction of pulse signals is investigated and applied to 'return to zero' and 'non return to zero' recording. Methods are considered which would improve reliability. Equipment is described for testing tape under widely varying recording conditions. Commercial tapes are assessed and an economical performance specification is suggested.

551.508.822 **3591**

Comparison of Aerological Soundings made Simultaneously by Radiosonde and Aircraft.—F. H. Ludlam & P. M. Saunders. (*Tellus*, Feb. 1958, Vol. 10, No. 1, pp. 83-87.) The results of five soundings by Väisälä radiosonde and by aircraft fitted with electrical resistance thermometers show that the temperatures given by the radiosonde were usually 1–1½°C, but occasionally 2½–3½°C, too great. Shallow layers of very dry air were often not revealed by the radiosonde due to the large time lag of the hygrometer unit.

621.362 : 536.8 **3592**

Measured Thermal Efficiencies of a Diode Configuration of a Thermo-electron Engine.—G. N. Hatsopoulos & J. Kaye. (*J. appl. Phys.*, July 1958, Vol. 29, No. 7, pp. 1124–1125.) Note on a practical engineering method of converting heat directly into electricity.

621.384.612 **3593**

Electron Losses due to Phase Oscillations Induced by Radiation Fluctuations in Synchrotrons.—A. N. Matveev. (*Zh. eksp. teor. Fiz.*, Nov. 1957, Vol. 33, No. 5(11), pp. 1254–1260.) An approximate method of calculation is described taking account of nonlinear effects by considering appropriate boundary conditions in linear theory.

621.384.7 : 537.533.8 **3594**

Source of Ions due to Electron Bombardment.—D. Blanc & A. Degeilh. (*C. R. Acad. Sci., Paris*, 10th Feb. 1958, Vol. 246, No. 6, pp. 936–939.) The characteristics of an ion source of Nier type (see *Rev. sci. Instrum.*, June 1947, Vol. 18, No. 6, pp. 398–411) without an auxiliary magnetic field are described.

621.385.833 : 061.3 **3595**

Summarized Proceedings of a Conference on Electron Microscopy—Bangor, September 1957.—H. W. Emerton. (*Brit. J. appl. Phys.*, Aug. 1958, Vol. 9, No. 8, pp. 306–312 . . 322.)

621.385.833 : 537.533.72 **3596**

Magnetic Deflection of Electron Beams without Astigmatism.—G. D. Archard & T. Mulvey. (*J. sci. Instrum.*, Aug. 1958, Vol. 35, No. 8, pp. 279–283.) The system described uses circular pole pieces from which semicircular portions have been removed. An application to reflection-type electron microscopes is described.

621.385.833 : 621.373.44 **3597**

Construction of a 100-kV Pulse Generator.—J. Gardez. (*C. R. Acad. Sci., Paris*, 17th Feb. 1958, Vol. 246, No. 7, pp. 1023–1025.) A pulse generator for an electron microscope is described, with pulse length 2 μs, and repetition frequency 200/s.

621.387.4 **3598**

The Design, Performance and Use of Fission Counters.—W. Abson, P. G. Salmon & S. Pyrah. (*Proc. Instn elect. Engrs*, Part B, July 1958, Vol. 105, No. 22, pp. 349–356. Discussion, pp. 365–369.) General design criteria applicable to the measurement of fission cross-sections, the analysis of neutron spectra and the relative measurement of neutron flux are discussed.

621.387.424 **3599**

Firing Characteristics of Halogen-Quenched Geiger-Müller Counters.—S. P. Puri & P. S. Gill. (*Proc. nat. Inst. Sci. India*, Part A, 26th Jan. 1958, Vol. 24, No. 1, pp. 66–67.)

621.387.426.2 **3600**

Boron Trifluoride Proportional Counters.—W. Abson, P. G. Salmon & S. Pyrah. (*Proc. Instn elect. Engrs*, Part B, July 1958, Vol. 105, No. 22, pp. 357–365. Discussion, pp. 365–369.) Operating characteristics and the effect of circuit parameters on output pulse amplitude are discussed.

621.398 : 623.451.8-519 **3601**

Telemeter Transmitter for Vanguard Rocket.—N. Raskhodoff. (*Electronics*, 4th July 1958, Vol. 31, No. 27, pp. 46–47.) Details of engine performance are relayed using a p.w.m./f.m. system.

PROPAGATION OF WAVES

621.396.11 : 551.510.535 **3602**

Electromagnetic Propagation in an almost Homogeneous Medium.—V. W. Bolie. (*Aust. J. Phys.*, March 1958, Vol. 2, No. 1, pp. 118–125.) An equation is derived for calculating the scattering energy resulting from a single Gaussian perturbation in refractive index. A turbulent ionosphere may be considered as being composed of such perturbations.

621.396.11 : 551.510.535 **3603**

Single-Hop Propagation of Radio Waves to a Distance of 5 300 km.—F. Kift. (*Nature, Lond.*, 24th May 1958, Vol. 181, No. 4621, pp. 1459–1460.) Path lengths and angles of elevation of rays arriving at Slough from Ottawa have been calculated from the Appleton & Beynon equations for propagation via a parabolic F_2 layer, and show good agreement with experimental results of Warren & Hagg (2202 of July).

621.396.11.029.45/.5 : 551.510.535 **3604**

Low-Frequency Reflection in the Ionosphere.—H. Poeverlein. (*J. atmos.*

terr. Phys., 1958, Vol. 12, Nos. 2/3 & 4, pp. 126–139 & 236–247. Correction, *ibid.*, No. 4, p. 352.) Theoretical investigation of ionospheric reflection in the frequency range 1–100 kc/s approximately. The ionospheric layer is considered as a thin conductive sheet or as consisting of many thin sublayers. Some typical cases are discussed with reference to observational results.

621.396.11.029.45 : 551.594.6 **3605**

Velocity of Propagation of Electromagnetic Waves at Audio Frequencies.—Ya. L. Al'pert & S. V. Borodina. (*Zh. eksp. teor. Fiz.*, Nov. 1957, Vol. 33, No. 5(11), pp. 1305–1307.) Note of an investigation covering the frequency range 1–30 kc/s based on waveform analysis of thunderstorm discharges at distances of 800–3 100 km. Experimental and theoretical values deviate significantly below 3 kc/s, at which frequencies the model of the ionosphere used in the calculations may be inappropriate. See also 920 of 1957.

621.396.11.029.53 : 551.510.535 **3606**

Investigation of Magneto-ionic Fading in Oblique-Incidence Medium-Wave Transmissions.—M. S. Rao & B. R. Rao. (*J. atmos. terr. Phys.*, July 1958, Vol. 12, No. 4, pp. 293–305.) Periodic fading of magneto-ionic origin observed in oblique-incidence medium-wave records is interpreted theoretically by calculating the phase paths by a graphical integration method assuming Chapman and parabolic ion distribution. Analytical expressions have also been derived for phase paths of both magneto-ionic components by an approximate method involving the use of an empirical formula for *q–x* curves. The theoretical values of fading periods compared very well with the experimental data, the agreement being particularly good for the case of Chapman distribution."

621.396.11.029.6 : 551.510.5 **3607**

Atmospheric Effects on V.H.F. and U.H.F. Propagation.—G. H. Millman. (*Proc. Inst. Radio Engrs*, Aug. 1958, Vol. 46, No. 8, pp. 1492–1501.) Tropospheric refractive-index profiles and ionospheric electron-density models representative of average conditions are presented, and mathematical relations are derived for calculating refraction effects, time delays, Doppler errors, polarization changes, and attenuation experienced by radio waves traversing the entire atmosphere.

621.396.11.029.62 : 523.5 **3608**

A Theoretical Rate/Amplitude Relation in Meteoric Forward Scattering.—C. O. Hines. (*Canad. J. Phys.*, May 1958, Vol. 36, No. 5, pp. 539–554.) The theory of forward scattering of radio waves by ionized meteor trails is applied to the development of a relation which expresses the expected occurrence rate of scattered signals exceeding a given amplitude level as a function of that level. Comparison with provisional observational data shows good agreement qualitatively and quantitatively. Closest agreement is obtained only with an appropriate choice of two scaling factors which provide a convenient condensed version of the observations for further interpretation.

621.396.11.029.62 : 523.5 **3609**

Observations of Angle of Arrival of Meteor Echoes in V.H.F. Forward-Scatter Propagation.—K. Endresen, T. Hagfors, B. Landmark & J. Rödsrud. (*J. atmos. terr. Phys.*, July 1958, Vol. 12, No. 4, pp. 329–334.) Observations were made in November and December 1957 near Tromsö, using a frequency of 46·8 Mc/s. Histograms show the properties of background meteor reflections as well as of shower reflections as a function of azimuth. Diurnal variations agree well with present theories.

621.396.11.029.62 : 523.5 **3610**

The Fading of Long-Duration Meteor Bursts in Forward-Scatter Propagation.—B. Landmark. (*J. atmos. terr. Phys.*, July 1958, Vol. 12, No. 4, pp. 341–342.) Application of the theory presented by L. A. Manning at the 12th General Assembly of U.R.S.I., 1957, Boulder, Colorado, allows the seasonal variations of wind sheer in the lower E layer to be studied.

621.396.11.029.62 : 551.510.535 **3611**

Preliminary Results of Studies of the Angular Distribution of a V.H.F. Ionospheric Forward-Scatter Signal.—T. Hagfors. (*J. atmos. terr. Phys.*, July 1958, Vol. 12, No. 4, pp. 340–341, plate.) The angular spectrum is determined by correlation over the wavefront. Results obtained at 46·8 Mc/s over a 1 150-km N–S path indicate that the Rayleigh-type background is not due to the overlapping of many small meteoric echoes.

621.396.11.029.62 : 621.397.81 **3612**

Phase-Coherent Back-Scatter of Radio Waves at the Surface of the Sea.—E. Sofaer. (*Proc. Instn elect. Engrs*, Part B, July 1958, Vol. 105, No. 22, pp. 383–394.) An investigation into interference with reception of the B.B.C. Devon television transmitter in coastal regions near Plymouth. Rhythmic variations in amplitude due to beating between direct and back-scattered signals occur when sea waves within the irradiated area are correctly spaced and suitably oriented with respect to frequency and geometry of the transmitter/receiver circuit. The effect is studied theoretically and correlated with meteorological data.

621.396.11.029.64 **3613**

Multipath Propagation of Microwaves.—T. Omori & R. Sato. (*Rep. elect. Commun. Lab., Japan.* Jan. 1958, Vol. 6, No. 1, pp. 1–11.) Results are given for five different paths at frequencies near 4 kMc/s; frequency-sweep and pulse techniques were both used to measure the delayed signals. The mean value of the instantaneous distortion in the worst 1-h period was shown to be negligibly small.

RECEPTION

621.376.2 **3614**

The Demodulation of Linearly Distorted A.M. Spectra.—H. Schneider & G. Petrich. (*Nachr Tech.*, Jan. 1958, Vol. 8, No. 1, pp. 17–21.) Continuation of 2893 of 1957 dealing with s.s.b. and common-frequency reception and the distortion effects of overmodulation.

621.376.23 : 621.396.822 **3615**

The Rectification of Non-Gaussian Noise.—J. A. Mullen & D. Middleton. (*Quart. appl. Math.*, Jan. 1958, Vol. 15, No. 4, pp. 395–419.) A noise model in which the noise events occur with a Poisson distribution in time is analysed. Atmospherics and some types of radar clutter may approximate to this model. The influence of linear and quadratic detectors on the noise is studied, and account is taken of narrow-band filters preceding the detector.

621.376.23 : 621.396.822 **3616**

Effects of Signal Fluctuation on the Detection of Pulse Signals in Noise.—M. Schwartz. (*Trans. Inst. Radio Engrs*, June 1956, Vol. IT-2, No. 2, pp. 66–71. Abstract, *Proc. Inst. Radio Engrs*, Nov. 1956, Vol. 44, No. 11, p. 1642.)

621.376.23 : 621.396.822 **3617**

Rectification of Two Signals in Random Noise.—L. L. Campbell. (*Trans. Inst. Radio Engrs*, Dec. 1956, Vol. IT-2, No. 4, pp. 119–124. Abstract, *Proc. Inst. Radio Engrs*, April 1957, Vol. 45, No. 4, p. 575.)

621.376.23 : 621.396.822 **3618**

Optimum Detection of Random-Signals in Noise, with Applications to Scatter-Multipath Communication: Part 1.—R. Price. (*Trans. Inst. Radio Engrs*, Dec. 1956, Vol. IT-2, No. 4, pp. 125–135. Correction, *ibid.*, Dec. 1957, Vol. IT-3, No. 4, p. 256. Abstract, *Proc. Inst. Radio Engrs*, April 1957, Vol. 45, No. 1, p. 575.)

621.376.23 : 621.396.822 **3619**

A Coincidence Procedure for Signal Detection.—M. Schwartz. (*Trans. Inst. Radio Engrs*, Dec. 1956, Vol. IT-2, No. 4, pp. 135–139. Abstract, *Proc. Inst. Radio Engrs*, April 1957, Vol. 45, No. 4, p. 575.)

621.376.332 : 621.3.018.78 **3620**

Amplitude Modulation Suppression in F.M. Systems.—C. L. Ruthroff. (*Bell Syst. tech. J.*, July 1958, Vol. 37, No. 4, pp. 1023–1046.) Limiter circuits are analysed in terms of low-index modulation theory. The analysis of a diode limiter shows that perfect a.m. suppression is possible with only small loss to the f.m. signal. Experimental verification is given.

621.396.62 : 621.396.662 **3621**

A Novel Sideband Selector System.—E. P. Alvernaz. (*QST*, May 1958, Vol. 42, No. 5, pp. 18–20.) Two mixers and a common v.f.o. are used in a selector system by means of which an incoming signal, or any part of it, can be placed in or out of the pass band of a fixed-frequency band-pass filter without changing the receiver tuning.

621.396.662 **3622**

Some Aspects of Permeability Tuning.—W. D. Meewezen. (*Proc. Instn Radio Engrs, Aust.*, 1957, Vol. 18, No. 8, pp. 263–275.) Capacitance- and permeability-tuned circuits are compared, and the construction and applications of permeability tuners are described.

621.396.8 : 519.2 **3623**

Cumulative Frequency Curves of Eccentric Rayleigh Distribution and their Application to Propagation Measurements.—H. Zuhrt. (*Arch. elekt. Übertragung*, Dec. 1957, Vol. 11, No. 12, pp. 478–484.) Equations and curves of eccentric Rayleigh distribution are given which are applicable to received voltage waveforms considered as a number of statistically fluctuating interference waves superimposed on the signal waveform. Probability distribution curves based on propagation measurements at 2·5, 4·15 and 15 kMc/s are compared with the theoretical curves; agreement is close except for short-term probabilities.

621.396.82 **3624**

Radio Interference: Part 3—Suppression.—R. A. Dilworth. (*P.O. elect. Engrs' J.*, April 1958, Vol. 51, Part 1, pp. 40–45.) Interference produced by sparking from electrical appliances is discussed. Reduction of interference by measures taken at the receiving installation, and by suppression at source are considered. Practical suppression arrangements are described and illustrated for various kinds of appliance. Part 2: 2213 of July (Britton).

621.396.821 **3625**

Atmospheric Noise Interference to Medium-Wave Broadcasting.—S. V. C. Aiya. (*Proc. Inst. Radio Engrs*, Aug. 1958, Vol. 46, No. 8, pp. 1502–1509.) The electrical discharges associated with a tropical thundercloud are described. It is suggested that discharge mechanisms within the cloud contribute noise only on frequencies above 2·5 Mc/s. The power radiated by a flash in the medium-wave band is deduced by assuming that the energy is produced by the first stepped leader propagated as an air or ground discharge. See also 1866 of June.

STATIONS AND COMMUNICATION SYSTEMS

621.391 **3626**

Bits of Information.—A. S. Zamanakos. (*Commun. & Electronics*, May 1958, No. 36, pp. 197–201.) Concepts of information, channel capacity and equivocation are reviewed. The probability of an error is used to calculate the equivocation. The method of coding a message to incorporate error detecting and correcting information is explained, and examples are given of a parity checking procedure.

621.391 **3627**

On the Shannon Theory of Information Transmission in the Case of Continuous Signals.—A. N. Kolmogorov. (*Trans. Inst. Radio Engrs*, Dec. 1956, Vol. IT-2, No. 4, pp. 102–108.)

621.391 **3628**

On Noise Stability of a System with Error-Correcting Codes.—V. I. Siforov. (*Trans. Inst. Radio Engrs*, Dec. 1956, Vol. IT-2, No. 4, pp. 109–115. Abstract, *Proc. Inst. Radio Engrs*, April 1957, Vol. 45, No. 4, p. 575.)

621.391 **3629**

Optimum, Linear, Discrete Filtering of Signals containing a Nonrandom Component.—K. R. Johnson. (*Trans. Inst. Radio Engrs*, June 1956, Vol. IT-2, No. 2, pp. 49–55. Abstract, *Proc. Inst. Radio Engrs*, Nov. 1956, Vol. 44, No. 11, p. 1642.)

621.391 : 519.272 **3630**

Correlation Electronics.—F. H. Lange. (*NachrTech.*, Jan. 1958, Vol. 8, No. 1, pp. 3–11.) The principles and purposes of correlation analysis are outlined with examples of applications in communications and electroacoustics.

621.391 : 519.272 **3631**

Simple Methods of Correlation Measurement.—R. Fey. (*NachrTech.*, Jan. 1958, Vol. 8, No. 1, pp. 12–16.) The analytical bases of four methods of determining autocorrelation functions are discussed, with an outline of appropriate measurement techniques.

621.391 : 534.75 **3632**

Information Transmission with Elementary Auditory Displays.—Sumby, Chambliss & Pollack. (See 3314.)

621.391 : 534.75 **3633**

Confidence Ratings and Message Reception for Filtered Speech.—Decker & Pollack. (See 3315.)

621.391 : 621.396.822 **3634**

Probability Densities of the Smoothed 'Random Telegraph Signal'.—W. M. Wonham & A. T. Fuller. (*J. Electronics Control*, June 1958, Vol. 4, No. 6, pp. 567–576.) The probability distribution of the output from a simple *RC* smoothing network is found when the input is a sequence of random square waves generated by a Poisson process. Results suggest a convenient experimental method for generating l.f. noise with Gaussian, rectangular, parabolic or elliptical probability density functions.

621.391 : 621.396.822 **3635**

Nonstationary Velocity Estimation.—T. M. Burford. (*Bell Syst. tech. J.*, July 1958, Vol. 37, No. 4, pp. 1009–1021.) A nonstationary noise is approximated by the product of a stationary noise and a deterministic function of time. From observations of the sum of such a nonstationary noise and a linear signal, an estimate of the rate of change of the signal is obtained.

621.396.4 : 551.510.52 **3636**

White Alice—a New Radio Voice for Alaskan Outposts.—W. H. Tidd. (*Bell Lab. Rec.*, Aug. 1958, Vol. 36, No. 8, pp. 278–283.) A tropospheric-scatter system is described for multichannel telephone and telegraph communication between points 100–200 miles apart. 10-kW transmitters and 60-ft parabolic aerials are used at frequencies in the 750–950 Mc/s band.

621.396.41 **3637**

Compressed Time boosts Single-Sideband Capacity.—M. I. Jacob & J. Mattern. (*Electronics*, 4th July 1958, Vol. 31, No. 27, pp. 52–55.) Description of a time-sharing multiplex system which needs only one r.f. channel, with a single transmitter and receiver at each station. Received information is stored, and then expanded and read out between transmissions.

621.396.41 : 621.396.65 **3638**

The Simultaneous Transmission of Television and Telephone Multiplex over a Single Microwave Channel on the Trans-Canada TD-2 System.—H. E. Curtis, V. C. P. Strahlendorf & A. J. Wade. (*Commun. & Electronics*, May 1958, No. 36, pp. 185–190.) Transmission considerations, terminal circuits and tests are discussed for a system simultaneously transmitting a television signal and a maximum of 180 telephone channels.

621.396.61/.62 : 535-14 **3639**

500-Million-Mc/s Transceiver.—H. Pallatz. (*Radio - Electronics*, Oct. 1957, Vol. 28, No. 10, pp. 93–94.) Simple voice-communication equipment using a caesium-vapour lamp as transmitter is described.

621.396.932 **3640**

The Development of Radio Services for Coastal Traffic, Inland Waterways and Harbours.—J. Mohrmann. (*Telefunken Ztg*, Dec. 1957, Vol. 30, No. 118, pp. 225–232. English summary, p. 286.) The development of R/T services for ship-to-shore communication in Germany is outlined and details of some modern installations, including v.h.f. services, are given.

SUBSIDIARY APPARATUS

621.316.5.004.6 **3641**

Physical Processes in Contact Erosion.—L. H. Germer. (*J. appl. Phys.*, July 1958, Vol. 29, No. 7, pp. 1067–1082.) A general survey of erosion effects for relatively low voltages and currents.

621.316.721/.722 : 621.314.7 **3642**

Transistor Voltage and Current Stabilizers.—E. Cassignol & G. Giralt. (*C. R. Acad. Sci., Paris*, 17th Feb. 1958, Vol. 246, pp. 1020–1023.) Details are given of a current generator and a voltage generator using transistors and a Zener diode. Coupled together, the circuits provide a stabilized current supply of up to 300 mA.

621.316.93 : 621.314.63 **3643**

Electrical Protection for Transistorized Equipment.—J. W. Phelps. (*Bell Lab. Rec.*, July 1958, Vol. 36, No. 7, pp. 247–249.) Semiconductor diodes are used to limit excessive voltages accidentally placed on telephone circuits.

621.353/.355 **3644**

New Batteries for the Space Age.—D. Linden & A. F. Daniel. (*Electronics*, 18th July 1958, Vol. 31, No. 29, pp. 59–65.) A survey of short-life electrochemical batteries, developed for extreme reliability at high discharge rates under stringent operating conditions. The main characteristics of recent types are given in tabulated form.

TELEVISION AND PHOTOTELEGRAPHY

621.397.5 **3645**
567 Lines.—P. T. Weston. (*Wireless World*, Sept. 1958, Vol. 64, No. 9, pp. 442–443.) An alternative to the British 405-line television system is suggested in which a greater number of lines is achieved with a minimum of equipment changes.

621.397.5 : 535.623 **3646**
A Method for Controlling the Gray-Scale Equivalent of Colours used in Live and Filmed Television Scenic and Graphic Art.—W. J. Wagner. (*J. Soc. Mot. Pict. Telev. Engrs*, June 1958, Vol. 67, No. 6, pp. 369–373. Discussion.) Greys are graded in a scale of 20 steps from white to black, and the equivalence of colours presented on a monochromatic screen is based on this scale.

621.397.6.029.63 **3647**
A U.H.F. Television Link for Outside Broadcasts.—K. C. Quinton. (*B.B.C. Engng Div. Monographs*, June 1958, No. 19, pp. 1–20.) The merits of f.m. and a.m. systems are considered, and preliminary comparison tests over a short link with a mobile transmitter at 190 and 511 Mc/s indicated f.m. to be preferable. A mobile transmitter delivering 17 W at about 630 Mc/s with 6-Mc/s deviation to either a Yagi or corner-reflector aerial is described. Receiver i.f. is either 30 or 60 Mc/s, with a noise factor of 14 dB. Multipath distortion is still troublesome over such links, and possible means of reducing it are suggested.

621.397.611 **3648**
Improved Television Standards Converter.—T. Worswick. (*Wireless World*, Sept. 1958, Vol. 64, No. 9, pp. 443–444.) For the B.B.C. Eurovision converter system an improvement of 10 dB in signal/noise ratio has been achieved by using a 4½-in. image-orthicon tube Type P812 in place of a 3-in. Type P807.

621.397.611 : 535.623 **3649**
A Flying-Spot Film Scanner for Colour Television.—H. E. Holman, G. C. Newton & S. F. Quinn. (*Proc. Instn elect. Engrs*, Part B, July 1958, Vol. 105, No. 22, pp. 317–328. Discussion, pp. 329–330.) Film moving with uniform velocity is scanned by a series of displaced rasters in such a sequence that the system is applicable to 50- or 60-c/s conditions. Three photomultipliers provide colour analysis of the image, element by element, and directly produce a video-frequency signal. A particular equipment is described.

621.397.611.2 **3650**
A French Portable TV Camera.—J. Polonsky. (*J. Telev. Soc.*, April/June 1958, Vol. 8, No. 10, pp. 423–431.) Technical requirements and design considerations are described for the Type-CP103 equipment weighing about 29 lb and based on a vidicon camera tube. Transistors are used in the power supply circuits and synchronizing generator.

621.397.62 **3651**
Ultrasonic Tones Select TV Channels.—N. Frihart & J. Krakora. (*Electronics*, 6th June 1958, Vol. 31, No. 23, pp. 68–69.) Television receiver tuning and power supply are remotely controlled by means of an ultrasonic magnetostriction transducer with transistor oscillator transmitting via an air path to a microphone in the receiver. See also 3669 of 1957 (Adler et al.).

TRANSMISSION

621.376.222 : 534.78 **3652**
Some Aspects of High-Level Modulation.—A. H. Koster. (*R.S.G.B. Bull.*, June 1958, Vol. 33, No. 12, pp. 552–556.) The effects of speech compression on the output of a typical transmitter, together with circuits for reducing the resulting distortion, are described.

621.396.61 : 621.396.967 **3653**
The Frequency Stability of Self-Excited Transmitters Connected to a Load with Variable Phase.—H. Schwindling. (*Telefunken Ztg*, Dec. 1957, Vol. 30, No. 118, pp. 246–250. English summary, pp. 287–288.) The Rieke-diagram method is used to investigate the 'long-line' effect with reference to rotating radar aerials.

VALVES AND THERMIONICS

621.314.63 + 621.314.7 **3654**
Crystal Valves.—T. R. Scott. (*J. Telev. Soc.*, April/June 1958, Vol. 8, No. 10, pp. 401–412.) The development of the crystal valve is reviewed with particular reference to economic aspects. The likely future relation between the economics of crystal and thermionic valves is discussed and the role of the former in various fields of electronic application is examined. The difficulties and advantages of the manufacture and use of crystal valves is also discussed.

621.314.63 : 621.372.632 **3655**
Shot Noise in *p-n* Junction Frequency Converters.—A. Uhlir, Jr. (*Bell Syst. tech. J.*, July 1958, Vol. 37, No. 4, pp. 951–988.) General equations for the noise figure of a *p-n*-junction diode with arbitrary minority-carrier storage are derived, and it is shown that a junction with purely capacitive nonlinear admittance, in theory, permits noiseless amplification. Nonlinear-resistance diodes can give low-noise frequency conversion with pulsed local-oscillator current, but cannot amplify. See also 3897 of 1956.

621.314.63 : 621.372.632 **3656**
Gain and Noise Figure of a Variable-Capacitance Up-Converter.—D. Leenov. (*Bell Syst. tech. J.*, July 1958, Vol. 37, No. 4, pp. 989–1008.) The upper-sideband frequency-conversion performance of a *p-n*-junction nonlinear-capacitance diode is analysed. The maximum available gain and the noise figure are derived for the equivalent circuit consisting of a time-varying capacitance and constant series resistance. Overall noise figures are given for three types of receiver with diode preamplifiers.

621.314.7 **3657**
The Tecnetron—Competitor to the Transistor ?—E. Aisberg. (*Radio-Electronics*, May 1958, Vol. 29, No. 5, pp. 60–61.) Description of a semiconductor device invented by S. Teszner (see e.g. 3599 of 1954). It consists of a small rod of *n*-type Ge 0·5 mm in diameter with a central portion reduced to 30 μ and surrounded by a cylinder of indium. Transconductance increases with frequency and in experiments a gain of 16 dB was obtained at 200 Mc/s. See also *Toute la Radio*, Feb. 1958, Vol. 25, No. 223, pp. 47–48 and *Wireless World*, March 1958, Vol. 64, No. 3, p. 132.

621.385 + 621.375].029.65 **3658**
The Generation and Amplification of Millimetre Waves.—Kleen & Föschl. (See 3384.)

621.385.4 : 621.384.622 **3659**
The Resnatron as a 200-Mc/s Power Amplifier.—E. B. Tucker, H. J. Schulte, E. A. Day & E. E. Lampi. (*Proc. Inst. Radio Engrs*, Aug. 1958, Vol. 46, No. 8, pp. 1483–1492.) A description of the valves used in the Minnesota linear proton accelerator. They are continuously pumped grid-pulsed amplifiers with a peak power output of 3·5 MW during 300-μs pulses.

621.385.832.032.2 **3660**
Space-Charge-Grid High-Transconductance Guns.—P. H. Gleichauf. (*Proc. Inst. Radio Engrs*, Aug. 1958, Vol. 46, No. 8, p. 1542.) Brief description of the development of a c.r. tube gun capable of delivering a screen current of 500 μA at a drive voltage of less than 7 V.

621.385.832.032.36 **3661**
The Screen Efficiency of Sealed-Off High-Speed-Oscillograph Cathode-Ray Tubes.—R. Feinberg. (*Proc. Instn elect. Engrs*, Part B, July 1958, Vol. 105, No. 22, pp. 370–372.) Factors affecting efficiency are summarized. Reduced screen efficiency is due to energy lost by nonradiative dissipation.

MISCELLANEOUS

551.58 : 621.3.002 **3662**
A Contribution to the Climatic Classification of Technical Apparatus.—H. Burchard & G. Hoffmann. (*Elektrotech. Z.*, Edn A, 1st May 1958, Vol. 79, No. 9, pp. 315–321.) A world map of climatic zones is given which is based on a statistical analysis of maximum and minimum temperatures, and the distribution of population density in these zones is tabulated. A simplified classification of climates is derived so that design and manufacture of equipment can be planned for the widest distribution combined with maximum economy.

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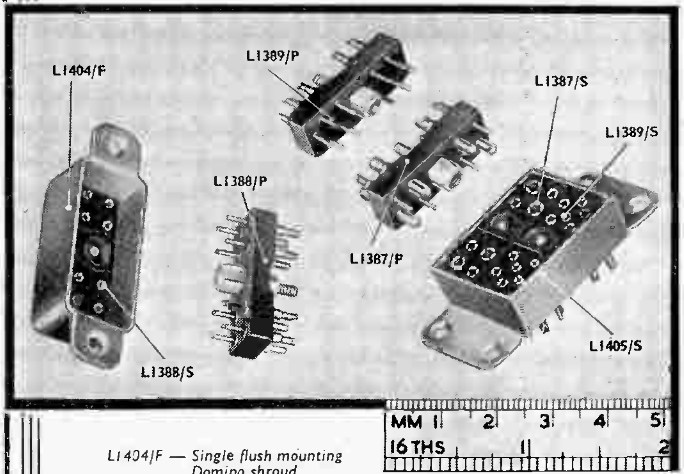

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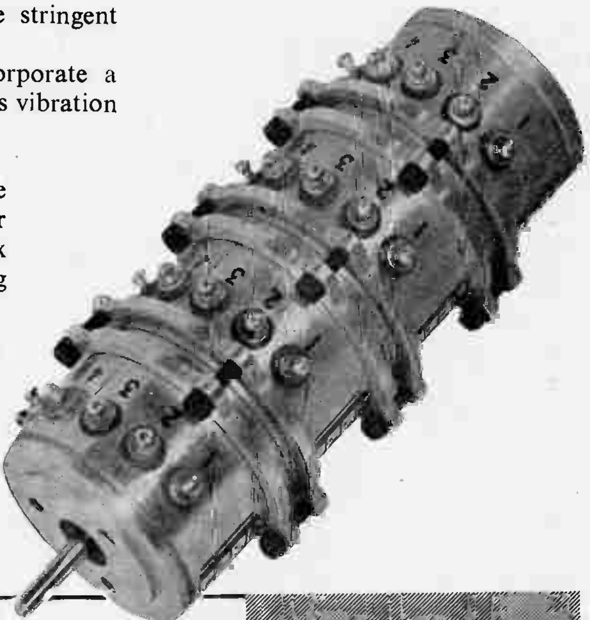

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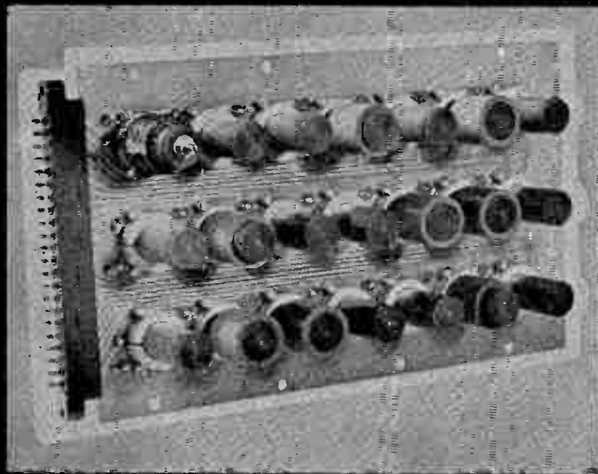

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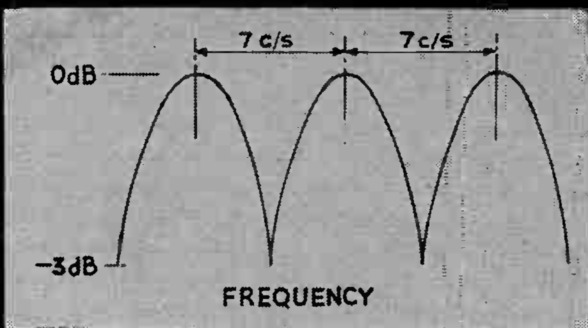

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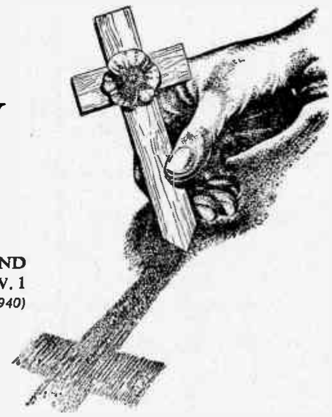

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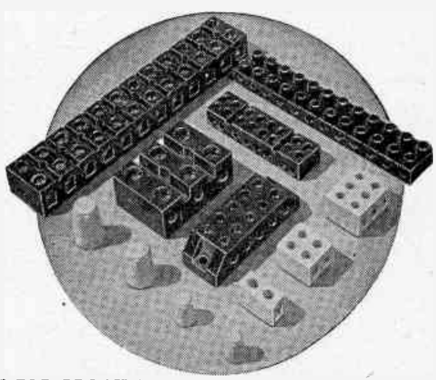

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APPLICATIONS are invited from experienced technicians. The department also serves other hospitals in the district and a new research unit for neuro-surgery which opens shortly. Whitley Council salary scales and conditions apply. Apply, giving qualifications, experience, and quote two referees to Medical Superintendent, Parkside Hospital, Macclesfield. [1242

SITUATIONS VACANT

FEDERAL GOVERNMENT OF NIGERIA
Mechanical/Electrical Engineers, Posts and Telegraphs Department

TO take charge of a section or sections of a workshop engaged in the overhaul and repair of all types of equipment in use in the Posts and Telegraphs Department.

CONTRACT appointments. Salary range £1,290 and £1,962 p.a. Gratuity of £37 10s. for each three months service payable on satisfactory completion of contract.

FREE passages for officer and wife and refund of up to cost of two adult passages for children. Allowance of £75 each for two children maintained outside the territory. Quarters at low rent. Generous home leave.

CANDIDATES should be A.M.I.E.E. and should have had some experience in an organisation engaged in the manufacture or overhaul of telecommunications and light electrical equipment. A knowledge of mechanical engineering would be an advantage.

WRITE Director of Recruitment, Colonial Office, London, S.W.1, giving briefly age, qualifications and experience, quoting BCD.108/14/052. [1258

LIVERPOOL RADIUM INSTITUTE MANAGEMENT COMMITTEE
1 MYRTLE STREET, LIVERPOOL, 7

APPLICATIONS are invited for the post of Electronics Technician (Senior Grade) in the Physics Department. Duties are mainly concerned with the maintenance of electronic measuring instruments for the Radio-Isotope Department. Candidates should be capable of maintaining the existing specialized equipment and of taking part in the development and installation of new apparatus. A sound knowledge of electronics is required, preferably with experience of pulse techniques. Whitley Council conditions of service and salary scale, viz. £625 to £810 per annum. Applications, giving full details of previous experience together with the names and addresses of two referees, to be sent to the undersigned not later than 10th November, 1958.

D. BRYSON
Secretary to the Committee
[1249

DESIGN Engineer for Cape Town, South Africa. This top ranking position is shortly becoming vacant. A design engineer of the highest calibre in the light current field with the accent on industrial electronic equipment and transformer design is required. An attractive salary being offered to an experienced applicant. The position calls for high technical qualifications, progressive ideas and, what is really essential, a practical outlook. These qualifications are necessary in order to produce equipment for the market that is of high quality and yet competitive. A written application is invited in the first instance giving full details of educational and academic qualifications together with achievements in the practical field. To Box No. 8910. [1251

THE Research Laboratories of a large Midlands Company have a vacancy for a senior engineer to set up and take charge of section a new engaged in the development of point-to-point V.H.F. and U.H.F. radio links. It is envisaged that in addition to the development group there will be field survey and installation teams. Applicants for this post must have had recent responsible experience in this kind of work and must be capable of design work *ab initio*.

APPLICATIONS are also invited from engineers to assist in this development and for posts in field survey teams. Experience in a relevant sphere is essential in all cases.

SALARIES for these posts will be assessed, according to experience and qualifications, in the ranges £1,100 to £1,750 or £800 to £1,300.

A summary of training and experience, and quoting reference LZ/R, should accompany all applications, which should be sent to Box No. 0047. [1255

SITUATIONS VACANT

TECHNICIANS
Required By
The Atomic Weapons Research Establishment Aldermaston, Berkshire

TO service and where necessary modify a wide variety of nuclear particle counting equipment including multi-channel kick sorters, scalers, coincidence units, D.C. amplifiers and other special electronic instruments developed by A.W.R.E. and A.E.R.E. for use in a Nuclear Physics Group.

A recognized apprenticeship or equivalent approved practical training in the field of electronics required. Previous experience with nuclear particle counting equipment or in servicing radar or similar electrical equipment is desirable.

SALARY £755 (at age 28 or over)—£875.

CONTRIBUTORY superannuation scheme. A house or alternatively substantial assistance in house purchase will become available for married officers living beyond daily travelling distance.

POSTCARDS for application forms to the Senior Recruitment Officer at above address. Please quote Ref. B1600/46. [1256

ASSISTANT Engineer Grade II required by East Africa High Commission Directorate of Civil Aviation on probation for pensionable employment. Gross salary according to age and qualifications up to £1,173 a year in scale £813 rising to £1,341 a year. Outfit allowance £30. Free passages. Liberal leave on full salary after each tour 30–36 months. Candidates, who should hold at least two second-year and preferably one third-year C. and G. Certs in Telecomms. Principles or Radio must have had at least three years' experience in erection and maintenance of ground station transmitters, radio and radar navigational aids and serial systems. Up-to-date knowledge of workshop practice essential and a knowledge of teleprinter and perforator equipment or diesel electric power plant maintenance would be an advantage. Write to the Crown Agents, 4 Millbank, London, S.W.1. State age, name in block letters, full qualifications and experience and quote M2C/49960/EO. [1252

MINISTRY of Supply Research and Development Establishments, mainly in southern half of England, require (*a*) Senior Scientific Officers (min. age 26) and (*b*) Scientific Officers for work in physics, electronics, electrical or mechanical engineering, applied mathematics, aerodynamics, chemistry or metallurgy. 1st or 2nd class honours degree or equivalent required and for S.S.O. at least three years' post-graduate experience. Starting salary in range (*a*) £1,130–£1,330, (*b*) £595–£1,050 (male, in provinces). Rates for women reaching equality in 1961. Superannuation under F.S.S.U. Opportunity for those under 32 to compete for established posts. Candidates should indicate fields of work in which interested. At National Gas Turbine Establishment, Pyestock, Hants, houses available for letting to married staff, and opportunities for new graduates to have workshop training. Forms from M.L.N.S. Technical and Scientific Register K, 26 King Street, London, S.W.1. (Quote A.300/8A.) [1248

INSPECTOR of Lights required by Sarawak Government Marine Dept. either on probation to pensionable establishment or on contract with gratuity of 12½% of final monthly salary for each completed month of service. Salary scale (including inducement pay) equivalent to £1,176 to £1,932 a year. Child allowance between £72 and £123 a year. Education allowance up to £280 a year. Outfit allowance £60. Free passages. Liberal leave on full salary. Candidates preferably under 35, should be A.M.I.E.E. or A.M.I.Mech.E., and have a good all-round knowledge of electricity especially in connection with the operation of lighthouse flashers (Chance/Londex), Reed and Klaxon Motors, Echo sounding gear, straightforward small unit diesel electric generation, current conversion, etc., a knowledge and experience of small diesel engines, working knowledge V.H.F. radio equipment and have a good head for heights up to 130 ft. Write to the Crown Agents, 4 Millbank, London, S.W.1. State age, name in block letters, full qualifications and experience and quote M2A/50186/EO [1247

SITUATIONS VACANT

MINISTRY of Transport and Civil Aviation requires Electrical Engineers (Assistant Signals Officers) for aviation telecommunications and electronic navigational aids. Minimum age 23, 1st or 2nd class degree in Physics or Engineering, or A.M.I.E.E. or A.F.R.Ae.S. (candidates with Parts I, II and III of A.M.I.E.E. or Parts I and II of A.F.R.Ae.S. or equivalent, or of very high professional attainment without these qualifications considered). Salary £665 (age 23) to £1,085 (age 34). Maximum £1,250. Slightly lower outside London and for women. Five-day week. Further details and forms from M.L.N.S., Technical and Scientific Register (K), 26 King Street, London, S.W.1, quoting D129/8A. [1250

PHYSICISTS, CHEMISTS AND ENGINEERS

A large electrical engineering establishment in South-west Lancashire is setting up a research laboratory to study fundamental aspects of electronic logical devices. Three types of post are available:

(*a*) Physicists or chemists for research on conduction and other effects in semi-conductors and allied materials.

(*b*) Physicists or electronic engineers for work on fabrication of experimental electronic devices.

(*c*) Electronic engineers for study of applications and circuital aspects of new electronic elements.

These are senior posts which will involve responsibility for leading research in particular fields. Candidates should possess high academic qualifications together with appropriate experience. Candidates not possessing such academic qualifications but who can produce evidence of outstanding research contributions in these fields would not be excluded from consideration.

Salaries will be realistic, taking full account of qualifications and experience and the calibre of the work to be undertaken. Successful applicants will be required to join the Company's Pension Scheme.

Please write to Box No. 0032, c/o "E. & R.E.", giving full details of age, qualifications and experience.

BOOKS, ETC.

"**BASIC** Mathematics for Radio and Electronics." By F. M. Colebrook, B.Sc., D.I.C.A.C.G.I. Revised and enlarged by J. M. Head, M.A. (Cantab.). Presents in readable form a complete course in basic mathematics for engineering students of all kinds and leads on to the more advanced branches of mathematics of increasing importance to radio engineers. In this edition the chapter covering the application of mathematics to radio has been revised and enlarged, while new subjects covered include Stability, Linear Differential Equations, Elementary Statistics, Short Cuts to Numerical Calculations and an Introduction to Matrices. Will be invaluable to those requiring a refresher course as well as to those without previous knowledge of the subject. 17*s.* 6*d.* net from leading booksellers, by post 18*s.* 6*d.* from Iliffe & Sons, Ltd., Dorset House, Stamford Street, S.E.1.

"**TELEVISION** Explained." By W. E. Miller, M.A. (Cantab), M.Brit.I.R.E. Revised by E. A. W. Spreadbury, M.Brit.I.R.E. The sixth edition of a book which assumes a knowledge of the ordinary sound radio receiver but no previous knowledge of television circuits. It is non-mathematical, written in simple language, and comprehensively illustrated by many diagrams and photographs. It will prove of great assistance to all students of television, to radio service engineers who wish to embark upon television work and want to understand the principles and circuits involved, and to knowledgeable owners of television receivers who would like to understand the working of their set. 12*s.* 6*d.* net from all booksellers. By post 13*s.* 5*d.* from Iliffe & Sons, Ltd., Dorset House, Stamford Street, London, S.E.1.

"**TELEVISION** Receiving Equipment." By W. T. Cocking, M.I.E.E. The fourth edition of one of the most important British books on television deals in a comprehensive manner with television receiver equipment and gives many practical details and much design data. The circuits of a television receiver are split into a number of sections and a separate chapter is devoted to each. Other chapters deal with general principles, the signal, superheterodyne interference problems, special circuits, the aerial, the complete receiver, faults and servicing. 30*s.* net from leading booksellers. By post 31*s.* 9*d.* from Iliffe & Sons, Ltd., Dorset House, Stamford Street, S.E.1.

"**RADIO** Interference Suppression: As Applied to Radio and Television Reception." By G. L. Stephens, A.M.I.E.E. 2nd Ed. An up-to-date guide to the various methods of suppressing electrical interference with radio and television reception. Many practical applications are given, particular attention being paid to the problem of interference at television frequencies. Other chapters deal with the design and choice of suppressor components, methods of locating the source of interference, and suppression at the receiver itself. 10*s.* 6*d.* net from all booksellers. By post 11*s.* 2*d.* from Iliffe & Sons, Ltd., Dorset House, Stamford Street, London, S.E.1.

BOOKS, ETC.

"**ADVANCED** Theory of Waveguides." By L. Lewin. Sets out various methods of treating problems arising in work on this complex subject. The author has selected for discussion a number of topics as representative of the field in which the centimetre-wave engineer is engaged, many of the examples being concerned with the rectangular waveguide. 30*s.* net from all booksellers. By post 31*s.* from Iliffe & Sons, Ltd., Dorset House, Stamford Street, London, S.E.1.

"**RADIO** Laboratory Handbook." By M. G. Scroggie, B.Sc., M.I.E.E. This well-known practical work describing laboratory equipment and methods of operation has been entirely rewritten and greatly enlarged. Among the subjects considered are layout and furnishing of premises, methods of measurements, sources of power and signal measurements. There is a comprehensive reference section and many photographs, diagrams, graphs and tables. 25*s.* net from all booksellers. By post 26*s.* 9*d.* from Iliffe & Sons, Ltd., Dorset House, Stamford Street, S.E.1.

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100 bays of brand new adjustable STEEL SHELVING, 72" high × 34" wide × 12" deep, stove enamelled, dark green, sent unassembled, six-shelf bay, £3 15s. 0d.

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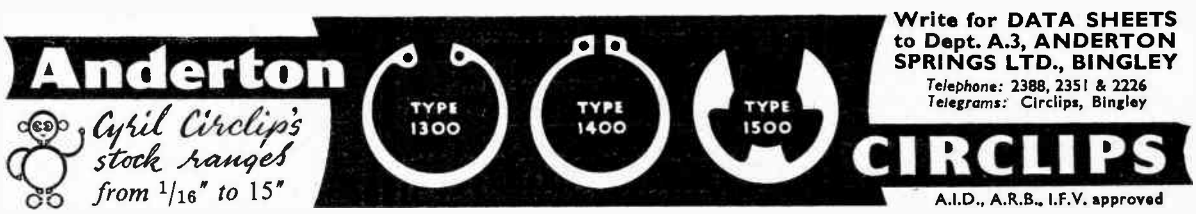

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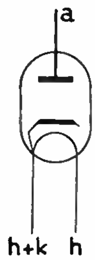
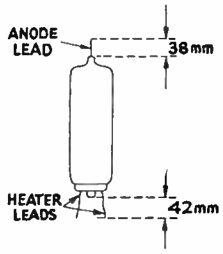
Introducing other outstanding Ediswan Mazda valves, types U25 and U26

For the information of set designers we are publishing details of individual 0.3 amp heater valves in our 'First Preference' Range for TV circuits. If you are a TV manufacturer, we shall be pleased to supply full technical details of our 'First Preference' Range together with a set of valves for testing, on receipt of your enquiry. The valves dealt with here are the Types U25 and U26, half wave rectifiers intended for use in "Flyback" or R.F. high voltage power supplies for Television Receivers.

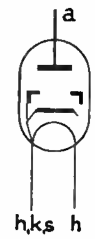


U25

BASE: WIRE LEADS

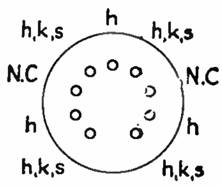


Cap-wire lead



U26*

BASE: B9A (NOVAL)



Top Cap-anode

View of free end

*Pins 3 and 7 marked N.C. have no internal connection but must not be left unconnected. They should be connected to the external circuit with not more than 100 V between adjacent pins.

		U25	U26
Heater Current (amps)	I_h	0.2	0.35
Heater Voltage (volts)	V_h	2.0	2.0

MAXIMUM RATINGS
(Flyback Pulse)†

		U25	U26
Peak Inverse Voltage (Design Centre) (kV).............	$PIV_{(max)}$	19.0	23.5
Peak Inverse Voltage (Absolute) (kV)	$PIV_{(max)}$	22.0	27.0
Mean Anode Current (Design Centre) (mA)	$I_{a(max\ av)}$	0.2	0.2
Peak Anode Current (Design Centre) (mA)	$I_{a(max\ peak)}$	25.0	60.0

†Where the applied voltage pulse does not exceed 15% of one scanning cycle or 15μS duration.

With suitable circuits the U25 can be employed in television receivers to give d.c. output voltages up to 16kV. The U26 can give d.c. output voltages up to 18kV.

INTER-ELECTRODE CAPACITANCES (pF)

		U25	U26
Anode to heater and cathode	$C_{a\text{-}h,k}$	0.6	
Anode to heater, cathode and shield	$C_{a\text{-}h,k,s}$		0.9‡

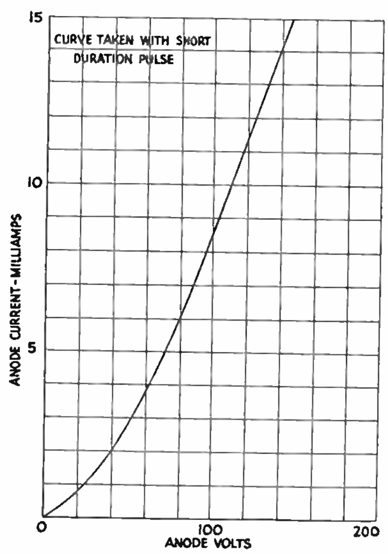
‡Total capacity including unscreened B9A ceramic holder, i.e., without can or skirt.

MAXIMUM DIMENSIONS

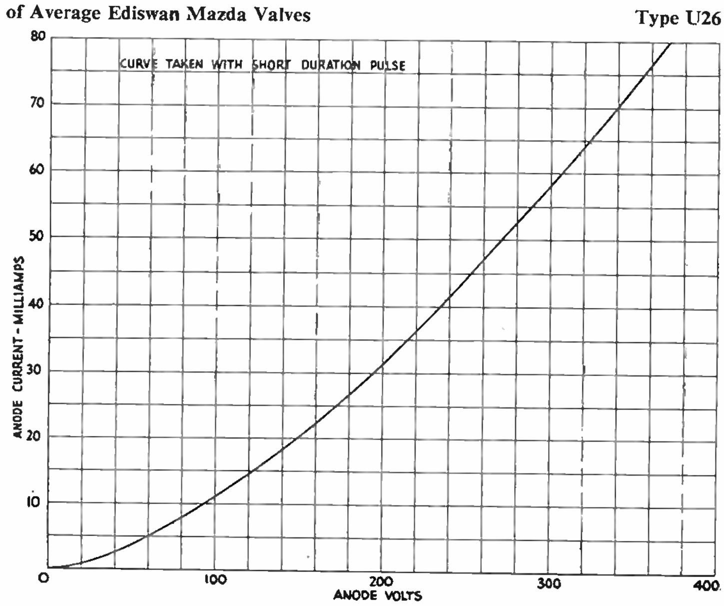
	U25	U26
Overall length (mm) (excluding leads)	58	
Overall length (mm)		76
Diameter (mm)	19	21
Seated height (mm)		69

Characteristic Curves of Average Ediswan Mazda Valves

Type U25



Type U26



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