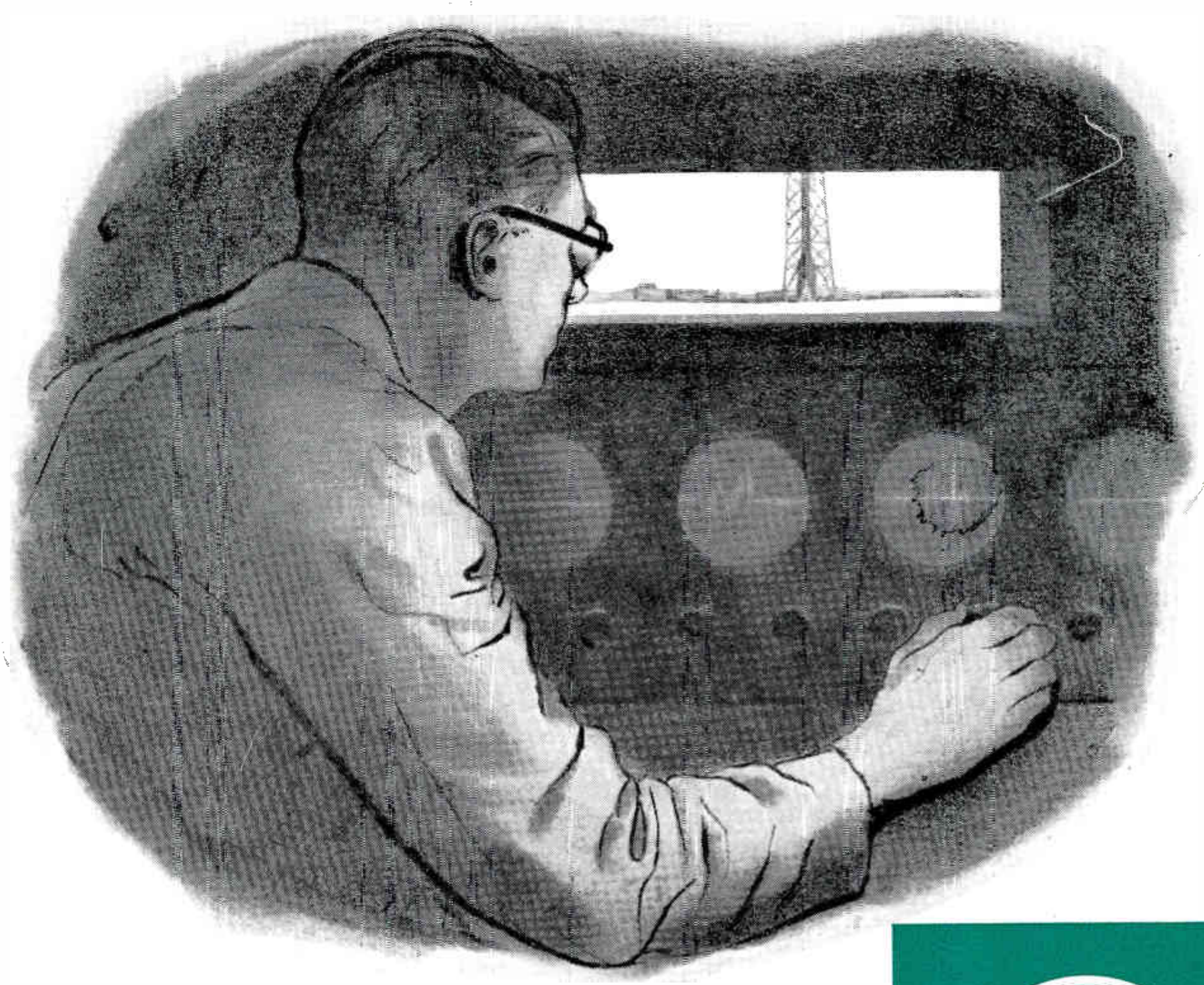
ELECTRONIC & RADIO ENGINEER

Incorporating **WIRELESS ENGINEER**

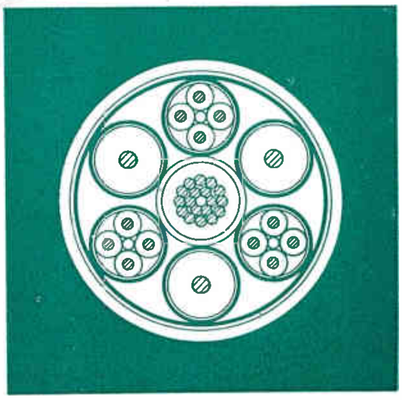
In this issue

Three shillings
and sixpence

DECEMBER 1958 Vol 35 *new series* No 12



"FOUR-THREE-TWO-ONE-!"



Testing time for guided missiles — with cables providing the nervous system for the control equipment . . . BICC design and manufacture a wide variety of control cables for both ground and airborne use. Standard types are also available for use with ancillary equipment such as ground radar, centimetre radio links and closed circuit television.

For outdoor connections

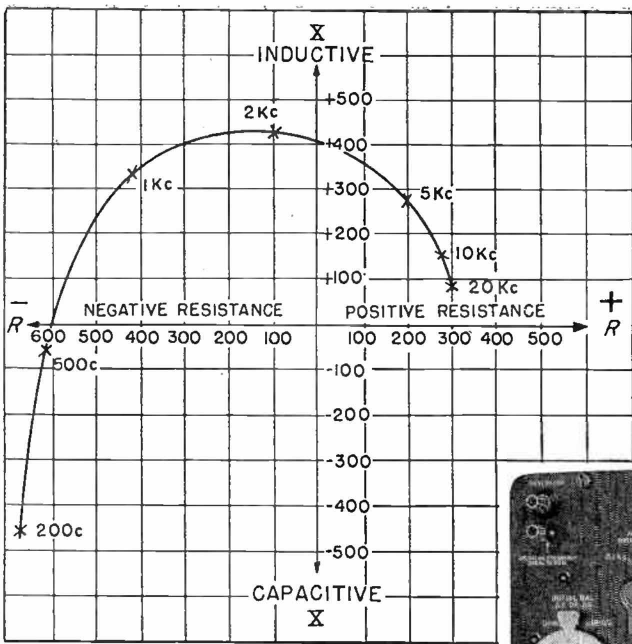
BICC Polypole Couplers are also particularly suitable for use with ground control equipment, since they ensure a tough, permanent, moisture-resistant assembly which virtually eliminates the possibility of conductor breakages at the coupler.

Further information about these products is available on request.

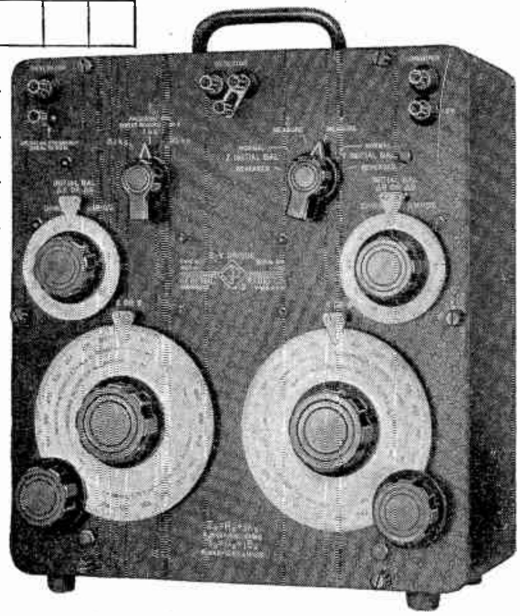
BICC control cables

BRITISH INSULATED CALLENDER'S CABLES LIMITED • 21 Bloomsbury Street, London, W.C.1

Type 1603-A
Z-Y Bridge



Impedance of Feedback Circuit ... illustrates ability of the Z-Y Bridge to measure any impedance; quadrature components may be positive or negative, real or imaginary.



Measures Any Impedance...

- From O to ∞ ohms
- Positive or Negative
- At Any Phase Angle
- Over 20-c/s to 20-kc Range

The General Radio Z-Y Bridge measures impedances from short circuit to open circuit, at small or large phase angle. Quadrature components, R & X or G & B, are measured directly at calibrated 100 c, 1-kc, and 10-kc bridge positions. Basic accuracy is 1% over most of this range.

The ability to measure impedances of any magnitude accurately with one instrument is an extremely valuable asset in many measurement situations. The Z-Y Bridge can be used for measuring conductivity of liquids, in dielectric cells as readily as it can be used for R-L-C component measurements in the laboratory or production-test department. It will measure open-circuit and short-circuit transformer parameters . . . impedances of batteries and electrolytic capacitors . . . characteristics of audio-transmission networks . . . impedance of electro-acoustic transducers . . . Q and resonant frequency of chokes . . . and impedances of feedback loops, since negative real parameters can be directly measured.

The Bridge also can be used to determine cable-fault locations and circular-arc plots of liquids or solids having lossy polarizations in the audio-frequency range. These are but a few of the countless applications for this unique and versatile device. *You name it — this Z-Y bridge can probably measure it.*

For complete information request a copy of the current "G.R." Catalogue "O" (258 pages), where data is given on pages 34/35.

Impedance and Admittance Range
R: ±1000 ohms G: ±1000 μmhos
X: ±1000 ohms B: ±1000 μmhos

Accuracy
R or G: ±(1% + (2 ohm or 2 μmho))
X or B: ±(1% + ($\frac{2f_o}{f}$ ohm or $\frac{2f}{f_o}$ μmho))

f is operating frequency, f_o is frequency setting of panel selector switch

Impedances of less than 100Ω or (100 μmhos) can be measured on "Initial Balance" dials with considerably greater accuracy—
R or G: ±(1% + (0.2 ohm or 0.2 μmho))
X or B: ±(1% + ($\frac{0.2f_o}{f}$ ohm or $\frac{0.2f}{f_o}$ μmho))

Frequency Range—20 cycles to 20 kc

Maximum Applied Voltage
130 volts, rms on bridge;
less than 32v on unknown

Accessories Recommended
"G.R." Type 1210-B Unit R-C Oscillator and
"G.R." Type 1212-A Unit Null Detector

Accessories Supplied
2 Shielded Cables for generator and detector

Dimensions—12½" x 13½" x 8½"

Net Weight—21½ lbs.

Type 1603-A Z-Y Bridge £222

Claude Lyons Ltd.

76 Oldhall Street Liverpool 3, Lancs.
Telephone: Central 4641/2

Valley Works, Ware Road, Hoddesdon, Herts.
Telephone: HODdesdon 3007-8-9

CL.45

Transistor News

Important News for Radio Manufacturers

The 'CIRCLE LINE'

Newmarket introduces matched sets of transistors for better performance

Newmarket, Monday.

This is news that no radio manufacturer can afford to ignore —transistors in matched sets, or complements, at really competitive prices. A choice of 5 different complements is available, each complete with diode, to suit any conventional circuit arrangement.

Cheaper all-transistor radios

This bold step forward should give a tremendous fillip to the mass production of transistorized radios.

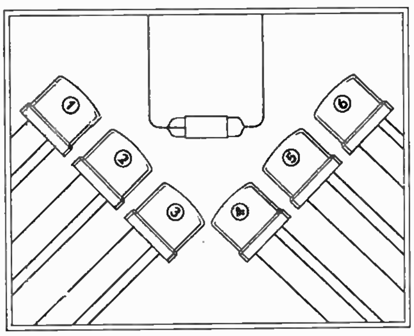
Combined performance is what counts

Newmarket Transistors Limited, pioneers of transistor development in Britain, have the advantage of more than 3 years' experience both of transsistor production and of the problems associated with design and production of equipment incorporating them.

This experience has shown that the maintenance of adequate performance standards depends as much upon the combined performance of the transistor complement as on the performance of individual transistors.

New coloured circle coding

To distinguish these 'Circle Line' complements Newmarket have replaced their conventional type numbers by a new colour-coding system, in which a coloured circle denotes the particular series or complement and a number within the circle indicates its position in the circuit



The following is a typical example:

White Circle 6

1	2	3	4	5	6
Osc/mixer	IF	IF	driver	O/P	O/P

(plus detector diode)

The range of Circle Lines at present available is as follows:

Red Circle 5

For pocket receivers with 6v supply. Five transistors numbered from 1 to 5 in RED.

White Circle 6

For handbag style receivers, 6v or 9v supply. Six transistors numbered 1 to 6 in WHITE.

Blue Circle 7

For handbag or general-purpose portable, 6v or 9v supply. Seven transistors numbered 1 to 7 in BLUE. Average stage gain lower than White Circle but overall performance better.

Green Circle 7

Similar to Blue Circle but one IF stage replaced by an audio stage.

Yellow Circle 8

For larger portables and domestic receivers where performance is of first importance. 6v or 9v supply.

Reliability of Supply

Replacements are only a minor problem in Transistor Receivers but every possible provision has been made to ensure replacement availability. When re-ordering, Circle colour and number only need be given. Prompt deliveries in almost any quantities can be guaranteed.

NEWMARKET TRANSISTORS

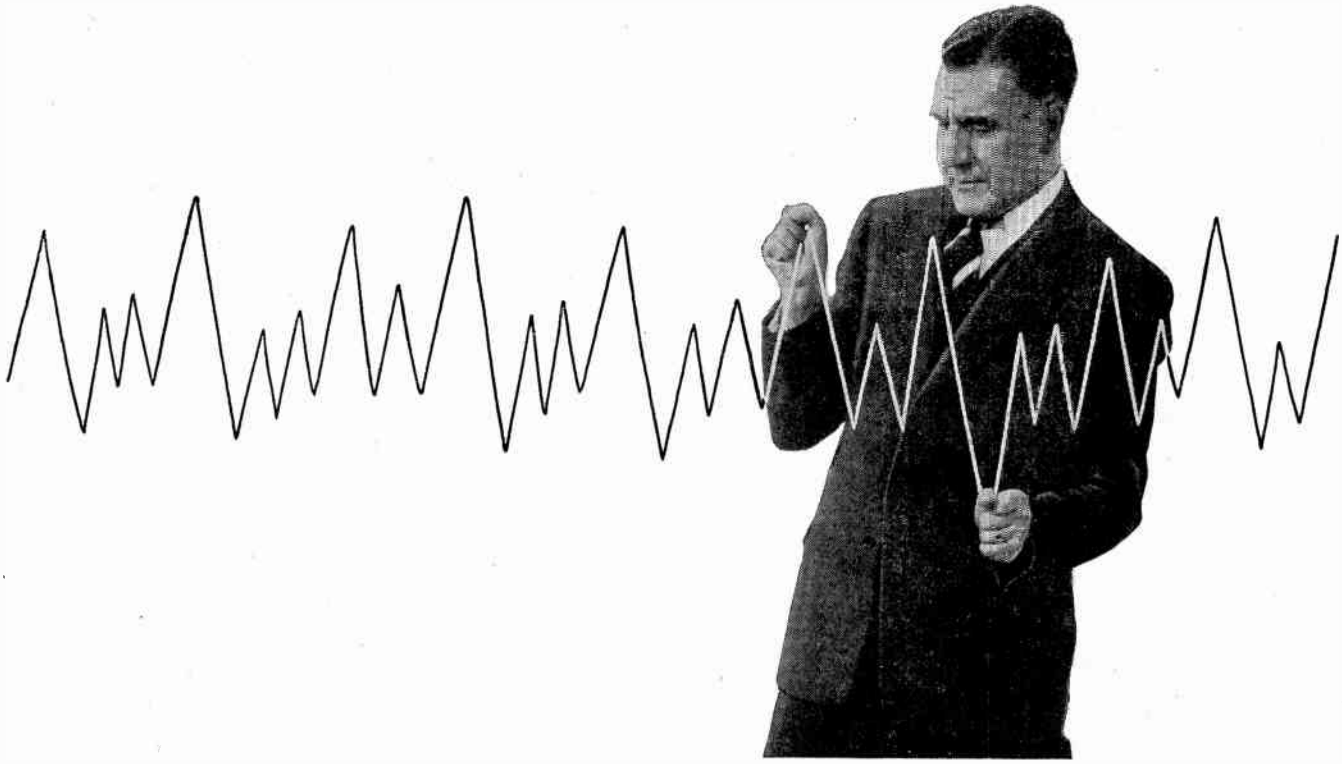
All enquiries to :

Newmarket Transistors Limited.

Exning Road, Newmarket, Suffolk

Tel : Newmarket 3381

Cables & 'grams : Semicon Newmarket.



Why struggle with Mains Voltage Fluctuation ?

If you have <u>*any*</u> *problem involving a.c. voltage regulation, the solution is to call in 'Advance' — the C.V.T. specialists.*

Investigation of your problem may prove that a standard type Constant Voltage Transformer will meet the case; or maybe, a special design is called for. In either event, the wealth of experience gained by 'Advance' over many years in probing every aspect of mains stabilization provides the surest, quickest, and certainly the most economical, solution to your difficulties.

let *Advance* give you a hand

VISIT US ON
STAND 31
THE PHYSICAL SOCIETY EXHIBITION
ROYAL HORTICULTURAL HALL, LONDON
JANUARY 19th to 22nd

CVT

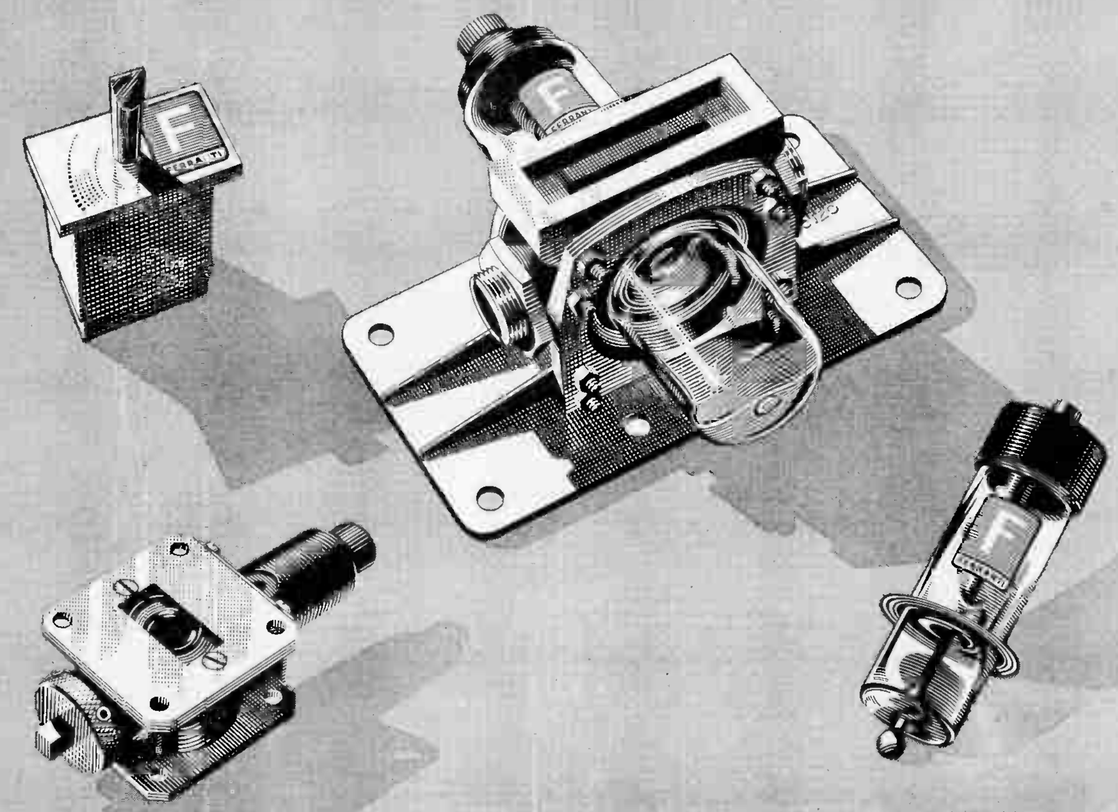
CONSTANT VOLTAGE TRANSFORMERS

Full technical details available—Leaflet R54

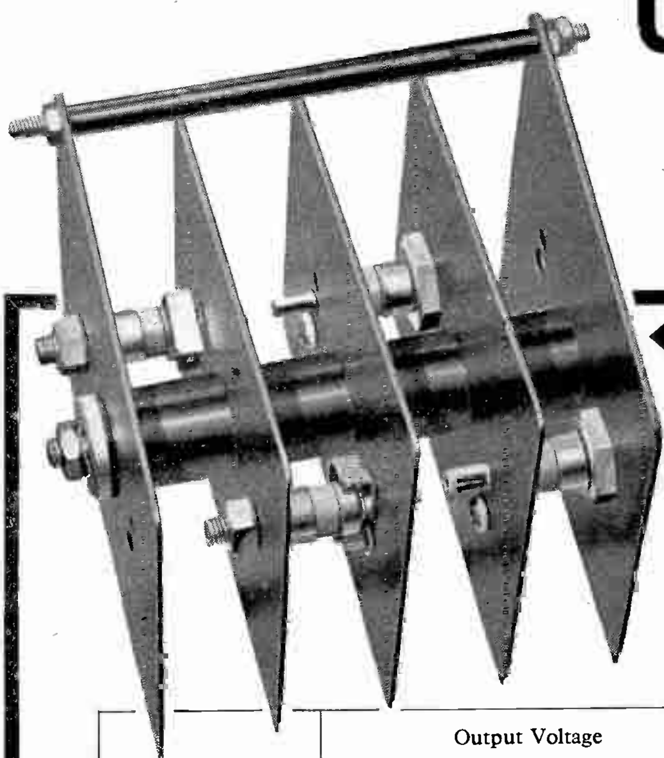
ADVANCE COMPONENTS LIMITED

ROEBUCK ROAD · HAINAULT · ILFORD · ESSEX · Telephone: Hainault 4444

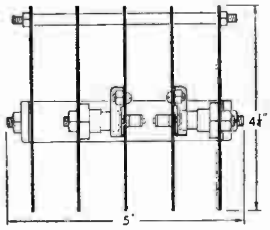
GD10



The NEW SYLVANIA GERMANIUM DIODE



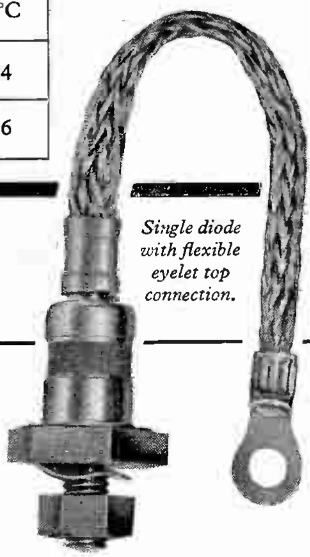
Full wave bridge with anodised fins. Overall size: 5" long, 4¼" high, 4" deep



BGR411 SERIES
Single phase full-wave bridge rectifier maximum storage temp. 85°C

ELECTRICAL RATINGS

	Output Voltage				Output Current, Amperes		
	GR421	GR413	GR412	GR411	25°C	45°C	65°C
Resistive Load	63	47	31	15	28	18·6	8·4
Battery or Capacitative Load	99	74	49	24	22	14·6	6·6



Single diode with flexible eyelet top connection.

Tops all existing standards
COMPACT · EFFICIENT · ROBUST

The new Sylvania series of bridges offers you the smallest size and weight per watt. Ceramic-metal seals and strongly welded closures ensure that robust Sylvania Diodes maintain efficiency in high ambient temperatures and adverse climatic conditions. They are conservatively rated, have low reverse leakage and their low capacity allows use at high power frequencies. There is a complete absence of forward ageing and unforming and they operate instantly after long periods without power. Detailed information on these Sylvania Germanium Diodes is now available. Please write for your copy.

GR411 SERIES
BASIC DIODE RATINGS
UP TO 100v. PEAK INVERSE
HIGHER VOLTAGE UNDER DEVELOPMENT

MEAN D.C. { 14 AMPS @ 25°C, 9 AMPS @ 45°C, 4.2 AMPS @ 65°C

SYLVANIA-THORN COLOUR TELEVISION **LABORATORIES LTD**

DEPARTMENT GD3, GREAT CAMBRIDGE ROAD, ENFIELD, MIDDLESEX

. . . I.C.I. provides industry with anhydrous ammonia,

a cheap source of pure nitrogen and hydrogen gases.

And to convert the ammonia into these gases efficiently

and economically, I.C.I. offers a full range of crackers and burners.

Transport and handling charges are low because I.C.I. anhydrous ammonia is

conveniently transported in large-capacity cylinders and in tank wagons.

I.C.I. Anhydrous Ammonia

Full information on request:

Imperial Chemical Industries Limited, London, S.W.1.

B.I.4

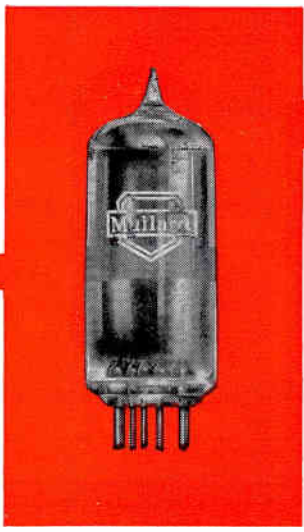
The best 75 volt stabilisers in the world

BRITISH SERVICES PREFERRED TYPE

M8225/CV4080

The high performance of the Mullard stabiliser 75C1 has led to the recent adoption of its Special Quality equivalent M8225/CV4080 by the British Services as their Preferred 75-volt stabiliser. The M8225/CV4080 is tested for specialised applications in which conditions of extreme shock and vibration are encountered.

- **Wide Current Range . . .**
  2 to 60 milliamps
- **Small Regulation Voltage . . .**
  Less than 9 volts
- **High Stability . . .**
  Typical variation in burning voltage less than ± 2% in any 10,000 hours of operation.



GENERAL PURPOSE TYPE

75C1

The 75C1 is the best 75 volt stabiliser available in the world for general purpose use in industry and communications. It has the same electrical characteristics as the M8225/CV4080 and like this British Services Preferred valve provides an exceptional *combination* of long life, stability and good regulation.

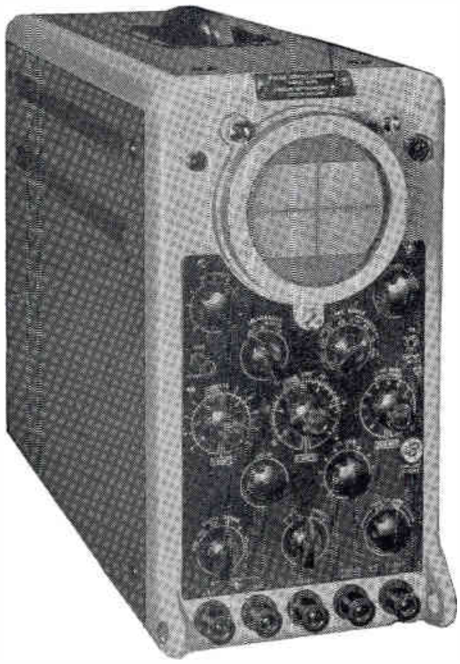
Full data is readily available from the address below.

MULLARD LIMITED
MULLARD HOUSE
TORRINGTON PLACE
LONDON · W.C.1
TEL: LANGHAM 6633

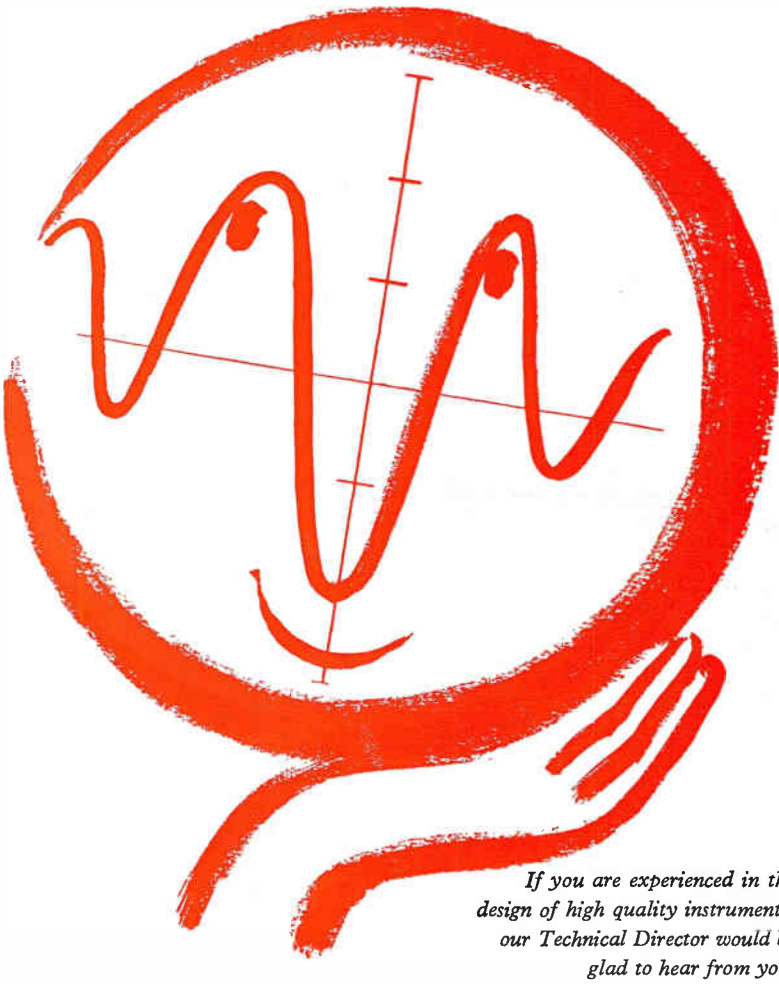
Mullard
GOVERNMENT AND INDUSTRIAL VALVE DIVISION

Mullard

MVT355a



Thinking about an oscillograph?



Consider Model 1065

Designed for a wide variety of laboratory applications, it has a very interesting specification including:
Y amplifier of sensitivity 250 mV/cm with a bandwidth of d.c. to 20 Mc/s and rise-time better than 40 mμsec;
X amplifier: time measurement by calibrated shift and internal oscillator for timing marks; voltage measurement by calibrated shift; probe providing an input impedance of 1.5 MΩ 12 pF. We shall be pleased to send you full data on this and other equipment in the Cossor range.
An export model (1065X) is also available.

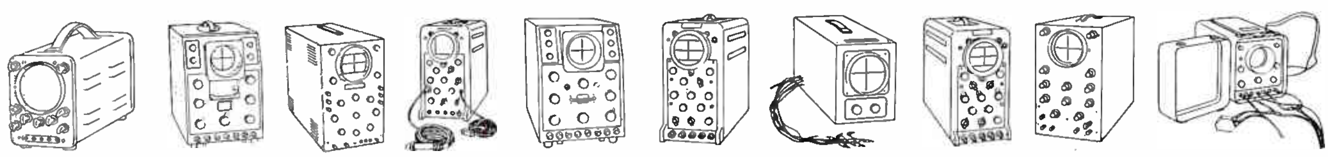
If you are experienced in the design of high quality instruments, our Technical Director would be glad to hear from you.

Write for information to:

COSSOR INSTRUMENTS LIMITED

The Instrument Company of the Cossor Group

COSSOR HOUSE, HIGHBURY GROVE, LONDON, N.5.
Telephone: CANonbury 1234 (33 lines). Telegrams: COSSOR, NORPHONE, LONDON. Cables: COSSOR, LONDON. Codes: BENTLEY'S SECOND.



TAS/CI.3

A new Plessey range of Plugs and Sockets

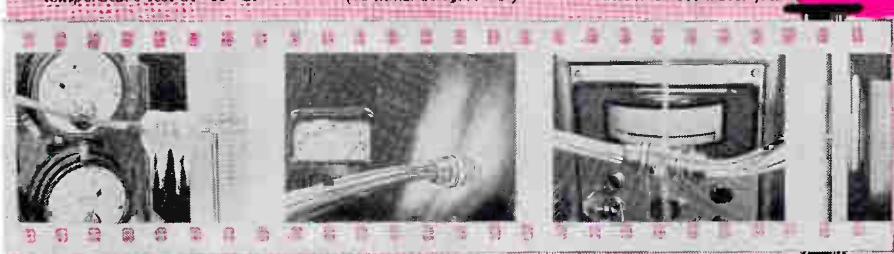
COVERING THE ENTIRE 'AN' RANGE

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

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

Write for test reports and full technical details.

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



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

ELECTRICAL CONNECTORS DIVISION

THE PLESSEY COMPANY LIMITED · CHENEY MANOR · SWINDON · WILTS

Overseas Sales Organisation: PLESSEY INTERNATIONAL LIMITED · ILFORD · ESSEX

PW2

THE WAYNE KERR WIDE RANGE

Audio Oscillator

TYPE S.121

This instrument is now approved for Armed Services use. The reference numbers are:

ARMY—ZD02957
INTER-SERVICE—CT417

- ★ 10 c/s — 120 kc/s
- ★ Effective scale length 15 ft.
- ★ Rapid frequency selection
- ★ Accuracy $\pm 1\%$ ± 0.5 c/s
- ★ Output : 0 — 30V and
- ★ +10 to — 70dB on 1 milliwatt into 600 Ω
- ★ Output stabilised to 0.2dB
- ★ Distortion $<.25\%$ to 20 kc/s, $<.4\%$ to 120 Kc/s

THIS instrument meets the need for a first class audio signal generator in transportable form. Its wide frequency range and amplitude stabilised alternative output facility provide exceptional flexibility. For balanced output requirements a transformer is available with 600 Ω and 150 Ω secondary windings, both centre tapped.

A unique dial arrangement allows rapid selection of frequency over a scale effectively 15 feet long and greatly simplifies interpolation and extrapolation.

The S.121, which is mains operated from 110 to 250V, has overall dimensions of 17″ x 11½″ x 7½″ deep and weighs less than 30 lbs. The price is £130.

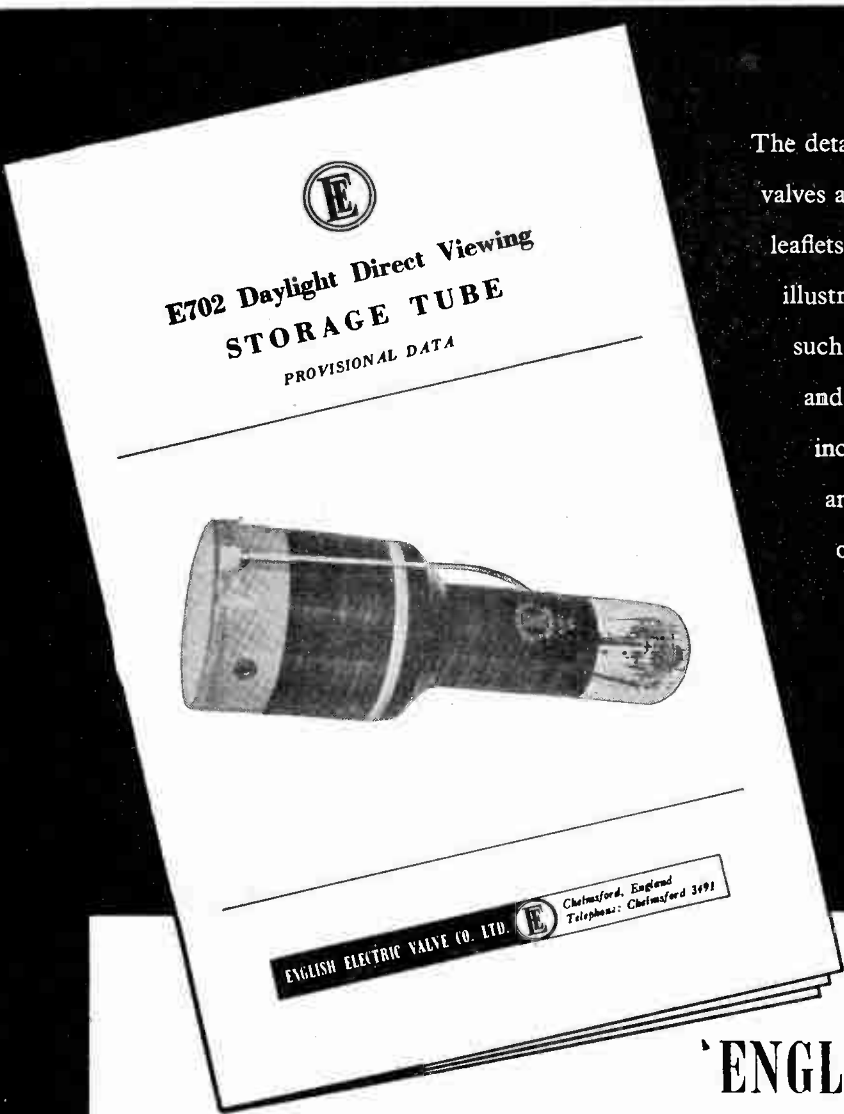
Other instruments in the Wayne Kerr range include:

A.F., R.F., V.H.F. BRIDGES, A.F., V.H.F. SIGNAL SOURCES, A.F. WAVEFORM ANALYSER, ELECTRONIC MICROMETERS, CENTIMETRIC EQUIPMENT

For further details write or telephone.

WAYNE KERR

THE WAYNE KERR LABORATORIES LTD • ROEBUCK ROAD • CHESSINGTON • SURREY • TEL: LOWER HOOK 1131



The details of a number of our valves are given in a series of leaflets similar to that illustrated. The present list of such valves is tabulated below and is constantly being increased. If you would like any of the leaflets listed, or indeed information concerning any of our wide range of thermionic devices, please write to the company.

'ENGLISH ELECTRIC'

Leaflet No.	Valve No.	Type of Valve	Freq. range
M1	M555	Magnetrons	J Band
M2	4J52A	,,	X Band
M3	M506A	,,	X Band
M4	5586 and 5657	,,	S Band (Tunable)
M5	M543	,,	S Band
M6	M554	,,	L Band
K1	K345	Klystrons	5925/8025 Mc/s
K2	K336	,,	8500/10,000 Mc/s
K3	K350	,,	8500/10,000 Mc/s
K4	K343 and K346	,,	12000/17,000 Mc/s
E1	E702	Storage Tube	—
VA3	VA719 Germanium Rectifiers		—

ENGLISH ELECTRIC VALVE CO. LTD.

Chelmsford, England
Telephone: Chelmsford 3491

AP/116

ANNOUNCING THE BRITISH-MADE

Heathkit

'BUILD-IT-YOURSELF' ELECTRONIC EQUIPMENT

The
WORLD'S
MOST
POPULAR

KIT SET VALVE VOLTMETER

The new model S-88 High Fidelity Stereophonic Sound,—combined Pre-amps and Power Amplifiers. all in one unit, 8 + 8 Watts ; ·1% Distortion

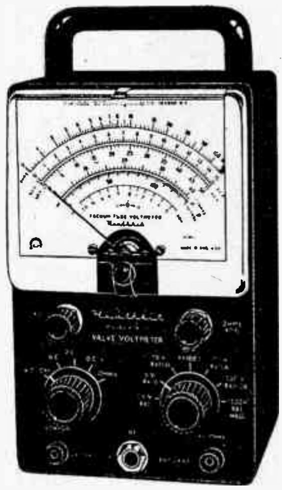
£25 Kit complete with comprehensive instruction manual

(Postage 5/6 extra)

Delivery week commencing December 8th 1958

DESIGNED FOR THE DISCRIMINATING ENGINEER AND MUSIC LOVER

MODEL
V-7A



ABRIDGED SPECIFICATION

7 Voltage Ranges (a.c. & d.c.).	1·5 to 1500 volts
Electronic Ohmmeter (7 ranges).	·1 Ω to 1000 MΩ
Input Resistance.	11 MΩ
Multipliers.	1% precision type
Circuit Board.	Printed circuit, gold plated
Frequency Response.	± 1dB, 42 c/s to 7·2 Mc/s
Meter.	4½" scale, 200μA movement, reading directly d.c. and a.c. volts (r.m.s. and pk. to pk.), ohms and decibels
Instruction Manual.	Comprehensive construction manual for simplified assembly, operation and servicing

Coming Shortly

OSCILLOSCOPE
TRANSISTOR RECEIVER
TRANSISTOR PORTABLE
TRANSMITTER

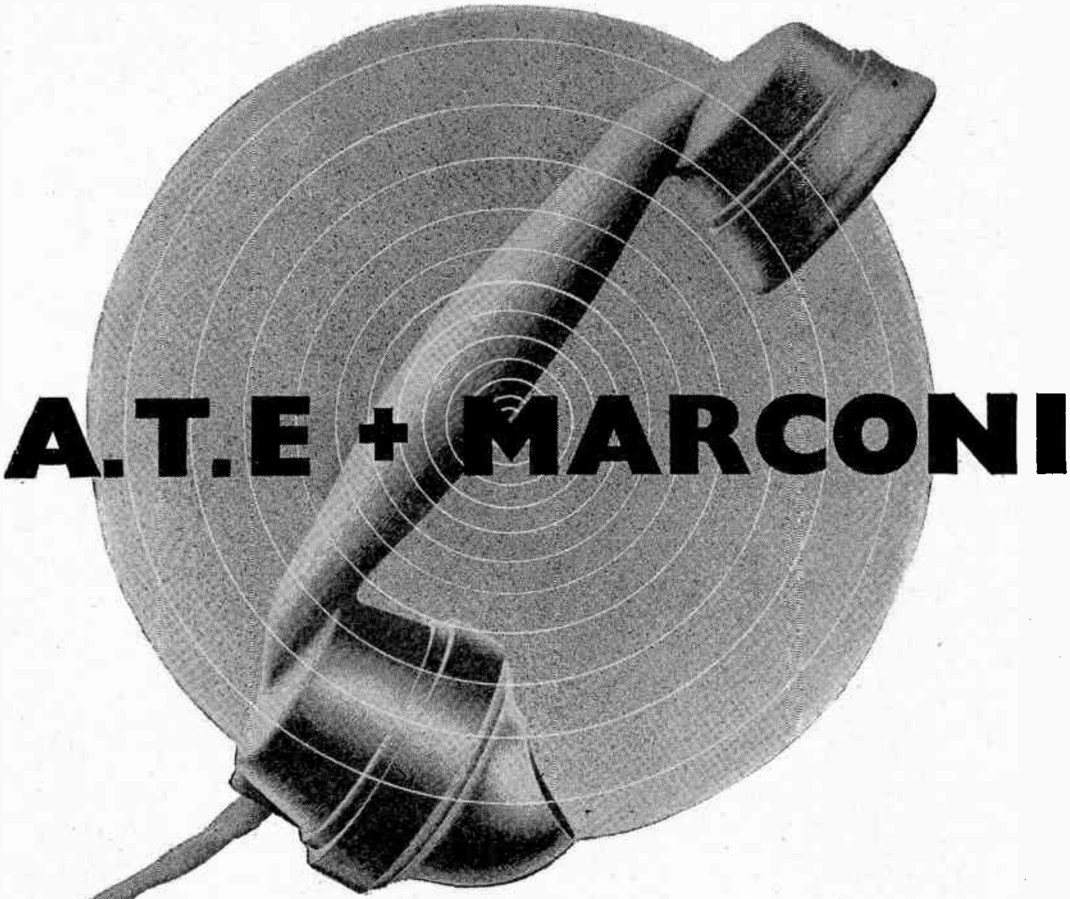
£15-14-0

Delivery Free U.K.
Complete with Test Leads and Battery
Deferred Terms available
Delivery Ex Stock

DAYSTROM LTD — *INSTRUMENTS DIVISION* GLOUCESTER, ENGLAND

A Member of the Daystrom Group. Manufacturers of

THE LARGEST-SELLING ELECTRONIC KITS IN THE WORLD



Combined Operations

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

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

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

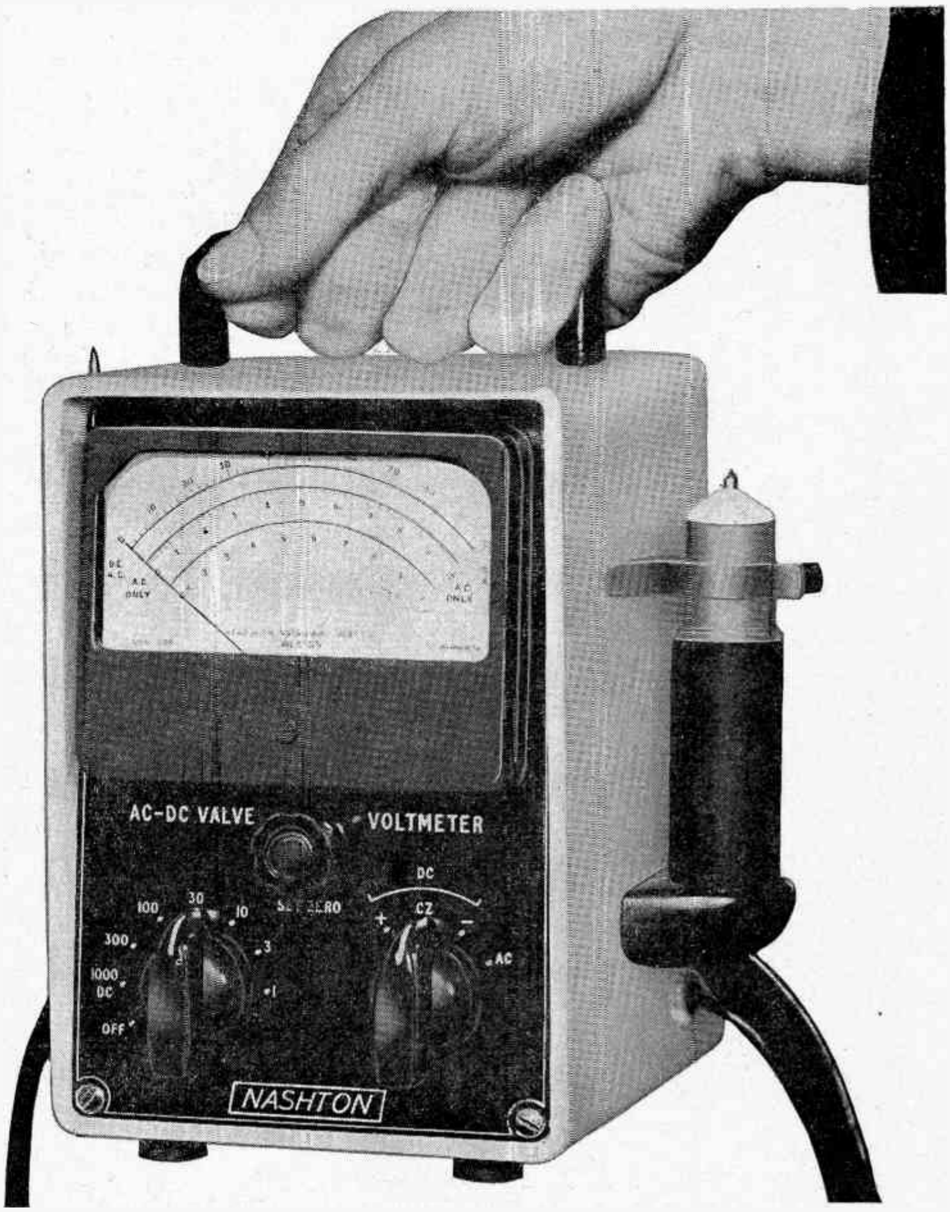
or AUTOMATIC TELEPHONE & ELECTRIC CO. LTD., STROWGER HOUSE, ARUNDEL STREET, LONDON, W.C.2

ANOTHER

NEW

NASHTON

INSTRUMENT



A.C.-D.C. Valve Voltmeter

VOLTAGE RANGES:

D.C. Voltages from
100 mV to 1 kV in seven ranges
A.C. Voltages from
300 mV to 300 volts in six ranges.

Accuracy better than 3% f.s.d. on most ranges · High Input Impedance · Excellent stability against mains fluctuations · Good frequency response between 50 c/s and 200 Mc/s · Top quality moving coil meter to B.S. 89:54 · Fully guaranteed for one year from date of purchase.

This new addition to the 'Nashton' range of miniaturised electronic test gear is a Valve Voltmeter capable of accurate measurements of D.C. and A.C. voltages over a wide range. Two probes are supplied, one an isolating D.C. probe providing an input impedance of 10 Megohms and the other an A.C. rectifying probe incorporating a coaxial diode of the highest performance yet available.

For further information on this and other instruments in the 'Nashton' range of miniaturised electronic test gear write to:

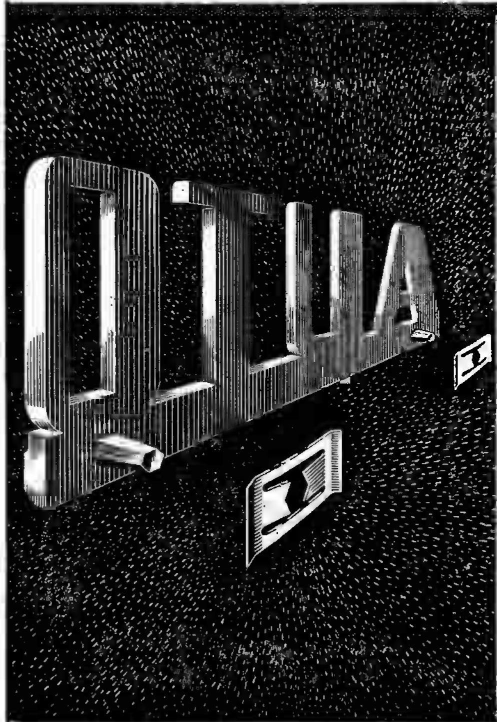
Nash and Thompson

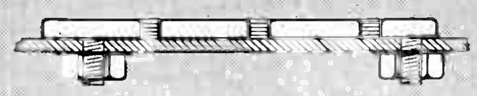
LIMITED

OAKCROFT ROAD, CHESSINGTON, SURREY. ELMBRIDGE 5252

WHG/NT67

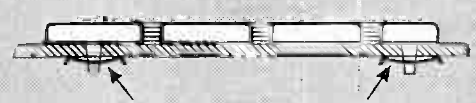
The logical advance in **Retaining**





OLD WAY

Threaded studs were spot welded (or inserted if die-cast) to the name-plate. To hold this in position, washers and nuts were laboriously assembled with great difficulty especially on blind applications.



THE SALTER WAY

Studs are cast in with the nameplate, and the Fixes are simply pushed on, even on blind applications. The whole is firmly retained with an even spring tension.

save material–reduce assembly time – cut costs

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

SMITHFIELD SHOW Dec. 8-12
STAND No. 239

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

NEATER – MORE POSITIVE – PERMANENT RETAINING

SALTER "TRUARC" Regd. Trade Mark

Circlips · *Fasteners* · *Retainers* · *Fixes*

Geo. Salter & Co. Ltd., West Bromwich · Spring Specialists since 1760

H-W.446

Hermetic Sealing

STEATITE & PORCELAIN
NICKEL METALLISING

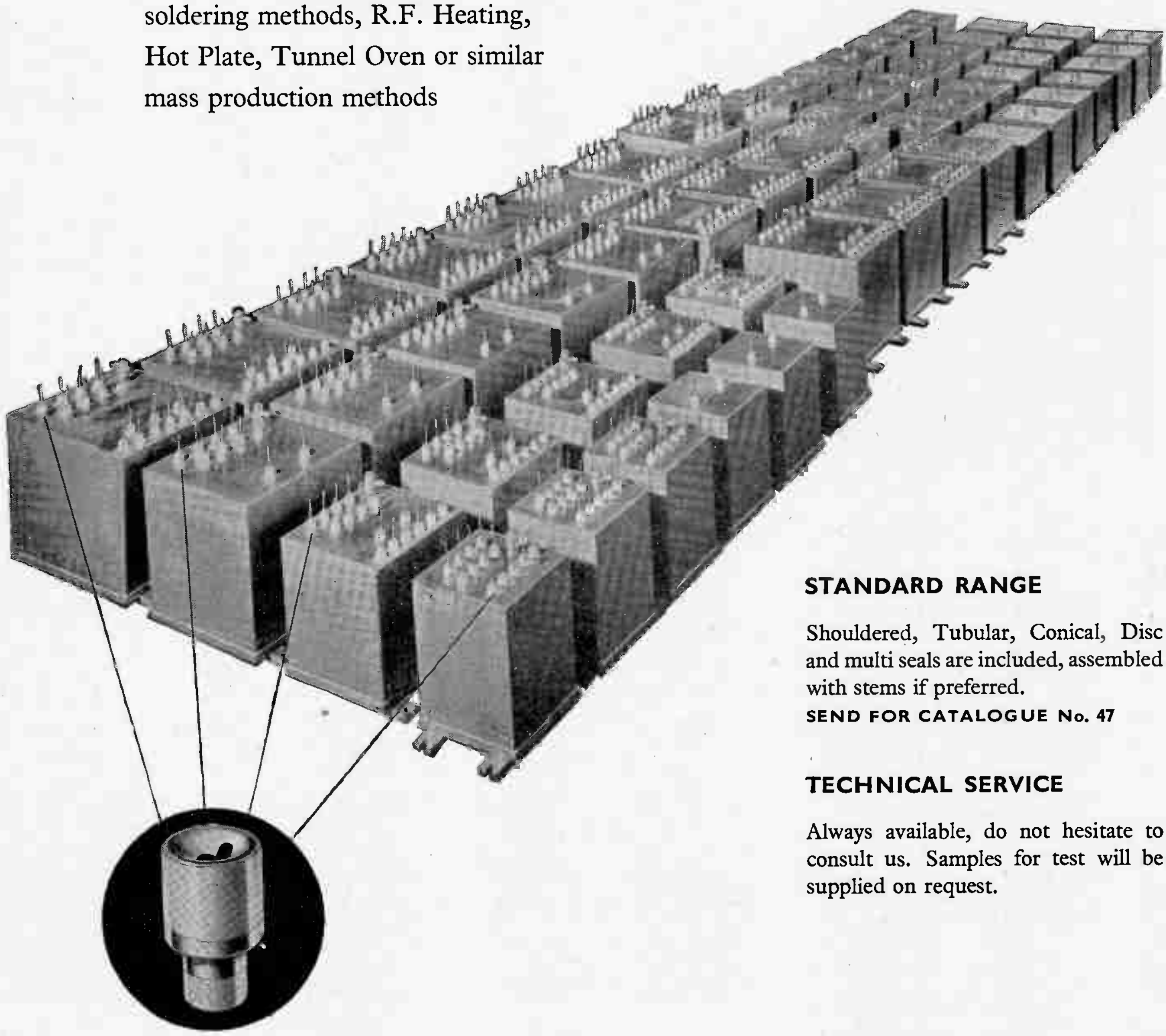
Quality Approved (Joint Service R.C.S.C.)

WILL MEET THE MOST EXACTING REQUIREMENTS

METALLISED BUSHES

Perfect Terminations

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



STANDARD RANGE

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

SEND FOR CATALOGUE No. 47

TECHNICAL SERVICE

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

STEATITE & PORCELAIN PRODUCTS LTD.

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

SP100

Marconi

F.M. SIGNAL GENERATOR TF 1066A

and AMPLITUDE MODULATOR TF 1102

Tuning range 10 to 470 Mc/s . . . carrier stability 0·0025% . . . both stepped and continuously-variable incremental tuning . . . output level adjustable from 0·2 μV to 200 mV . . . two modulation frequencies . . . any deviation up to 100 kc/s. These are just a few of the features which have gained the Marconi TF 1066A its world-wide reputation for precision f.m. measurements. Couple the TF 1066A to its auxiliary Amplitude Modulator TF 1102 and high-fidelity a.m. signals are also available. Together the two instruments form a combination of almost unlimited application. If you would like further details, please write for Leaflets V 137.

AM & FM SIGNAL GENERATORS · AUDIO & VIDEO OSCILLATORS
FREQUENCY METERS · VOLTMETERS · POWER METERS
DISTORTION METERS · FIELD STRENGTH METERS
TRANSMISSION MONITORS · DEVIATION METERS
OSCILLOSCOPES, SPECTRUM & RESPONSE ANALYSERS
Q METERS & BRIDGES

MARCONI INSTRUMENTS LTD · ST. ALBANS · HERTFORDSHIRE · TELEPHONE ST. ALBANS 56161

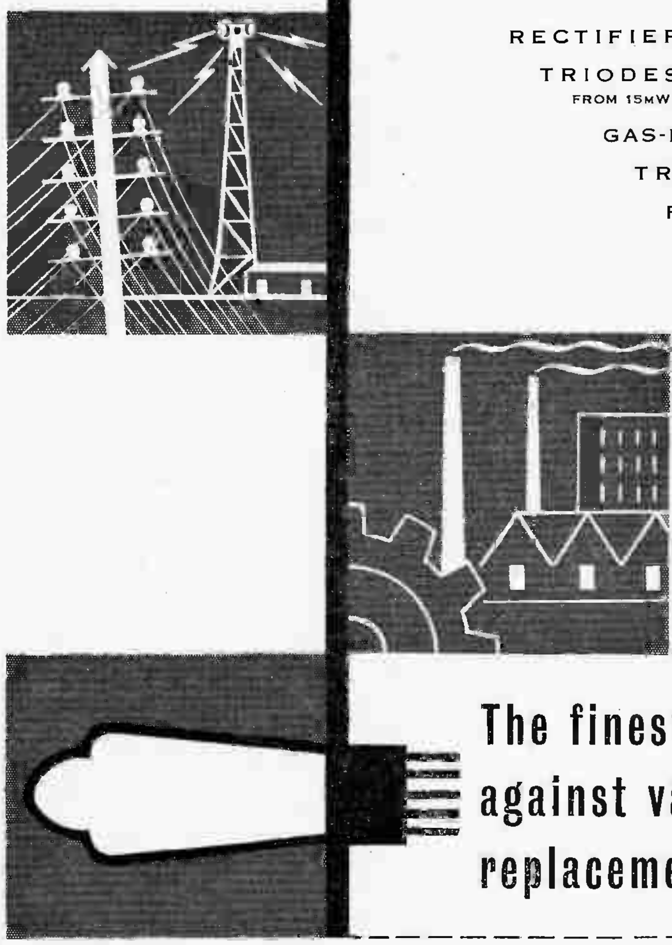
London and the South: Marconi House, Strand, London, W.C.2. Tel: COVent Garden 1234. *Midlands:* Marconi House, 24 The Parade, Leamington Spa. Tel: 1408
North: 23/25 Station Square, Harrogate. Tel: 67455.

TC 137

S.T.C.

VALVES

FOR COMMUNICATION



RECTIFIERS & THYRATRONS,
TRIODES, TETRODES & PENTODES
FROM 15mW TO 150kW ANODE DISSIPATION FOR ALL FREQUENCIES FROM AF TO SHF
GAS-FILLED STABILISERS AND TRIGGER TUBES
TRAVELLING WAVE TUBES
PULSE MODULATORS
VELOCITY MODULATED OSCILLATORS
VACUUM CAPACITORS · TRANSISTORS

AND INDUSTRY

The finest insurance against valve replacement costs

4H/181E FORCED AIR COOLED TETRODE

BROCHURE AND TECHNICAL DATA AVAILABLE FROM

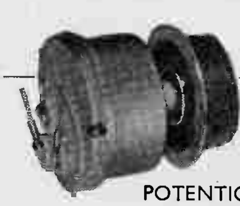
Standard Telephones and Cables Limited

Registered Office: Connaught House, 63 Aldwych, London, W.C.2.

VALVE DIVISION: FOOTSCRAY, SIDCUP, KENT

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

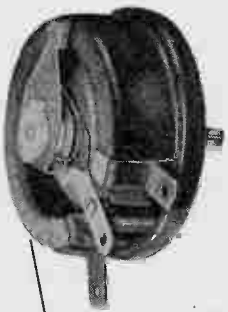
'REGAVOLT'
ROTARY VARIABLE TRANSFORMERS
Exact voltage control
6 standard models
250VA — 2.5 kVA



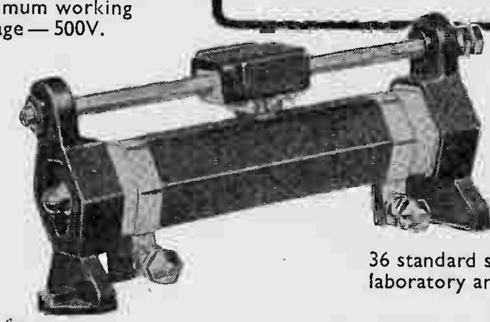
SEALED POTENTIOMETERS
— 1 and 5 watt models
Proofed against Dust, Fumes, Climate etc.
Maximum working voltage — 500V.

BERCO

VOLTAGE & CURRENT CONTROL EQUIPMENT



BERCOSTAT RHEOSTATS
Accurate — tough — compact.
8 sizes from 25-500 watts.



SLIDING RESISTANCES
36 standard sizes for laboratory and industrial use.

★ Please write for our Catalogue which will be despatched by return of post.

Full Technical Details from—

THE BRITISH ELECTRIC RESISTANCE CO LTD

in association with

THE BRITISH POWER TRANSFORMER CO LTD

QUEENSWAY · ENFIELD · MIDDLESEX · Telephone: HOWard 2411

IB

ACTUAL SIZE OF A 4 BA NUT

A DEEP TAPPED HOLE IN THIN SHEET METAL?

The ROSAN Press Nut is the designer's answer to this problem. It is simple to secure and no counterboring or countersinking is required. Once in, it is there for good.

The ROSAN Press Nut is made in **all** threads up to $\frac{3}{8}''$ and to special requirements.

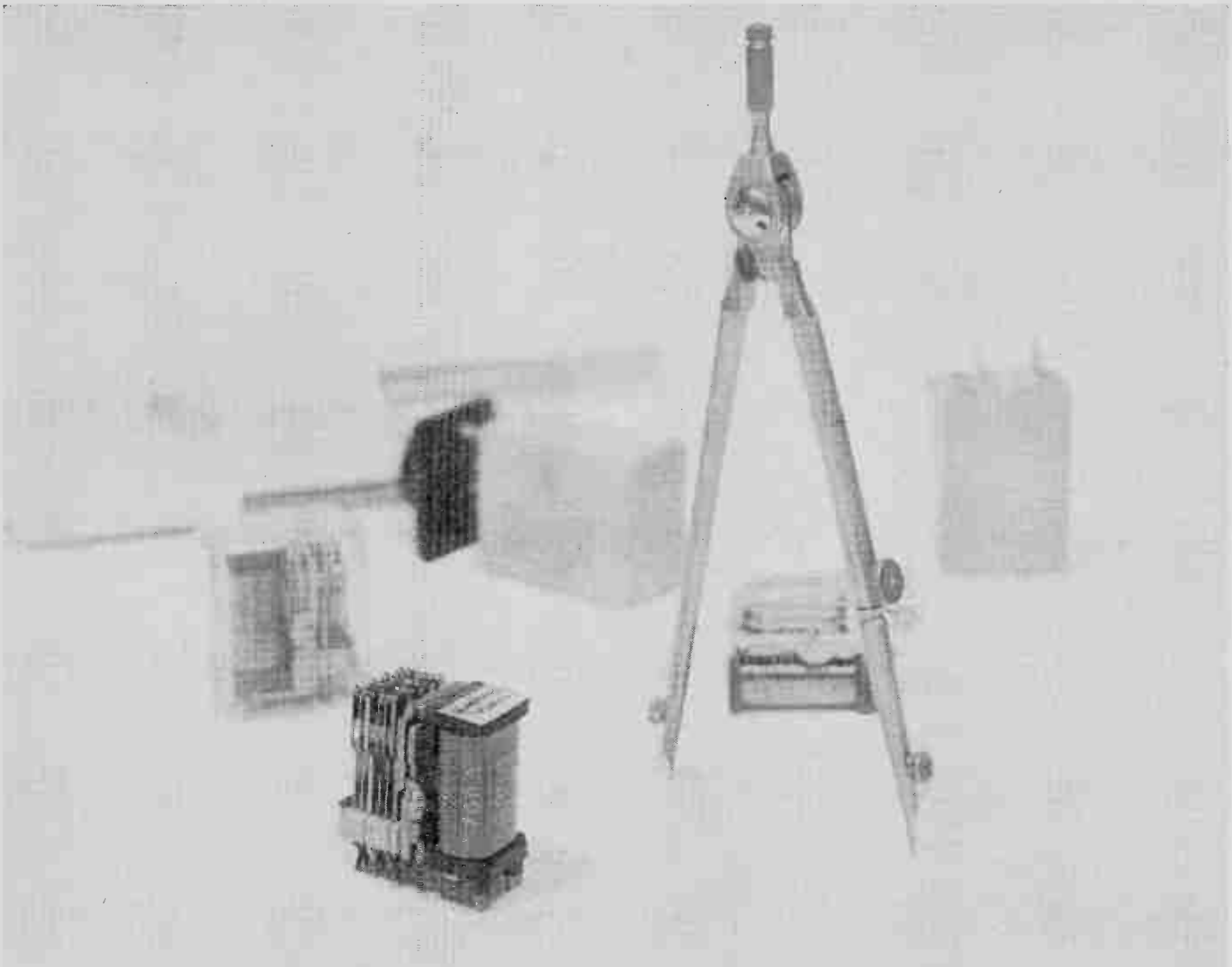
To obtain full details of the ROSAN Press Nut, write or 'phone the **Instrument Screw Co. Ltd.**, Northolt Road, South Harrow, Middlesex, Telephone BYRon 1141, who will send you a descriptive leaflet and a sample.

ACTUAL SIZE OF A 4 BA NUT

Specialists in precision turned parts up to $2\frac{3}{8}''$ dia. to customers' special requirements.

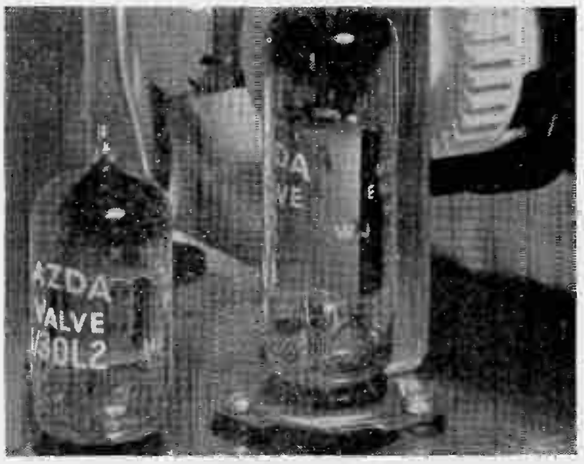
Pat. App. No. 19826/57.

TAS/IS. 4

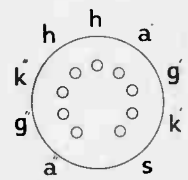


Introducing another outstanding Ediswan Mazda valve, type 6/30L2

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 valve dealt with here is the Type 6/30L2, a general purpose twin triode.



B9A BASE



VIEW OF FREE END

MAXIMUM DIMENSIONS

Overall length (mm) 56
Seated height (mm) 49
Diameter (mm) 22·2

RATINGS

Heater current (amps)	I_h	0·3
Heater voltage (volts)	V_h	6·3
Maximum heater to cathode voltage (volts rms)	$V_{h\text{-}k(max)}$	150*
Maximum anode voltage (volts) ...	$V_{a(max)}$	250†
Maximum anode dissipation (watts) (either section)	$P_{a\,(max)}$	2·0†
Maximum total anode dissipation (watts)	$P_{(tot)\,max}$	2·5†

The potential of the internal sh.eld must not be positive to that of either cathode.

* Measured with respect to the higher potential heater pin.

† At these maximum dissipations the grid-cathode resistance should not exceed 0·25 megohms when using cathode self-bias. With higher grid-cathode resistance, the permissible anode dissipation is reduced.

CHARACTERISTICS

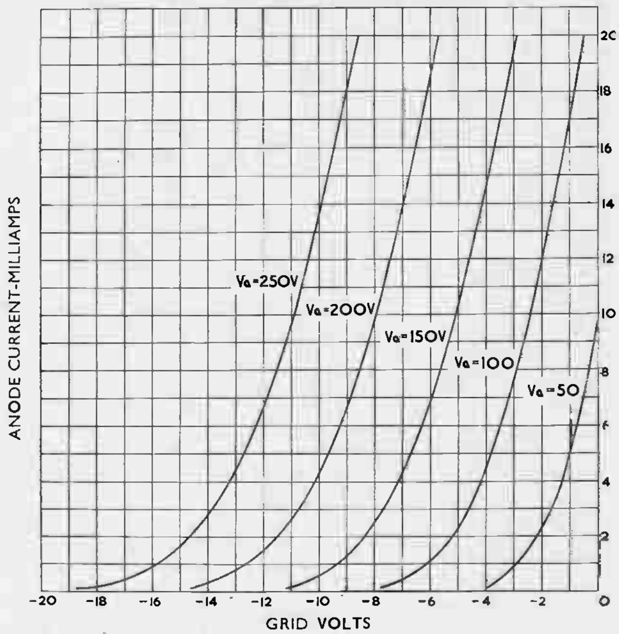
Anode voltage (volts)	V_a	200
Anode current (mA)	I_a	10
Mutual conductance (mA/V)	(gm)	3·4
Amplification factor	μ	16

INTER-ELECTRODE CAPACITANCES (pF)

	(a)	(b)
$c_{g'}$–E	2·5	3·5
$c_{g''}$–E	2·4	3·5
$c_{a'}$–E	2·1	3·2
$c_{a''}$–E	2·0	2·9
$c_{a'}$–g'	2·5	2·8
$c_{a''}$–g''	2·5	2·8
$c_{a'}$–a''	0·038	0·038
$c_{g'}$–a''	0·006	0·0064
$c_{g''}$–a'	0·014	0·015

(a) Excluding holder capacity
(b) In a typical B9A ceramic valveholder.

preliminary characteristic curves
of Ediswan Mazda Valve Type 6/30L2



APPLICATION NOTES

The Ediswan Mazda 6/30L2 provides two triodes of identical characteristics. A shield between the triodes and the arrangement of the base connections result in a very low level of capacitive and electron coupling so that the triodes may be used in diverse applications without their performance being significantly affected by interaction. The heater characteristics enable the valve to be connected either in the series chain of a television receiver operating from a.c./d.c. mains or in a parallel heater arrangement.

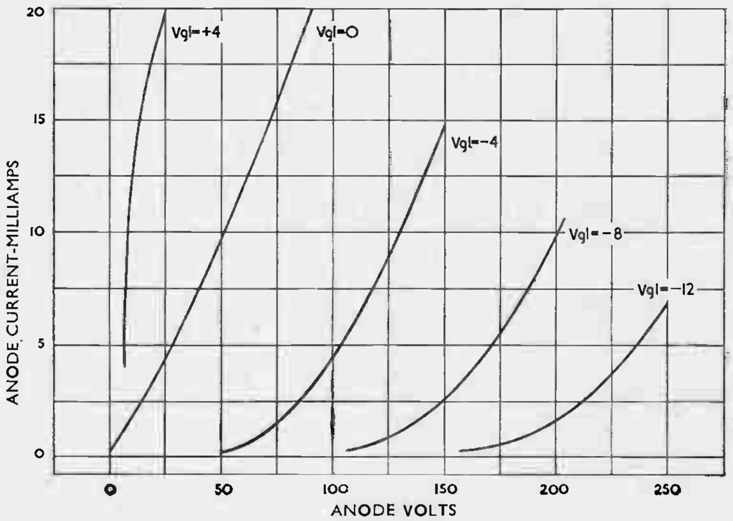
(a) Scanning Drive Generators

The 6/30L2 may be used to generate sawtooth or square pulse voltages for driving the output stages of line or frame scanning circuits. The high peak current available at low anode voltages makes it particularly suitable where a large and rapid voltage change at the anode is required.

(b) Pulse Circuits

Wherever shaping or gating of pulses is required in a television receiver, the 6/30L2 is useful. Applications of this type are in frame synchronising pulse separators, pulse-gated automatic gain control systems, cathode followers, interference pulse cancelling circuits, flywheel line synchronising phase comparators and phase splitters.

The triode sections of the Ediswan Mazda valves type 30FL1 and 30PL1 have identical characteristics to those of the 6/30L2.



SIEMENS EDISON SWAN LIMITED *An A.E.I. Company,*
Technical Service Department, 155 Charing Cross Road, London, W.C.2
Telephone: GERrard 8660 *Telegrams:* Sieswan, Westcent, London.

EDISWAN
MAZDA

CRC 15/25

ELECTRONIC & RADIO ENGINEER

incorporating WIRELESS ENGINEER

HUGH S. POCOCK M.I.E.E. *Managing Editor*
W. T. COCKING M.I.E.E. *Editor*
Professor G. W. O. HOWE D.Sc., LL.D., M.I.E.E., Hon. M. Brit. I.R.E. *Technical Consultant*

CONTENTS

VOLUME 35 NUMBER 12 DECEMBER 1958

Established 1923
Published on the fifth of each month

ANNUAL SUBSCRIPTION
(including Annual Index to Abstracts and References)
Home and Overseas £2 9s 0d Canada and U.S.A. $7.50
Second-class mail privileges authorized at New York, N.Y.

Published by

ILIFFE & SONS LTD. DORSET HOUSE STAMFORD STREET LONDON S.E.1
Telephone · Waterloo 3333 Telegrams · Wirenger, Sedist, London

Branch Offices

COVENTRY · *8-10 Corporation Street—Telephone · Coventry 25210* : BIRMINGHAM · *King Edward House, New Street, 2—Telephone · Midland 7191*
MANCHESTER · *260 Deansgate, 3—Telephone · Blackfriars 4412 and Deansgate 3595* : GLASGOW · *26b Renfield Street, C.2—Telephone · Central 1265*

Permanent Magnets

Design Advisory Service

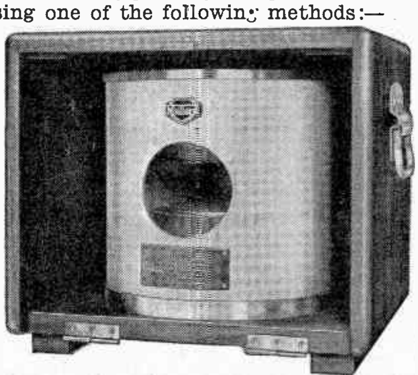
No. 9

Testing Permanent Magnets

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.

The testing of magnets for general applications is normally limited to checking the value of the magnetic flux density (B_d) at the operating value of demagnetising force (H_d). In cases where the magnets are working under high recoil conditions, the H_d value will vary considerably and therefore two checks are advised, one near each end of the range. It is preferable that magnets are tested in a magnetic circuit having a reluctance similar to that at which the magnet is required to operate, but it is sometimes more convenient to test the performance of the magnets by observing the operation of the instrument of which they form a part. Such applications include cycle dynamos, d.c. motors, kilowatt hour meters, etc.

The flux density given by a magnet can be measured by using one of the following methods:—



Typical Magnetic Reference Magnet Type C 1219.

Search Coil and Fluxmeter

This method is particularly suitable for measuring both the useful and leakage flux of magnets and magnet circuits. The fluxmeter is essentially a galvanometer with negligible restoring torque and a scale usually calibrated in maxwells. It is normally used in conjunction with a search coil having a known effective cross-section (area × turns). The coil is placed over the magnet, or in the air gap depending on the requirements, and rapidly withdrawn. The deflection on the fluxmeter is a direct indication of the flux cut by the coil.

With the familiar Grassot type fluxmeter, a calibrated search coil having a resistance of about 7Ω is advised.

An accurately known field for reference purposes such as is maintained by the permanent magnet illustrated, is extremely useful both for calibrating experimental search coils and for checking the accuracy of a fluxmeter.

'Hall Effect' Probe

The 'Hall effect' can be utilised very conveniently for measuring the intensity of magnetic fields. A probe with a comparatively small element can be made and is particularly useful where mechanical dimensions make it impracticable to use a search coil and fluxmeter. 'Hall effect' probes are generally susceptible to temperature effects and care should be taken to compensate for this.

Direct Reading Magnetometer

This instrument is generally used for measuring the fields in comparatively large air gaps. It usually consists of a small magnet manufactured from a material with a high coercive force, which, being placed normal to the field under test is deflected in proportion to the field. The probe should not be placed in a field stronger than the specified maximum, otherwise the calibration of the meter may be impaired.

Calculation of Flux by Measuring its Physical Pull

In certain circumstances it may be more convenient to calculate the value of magnetic flux by measuring its direct physical pull on a suitable armature or steel plate.

From the formula—

$$F = \frac{B^2 A}{8\pi}$$

we derive the direct relation between flux and magnetic force

$$\therefore B = \sqrt{\frac{8\pi F}{A}}$$

Where B = flux density at contact in gauss.
A = area at contact in sq. cm.
F = force in dynes.

It should be noted that this method of measuring must be used with due caution since practically all the flux the magnet produces will go into the armature. When the armature is removed a considerable proportion of the total flux is usually lost as leakage, while the remaining, generally much smaller portion, becomes the useful operative flux of the system.

However, this method of measuring can be adapted to very speedy workshop use.

If you wish to receive reprints of this advertisement and others in this series write to the address below.

Mullard Mullard

'TICONAL' PERMANENT MAGNETS
'MAGNADUR' CERAMIC MAGNETS
FERROXCUBE MAGNETIC CORES

MULLARD LIMITED, COMPONENT DIVISION, MULLARD HOUSE, TORRINGTON PLACE, W.C.1 LANgham 6633
MC270

ELECTRONIC & RADIO ENGINEER

VOLUME 35 NUMBER 12

DECEMBER 1958

incorporating WIRELESS ENGINEER

Photography and Television

GLANCING through some photographic literature recently, we came across a diagram which, in another sphere, we should have interpreted as a step-response curve. It showed overshoots and all the general characteristics of the response of a phase-equalized network to a unit-step input.

To our surprise, we discovered that it was indeed closely analogous to this. It showed the spatial density of a photographic negative. It was an amplitude–distance response curve instead of the amplitude–time curve we meet in television. The effect on a picture is, of course, the same since the scanning process of television corrects the time effect to a spatial one.

It is a commonplace that there are close analogies between quite distinct physical processes. Here we have, hardly an analogy, but a very close resemblance between visible effects on photographic and on television pictures. It suggests that there should be an analogy between the physical processes, too.

It is doubtful, however, if there is any real analogy in this case, for the underlying mechanisms appear to be entirely different. In photography, an abrupt change of density does not occur in the negative, because light is scattered sideways in the sensitive coating. This results in a gradual transition between tone values.

Some compensation can be obtained by a special technique of development by which a sideways diffusion of developer occurs and effectively varies the time of development for different tone values. Carried to excess, this results in 'overshoots' before and after transitions.

The television response is, in the main, a time one, which becomes spatial in scanning. Something similar to the photographic case occurs also, of course, due to the finite size of the scanning spot and there are certain halation troubles, all of which cause direct spatial effects.

Since such similar effects occur in both photography and television, we are wondering if some revision of the usual methods of specifying television picture definition is not called for. The number of lines has meaning only vertically. Bandwidth or rise-time has meaning only horizontally unless the number of lines is specified as well.

A picture element basis, using a chess board pattern, suggests itself as one way of specifying definition. In television, a double number giving the numbers of horizontal and vertical elements which are resolvable would be needed; in photography, one number would suffice. There are difficulties, we know, but could not the television and the photographic people get together and devise a common method?

Ultrasonic Mercury Delay Lines

CHARACTERISTICS OF LINES AND TRANSDUCERS

By C. F. Brockelsby, A.R.C.S., B.Sc.*

The need to delay a signal or to store information arises in radar systems, computers and in fields of instrumentation and measurement. When the signal is a complex electrical waveform, requiring a large bandwidth, inductance-capacitance networks with lumped or distributed constants are convenient for delays up to perhaps 1 μsec, but become bulky and costly for longer delays. In this range, up to a few milliseconds delay, with bandwidths of the order of 10 Mc/s, a satisfactory solution is obtained by using the ultrasonic delay line, Fig. 1, in which the electrical signal is converted by an electro-mechanical transducer (such as a quartz crystal) into an acoustic wave ; this wave is transmitted through a solid or liquid medium to a second transducer, which regenerates the electrical signal, Fig. 2. The velocity of propagation of sound in liquids is about 1·5 mm per μsec ; this gives a scale factor of 2×10^5 compared with electromagnetic waves in space, and results in units of convenient size. A liquid medium has one very great attraction: the acoustic path length, and hence the delay, can easily be varied. The delay can thus be preset to a desired value, and it has even been found possible to change the delay rapidly during operation without generating spurious signals or losing the desired signal. A continuous variation over a delay range of ten-to-one can be obtained without undue mechanical complexity.

Applications

One of the earliest applications of fixed mercury delay lines was in computer stores, and lines are still used for this purpose. The storage of information in binary-digit form does not make full use of the capabilities of the lines, because their wide dynamic range of linear operation is irrelevant in this application. The storage capacity is proportional to the product of bandwidth and delay ; about 5,000 bits is a convenient upper value. For delays which are not too long, the great bandwidth permits the use of a very high digit rate (e.g., with a 100-μsec delay, a digit rate of 10 Mc/s is easily achieved, giving a store of 1,000 bits, and such lines have specialized applications in the computer field).

Both fixed and variable lines have important applications in the fields of radar and instrumentation. One established application is in 'moving target indicator' pulse radar systems. If the echo signal from a fixed object is passed through a line which delays it by exactly the pulse repetition interval, and the delayed signal is subtracted from the undelayed signal, substantially complete cancellation of the pulses can be achieved, especially if the pulses are re-shaped. When an echo from a moving object is received, the time separation of the reflected pulses is altered and cancellation does not occur. In this way the echo from a moving object can be made to stand out from a mass of echoes from fixed objects which would otherwise mask it.

An application which has been used successfully in some special pulse-radar systems is the improvement of the signal-to-noise ratio and, hence, the range. The time separation of the pulses is again made equal to the delay in the line, but this time the delayed and undelayed signals are added (not subtracted) in a closed loop so that successive pulses are superimposed. The loop gain must be less than 0 (zero) dB ; i.e., the amplitude of the delayed pulse must be less than that of the undelayed pulse, otherwise the system will oscillate. If it is less by $(100/r)\%$, the received pulses, being coherent, add in amplitude giving a signal improvement of r times. The noise, however, being incoherent, adds only in power, so both the noise amplitude and the signal-to-noise ratio increase $\sqrt{r}$ times.

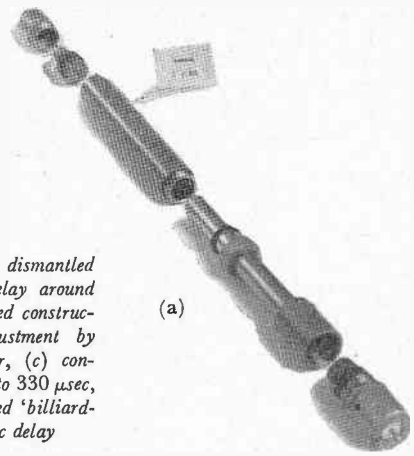
This re-circulation system, with delay T, is equivalent to a comb filter having a very large number of very narrow pass-bands at frequencies n/T, $n = 1, 2, 3 \ldots$ This, however, would require a prohibitive number of LC elements.

An improvement of 12 dB was obtained in one experimental installation, with a corresponding increase of range. In this example, the delay line was fitted with a micrometer adjustment driven by a servo motor actuated by the output pulse so as to keep the delay accurately matched to the p.r.f.

This re-circulation method of signal-to-noise improvement is equally applicable to any measurement or communications system using a train of pulses whose time separation can be matched by a delay line.

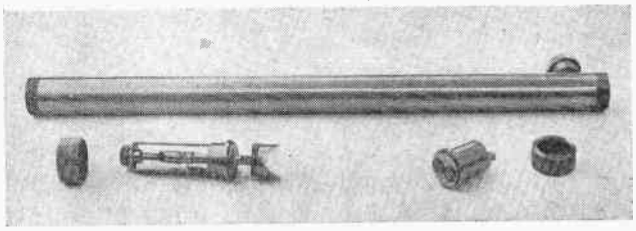
The bandwidth obtainable at delays of a few hundred microseconds is great enough for the most complex signal at present in use ; i.e., a colour television signal. The variable-delay line of Fig. 1 (c) has been used for laboratory investigation of the effect of multipath propagation on colour television signals ; two channels are provided, one with a short fixed mercury delay line and one with the continuously-variable line. The combined output simulates exactly the signal produced from an aerial receiving signals by two different path lengths ; e.g., directly, and by reflection from an aircraft. The

* *Mullard Research Laboratories*

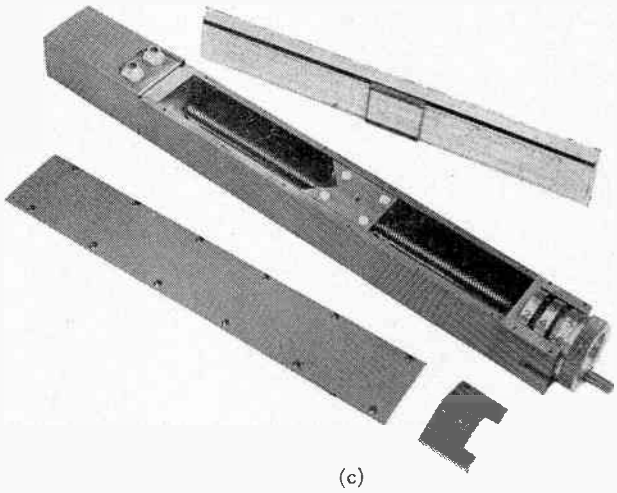


(a)

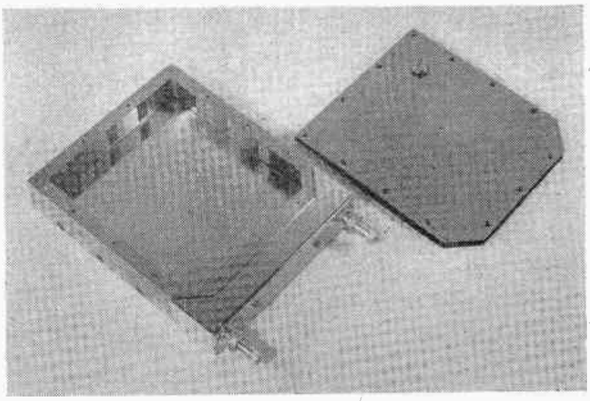
Fig. 1. *Delay lines; (a) dismantled telescopic line for preset delay around 100 μsec, (b) simple folded construction with micrometer adjustment by means of a corner reflector, (c) continuously-variable line, 30 to 330 μsec, (d) line with multiply-folded 'billiard-table' path, 1,250-μsec delay*



(b)



(c)



(d)

variable line has also been used to simulate radar echoes of variable delay and makes a valuable general-purpose addition to the equipment of a laboratory working in television, radar and allied fields.

Construction

The simplest arrangement consists of two crystals mounted at opposite ends of a cylindrical container filled with mercury. The dismantled parts of such a delay line are shown in Fig. 1 (a). The centre section is telescopic to permit the delay to be preset over a range of about 1·5 to 1.

For delays above about 100 μsec the line becomes inconveniently long if a single straight transmission path is used. Sound in mercury is totally reflected from steel at angles of incidence greater than about 20°, so it is easy to 'fold' the transmission path. A simple 'there-and-back' path, with two crystals side-by-side and a corner reflector, is used in the adjustable line of Fig. 1 (b) and the continuously-variable line of Fig. 1 (c), which covers the range 30 to 330 μsec. The pitch of the lead screw is chosen so that one turn gives 10 μsec change of delay; the drive can be calibrated directly in delay time, and set to within about 0·01 μsec. The spindle can also be rotated by a servomotor for remote control.

For still longer delays a multiply-folded path can be used. Fig. 1 (d) shows the construction of a 1,250-μsec line consisting of a rectangular steel box with the two crystals mounted at the 45° corners of the box.

To prevent the escape of mercury, as either liquid or vapour, the lines are hermetically sealed. If operation in any position or under vibration is required, they must be completely full of mercury; an expansion capsule is then included to allow for temperature changes.

Characteristics

The properties of an ultrasonic delay system are determined by (a) the transducers, (b) the propagation in the acoustic medium and (c) the electrical input and output circuits. The transducer performance depends upon the medium to which it is coupled; their joint behaviour is the crux of the design problem, which is here discussed.

The attenuation of most liquids is too high; apart from liquified monatomic gases (the use of which would present some technological difficulties) only mercury, water and the lower alcohols have a low enough attenuation. Of the non-metals, water is the best, so the choice is between water and mercury. Their great difference in density causes a corresponding difference in the load imposed on the vibrating face of the transducer and, as a wide bandwidth requires heavy loading, mercury is preferable. Also, the attenuation of mercury is only about one-third that of water.

A large working bandwidth is required. The fractional bandwidth attainable is limited, so the band centre frequency must be high.

The attainable fractional bandwidth is determined by the acoustic properties of the transducer material and of the delay medium, which must be approximately matched to obtain both a large bandwidth and a good phase characteristic. Quartz is the only material which approximately matches mercury acoustically and can easily operate at frequencies of the order of 10 Mc/s; it is fortunate that these two well-known and readily available materials should form a nearly ideal combination.

A possible alternative to quartz might be one of the polycrystalline piezoelectric ceramics, but their acoustic impedance and permittivity are both inconveniently high and it is difficult to make transducers of them at high enough frequencies. These disadvantages outweigh the advantage offered by their higher electroacoustic coupling factor.

Signals reflected from the receiving transducer and again from the transmitter, which arrive at the receiving transducer after traversing the acoustic path three times, must usually be kept small. Attenuation in the path will have this effect, but is undesirable since it increases

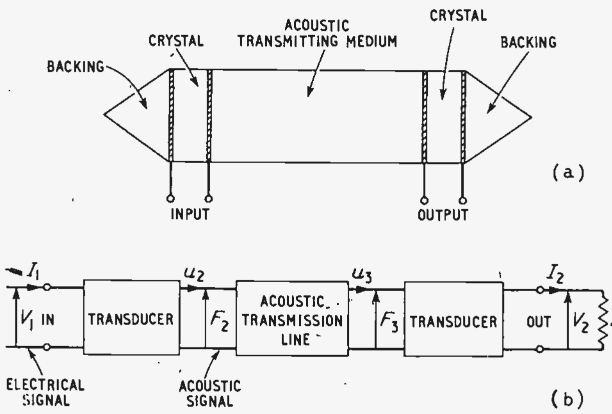


Fig. 2. *General form of delay line (a) and its block diagram (b)*

the insertion loss of the line. A preferable method is to terminate the acoustic path with absorbing material giving a low reflection coefficient. One suitable material is lead which is often used for backing both the transmitting and receiving crystals. An alternative is mercury enclosed in a capsule whose geometry makes it a 'black body' so that the ultrasound entering it is not reflected out again in spite of the low absorption in the mercury. The fractional bandwidth is greater with mercury (0·86) than with lead (0·6), but the engineering of a robust mercury-backed system is difficult.

Coupling circuits are required, at both the sending and receiving ends of the delay line, to provide an efficient broad-band transfer between the electrical input (and output) system and the quartz crystal, the impedance of which is essentially that of its capacitance.

Transducer Theory

The most convenient way of expressing the performance of an electro-acoustic transducer is to construct a four-terminal equivalent circuit, which at one pair of terminals represents directly the electrical side of the transducer, and at the other pair represents the acoustic side by means of the analogy in which sound pressure corresponds to voltage and acoustic particle velocity to current.

An equivalent circuit for an X-cut crystal transducer, vibrating only in the thickness mode, is given in Fig. 3 (a); the transmission line represents the mechanical aspects of the crystal, and the electromechanical transformer the piezoelectric coupling from the electrical terminals.

Using the T equivalent of the transmission line and inserting impedances Z_1 and Z_2 to represent the backing material and the delay medium gives the required four-terminal network, Fig. 3 (b).

In practical systems the diameter of the crystal is much greater than the acoustic wavelength. The mechanical impedance loading a crystal face is then essentially resistive and is given by

$$Z = A\sqrt{e\rho} = A\rho c$$

where A = area of crystal,
e = elastic modulus of medium relevant to the wave propagated in it,
ρ = density of medium,
and $c = \sqrt{e/\rho}$ = velocity of wave in medium.

The product ρc is called the specific acoustic impedance of the medium.

The series-connected negative capacitance has a negligible reactance under all practical conditions.

The network of Fig. 3 (b), omitting the negative capacitance, and using the relation

$$\tan \theta/2 = \frac{1 - \cos\theta}{\sin\theta}$$

gives

$$\frac{F_2}{DCV_1} = \frac{z_2(\cos\theta - 1 + jz_1 \sin\theta)}{(z_1+z_2)\cos\theta + j(1+z_1z_2)\sin\theta} = G(\theta) \quad (1)$$

where $\theta = \pi f/f_0$
f_0 = half-wave resonance frequency of crystal
$z_1 = Z_1/Z_0$
$z_2 = Z_2/Z_0$
D = piezoelectric coefficient of the material of the crystal
C = capacitance of the clamped crystal
DC = 'turns ratio' of the electromechanical transformer, which transforms electrical potential difference on one winding into its mechanical analogue, force, on the other winding.

When a constant voltage V_1 is applied to the crystal, the force F_2 transmitted to the delay medium goes through a series of zeros and maxima as θ increases.

$$F_2 = 0 \text{ at } \theta = 2n\pi$$

$$\frac{F_{2,0}}{DCV_1} = G(\pi) = \frac{2z_2}{z_1 + z_2} \text{ at } \theta = (2n+1)\pi \quad .. \quad (2)$$

$$n = 0, 1, 2, 3, \ldots$$

The response is arithmetically symmetrical about $\theta = \pi$ and repeats itself every 2π radians. This shows that there is no advantage in working the crystal at a harmonic frequency; the absolute bandwidth and peak response are the same at all the harmonics as at the fundamental.

The response relative to that at resonance is

$$\frac{F_2}{F_{2,0}} = \frac{G(\theta)}{G(\pi)} \quad .. \quad .. \quad .. \quad .. \quad .. \quad (3)$$

The squared magnitude of the relative response is

$$\left|\frac{F_2}{F_{2,0}}\right|^2 = \left|\frac{G(\theta)}{G(\pi)}\right|^2$$

$$= (0{\cdot}25)\left[\frac{(\cos\theta - 1)^2 + z_1^2\sin^2\theta}{\cos^2\theta + z^2\sin^2\theta}\right] \quad .. \quad (4)$$

where $z = \dfrac{1 + z_1 z_2}{z_1 + z_2}$

The above analysis is based on constant-voltage drive. This is a sufficient approximation to the practical case because the impedance reflected through the electro-mechanical transformer from the mechanical side is, in practice, always very much greater than the impedance of the electrical branch.

The response at $\theta = \pi$ is greatest when the crystal is unbacked ($z_1 = 0$) and then has the value

$$\hat{F}_{2,0} = 2DCV_1 \quad .. \quad .. \quad .. \quad .. \quad .. \quad (5)$$

With a backing material, the response is reduced:

$$\frac{F_{2,0}}{\hat{F}_{2,0}} = \frac{Z_2}{Z_1 + Z_2} \quad .. \quad .. \quad .. \quad .. \quad .. \quad (6)$$

The reflection of an incident acoustic wave by the backed crystal depends upon the frequency but, at mid-band ($\theta = \pi$), the crystal is a half-wavelength thick and so presents to the medium an impedance equal to that of the backing material.

The mid-band amplitude reflection coefficient A_R is therefore

$A_R = (Z_1 - Z_2)/(Z_1 + Z_2)$

The equivalent circuit of Fig. 3(b) applies also to the receiving crystal. Since the network is reciprocal, an expression for the output current I_2, Fig. 2(b), can be obtained from Equ. (4).

The current is substantially unaffected by the electrical termination because its impedance, in practice, is always much lower than the internal output impedance of the crystal.

Reciprocity gives:

$$I_2/F_3 = u_2/V_1 = F_2/(Z_2V_1) \quad .. \quad .. \quad .. \quad (7)$$

Hence, with Equ. (4),

$$I_2/F_3 = DC \,.\, G(\theta)/Z_2 \quad .. \quad .. \quad .. \quad .. \quad (8)$$

The frequency response of the receiving crystal is thus identical with that of the transmitting crystal.

Coupling Circuits

The output current I_2 of the crystal flows, in the simplest case, into a parallel-tuned circuit, resonated at the band centre and comprising the total output capacitance C_2 in parallel with an inductance L_2 and a shunt resistance R_2.

The output voltage V_2 is therefore given by

$$\frac{V_2}{I_2} = \frac{R_2}{1 + jQ\,(f/f_0 - f_0/f)} = Z_T \quad .. \quad .. \quad (9)$$

where $Q = R_2\omega_0 C_2$

The squared magnitude of the response is

$$\left|\frac{V_2}{I_2}\right|^2 = \frac{R_2^2}{1 + Q^2\,(f/f_0 - f_0/f)^2} \quad .. \quad .. \quad (10)$$

The gain-bandwidth product can often be improved by inserting a four-terminal impedance transforming coupling network between the crystal and the electrical input or output.

Overall Frequency Response with 'Ideal' Medium

The only system of interest is that in which the acoustic terminations are good enough to suppress reflections almost completely. If the attenuation in the delay medium is small, the transmission through it then contributes nothing to the overall amplitude response.

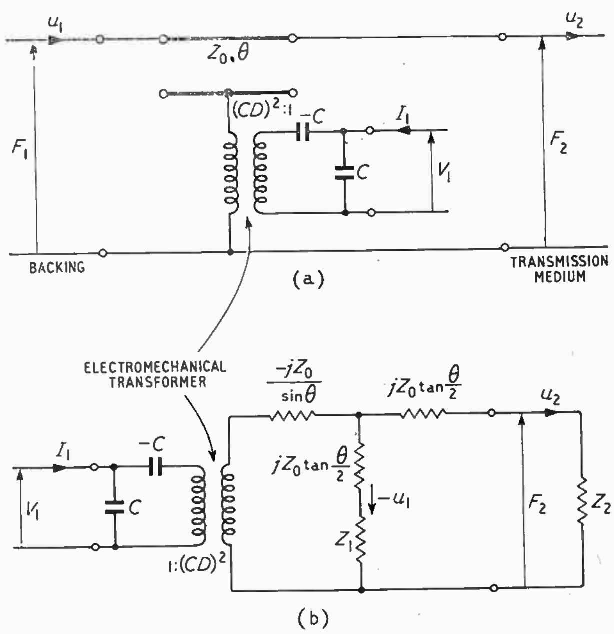


Fig. 3. *Equivalent circuits of transducer; (a) basic form, (b) T-form convenient for computation*

This 'ideal' state is closely approached in a short mercury line, and represents a limiting performance which cannot be surpassed.

The frequency response for the delay line, neglecting the transmission path, is given by the product of the three frequency responses described above, Equs (1), (8) and (10).

Insertion Loss at Mid Band

The insertion loss, for the present purpose, is most conveniently defined as 20 $\log_{10}(V_1/V_2)$, see Fig. 2(b).

$$\frac{V_2}{V_1} = \frac{V_2}{I_2}\cdot\frac{I_2}{F_3}\cdot\frac{F_3}{F_2}\cdot\frac{F_2}{V_1} \quad .. \quad .. \quad .. \quad (11)$$

Collecting the results from previous paragraphs

$$\frac{V_2}{I_2} = Z_T$$

$$\frac{I_2}{F_3} = \frac{DC \,.\, G(\theta)}{Z_2}$$

$\dfrac{F_3}{F_2} = 1$, No transmission loss in the mercury.

$$\frac{F_2}{V_1} = DC \,.\, G(\theta)$$

Hence $$\frac{V_2}{V_1} = \frac{Z_T}{Z_2}\left\{DC \,.\, G(\theta)\right\}^2 \quad .. \quad .. \quad .. \quad (12)$$

The mid-band response is

$$\left|\frac{V_2}{V_1}\right|_0 = \frac{R_2}{Z_2}(DC)^2\left\{\frac{2Z_2}{Z_1 + Z_2}\right\}^2 \qquad \ldots \quad \ldots (13)$$

This expression can be written in a more instructive form as follows:

If the output circuit has stray capacitance C_0, the total circuit capacitance $C_2 = C + C_0$. The value of R_2 is then fixed since a certain Q value is necessary to give the required bandwidth.

$$R_2 = Q/\omega_0 C_2$$

$$= \frac{Q}{\omega_0 C} \cdot \frac{C}{C + C_0} \qquad \ldots \quad \ldots \quad \ldots \quad \ldots (14)$$

The crystal capacitance depends upon its permittivity and dimensions; the thickness (h) is determined by the fundamental resonance frequency, at which the crystal is one half-wave thick, and the velocity c of compression waves in the crystal.

Hence

$$h = \frac{c}{2f_0} = \frac{1}{2f_0}\sqrt{\frac{e}{\rho}} = \frac{1}{2f_0} \cdot \frac{e}{\sqrt{e\rho}} = \frac{Ae}{2f_0 Z_0}$$

The capacitance is therefore

$$C = \frac{KZ_0 f_0}{2\pi e} \text{ e.s.u.} \qquad \ldots \quad \ldots \quad \ldots \quad \ldots (15)$$

Using Equs (14) and (15), Equ. (13) becomes

$$\left|\frac{V_2}{V_1}\right|_0 = k^2 \cdot \frac{Z_0}{Z_2}\left\{\frac{2Z_2}{Z_1 + Z_2}\right\}^2 \frac{Q}{\pi} \cdot \frac{C}{C + C_0} \qquad \ldots (16)$$

where $k^2 = \dfrac{D^2 K}{4\pi e}$

The four factors of Equ. (16) represent respectively the contributions of the quartz, the quartz to medium transfer, the backing and the electrical termination. The insertion loss is seen to be basically independent of the mid-band frequency and, since only ratios of the mechanical impedances are involved, of the area of the crystals.

Transfer Admittance

If the propagation in the delay medium is governed by a propagation constant γ and the path length is s,

$$F_3/F_2 = \exp(-\gamma s)$$

and Equs (1) and (8) give directly

$$I_2/V_1 = (D^2C^2/Z_2)\exp(-\gamma s) \,.\, G^2(\theta) \qquad \ldots (17)$$

The electrical impedance Z_2/D^2C^2 is the acoustic impedance loading one of the transducers, seen through the electromechanical transformer of turns ratio CD. For example for a 1-sq. cm, 15-Mc/s crystal, at the crystal resonance the equivalent circuit of the line (apart from the delay) reduces to a π consisting of two capacitors of 21 pF each and the transfer resistance of 236 kΩ.

Frequency Response

The frequency response, Equ. (4), depends upon the acoustic impedances of both the backing and transmission media. Some illustrative curves are given in Fig. 4. The response is double-humped when

$$4z^2 - z_2^2 < 2.$$

Table 1 summarizes the performance in some special cases. The 1·5-dB bandwidth is chosen so that

Fig. 4. *Frequency response curves*; (*a*) *unbacked crystal with transmission media of different acoustic impedances*, (*b*) *backed crystal for water, and for mercury, including experimental verification and phase response*

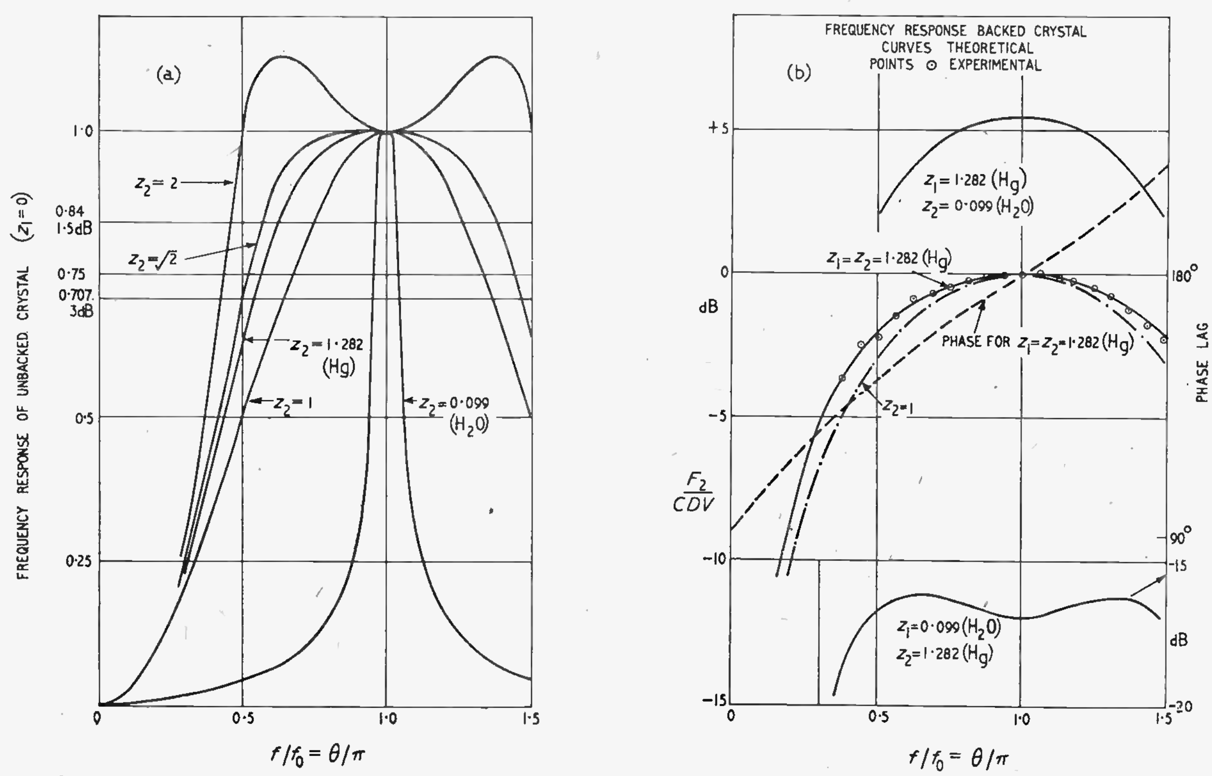


TABLE I
Theoretical Performance of Transducers

Delay Medium	Backing Medium	1·5 dB Fractional Bandwidth	Backing Loss dB	Reflection Coefficient dB
Water	Air	0·05	0	0
	Water	0·08	6	−∞
	Glycerine	0·13	8·6	−12
	Mercury	1·20	23·2	−0·2
Mercury	Air	0·76	0	0
	Water	0·72	0·6	−0·2
	Lead	0·66	4·2	−13·0
	Indium	0·70	4·7	−15·7
	Mercury	0·88	6·0	−∞

the figure gives the 3-dB bandwidth of a line with two transducers.

The values of the parameters of X-cut quartz are

$\rho = 2{\cdot}65$ g. cm^{-3}
$e = 8{\cdot}7 \times 10^{11}$ dyne. cm^{-2}
$c = 5{\cdot}73$ km. sec^{-1}
$Z_0 = 1{\cdot}52 \times 10^6$ g. cm^{-2} sec^{-1}
$D = 1{\cdot}43 \times 10^5$ dyne/e.s.u.
$K = 4{\cdot}58$
$k = 0{\cdot}093$

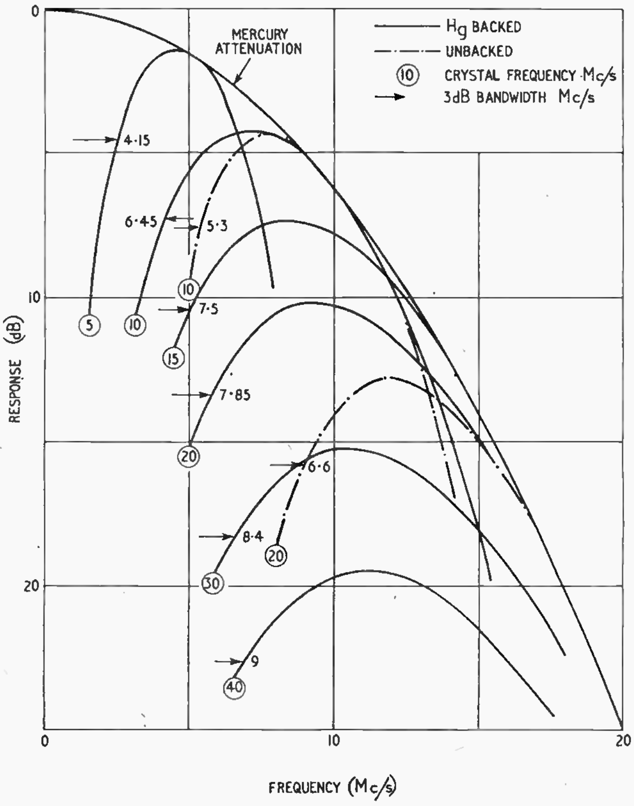


Fig. 5. *Effect of mercury attenuation on frequency response of* 1,000-*μsec line*

Propagation in the Mercury

The sound pressure produced in the mercury by the transmitting crystal varies with distance because of the absorption in the liquid and diffraction effects. These effects also control the directivity (the polar diagram) and depend upon the crystal dimensions and the frequency.

Directivity Effects

Considering the crystal as a circular piston of radius r vibrating in a large baffle, the diffraction effects can be predicted. Near the crystal, the Fresnel zone pattern gives rise to a very complex distribution of sound pressure, but the beam spread is very small. This region extends to a distance of about r^2/λ (where λ is the wavelength in the medium) corresponding to a delay of r^2f/c^2 sec; e.g., 120 μsec for $r = 0{\cdot}5$ cm, $f = 10$ Mc/s. Although the sound field is complex, having many points of zero pressure and many maxima, the integrating effect of the receiving crystal gives an output signal whose amplitude fluctuates with distance by only a few per cent about the nearly constant value estimated from the absorption alone.

Beyond a distance r^2/λ there is a transition zone to a distance $\pi r^2/\lambda$, at which far-field conditions are fully established. Beyond this, in the Fraunhofer region, the sound pressure falls inversely as the distance due to the spreading of the beam (giving the normal inverse-square variation of intensity) and also falls due to absorption.

The directivity function (i.e., the ratio $P(\psi)$ of the sound pressure at an angle ψ to the axis to the pressure on the axis), is

$$P(\psi) = (2/X).\ J_1(X) \qquad (18)$$

where J_1 is the first-order Bessel function and

$$X = (2\pi r/\lambda) \sin \psi$$

The directivity function of the receiver is identical, so that if the line adjoining the centres of the two crystals makes angles ψ_1, and ψ_2 with their normals, the overall directivity function is $P(\psi_1) \,.\, P(\psi_2)$.

The polar diagram represented by $P(\psi)$ is, of course, the same as that for an aerial, such as a microwave parabola, with uniform phase and amplitude across its aperture. It has zeros at the roots of $J_1(X) = 0$, the first being at $X = 3{\cdot}83$. It also has side-lobes at the maxima of $J_1(X)/X$, the first side-lobe amplitude being about 18 dB below that of the main lobe. The aperture in practical ultrasonic systems is large (e.g., the acoustic wavelength in water or mercury at 15 Mc/s is about 0·01 cm so a crystal of 1 cm diameter is 100 wavelengths across). The directivity is therefore high, the first zero in this example being at $\psi = 40$ minutes and the first side lobe at 55 minutes.

This gives a means of discriminating against multiple-reflected signals. If the crystal planes are inclined at an angle ψ, then this is the angle of incidence of the main beam while the 'third-time-round' signal is incident at 3 ψ. If $X = 3{\cdot}83$ at 3 ψ, the 'third-time-round' signal is suppressed.

For the main beam, $X = 3{\cdot}83/3 = 1{\cdot}24$. Since $J_1(1{\cdot}24) = 0{\cdot}506$, the directivity function for the main beam becomes 0·82 and this additional attenuation of 1·8 dB is the price paid for the complete suppression of the 'third-time-round' signal.

The critical angle of tilt is given by

$$(2\pi r/\lambda) \sin 3\,\psi = 3{\cdot}83$$

or, since ψ is very small,

$$\psi = 0{\cdot}2\ \lambda/r$$
$$= 2 \times 10^8/f \text{ minutes of arc for } r = 0{\cdot}5 \text{ cm.}$$

In the Fresnel and transition regions, the above analysis is not exactly applicable, but the behaviour is qualitatively similar. With a short delay, the measured attenuation of the main signal, when one crystal is tilted to suppress the 'third-time-round' signal completely, is about 4 dB. A 'compromise' setting of 3 dB is often useful.

The polar diagram is a function of the wavelength and alters with frequency. Thus, when the crystals are tilted the frequency response is tilted, the insertion loss increasing slightly more at the high-frequency end of the band. The 'third-time-round' signal also varies over the band, but can be kept 15 dB below the main signal due to the crystal tilt alone; i.e., with reflection coefficients of unity at both crystals and no absorption in the medium. With acoustic terminations and some absorption, 'third-time-round' signals can easily be kept to — 40 dB.

Acoustic Absorption

The classical theory of the absorption of sound in liquids takes account of viscosity and thermal conductivity. The observed absorption in most liquids is higher than this theoretical value because the theory neglects the effects of molecular vibration and rotation, but mercury is monatomic and the classical theory applies. It predicts an attenuation constant α proportional to the square of the frequency; the theoretical value of α/f^2 is 5×10^{-17} cm^{-1} sec^2, corresponding to $6{\cdot}3 \times 10^{-17} f^2$ dB/μsec; e.g., about 15 dB in 1,000 μsec at 15 Mc/s.

The theoretical value of the absorption coefficient has been confirmed by measurements at frequencies up to about 50 Mc/s.

The absolute value of the attenuation is not very great, but its quadratic increase with frequency is the most important factor limiting the performance of long mercury delay lines. Consider the mercury-backed crystal, giving a fractional bandwidth of 0·86. The ratio of the upper and lower 3-dB frequencies is then $(1 + 0{\cdot}43)/(1 - 0{\cdot}43) = 2{\cdot}52$. The attenuation in the mercury path is, therefore, 6·3 times as great at the upper as at the lower 3-dB frequency, so that unless the delay is so short or the frequency so low that the mercury attenuation is negligible, it has a marked effect on the frequency response. As the transducer resonant frequency is raised the absolute bandwidth at first increases proportionately but, when the mercury attenuation becomes significant, it begins to limit the bandwidth and depress the frequency of maximum response to a value below the crystal frequency. The effect in a 1,000-μsec delay line is illustrated in Fig. 5.

Temperature Coefficient

The temperature coefficient of delay of a mercury-in-steel line is — 0·03% per °C. This is small enough to be neglected in many applications. The thermal capacity of a line is quite high, which makes it easy to apply adequate thermostatic control, if necessary, by simple means. It has been proposed to join a capillary to the mercury and use the line as the bulb of an extremely sensitive mercury-in-steel thermometer directly operating a thermostat switch, which could have a differential of a few millidegrees.

Acknowledgement

The author wishes to thank the Director of the Mullard Research Laboratories for permission to publish this article.

PRINTED CIRCUITS BY METAL SPUTTERING

Cathodic sputtering of metals in low-pressure glow-discharge tubes was first noted over a century ago. Recent research in this field, carried out at the Bell Telephone Laboratories, indicates that the sputtering process may be useful in producing precision printed circuits for modern communication equipment. It now appears that entire circuits, including resistors, capacitors and leads may be laid down by this technique.

A number of thin films of electrically interesting high-melting point metals have been produced. For example, tantalum and titanium, melting at 3,000° C and 1,670° C respectively, can be laid down in films which show sufficiently high resistivity to be useful as resistors in printed circuits. With the proper masking of the substrate, lines and patterns of practically any desired shape and size can be formed, down to a few mils in width. These films are generally between several hundred and only a few angstroms thick.

In addition to pure metals, alloys such as those of nickel-copper and nickel-chromiums can be sputtered without difficulty, apparently retaining their approximate original composition.

Printed capacitors have also been produced by combining sputtering and chemical methods. A tantalum film, of the proper shape and size, was first sputtered on to the substrate and then anodically oxidized to form a tantalum oxide dielectric film. The counter electrode, a film of gold, was then evaporated on to the dielectric.

Copper leads, to connect the various components on the printed-wiring board, can be sputtered without difficulty; this technique makes adhesives unnecessary.

In cathodic sputtering, a plate of the metal to be deposited is used as a cathode. The substrate on which the film is to be deposited is placed on a table close to the cathode. After evacuation, argon or some other suitable gas is introduced and maintained at a low pressure. When a voltage is applied, ionized atoms of the gas bombard the cathode, dislodging metal atoms or clusters of atoms, which then re-deposit on the substrate.

In 'reactive sputtering' films of inorganic compounds are formed by introducing a small amount of a reactive gas such as oxygen, nitrogen or hydrogen sulphide into the apparatus. Compounds which can be formed in this way include the oxides, nitrides and sulphides of a number of metals.

Sputtering is one of the most convenient methods known for producing thin films of high-melting point metals. In general, films produced by sputtering are strongly adherent and their thickness may be controlled within narrow tolerances.

Step Detection

REDUCING CROSSTALK IN TIME-DIVISION MULTIPLEX SYSTEMS

By A. R. Billings, B.Sc., Ph.D., A.M.I.E.E.*

SUMMARY. *The spectrum of a step-detected signal is derived both for an ideal and a practical step detector. It is shown that the attenuation distortion produced by step detection is small, and that step detection, when applied to time-division multiplex systems, can produce a considerable reduction in adjacent-channel crosstalk.*

A step detector is a device which converts a train of amplitude-modulated pulses into a continuous stepped waveform, as illustrated in Fig. 1, and for an ideal step detector, the output waveform has an amplitude which at all times is equal to that of the immediately preceding input pulse. Such a detector can be used to advantage in time-division multiplex systems[1, 2] in which the normal method of regenerating the original signal from the received pulses, is that of applying the pulses to a regenerating low-pass filter. In the alternative method provided by the step detector, the pulses are applied to a step detector and the detector output is passed through a low-pass filter. It will be shown that when using this technique, adjacent-channel crosstalk can sometimes be considerably reduced, at the expense of introducing attenuation distortion. This attenuation distortion is small and can be tolerated by the ear but, if necessary, it can be removed by a post equalizer. The actual magnitude of this distortion will be derived by an extension of the method due to Fitch[3].

Application of Step Detection to Time-Division Multiplex Systems

The waveforms of Fig. 2 indicate the operation of an N-channel time-division multiplex system and, with the exception of Fig. 2 (h), these waveforms are applicable to systems employing either conventional or step-detection regenerating techniques. Figs. 2 (a) and 2 (b) show the signals $g_n(t)$ and $g_{n-1}(t)$ to be transmitted in the nth and $(n-1)$th channels, and Fig. 2 (c) shows the pulses which are derived by sampling these two signals at times τ apart. In the complete system each of the N-channel signals is sampled every $N\tau$ seconds; in other words, the sampling frequency for each channel signal is $1/N\tau$ c/s. The pulses $g_p(t)$ produced by sampling each of the N-channel signals are supplied as an input to a common transmission system which is assumed to have an overshooting output when pulsed at the input. The outputs due to the pulses derived from the $(n-1)$th and nth channels are shown in Figs. 2 (d) and 2 (e), and the total output from the transmission system is the superposition of N such waveforms staggered in time.

The regeneration technique requires that, as far as possible, the N-different channel signals shall be isolated from each other, and this is achieved by sampling the composite output at a frequency $1/\tau$ and sorting the received pulses thus produced into N separate pulse trains each having a repetition frequency $1/N\tau$ and each specifying one original channel signal. In this instance, the sampling technique is similar to that illustrated in Fig. 1 (a) and (b) with the difference that $g_m(t)$ is now the composite output from the transmission system. With finite width sampling at the receiver, it is impossible completely to isolate one channel signal from the others and the effect of this is to introduce crosstalk. The reason for this is illustrated in Fig. 2 (f) and (g). In these diagrams the contributions of the $(n-1)$th and nth channel signals to the train of pulses specifying the nth channel received signal are shown. It can be seen that there is a contribution

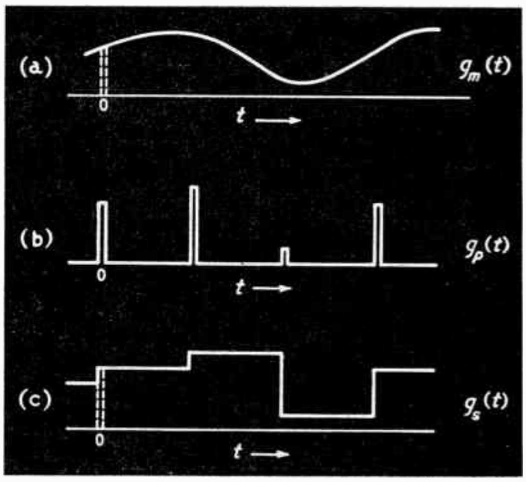


Fig. 1. *Step-detector waveforms; (a) original modulating function, (b) input pulses to step detector, (c) output of ideal step detector*

* *Lecturer in Electrical Engineering, University of Bristol.*

to the nth channel received signal which originates in the $(n-1)$th channel and, indeed, there are contributions from all N-channels.

In the normal method of regenerating the N-channel signals, the N trains of received pulses are applied to regenerating low-pass filters which integrate them. In this conventional system, those portions of the received pulse which have originated in other channels are treated in the same way as that portion derived from the original signal channel. Thus, in the regenerated signal, the ratio of wanted to unwanted signal is the same as in the received pulses themselves. By the use of a step detector, it is sometimes possible to position the end of the received pulses so that the step amplitudes are independent of the signal in one of the interfering channels. It is only possible to do this if the transmission system has a step response which has an overshoot, but this is a common situation in systems including filters and is the situation assumed in Fig. 2. Since the largest interfering signal is provided by the preceding adjacent channel, it is most profitable to make the step amplitudes independent of this signal. To do this, it is necessary to adjust the position of the trailing edge of the received pulses.

If, as in Fig. 2 (g), the received pulse in the nth channel ends at the instant when the response to the received pulse from the preceding channel is going through zero then, as indicated in Fig. 2 (h), the adjacent-channel crosstalk is eliminated during the duration of the step. The adjacent-channel crosstalk is finite during the period of the received pulse itself and therefore the total adjacent-channel crosstalk is not zero. However, if the step duration is $(N-r)\tau$ and the received pulse duration is $r\tau$, then adjacent-channel crosstalk is reduced by something of the order of

$$L = 20 \log_{10} \left[\frac{N}{r}\right] \text{ dB}$$

relative to the crosstalk obtained with conventional regenerating filters. When a narrow pulse is applied to the input of any practically realizable low-pass system of bandwidth Δf, the output goes through its first zero at a time somewhat later than $1/2\Delta f$ seconds after the beginning of the output pulse. Thus, to make use of the above multiplex method, the transmission path must have a bandwidth in excess of $1/2\tau$.

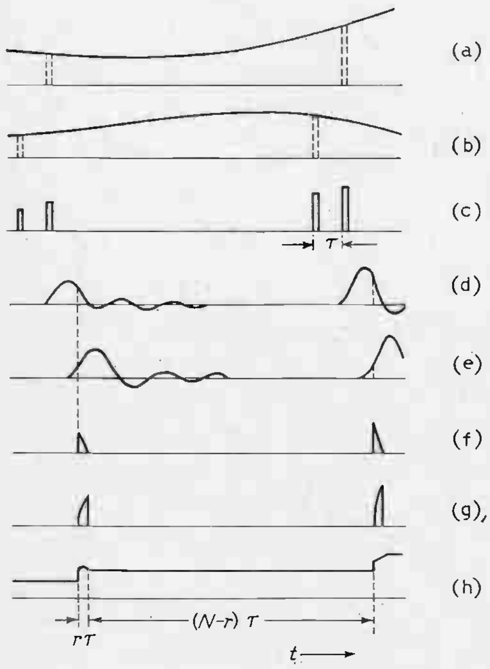


Fig. 2. *Waveforms for N-channel time-division multiplex system. (a) original signal in nth channel, (b) original signal in (n—1)th channel, (c) pulses in transmission system due to pulses from nth and (n—1)th channels, (d) output of transmission system due to pulses from (n—1)th channel, (e) output of transmission system due to pulses from nth channel, (f) received sample of (n—1)th signal in nth channel, (g) received sample of nth signal in nth channel, (h) step-detected form of nth signal*

The Spectrum of Output of Ideal Step Detector

It is now necessary to show that the attenuation distortion produced by step detection is small. The form of amplitude-modulated pulses $g_p(t)$, the amplitude-modulating function $g_m(t)$ from which they are derived, and the step-detected function $g_s(t)$ are illustrated in Fig. 1. If the pulse-repetition frequency is f_s, then the step durations are $1/f_s$ seconds and the step-detected waveform can be considered as the sum of a large number of similar amplitude-modulated pulse trains having a repetition frequency f_s and staggered in time. If each pulse train consists of pulses of Δt duration then there are $1/f_s\Delta t$ pulse trains, where each successive train is retarded Δt relative to its predecessor.

A train of narrow pulses of width Δt having unit amplitude and repetition frequency f_s can be expressed as

$$g_1(t) \approx \Delta t . f_s \sum_{r=-\infty}^{+\infty} \exp\left[j2\pi r f_s\,(t-\Delta t/2)\right] \quad .. \quad (1)$$

where the time axis is so chosen that one pulse in the train starts at time $t = 0$. The approximation is very good for frequencies where $rf_s \ll 1/\Delta t$, and by making $\Delta t \to 0$, the expression may be made to apply at all frequencies. An amplitude-modulated train of pulses $g_p(t)$ consists of the product of $g_1(t)$ and $g_m(t)$, the modulating function from which $g_p(t)$ is derived; i.e.,

$$g_p(t) = g_m(t) . \Delta t . f_s . \sum_{r=-\infty}^{+\infty} \exp\left[j2\pi r f_s\,(t-\Delta t/2)\right] \quad (2)$$

It is convenient to consider $g_m(t)$ to consist of a zero-frequency component plus a component of frequency f_m, and to use the superposition principle when extending the arguments to more complicated modulating functions. Such a simple modulating function can be written in terms of the symmetrical Fourier series as

$$g_m(t) = 1 + \frac{k}{2}\exp\left[j\,(2\pi f_m t + \psi_0)\right] + \frac{k}{2}\exp\left[-j(2\pi f_m t + \psi_0)\right] \quad .. \quad (3)$$

To find $g_s(t)$, the step-detected form of $g_p(t)$, a succession of similar pulse trains displaced in time are added together; i.e.,

$$g_s(t) = \sum_{m=0}^{1/f_s} g_p\,(t - m\Delta t) \quad .. \quad .. \quad .. \quad (4)$$

When $\Delta t \rightarrow 0$ this becomes an integral whence, combining equations (2) and (3),

$$g_s(t) = f_s \sum_{r=-\infty}^{+\infty} \left\{ \int_0^{1/f_s} \exp j\,[2\pi n f_s(t-\tau)]\, d\tau + \frac{k}{2}\int_0^{1/f_s} \exp j\,[2\pi(rf_s+f_m)\,(t-\tau)+\psi_0]\, d\tau + \frac{k}{2}\int_0^{1/f_s} \exp j\,[2\pi(rf_s-f_m)\,(t-\tau)-\psi_0]\, d\tau \right\} \quad \ldots \quad (5)$$

which leads to the result

$$g_s(t) = 1 + k \sum_{r=-\infty}^{+\infty} \frac{\sin \pi(r+f_m/f_s)}{\pi(r+f_m/f_s)} \cos\,[2\pi(rf_s+f_m)\,t+\psi_0-\pi\,(r+f_m/f_s)] \quad \ldots \quad (6)$$

It can be seen from this expression that the output of an ideal step detector consists of an attenuation-distorted reproduction of $g_m(t)$ plus a series of non-symmetrical sidebands centred about the harmonics of the reciprocal of the step length. Provided $f_s \geqslant 2f_m$ there is no overlap of sidebands and the attenuation-distorted reproduction of $g_m(t)$ can be selected by a low-pass filter of bandwidth $f_s/2$.

Equation (6) is valid whatever the ratio of f_m to f_s but, if $f_s < 2f_m$, then it is not possible to select $g_m(t)$ with a low-pass filter. This is illustrated in Fig. 3 which shows the amplitude spectrum of the output when the input spectrum is flat up to a frequency f_1. The output spectrum is shown for the conditions $f_1 < f_s/2$, $f_1 = f_s/2$ and $f_1 > f_s/2$ and it can be seen that sideband overlap occurs in the latter condition.

When $f_1 = f_s/2$ the attenuation distortion for the highest input frequency is 4 dB which is by no means extreme. To reproduce the original amplitude spectrum subsequent to the low-pass filter, an equalizer having a frequency response such that

$$F_r(f) = \left| \frac{f\pi/f_s}{\sin\,(f\pi/f_s)} \right| \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (7)$$

is required.

A practical step detector provides an output which differs slightly from that of the ideal step detector. The major difference is that the output voltage will not remain constant between the arrivals of the input pulses but will decay exponentially. In a well-designed system this decay is small and, consequently, the effect upon the output spectrum is small, but the modification of the spectrum can be calculated as shown in the appendix.

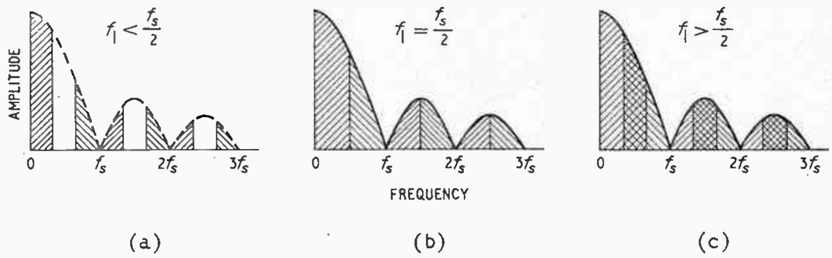


Fig. 3. *Amplitude spectrum of step-detector output, when modulating function has a spectrum which is flat up to f_1 c/s and is zero thereafter*; (*a*) $f_1 < f_s/2$, (*b*) $f_1 = f_s/2$, (*c*) $f_1 > f_s/2$

Conclusions

It has been demonstrated that a reasonable reduction of crosstalk can be obtained using a step detector as a regenerator of the original signal in an amplitude-modulated time-division multiplex system. This reduction is paid for by a widening of the transmission bandwidth and some distortion of the regenerated signal. The increase in transmission bandwidth is a common requirement for low-crosstalk systems and the distortion introduced is not unreasonable in the sense that the ear will be perfectly tolerant of it. Indeed, if speech quality is not important, it is possible to dispense with a post-detector filter altogether, while still maintaining high intelligibility. In this case, the ear receives a distorted form of the original signal plus the higher sidebands produced by sampling and, while this introduces an unnaturalness to the received signal, it does not alter the interpretation.

APPENDIX

The output of a practical step-detector differs from that of an ideal step detector in that the output voltage decays exponentially during the periods between input pulses. The spectrum of this output can be found from that already obtained for the ideal step detector. If the output of the practical step detector is $g_s'(t)$, then

$$g_s'(t) = g_s(t)\, g_y(t) \quad \ldots \quad (A1)$$

where $g_y(t)$ is the periodic time function of fundamental frequency f_s which is defined during the basic period from $t = 0$ to $t = 1/f_s$ as

$$g_y(t) = \exp\,(-f_y t)$$

where $1/f_y$ is the time constant of the step decay. Expressed as a Fourier series,

$$g_y(t) = M \sum_{n=-\infty}^{+\infty} \frac{\exp\,(j2\pi n f_s t)}{(f_y/f_s) + j2\pi n} \quad \ldots \quad (A2)$$

where

$$M = 1 - \exp\,(-f_y/f_s) \quad \ldots \quad (A3)$$

Combining Equ. (6) in the main text with Equ. (A2), and rearranging terms, leads to the solution for $g_s'(t)$ of

$$g_s'(t) = \sum_{q=-\infty}^{+\infty} \sum_{r=-\infty}^{+\infty} \frac{kM \sin\,[\pi\,(r+f_m/f_s)]}{2\pi\,(r+f_m/f_s)\,\sqrt{(f_y/f_s)^2+4\pi^2\,(q-r)^2}} \cos\,[2\pi\,(f_m+qf_s)\,t+\psi\,(q,n)] \quad \ldots \quad (A4)$$

where,

$$\psi\,(q,r) = \psi_0 - \pi\,(r+f_m/f_s) + \tan^{-1}(2\pi(r-q)f_s/f_y) \quad \ldots \quad (A5)$$

REFERENCES

[1] J. E. Flood and J. R. Tillman, "Crosstalk in Time-Division Multiplex Systems", *Proc. Instn elect. Engrs*, Part III, July 1951, p. 279.
[2] W. R. Bennett, "Time-Division Multiplex Systems", *Bell Syst. Tech. J.*, 1941, Vol. 20, p. 199.
[3] E. Fitch, "The Spectrum of Modulated Pulses", *J. Instn elect. Engrs*, Part IIIA, 1947, Vol. 94, p. 561.

A SENSE OF PROPORTION

It is a comforting reflection that when the scientist runs up against an intractable piece of mathematics he can always appeal to his sense of proportion. Sound, well-balanced chaps that we are, when things begin to get sticky we can close the book of Bessel functions, and after a quick look at the youngster's "Hall and Knight" (with answers) press on with Componendo and Dividendo. This has some superficial resemblance to the political technique of getting out of a jam by discarding the sense of proportion and bringing out Innuendo; though you observe a certain difference in practice, and may well take even more comfort from the comparison. However, it is not my purpose to fob you off with easy generalities or to sweeten you personally. I want to deal with three very particular examples of what I should call the use of a proportional argument rather than a straight dimensional calculation of the ordinary kind. In the first two, it is quite literally a case of proportion coming in where rigour has taken the story as far as it can.

You may have noticed a certain association of ideas behind the sequence of the more recent of these articles. It simply happens that while I am trying to find an explanation of one problem another one turns up. I say "problem", for it is always quite an undertaking to try to present modern physics in its simplest fundamental terms. Often, of course, it turns out that there was hardly a problem in the work itself at all, but simply some elementary physics that I hadn't understood well enough. For example, the vector operators grad, div, and curl are one and the same for dimensional purposes. You find this a confusing idea? Well, each of them involves terms which are partial differential coefficients of a vector with respect to length, so they must be *dimensionally* equivalent. Grad **U**, div **U**, and curl **U** are all levelled out to the dimensions U L^{-1}. Similarly, $\nabla^2\mathbf{U}$ is U L^{-2} dimensionally. Nobody, of course, could hope to get very far on this basis in an attempt to deduce vector equations; that would be nonsense. But, in cases where the fundamental general equations are well known and the results of a change of scale are being considered, then it simplifies things greatly to remember that the change works in exactly the same way in the *x*, *y*, and *z* directions. This is really the clue to the first two examples—a very elementary point which I must confess held me up for some time. There is a further point—that *numerical values* of the quantities can be substituted in the dimensionally-written expressions, to give results which should be of the right numerical order of magnitude. As J. W. Dungey points out in "Cosmic Electrodynamics" (Cambridge University Press, 1958) the validity of this step is by no means general, and it has to be taken with care. It is all right, apparently, if there is no ambiguity about the appropriate numerical values; but there has to be considerable foreknowledge if one is to be comfortable about this.

Elsasser on Magnetohydrodynamics

A good deal of this paper is concerned with numerical values and orders of magnitude, and we ought to get the symbols straight first. The usual black type, as **U**, denotes a vector; Roman, as U, the dimensions of the quantity; and italic, as *U*, a numerical value. Rationalized m.k.s. units are used, and the symbols ϵ, μ, here stand for $\epsilon_r\epsilon_0$ and $\mu_r\mu_0$. The underlying physics is to some extent covered in paragraphs 10.2 and 16.4 of Harnwell, on the induction of currents in continuous media, and the penetration of waves into conductors. There it is shown that, for angular frequency ω, and a medium of specific conductivity σ, "very good conductor" conditions hold if $\omega\epsilon/\sigma \ll 1$; and that the exponential decrement of current with respect to distance λ is $(\omega\mu\sigma/2)^{\frac{1}{2}}\lambda$. Apart from ϵ, μ, and σ, which are properties of the medium, the only quantities so far involved are ω, which can be regarded as a reciprocal time, and λ, which is a distance which, in a general treatment, can stand for "a typical length". Two additional properties of the medium may, however, be needed—the space-charge density η, and the ordinary mass-per-unit-volume density ρ. To avoid fancy symbols, square brackets, and so on, only one kind of Greek letter will be used; it will be clear, I hope, from the context or from other symbols in an expression whether this refers to numerical value or to dimensions.

Consider a conducting fluid moving with velocity **V** in a magnetic field of flux-density **B** and an electric field **E**. The conduction current is $\sigma\mathbf{E}$. There is an induced electric field $\mathbf{V} \times \mathbf{B}$ which gives an induced current $\sigma\,\mathbf{V} \times \mathbf{B}$. The displacement current is $\epsilon\partial\mathbf{E}/\partial t$; and the motion of the free charges in the fluid is a convection current $\eta\mathbf{V}$. Equating the curl of the magnetic field **H**, which is $\mathbf{B}/\mu$, to the total current, then

$$\text{curl}\,\mathbf{H} = \epsilon\frac{\partial\mathbf{E}}{\partial t} + \sigma\mathbf{E} + \sigma\mathbf{V}\times\mathbf{B} + \eta\mathbf{V}$$

displacement current	conduction current	induction current	convection current

Or, in terms of **B**,

$$\text{curl}\,\mathbf{B} = \mu\epsilon\frac{\partial\mathbf{E}}{\partial t} + \mu\sigma\mathbf{E} + \mu\sigma\mathbf{V}\times\mathbf{B} + \mu\eta\,\mathbf{V}.$$

The first object is to find the relative importance of the terms on the right-hand side of the current equation for a very good conductor; and the next to see what happens if **V** and λ become very large; that is, how the order of precedence is altered when we go from the laboratory to the cosmic scale.

First, for the displacement-current term, the dimensions of $\frac{\partial \mathbf{E}}{\partial t}$ are ET^{-1}, or $\mathrm{E}\omega$. In using this information to compare the sizes of displacement current and conduction current, it is valid to put in the numerical values E, ω, for the dimensions E, ω.

$$\frac{\text{displacement current}}{\text{conduction current}} = \frac{\epsilon E \omega}{\sigma E} = \frac{\epsilon\omega}{\sigma}.$$

Next, invoking Poisson's equation in the rationalized form div $\mathbf{E} = \eta/\epsilon$, the dimensions of η are seen to be those of $\epsilon\,\mathrm{E}/\lambda$, where λ is a characteristic length. The ratio

$$\frac{\text{convection current}}{\text{conduction current}} = \frac{\epsilon E V}{\lambda\sigma E} = \frac{\epsilon V}{\sigma\lambda}.$$

and this, since V/λ is the reciprocal of a time, which can denoted by the symbol ω, is also $\epsilon\omega/\sigma$. Now, for a very good conductor, unless ω is extremely large, $\epsilon\omega/\sigma$ is very small. So, as is already well known, displacement current and convection current are negligible in this case, and the current equation becomes

curl $\mathbf{H} = \sigma\mathbf{E} + \sigma\mathbf{V} \times \mathbf{B}$, with
curl $\mathbf{B} = \mu\sigma\mathbf{E} + \mu\sigma\mathbf{V} \times \mathbf{B}$.

Finally, writing curl **B** for dimensional purposes as B/λ, the ratio

$$\frac{\text{induction current}}{\text{total current}} = \lambda\mu\sigma\frac{VB}{B} = \lambda\mu\sigma V.$$

This dimensionless product $\lambda\mu\sigma V$ is the magnetic Reynolds' Number R_m. Writing ν_m for $(\mu\sigma)^{-1}$, the magnetic viscosity, R_m can be written $V\lambda/\nu_m$, which is exactly of the same form as the Reynolds' Number we were thinking of recently, but with ν_m instead of the ordinary kinematic viscosity ν.

It can be seen that if R_m is very large, then the total current is very small compared with the induced current, curl **B** is practically zero, and the electric field **E** is nearly equal to $-\mathbf{V} \times \mathbf{B}$.

Next, to compare the time of transport of the fluid λ/V with the time taken for induced currents to die out. The decay exponent given by Harnwell is $(\frac{1}{2}\omega\mu\sigma)^{\frac{1}{2}}\lambda$; taking $1/\omega$ to represent the time of decay, this time is proportional to $\mu\sigma\lambda^2$. Thus, for order-of-magnitude purposes the ratio

$$\frac{\text{time of decay of induced currents}}{\text{time of transport of the fluid}} = \frac{\mu\sigma\lambda^2}{\lambda/V} = \mu\sigma\lambda V = R_m.$$

If R_m is very large, then the time for which the induced currents persist is very long compared with the time the fluid takes to move about. Now, in the ordinary way induced currents last only while a conductor is moving in a magnetic field, and cease when it has moved beyond it. A very long decay time implies that the conductor clears the field, or that the field diffuses out beyond the conductor, very slowly indeed; in other words, that the field moves with the conductor, just as if it were attached to it. This is the sense in which the size of R_m is said to measure the "degree of attachment of the fluid to the magnetic lines of force".

The processes by which energy can be dissipated in such a fluid are both of the same general nature, but different in detail. There is the molecular generation of heat by viscous friction, and the production of Joule heating by the induced currents. The ratio

$$\frac{\text{frictional dissipation}}{\text{electromagnetic dissipation}} = \frac{\nu}{\nu_m} = \frac{R_m}{R} = \mu\sigma\nu.$$

As ν is inversely proportional to the density ρ, the density is in fact a decisive factor. In interstellar gas clouds, the dissipation is almost entirely frictional; within the interior of stars, the density is high, and the dissipation mainly electromagnetic. The ratio is nearly unity under the conditions holding in the photospheres of stars.

A number of other interesting matters are considered in this paper—what happens when V is so great that relativity considerations come in, and a possible process for the acceleration of cosmic rays. The most important features for our present story are, however, the cheerful shedding of the vector character for dimensional purposes, and the way in which dimensional analysis has been worked in reverse. For instead of trying to deduce a general relation by suitable choice of the relevant factors, a dimensional argument has been used to find the criteria for rejecting unimportant terms from a full-dress general equation. It may be some consolation to you now to learn that I have at last worked Reynolds' Number out of my system.

Lehmann and Vallarino on the U.H.F. Valve

This example is discussed in C. M. Focken's "Dimensional Methods and their Applications", p. 146. The problem was to explore the efficiency of ultra-high-frequency vacuum valves of the same general design as a function of the frequency of oscillation f, the cathode–anode distance d, the potential difference V between these electrodes, and the cathode current density A.

The assumptions made to limit the scope of the enquiry are that the current is limited only by space-charge, that V is considerably greater than 1 volt (so that the velocity of emission of electrons from the cathode is negligible compared with the result of their acceleration) and is very much less than 10^5 volts (so that relativity mechanics is not needed), that the dimensions of the valve are small compared with the wavelength at which it is operating, and that no magnetic field has to be considered.

Next, Poisson's equation and the equation of motion of an electron in the field between the electrodes are written down; Focken gives the latter in the form $m\ddot{x} = -e\,dV/dx$, though the authors are more general, and go to some trouble to explain that constancy of the potential gradient depends on the electrodes being perfect conductors and therefore equipotential surfaces. The three fundamental quantities chosen for the argument are V, L, and T; it looks at the start as if e/m for the electron is being put in as a fourth, but this quantity is not independent of the other three. From the equation of motion, $\frac{m}{e}\cdot\frac{\ddot{x}}{dV/dx}$ = a number, whence in dimensions $\left(\frac{\mathrm{m}}{\mathrm{e}}\right)\cdot\mathrm{L}^2\mathrm{T}^{-2}\mathrm{V}^{-1}$ is a dimensionless product. The appropriate quantities attaching as numerical values to length (L) and frequency (T^{-1}) are d and f, so the dimensionless product which should presumably be the same for all valves of the same design, a sort of electronic Reynolds' Number, is $\frac{m}{e} \cdot \frac{f^2 d^2}{V}$, given the symbol Φ_1. This is reduced a little for the purpose of experimental checking, by removing e/m which is the same for all valves, and then taking the square root. The authors give a series of curves showing results for the efficiency as a function of the reduced Φ_1 for several valves; these ought to be a single curve, and not a series, and presumably they would be if the efficiency of the circuit containing the valve were allowed for, as they present the overall efficiency.

The next stage is to find the relation between the current density A per unit area, the p.d. V, and the efficiency. If η is the space-charge density and v the electron velocity at the same place, then $A=\eta v$. From Poisson's equation, $\nabla^2\mathbf{V}=4\pi\eta$ in c.g.s. units, so the dimensions of η are V^1L^{-2}; similarly, from the energy equation $\frac{1}{2}mv^2 = eV$, the dimensions of e/m are $L^2 T^{-2} V^{-1}$. Supposing then that A is a function of e/m, V, and d, putting in the dimensions of each of these quantities and going through the usual drill of equating powers of V, L, and T, it is seen that $A = k\,(e/m)^{\frac{1}{2}}\,V^{3/2}\,d^2$. This is the Child-Langmuir formula, the well-known "three-halves-power law".

Writing the dimensionless product l/k as Φ_2, we have

$$\Phi_2 = (e/m)^{\frac{1}{2}}\,V^{3/2}\,d^2\,A^{-1}.$$

Of the two dimensionless products obtained, the first, Φ_1, is constant in value for a constant efficiency, while Φ_2 enables d or V to be eliminated in terms of A from Φ_1.

Eliminating d, by taking the product $\Phi_1\ \Phi_2$, and including (e/m) or its powers in the constant k_1,

$V = k_1 A^2/f^4$. Hence, for a given efficiency, the maximum useful anode voltage is proportional to A^2 and to $1/f^4$. This means that at high frequencies, the maximum useful anode voltage is small, unless A is made fairly large.

Or, by eliminating V, it is found that, at constant efficiency, $d = k_2\,A/f^3$, which shows that at very high frequencies the value of d must be made very small.

The argument continues to show that the power handled is proportional to A^5/f^{10}, but I think I need go no further to illustrate the valuable information obtained by this approach. In principle, the line of attack is the same as Elsasser's. The physics of the problem is understood, and the basic equations have been written down; by suitable choice of the fundamental quantities, and by disregarding the vector aspect of the left-hand side of Poisson's equation, essential features common to all possible solutions of a mathematically unsolvable equation have been extracted.

Bickerton and London on Zeta and Such-Like

This paper, entitled "The Scaling Laws for the Stabilized Pinch", is brief and rather different in its outlook. It deals simply with the effect of the linear dimensions of the apparatus on the three stages of the processes taking place in the toroidal pinch discharge devices Zeta, Sceptre III, and Perhapsotron S-3. These are, the classical discharge phase, the contracting phase, and the contracted phase. In the first of these, the scaling law for classical discharges given by von Engel is involved, that two classical discharges are similar if E/p is constant, where E is the electric field and p the gas pressure. This certainly rang a bell. I mentioned earlier the association of ideas that these articles provoke; the bell in this case was that on the dilapidated alarm clock that Townsend used to bring into his lectures more than thirty years ago, when he was expounding topics like "(α/p) is a function of (X/p)" α being the "first Townsend coefficient" and X his symbol for E. I think we never really appreciated quite what all this implied; now it can be seen that he was really the founder not only of the study of discharge phenomena as they are known today, but also of the experimental-plus-dimensional approach towards unravelling their complexities. It may even be that C. M. Focken's interest in dimensions began at that time, for he was there in the Electrical Laboratory, patiently helping to unravel the squalid knitting of undergraduate circuitry, and coaxing the Townsend potentiometers and the Townsend wavemeters into action. However, I mustn't get carried away by associations; back to the consequences of scaling. In the third phase of operation, the authors show that the product of the ion density n and the time t for which the contracted phase remains stable is proportional to $NT^{3/2}$, where N is the number of ions per centimetre length of the discharge, and T the electron temperature in the third phase; this product, measuring how far the proceedings approach a truly self-sustaining nuclear reaction, is independent of the size of the apparatus. The closeness of this approach does, as we saw last month, increase rapidly as the temperature rises. From this point of view, then, it appears that Zeta with its torus of 50-cm radius, Sceptre III (15-cm), and the miniature Perhapsotron S-3 (2·5-cm) are more or less on equal terms. Applying the sordid criterion of price, the scaling laws show also that the cost per neutron per pulse is the same for each.

It looks too pretentious to list the references to these three papers at the end, in small print, like the more profound contributors to this journal; I did, however, mention them in detail in the October "Fringe". Having started on dimensions, I have seen the topic through as far as I can take it at the moment; I think it was worth it, and can only say that I have learned enough in the process to look on some of the rather pontifical statements about electrical dimensions in the books with a little scepticism. But that is quite another story, which I shall not be drawn on to for a while—I hope.

COMPUTER DISCUSSION MEETINGS

Specialist discussion meetings on new digital computer techniques, arranged by the Measurement and Control Section of the I.E.E. will be held in the Institution building, Savoy Place, London, W.C.2, on 16th and 17th February 1959.

The meetings, open to both members and non-members of the Institution, will consist of four sessions dealing with "Character Recognition", "Peripheral Equipment", "Low Temperature Storage and Switching Devices" and "Special Aspects of Logical Design".

Further particulars are obtainable from the Secretary of the Institution, Savoy Place, London, W.C.2.

Low-Frequency Sine-Wave Generators

REVIEW OF MODERN PRACTICE

The ideal 'low-frequency' generator would cover a frequency range extending down to a small fraction of a cycle per second (to satisfy the needs of servo engineers and biologists) and up to a frequency well within the legitimate radio range (so that the stability of negative-feedback audio amplifiers could be tested at frequencies outside the normal signal range). Needless to say, no such instrument is manufactured. Instead, separate designs have been evolved for different parts of the low-frequency spectrum. The vast majority of commercial instruments cover the upper region, which comprises the normal audio range and the lower radio frequencies, and there is often a substantial overlap between the coverage of a general-purpose low-frequency source and a general-purpose radio-frequency source.

Of the various rival methods of generating low frequencies, the RC oscillator is now the most widely used, because it lends itself so well to wide-range variable-frequency working. For fixed frequencies in the audio range, ordinary LC oscillators hold their own, but variable LC oscillators have vanished, and even the once ubiquitous beat-frequency oscillator has lost most of its popularity. The very low frequencies present special design problems, and circuitry has by no means become standardized at frequencies below about 10 c/s. This region really forms a subject on its own. Every instrument is different, unusual circuitry, even mechanical devices, being employed. The discovery a few years ago that thermistors can be used as oscillators at very low frequencies does not seem to have been applied commercially, but there is always the possibility that some equally unconventional method of generation may be adopted.

LC Oscillators

These are used mainly at fixed frequencies in the audio range. If the tuned-circuit Q is reasonably high, an output with a small harmonic content can be obtained, and this is useful for energizing bridges and in the measurement of distortion. Since the advent of the transistor and the ferrite pot core some very compact battery-operated oscillators have become available. These are particularly useful for bridge work by virtue of their small capacitance to earth.

Variable-frequency LC oscillators are not often met with partly because, with a maximum-to-minimum frequency ratio of about 3, which is typical of what can be obtained by using a variable capacitor, rather a large number of coils is required to cover the audio range. Another is the size of components required at the low-frequency end. If we use a variable capacitor of 0·01 μF maximum (equivalent to five four-gang 500-pF units), and an inductance of 1,000 H, the lowest frequency is about 50 c/s. The audio range could be covered in six bands, whereas an ordinary RC oscillator with a 10 : 1 frequency ratio could do the job in three bands, and a beat-frequency oscillator in one band. The stability and low harmonic distortion of the LC oscillator would probably give it the advantage over the beat-frequency type, but not necessarily over the RC oscillator.

Fixed-frequency oscillators are available from Venner Electronics in the form of small encapsulated units using transistors. Oscillators with a selection of fixed frequencies, intended for telephone-circuit testing, are made by Standard Telephones & Cables. One example, of simple type, is the model 74330. It has only one valve, connected as a tuned-anode oscillator, with a tapped anode coil to vary the frequency. Twelve frequencies in the range 300 c/s to 3,400 c/s are provided.

Quartz Crystal Oscillators

For fixed-frequency operation, the quartz crystal can be employed to enable exceptionally high frequency stability to be obtained. Crystals for frequencies down to about 1 kc/s are available.

Venner Electronics has produced crystal oscillators which operate at frequencies from 50 kc/s down to 5 kc/s. These oscillators provide a sine-wave output which is derived from an oscillatory circuit employing two point-contact transistor amplifiers and an XY flexural quartz resonator. Designed to operate from a nominal 10-V d.c. supply, the makers claim frequency stability of the order of 3 parts in 10^6, a nominal frequency accuracy of $\pm$0·01%, and an output of 2·8 V peak-to-peak when feeding into a 18-kΩ load.

The crystal oscillator, too, has application in the form of a crystal calibrator. The Salford audio-frequency oscillator, for example, is of the Wien-bridge type described later in this article and covers 50 c/s to 50 kc/s in three ranges. It has a built-in crystal oscillator with a frequency accuracy of 0·01% and the variable frequency oscillator can be checked against this at a number of discrete frequencies using a magic eye indicator.

Beat-Frequency Oscillators

The principal advantage of the beat-frequency oscillator (b.f.o.), Fig. 1, is that the frequency sweep obtained can be made arbitrarily large. A subsidiary advantage is that, by suitably designing the frequency-controlling elements of the variable oscillator, the law relating frequency to angular position of the control shaft can be given any desired form. A logarithmic law is often provided, since the measurement of frequency response can then be made with equal percentage errors at all points on the frequency scale.

Another advantage is the ease by which an increment of frequency may be added by a step change of frequency of the fixed oscillator.

Against these advantages must be set the major disadvantages that it is difficult, and therefore expensive, to obtain adequate stability when the two oscillator frequencies approach one another and the resulting beat note is low. The beat frequency is the difference between two high frequencies (often 100 kc/s or more) and its percentage error depends on the absolute errors of these.

In addition to the problem of stability, there is also one of distortion. Stray coupling between the oscillators

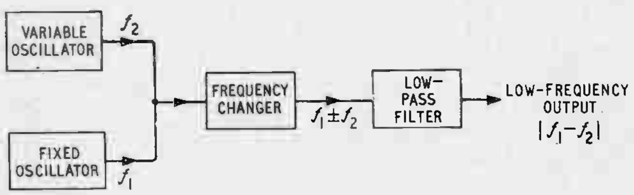


Fig. 1. *Essentials of beat-frequency oscillator. In a practical oscillator, there may be buffer amplifiers between the high-frequency sources and the frequency changer*

causes frequency pulling, and this gives rise to harmonic distortion in the low-frequency output. Distortion can also arise in the frequency changer. Both these effects have been analysed by Mayo[1,2]. In the case of the frequency changer, for least distortion, one of the two high-frequency signals should be a square wave and the other a sine wave. To minimize distortion resulting from 'pulling', the oscillators must be carefully isolated from one another by screening and by buffer stages. As the natural frequencies of the two oscillators are made to approach one another, the residual coupling

Sullivan 10A b.f.o. covers the range 0–16,000 c/s. Stability for a period of a day usually better than ±0·5 c/s and output level constant to within 0·1 dB

causes them to lock in synchronism. If the difference between the two natural frequencies at the point of locking is f_0, and f is the beat note in general, then the ratio of the second harmonic to fundamental is $f_0/2f$. Thus, if f_0 is 1 c/s and f is 2 c/s, the second-harmonic distortion is 25%. If the beat frequency is 50 c/s then, under the same conditions, the distortion is 1% which is generally tolerable. The amount of stray voltage E_s on the grid of one oscillator due to coupling from the other which will cause locking is given[3] by $E_s = [2QE_g(f_1 - f_2)]/f_1$, where E_g is the oscillator grid voltage and f_1 and f_2 the oscillator frequencies. If $Q = 100$, $E_s = 1$ V, and $f_1 = 100$ kc/s then, for locking at 1-c/s difference, $E_s = 2$ mV. If the output voltage of the oscillators is 10 V, the isolation required is about 74 dB. The amount of coupling occurring in the mixing circuit can be reduced by applying the two inputs to opposite diagonals of a bridge, or its equivalent, balanced at the frequency of the fixed oscillator. A twin-T network is suitable. Consideration of the degree of isolation required shows why the ranges of beat-frequency oscillators seldom extend below about 20 c/s.

It also shows that RC oscillators are unsuitable for the two oscillators of a b.f.o., since Q is then generally less than unity and the isolation required increases by a factor of over a hundred. Almost invariably the two oscillators are of the LC type.

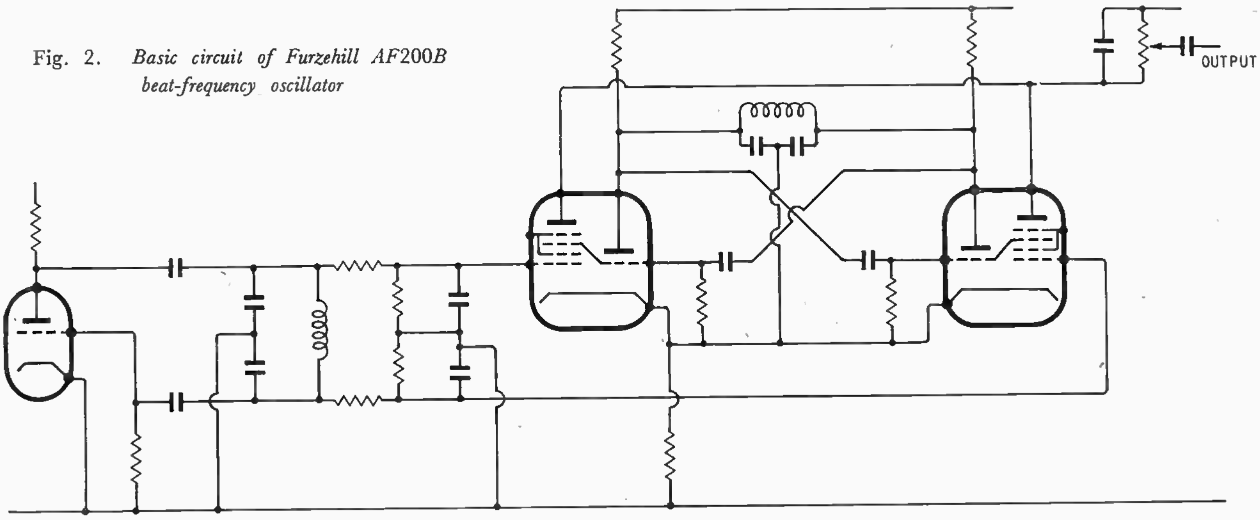
It is, of course, possible to minimize distortion by reducing the oscillator frequencies and, in principle, the fixed oscillator need only have a frequency slightly in excess of the highest beat frequency required. This, however, immediately puts up the cost of the low-pass filter needed to remove the oscillator frequencies from the output. An alternative scheme, which is actually used in the Furzehill AF200B oscillator, is to employ balanced frequency changers so that the fundamental frequencies of the oscillators cancel in the output.

The basic circuit of this oscillator is shown in Fig. 2. The fixed-frequency oscillator is a triode in the Colpitts' circuit and its output is fed in push-pull through RC filter circuits, to reduce harmonics, to the control grids of the two hexodes. The triode sections of these valves function as a push-pull oscillator of variable frequency and their grids are tied to the injector grids of the hexodes. The hexode anodes are commoned and so in the output the fundamental frequencies from each oscillator are in phase opposition and cancel. The beat frequencies are in the same phase and add, however.

The oscillator covers 20–10,000 c/s in one sweep and there is a switch providing an additional 10-kc/s increment. The calibration accuracy is given as ±1% ±2 c/s above 50 c/s. The harmonic content is of the order of 3% and the frequency drift does not exceed about 10 c/s during a day's operation (after an initial warming-up period).

In spite of the fact that the lowest frequency is rarely under 20 c/s, there are some oscillators which can provide much lower frequencies. In the Sullivan 10A, for instance, 'pulling' does not occur until the frequency is under 0·1 c/s ! The high-frequency oscillators incorporated have resonant circuits comprising Sullivan and Griffiths thermal-compensated inductances and temperature-coefficientless fixed capacitors and are accordingly of extremely high stability. The maximum frequency is

Fig. 2. *Basic circuit of Furzehill AF200B beat-frequency oscillator*

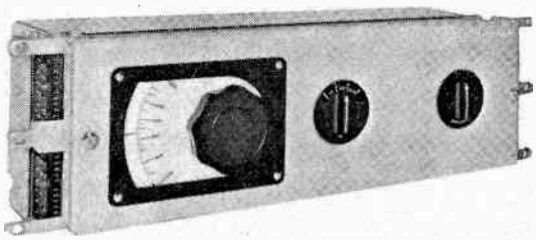


16 kc/s and the maximum output is 15 W; at 1 W, the harmonic content is below —64 dB.

Wien-Bridge Oscillators

Nearly all RC oscillators are of the type shown in Fig. 3 and generally referred to as 'Wien-Bridge' oscillators. The frequency at which the network shown has zero phase shift is also that at which maximum voltage appears across the parallel arm, and is given by $1/(2\pi\sqrt{R_1C_1R_2C_2})$. The amplifier output resistance forms part of R_1, and is usually made as small as possible. If it is comparable with the network impedance, the frequency is appreciably lower than that which would be expected from the values of the network components, since the amplifier resistance adds to R_1. This may not matter for some purposes but, in the case of a wide-range oscillator with C variable and R switched in steps, one virtue of the system is lost. As R is reduced, the amplifier load impedance is reduced, and the percentage frequency error differs on the various frequency ranges. Thus, a single-scale calibration will not suffice for all ranges. Many oscillators of this type incorporate a cathode-follower for driving the RC network. At audio frequencies, R can usually be made large compared with $1/g_m$. An alternative solution, made use of in Muirhead-Wigan decade RC oscillators, consists of inserting resistance equal to half the amplifier output resistance between the bottom end of the network and earth.

In commercial oscillators, frequency control is usually by means of ganged variable resistors or capacitors and, for convenience, $R_1 = R_2$, $C_1 = C_2$. Under these conditions, the network output at the frequency of oscillation is a third of the input, and the amplifier need therefore have a gain of only three times. A two-stage amplifier is necessary in order to produce the required phase conditions (input and output in phase), and the gain is readily made much greater than 3. The excess gain is generally reduced by



Standard Telephones & Cables Type 74560-*A oscillator covers the range* 300 *c/s*–300 *kc/s. Unlike most instruments, it is intended for use with external h.t. and l.t. supplies*

Muirhead-Wigan D-650-*B* 1 *c/s*–111,100-*c/s decade oscillator. The frequency is read off four decade dials and the output voltage is monitored at all times on the panel meter*

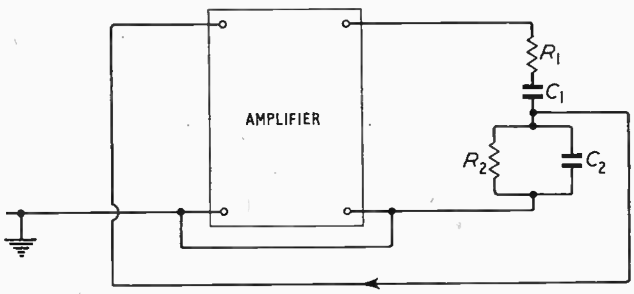


Fig. 3. *Essentials of a Wien-bridge oscillator*

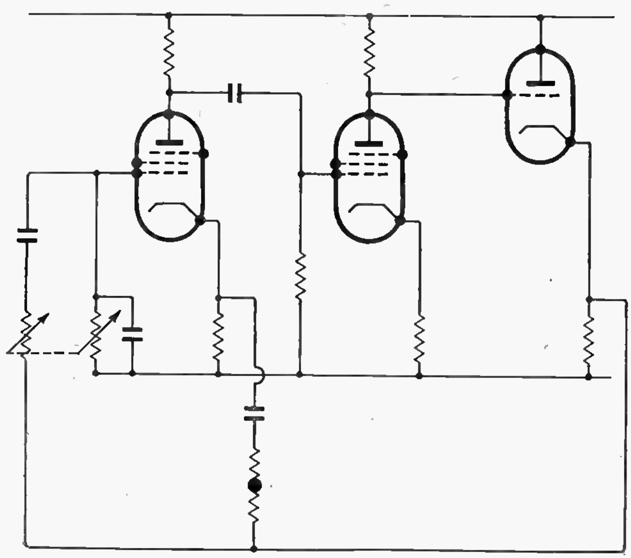


Fig. 4. *Typical Wien-bridge oscillator circuit*

negative feedback, so that the system only just oscillates. At the frequency of oscillation, the negative feedback is cancelled by the positive feedback through the *RC* network, but it is effective at other frequencies; viz., those of noise and harmonics. The outputs of oscillators of this type often have small harmonic contents, of the order of 1%.

Both variable-*R* and variable-*C* networks are used, the latter being preferable in that very smooth frequency variation is possible, and the impedance of the network $(3R/\sqrt{2})$ is constant over any one band. The ratio of maximum-to-minimum frequencies per band is, of course, limited to about 10 by the available capacitance variation but, although variable-*R* circuits could have much greater frequency ratios, the network impedance at the high-frequency end of the band is prohibitively low if the ratio is much greater than 10. More complicated tuning networks have been used to give ratios of as much as 1,000.

At frequencies below about 20 c/s, the magnitude of *R* becomes excessively large if *C* is limited to a practical value such as 1,000 pF, and variable-*R* circuits must be employed. At frequencies above the audio range, the effect of stray capacitances is serious, and both frequency and amplitude tend to depart from the expected values. The upper frequency limit of a wide-range Wien-bridge oscillator with switched frequency bands is generally in the range 100–500 kc/s, depending on the frequency and amplitude stability required. The lower-frequency limit is fixed, not so much by considerations of the size of components as by the difficulty of stabilizing amplitude without generating harmonics. Stabilization is typically effected by the circuit of Fig. 4, in which the thermistor resistance falls as the amplitude of oscillation rises, owing to self-heating. This increases the negative feedback and reduces the load impedance of the cathode-follower output stage, both effects tending to reduce amplitude. A stable state is reached in which the amplitude is constant.

Practical thermistors have heating time constants of the order of a few seconds for small bead types and a few minutes for large rod types. If the frequency of oscillation is reduced far enough, the resistance of the thermistor changes appreciably during the signal cycle, and distortion and phase shift are produced. The bead-type thermistors normally used begin to fail at the bottom of the audio band. It is generally undesirable to use large thermistors, because an excessive time would be taken for the amplitude to stabilize. These considerations limit the lowest frequency to about 1 c/s. It is a feature of thermistor-stabilized oscillators that the performance specification tends to be relaxed at the low-frequency end of the band. In practice, the performance may also fall off near the upper-frequency limit of an oscillator because the reduction in loop gain, due to stray capacitances and reduced tuning-network impedance, causes the negative feedback in the system to be reduced, with a consequent increase of distortion.

When, in the tuning network, $R_1 = R_2 = R$, $C_1 = C_2 = C$, the frequency is proportional to $1/R$. This makes it particularly simple to arrange the switching of network components in such a way that the required frequency can be set up on decade dials in terms of units, tens, hundreds, etc., of cycles. If we have a number of resistors associated with each arm of the network, and switched in pairs, the required

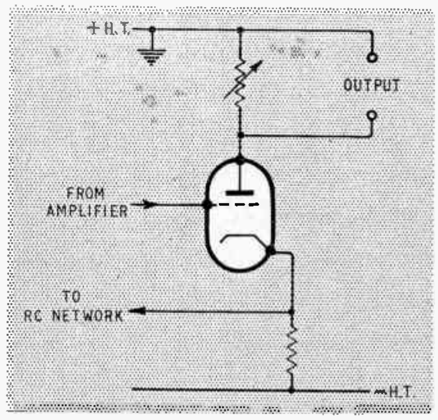
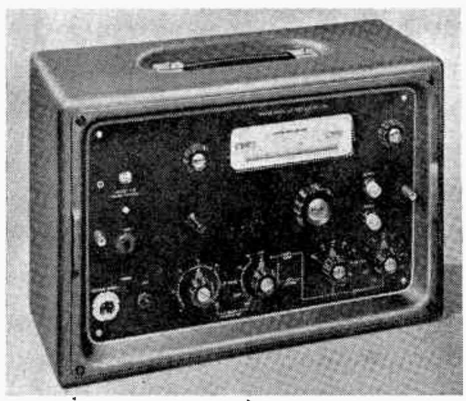


Fig. 5. *Constant-current output stage used in Wayne Kerr S.*121 *oscillator*



*Wayne Kerr wide-range audio-frequency oscillator S.*121 *has a frequency range of* 10 *c/s to* 120 *kc/s. A special dial system is incorporated; the major frequency intervals are selected by switches and the band limits displayed at each end of a continuously-variable interpolating scale*

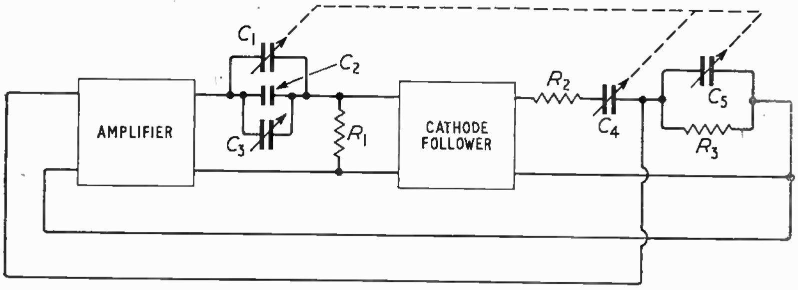
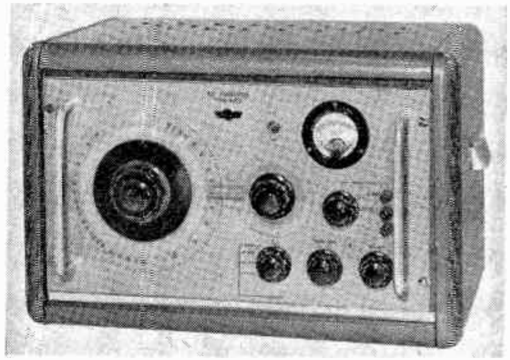


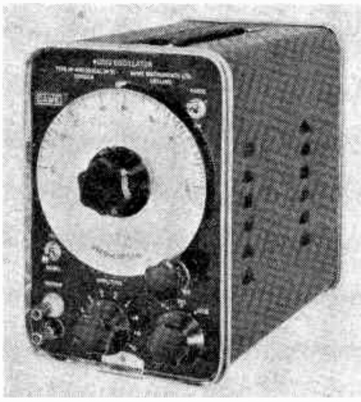
Fig. 6. *Essentials of incremental frequency control circuit of Furzehill G.432 oscillator*



Furzehill G432 incremental RC oscillator covers 25 c/s to 250 kc/s, with a special facility whereby a fixed increment of frequency can be added. The actual frequency is then the sum of the frequencies shown side by side on the two dials

frequency is obtained by paralleling resistors. Thus, if 10 kΩ corresponds to 100 c/s, 1 kΩ to 1,000 c/s, and 100 Ω to 10 kc/s, the parallel combination of these gives 11,000 c/s. This facility is incorporated in the Muirhead-Wigan 1 c/s–111,100-c/s decade oscillator. By changing the capacitors, multiplying factors can be readily obtained.

A somewhat similar system of frequency selection is used in the Wayne Kerr S.121 oscillator but, in this case, the 'units' are obtained by means of a continuously-variable interpolating scale which fills the gap between



Dawe Instruments 440 audio oscillator covers 20 c/s–20 kc/s. The oscillator section comprises a two-stage amplifier feeding a modified Wien-bridge selective network. Provides a 3-W output with less than 0·5% distortion from 40 c/s to 15 kc/s and less than 3% at 20 c/s and 20 kc/s

adjacent 'tens'. This instrument has an unusual type of output stage, shown simplified in Fig. 5. A cathode-follower is employed to supply the *RC* network of the oscillator, but this is also used as a constant-current output stage to set up a rigidly determined voltage across a low-resistance anode load. For convenience in taking the output from the instrument, h.t.+ is earthy.

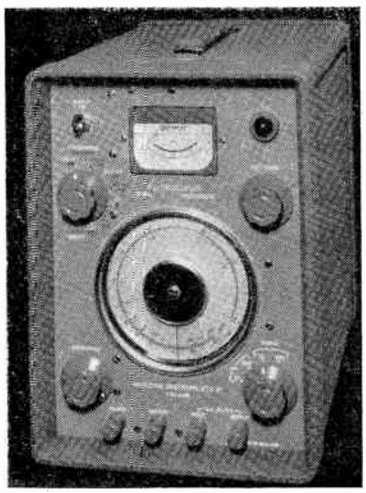
Some instruments, especially those with balanced low-impedance outputs, employ output transformers. Separate transformers may be used for low- and high-frequency parts of the frequency range. The use of a transformer is bound to restrict the frequency coverage at the low end, because at very low frequencies it would be prohibitively large. On the other hand, it is obviously useful to be able to deliver an appreciable amount of power to a low-impedance load. Resistance-capacitance couplings have been employed, but the power output is necessarily small for a given h.t. consumption. The 'single-ended push-pull' output stage now coming into use in transformerless audio amplifiers would appear to be well suited to the task of providing ample power over a wide frequency range and has, in fact, been used by General Radio in a b.f.o.

A new method of obtaining incremental frequency control is employed in the Furzehill G.432 oscillator. The object is to make the frequency the sum of two dial readings. An additional phase shift is introduced into the oscillator feedback loop (Fig. 6) by means of the coupling network C_1 C_2 C_3 R_1. C_3 is variable independently of the main frequency-controlling capacitors. Variation of C_3 alone would produce a change of frequency which is not constant at different settings of C_4 and C_5. To make it constant, an additional capacitor C_1, ganged to the main control, is incorporated. R_1 is switched, together with R_2 and R_3, for the purpose of band changing.

Another development, which has not yet found its way into commercial practice, is to employ Kelvin cables in place of the resistors of the Wien-bridge circuit[4].

It is not, of course, always desired to sweep through

Marconi Instruments TF1101 20 c/s–200-kc/s RC oscillator. The instrument comprises a two-stage thermistor-stabilized Wien-bridge oscillator and has an amplitude stability of ±0·5 dB over the entire frequency range. The output meter scale is calibrated from −60 dB to +28 dB relative to 1 mW to indicate power developed in an external 600-Ω load



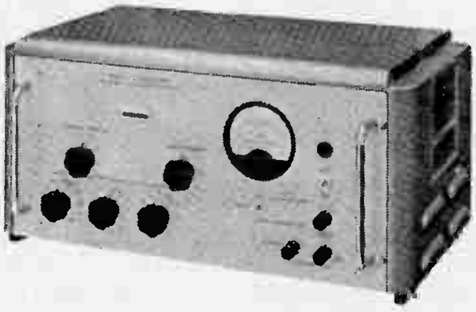
a very wide range of frequencies. The converse is sometimes wanted; that is, to sweep a narrow band centred about any desired frequency. This is done in the E.M.I. Electronics SRO.2A. 1-c/s to 100-kc/s decade oscillator in which a motor-driven frequency control is incorporated which may be set to sweep through any pre-set frequency band within the selected decade range. The magnetic clutch system employed permits very accurate setting of the frequency-control dial as well as preventing an over-run at the dial stops. Provision is made for disengaging the clutch and thereby allowing the dial to be turned by hand.

The performance specifications of commercial Wien-bridge oscillators show that it is not difficult to obtain one with a good performance as far as stability of frequency and amplitude, and low harmonic content are concerned. The majority of instruments have an amplitude stability of better than 2 dB, harmonic distortion of less than 2%, and a frequency accuracy ranging from 5% down to approximately 0·1%. Outputs from 0·5 V up to about 50 V can be obtained depending, of course, on whether the oscillator is fed into a high- or low-impedance load. These figures, however, do not indicate the quality of the construction or the ease of operation of an instrument, nor do they indicate the facilities available. Some oscillators have precise attenuators, balanced outputs, stabilized supplies, or special dial calibrations. A few interesting features of particular instruments are described below.

A conventional Wien-bridge circuit is used in the Taylor 191A wide-range RC oscillator which has a frequency range of 10 c/s to 100 kc/s. The oscillatory section, which is thermistor stabilized, is followed by a low-gain amplifier, a cathode-coupled trigger stage and a cathode follower. A sinusoidal or square-wave output may be obtained but, when the former is required, the trigger stage is switched out of circuit.

Siemens Ediswan R.2125 low-frequency oscillator covers the range 1 c/s–132 kc/s. The oscillator, of the Wien-bridge type, is designed primarily for a balanced output but may be operated with a single-sided output

Solartron Type BO567 two-phase low-frequency oscillator. Covers the range 0·1–111 c/s in 0·1-c/s steps with frequency multiplier switching of ×1 and ×10



Marconi Instruments also produce a thermistor-stabilized Wien-bridge RC oscillator, TF1101, which has a frequency range of 20 c/s to 200 kc/s. A 1-kc/s band-pass filter is incorporated which may be connected in series with the ouput when a 1-kc/s test-tone with a harmonic content less than 0·1% is required. The instrument has a frequency stability of ±0·15% after warm-up, and an amplitude stability of ±0·5 dB.

Other audio signal generators employing RC Wien-bridge oscillators are produced by Advance Components; their H and J types, which cover 10 c/s to 50 kc/s, are well known to the majority of radio and television service engineers. In their Type 81 model, which covers 15 c/s to 200 kc/s, printed circuits are used, and the frequency accuracy is said to be better than 0·1%.

Other Types of Audio-Frequency RC Oscillator

An inconvenience of the Wien circuit is that the phase shift at the resonant frequency is zero. This makes it necessary, in an ordinary valve circuit, to use two valves in order to obtain a positive-feedback loop. It would be much more convenient if the phase shift were 180°, so that a single-stage amplifier would suffice. Of course, the excess gain can be used as a means of reducing distortion, but one may not always require very low distortion and, in any case, there is not much point in reducing it much below that of any associated power amplifier.

The Wien-bridge proper, with two resistive and two reactive arms, produces phase reversal as the applied frequency passes through the balance point. It is not a convenient network to use in valve circuits, since one pair of terminals 'floats' above earth potential. However, an alternative is available in the form of the twin-T RC network, which is equivalent to the Wien-bridge but has one terminal common to output and input. This may be used in conjunction with a single-stage amplifier to obtain oscillation[5].

An older method of obtaining 180° phase shift[6] is to use three or more *CR* networks in cascade (Fig. 7). Either *RC* or *CR* networks may be used or, for that matter, *RL* or *LR* networks but, for the same component values, the frequency of oscillation is different for the two networks. In the usual circumstances in which the resistors and capacitors are equal, the three-section *RC* network yields a resonant frequency which is six times that of the *CR* network. Under the same conditions, the amplifier gain required is 29. Lower gains are needed if more sections are used, or if the impedance of successive sections is increased. The RC form of oscillator can readily be used at radio frequencies[7], since the grid capacitance of the valve forms part of the final *C*. With normal tuning capacitors, a frequency range such as 200 kc/s to 2 Mc/s may be achieved in one sweep.

Two separate networks, each giving 90° phase shift in the same direction, have been used. In this case, there is no saving in the number of valves but, in the usual form, the circuit (Fig. 8) has an advantage over

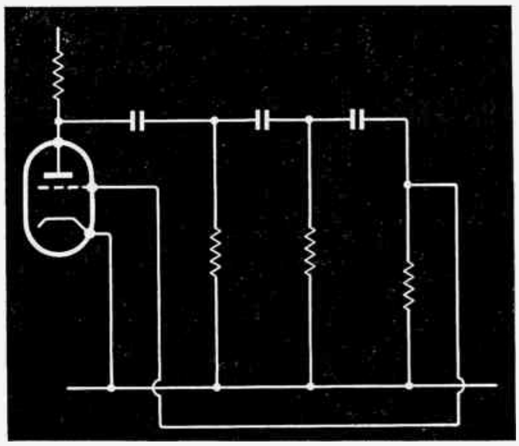
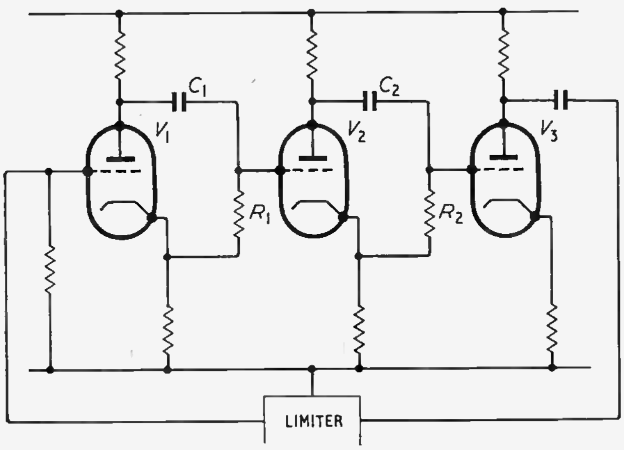


Fig. 7. *RC phase-shift oscillator*

the Wien circuit. V_1 and V_2 are 'concertina' phase splitters with equal anode and cathode loads, and their function is to supply a balanced signal voltage to the *CR* networks. The output of a network has, to a first approximation, constant amplitude, irrespective of the values of *C* and *R* and, therefore, of the phase shift. If frequency control is obtained by means of ganged resistors, small errors in the value of *R* due to mis-tracking do not affect the amplitude of oscillation. In a Wien-bridge oscillator, the network attenuation is altered under the same conditions. The difference is important in oscillators in which amplitude control is obtained by means of a limiter circuit because, although the limiter output is constant, the amplifier output would not be so if mistracking of the resistors took place. Very low frequency oscillators using the double phase-shift system are made by Solartron. Another method of obtaining 180° phase shifts is to cascade two Miller integrators[8].

Complicated *RC* networks have been used to obtain very wide frequency ratios (20 c/s to 3 Mc/s) in one sweep[9]. A possible method of obtaining wide coverage simply is to use a distributed-constant variable *RC* transmission line as in Fig. 9. At any position of the slider, the phase shift is 180° for an infinite number

Fig. 8. *RC oscillator with two* 90° *networks and a phase-reversing amplifier*



of frequencies, but oscillation will take place at the lowest, since the attenuation is then least. This type of oscillator is essentially the same as an *RC* phase-shift oscillator of the 3-section type but, in this case, both *R* and *C* are in effect variable, giving a larger frequency ratio. Large frequency sweeps are of use for rapid checks on frequency responses. One might wish to test a negative-feedback audio amplifier for the purpose of detecting peaks in the frequency response and, for this purpose, a sweep of 1 c/s to 100 kc/s or more may be necessary. The frequency accuracy need not be great, but the harmonic content of the output should be low, especially at the low-frequency end of the bands to avoid spurious responses, and the amplitude stabilizing system should be effective and quick-acting. (Thermistors are not fast enough to prevent amplitude variations from occurring when a frequency-control knob is turned quickly.)

If the internal resistance of a valve is used as part of a phase-shift circuit, it becomes possible to make an *RC*

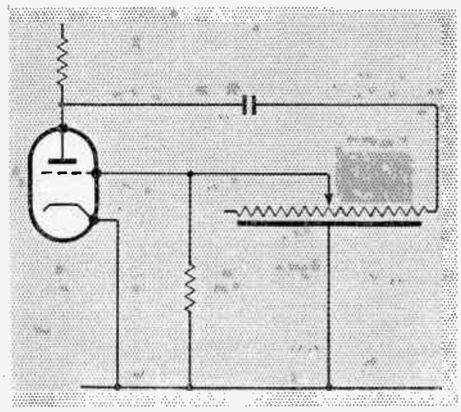


Fig. 9. *RC transmission line as frequency-determining element*

oscillator which can be tuned by suitably biasing the valve. Oscillators of this kind have applications in automatic frequency response or Nyquist diagram plotting, since the bias voltage can be made to synchronize the time-base of an oscilloscope on which the response is displayed.

Very Low Frequency Sine-Wave Sources

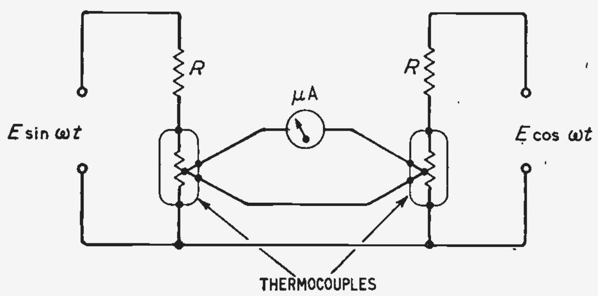
The main use for signals of extremely low frequency is in testing servo systems and process controllers. In this application, one might be interested in the response of a system from the low end of the audio range down to one cycle per half hour or so.

Frequencies in the upper part of the sub-audio range can be generated by extensions of audio-frequency circuitry, some of which have already been mentioned. But conventional oscillators have some characteristics which unsuit them to very low frequency applications. One is their starting-up behaviour. Consider a thermistor-stabilized oscillator. When it is switched on the thermistor is cold and has a high resistance so that the loop gain of the circuit is in excess of that required to maintain oscillation. When the oscillator starts up, therefore, the thermistor is not effective as a controller of amplitude, this function being momentarily performed by overloading elsewhere in the circuit. Under these conditions, both the peak amplitude and the rate of rise of the output wave may be far in excess of the steady-state values. If such an oscillator is used to drive a servo system, there is a danger of causing mechanical damage by forcing the system to respond at a rate in excess of its design maximum.

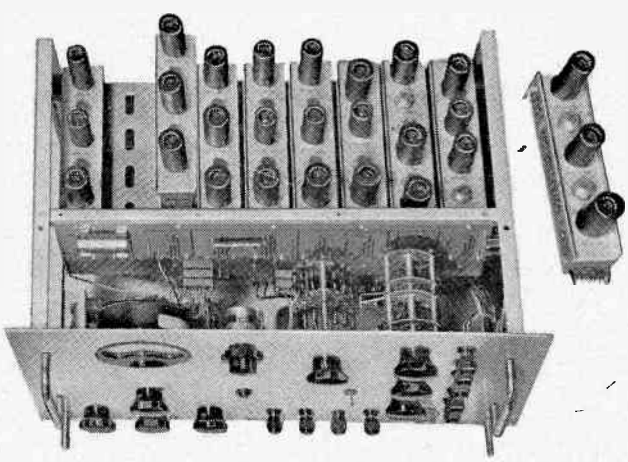
Another difficulty is that the actual frequency of an oscillator is liable to differ from the nominal frequency both while starting up and after switching to another band[10]. A steady state may be reached after a few cycles but, if the duration of a cycle is great, a considerable amount of time may be wasted in waiting for the oscillator to settle down.

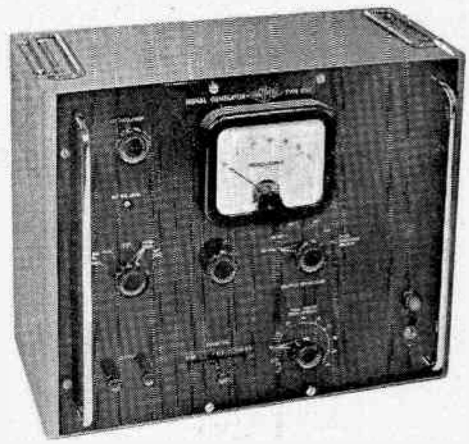
As a result of these difficulties, methods of generating very low frequencies tend to depart from the conventional ones in proportion as the frequency is distant from the audio band. For the upper part of the v.l.f. range, the principal change in practice is to abandon thermistors in amplitude-control systems. Instead, a squaring circuit is employed to limit the signal, and the square wave is passed through a selective filter to remove the harmonics[8,9,10]. The selective amplifier often takes the form of a pair of 90° phase-shift controls

Fig. 10. *Method of measuring the amplitudes of v.l.f. signals used by Solartron*



*Solartron OS.*103 *low-frequency decade oscillator showing sub-unit construction. Covers the range* 0·01–11·1 *c/s in steps of* 0·1 *c/s with multipliers of* 10, 100 *and* 1,000, *giving a maximum frequency of* 11·1 *kc/s. Provides a four-phase sine-wave output, each phase giving* 10 *V r.m.s. with respect to earth*





Airmec Type 852 *v.l.f. oscillator covers the range* 0·03–30 *c/s and employs a specially-designed motor-driven capacitor*

in cascade in a positive-feedback loop. In the Dawe Instruments Type 442 oscillator (0·1–10,000 c/s), Miller integrators are used, while the Solartron BO567 and OS103 have simple 90° RC phase shifters driven by 'phase splitters'. The latter has a frequency range of 0·01 c/s–11·1 kc/s. The use of 90° networks enables a two-phase output to be obtained, or a four-phase output if additional 180° shifts are incorporated.

The existence of two outputs spaced by 90° makes possible an ingenious method of measuring output amplitude (Fig. 10). The thermocouples are supplied with constant-current signals, and have square-law responses, so that the sum of their output currents is proportional to $E^2 \sin^2 \omega t + E^2 \cos^2 \omega t$ and, hence, to E^2. If the thermocouples are identical, the meter shows a steady reading, even though the input frequency is low enough to produce visible variations in deflection if applied directly.

A single integrator is used in the Servomex LF51, which has the lowest frequency limit of all (one cycle per 33 minutes or 0·0005 c/s). This instrument is basically a generator of non-sinusoidal waves, a sine-wave output being obtained by shaping a symmetrical triangular wave by means of an array of biased diodes. The harmonic content is specified as less than 1%. The arrangement used is shown in Fig. 11. Square waves of unity mark-space ratio are applied to an integrator and the resulting triangular wave is passed to the diode shaper. It is also passed to the 'amplitude detector', a comparison circuit which generates an output pulse

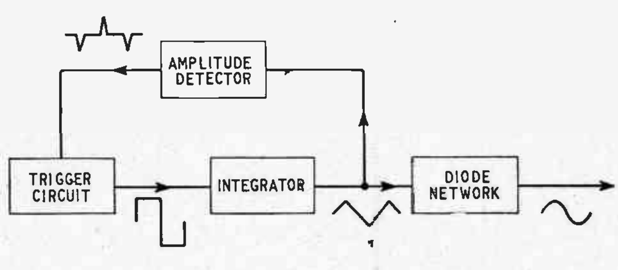


Fig. 11. *Block diagram showing principle of Servomex LF.*51 *generator*

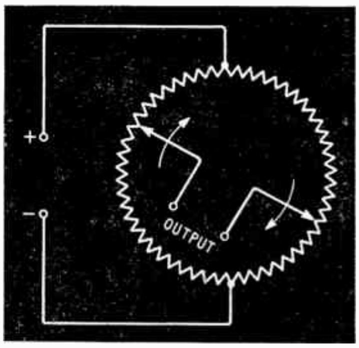


Fig. 12. *Sine-wave generation by rotating linear potentiometer*

when a predetermined amplitude is reached. The output pulse fires a trigger circuit which reverses the polarity of the signal fed to the integrator. The system is, therefore, a feedback loop capable of sustaining oscillation, and the frequency is determined by the integrator time constant. The arrangement is attractive because it is essentially simple, and is capable of yielding a large number of different waveforms.

Another simple method of producing low frequencies is to employ a rotating potentiometer, as in Fig. 12. The frequency is then controlled by the mechanism for rotating the control shaft. A variation on the basic idea, which avoids potentiometer-contact friction wear and noise, is employed in the Airmec Type 852. A motor-driven capacitor is used to control the amount of radio-frequency energy transformed from an oscillator to a detector, the detector output being a low-frequency sine-wave. It will be seen that the frequency depends only on the drive speed, which is controlled by a variable-speed motor in conjunction with a three-speed gear box. The amplitude depends on the r.f. amplitude, which is also readily controlled and measured.

REFERENCES

1 "Distortion in Beat-Frequency Sources", C. G. Mayo, *Wireless Engineer*, April 1952, p. 92.
2 "Beat-Frequency Tone Source", C. G. Mayo, *Wireless Engineer*, June 1952, p. 148.
3 "The Synchronization of Oscillators", D. J. Tucker, *Electronic Engng*, March 1943, p. 412.
4 "Wide-Range RC Oscillator", C. G. Mayo and J. W. Head, *Electronic & Radio Engr*, November 1958, p. 412.
5 "A Twin-T RC Oscillator", M. J. Tucker, *Electronic Engng*, August 1955, p. 346.
6 "Phase-Shift Oscillator", W. C. Vaughan, *Wireless Engineer*, December 1949, p. 391.
7 "High-Frequency Resistance Capacitance Oscillators", G. W. Holbrook, *Electronic Engng*, December 1953, p. 509.
8 "A Two-Phase Low-Frequency Oscillator", E. F. Good, *Electronic Engng*, April and May 1957, pp. 164 and 210.
9 "Seven-League Oscillator", F. B. Anderson, *Proc. Inst. Radio Engrs*, August 1951, p. 881.
10 "Polyphase Oscillators", A. S. Gladwin, *Electronic & Radio Engr*, January 1958, p. 16.
11 "The Design and Performance of a Simple V.L.F. Oscillator", R. A. Seymour and J. S. Smith, *Electronic Engng*, September and November 1955, pp. 380 and 507.
12 "A Very Low-Frequency Three-Phase Oscillator", M. D. Armitage, *Electronic Engng*, July 1957, p. 318.

MATHEMATICAL TOOLS **By Computer**

Interpolation and Extrapolation

Recently, especially since the invention of electronic computers, there has been a great increase in the number of functions which are tabulated, and the question frequently arises: How are we to obtain, to a satisfactory degree of accuracy, the value of the function for an argument which is not tabulated ?

Suppose therefore that we know from the table, which is at intervals α of the argument t for the function $f(t)$, that

$$f(t_0-\alpha) = f_{-1}\,;\; f(t_0) = f_0\,;\; f(t_0+\alpha) = f_1\,;$$
$$f(t_0+2\alpha) = f_2 \quad \ldots \quad (1)$$

so that f_{-1}, f_0, f_1 and f_2 are simply numbers read out from the table. Then if we require the value of $f(t)$ for any value $(t_0+k\alpha)$ of t between t_0 and $t_0+\alpha$ (so that $0<k<1$), we can obtain it by means of Bessel's (quadratic) interpolation formula

$$f(t_0+k\alpha) = f_0 + k\,[f_1 - f_0] - \frac{k(1-k)}{4}\,[(f_2-f_1)-(f_0-f_{-1})] \qquad (2)$$

We notice that Equ. (2) is quadratic in k and necessarily gives $f(t_0)$ correctly as f_0 when $k=0$; it also gives $f(t_0+\alpha)$ correctly as f_1 when $k=1$. It is not obvious that Equ. (2) is the best quadratic interpolation formula for obtaining $f(t)$ when t is between t_0 and $t_0+\alpha$, but we shall assume that this is so for the purposes of this article, and see what follows from that assumption. A discussion of the relative merits of Equ. (2) and other well-known interpolation formulae is outside the scope of these articles.

Consider first a numerical example—the derivation of tan 80° 3′ and tan 80° 5′ from a table giving tan θ at intervals of 6′ for θ, so that tan 79° 54′, tan 80°, tan 80° 6′ and tan 80° 12′ are tabulated. This example is chosen because some books of tables merely remark that 'differences' in this region of the tangent table are untrustworthy, and because it illustrates the full power of Equ. (2). There are many cases in which the contribution of the last term on the right-hand side of Equ. (2) is negligible for all values of k between 0 and 1, but we shall consider the simplification then possible later.

For using Equ. (2), the tabulated values and their differences should be arranged as in Table 1. Some sets of tables include first, second and even higher-

TABLE 1

θ	tan θ	First Differences	Second Differences
79° 54′	5·6140		
		0·0573	
80° 0′	5·6713		0·0011
		0·0584	
80° 6′	5·7297		0·0013
		0·0597	
80° 12′	5·7894		

order differences which are obtained similarly.

In this table, the second, or tan θ, column is obtained direct from the tabulated values. The column "First Differences" is obtained as the difference between two consecutive tabular entries ; as tan θ increases with θ, these differences are all positive, but the sign of the differences in important. The first difference 0·0573, which is 5·6713 — 5·6140 or tan 80° 0′ — tan 79° 54′, is conveniently placed half-way between the line 79° 54′ and the line 80° 0′, and similarly with the remaining first differences. Each entry in the second-difference column is likewise obtained as the difference between the two first-differences between which it lies, thus the second-difference entry 0·0011 is obtained as 0·0584 — 0·0573, and is placed on a level half-way between these two first-differences ; that is, on the 80° 0′ level. Again, the sign of the second-differences matters ; it is positive here because not only does tan θ increase with θ, but $\{\tan(\theta + 6') - \tan\theta\}$ also increases with θ in the range of θ under consideration.

We are now ready to apply Equ. (2). t_0 is 80°, α is 6′, f_{-1} is tan 79° 54′ or 5·6140, f_0 is tan 80° or 5·6713, f_1 is tan 80° 6′ or 5·7297 and f_2 is tan 80° 12′ or 5·7894. Hence the coefficient of k in Equ. (2) is merely 0·0584, the middle entry in the first-difference column. The coefficient of $\frac{1}{4}k(1-k)$ in the last term of Equ. (2) is $(f_2 - f_1) - (f_0 - f_{-1})$, that is, the difference between the lowest entry in the first-differences column and the highest entry in the first-differences column ; this is the sum of the two entries in the second-differences column. Thus Bessel's interpolation formula applied to the range of tan θ under consideration becomes

$$\tan(80°6k') = 5\cdot6713 + 0\cdot0584k - \tfrac{1}{4}k(1-k).\,0\cdot0024 \quad (3)$$

Notice that as the tabular interval is 6′, k is $\frac{1}{2}$ when we seek tan 80° 3′ and $\frac{5}{6}$ when we seek tan 80° 5′. Also, the sign of the last term of Equ. (3) needs watching; it is negative when the second-differences are positive as here. Putting $k = \frac{1}{2}$ and $k = \frac{5}{6}$ in Equ. (3), we obtain

$$\tan 80°\,3' = 5\cdot7003(5)\ ;\quad \tan 80°\,5' = 5\cdot7199 \quad (4)$$

and these agree with tabulated values of tan 80° 3′ and tan 80° 5′.

Thus we are able by means of the general interpolation formula, Equ. (2), to obtain tan 80° 3′ to the same degree of accuracy as the tabular entries in the tangent table in spite of the very rapid increase of tan θ in this neighbourhood. If we try to determine tan θ for values of θ very near 90°, we might find that Equ. (2) was not sufficiently accurate for tabulations at 6′ intervals. There are two obvious remedies: the interval of tabulation can be made smaller, say 1′, for such values of θ, or we can use a more general formula than Equ. (2) which is of higher degree in k and involves higher-order differences. We shall not consider this further here, because for the accuracy required in practical engineering problems, Equ. (2) is usually quite adequate. It remains to consider the easier case (which is fortunately the usual one) where the second-differences are so small that the last term of Equ. (2) can be neglected. Now in the case of the tangent table just considered, where Equ. (2) reduces to Equ. (3), the maximum value of $\frac{1}{4}k(1-k)$ is $\frac{1}{16}$ (when $k = \frac{1}{2}$), so that the last term of Equ. (3) is only just worth retaining. It would not have been worth retaining if the sum of the two second-differences in Table 1 had been less than 0·0008. This happens, for example, if we are concerned with tan 72° 3′. The table corresponding to Table 1 is then Table 2,

TABLE 2

θ	tan θ	First Differences	Second Differences
71° 54′	3·0595		
		0·0182	
72° 0′	3·0777		0·0002
		0·0184	
72° 6′	3·0961		0·0001
		0·0185	
72° 12′	3·1146		

so that Equ. (2) becomes

$$\tan(72°6k') = 3\cdot0777 + 0\cdot0184k - \tfrac{1}{4}k(1-k).\,0\cdot0003 \quad (5)$$

and the last term is never numerically greater than 0·00001875. When this happens, linear interpolation is sufficient, that is, for θ between 72° 0′ and 72° 6′ we can regard tan θ as increasing uniformly with respect to θ or k. However, the difference between tan 72° 6′ and tan 72° 0′ is 0·0184 whereas the difference between tan 73° and tan 72° 54′ is 0·0203. Hence between 72° 0′ and 72° 6′ we can regard tan θ as increasing by $\frac{1}{6}$ of 0·0184 per minute of increase in θ, whereas between 72° 54′ and 73° we must regard the increase as $\frac{1}{6}$ of 0·0203 per minute in θ, which is appreciably more. To obtain five-figure accuracy, therefore, we must subtract tan 72° 0′ from tan 72° 6′ to find the rate of increase for values of θ between 72° 0′ and 72° 6′, and we must subtract tan 72° 54′ from tan 73° to find the rate of increase for values of θ between 72° 54′ and 73°. We cannot use the same rate of increase for all values of θ between 72° and 73°. For values of θ between 62° and 63°, however, this can be done without serious error. For the difference between tan 62° 6′ (1·8887) and tan 62° (1·8807) is 0·0080, and the difference between tan 62° 54′ (1·9542) and tan 63° (1·9626) is 0·0084, so a mean rate of increase of 0·0082 per 6′ interval in the range 62°–63° is sufficiently accurate. To the nearest 0·0001, $\frac{1}{6}$ of 0·0082 is 0·0014, $\frac{1}{3}$ of 0·0082 is 0·0027, $\frac{1}{2}$ of 0·0082 is 0·0041, $\frac{2}{3}$ of 0·0082 is 0·0055, and $\frac{5}{6}$ of 0·0082 is 0·0068. Thus we obtain the entries 14, 27, 41, 55 and 68 which are found in the 'mean differences' or 'mean proportional parts' columns of five-figure tangent tables in the 62° row ; these mean differences apply to any angle between 62° and 63°. Where 'mean differences' are given, therefore, in any tables, the compiler of the tables has in effect done the interpolation for us; he knows that the second differences are so small that the last term of Equ. (2) does not contribute, and that the first differences are changing so slowly that a satisfactory 'mean' rate of increase can be used, and we are spared the trouble of having to find the difference between the two tabulated entries surrounding the point we require, and dividing that difference into suitable proportional parts.

Taylor's Theorem

It can also happen that at a given moment (say $t = t_0$) we know (theoretically or experimentally) the values of some function of time and of a number of its derivatives, and that we want to find a simple expression $F(t)$ which is indistinguishable from that function for values of t not too far removed from t_0. The function may be a very complicated expression, or it may not even be explicitly known; $F(t)$ will be effectively a polynomial in t, perhaps only a quadratic or even linear, but it may occasionally be worth allowing $F(t)$ to be a polynomial of higher degree. The formula which covers this situation is known as Taylor's Theorem. This can be stated by means of a single equation

$$F(t) = F(t_0 + h) = f(t_0) + \frac{h}{1!}f'(t_0) + \frac{h^2}{2!}f''(t_0) + \ldots + \frac{h^{r-1}}{(r-1)!}f^{(r-1)}(t_0) + \frac{h^r}{r!}f^{(r)}(t_0 + \theta h) \quad \ldots \quad (6)$$

but that equation requires considerable explanation, as follows. We require $F(t)$ when t is near t_0, say equal to $t_0 + h$; t_0 may have any size, but h may have to be small (though of either sign). $f(t_0), f'(t_0), \ldots f^{(r-1)}(t_0)$ are the known values of the function under consideration and its first $(r-1)$ derivatives when $t = t_0$. We assume that the function has an rth derivative, which we will call $f^{(r)}(t)$, for values of t sufficiently near t_0. For all functions relevant to practical engineering, this rth derivative will be finite. θ is an unknown quantity between 0 and 1. In using Equ. (6) we need to ensure that the last term of the right-hand side is negligible, so that its precise value need not be determined. If we can arrange this, Equ. (6) reduces, without the last term, to a polynomial of degree $(r-1)$ in h or $(t - t_0)$, and we can regard the function under consideration as effectively represented by $F(t)$ when t is sufficiently near t_0, or h is sufficiently small.

We can see the reasonableness of Equ. (6) by means of a simple example. By straightforward multiplication it is clear that

$$(t_0 + h)^4 = t_0^4 + 4t_0^3h + 6t_0^2h^2 + 4t_0h^3 + h^4 \quad \ldots \quad (7)$$

$$= t_0^4 + (4t_0^3)\cdot\frac{h}{1!} + (12t_0^2)\cdot\frac{h^2}{2!} + (24t_0)\frac{h^3}{3!} + (24)\frac{h^4}{4!} \quad \ldots \quad (8)$$

and t_0^4, $4t_0^3$, $12t_0^2$, $24t_0$ and 24 are precisely the values of t^4 and its successive derivatives when $t = t_0$; all higher derivatives of t^4 are zero for all values of t including t_0. Thus, if the function under discussion happened to be t^4, the representation of it by means of Equ. (6) would have been completely correct for all values of t so long as r was 5 or more, and the last term of Equ. (6) would be zero. It can similarly be shown that if the function under discussion is any polynomial of degree $(r-1)$, Equ. (6) will represent it correctly for *all* values of t with the last term omitted. If however h is sufficiently small, say numerically less than $0{\cdot}01\,t_0$, $(t_0 + h)^4$ is indistinguishable from $t_0^4 + 4t_0^3h$; if h is less than about $0{\cdot}05\,t_0$, $(t_0 + h)^4$ differs from the first three terms of Equ. (8) by less than $0{\cdot}0005\,t_0^4$, and not until h is about $0{\cdot}2\,t_0$ is there an appreciable contribution from the last term of Equ. (8). In the general case, the last term of Equ. (6) is not identically zero as above, but it can be made as small as we please, for a given value of r, by taking h sufficiently small. There will therefore be a limited range of h for which we can regard $F(t)$ as adequately represented by the first two terms on the right-hand side of Equ. (6), a somewhat wider range of h for which the first three terms of the right-hand side of Equ. (6) are adequate, and so on.

If the function under discussion is $A\sin(\omega t + \phi)$, its rth derivative is $A\omega^r \sin(\omega t + \phi + \frac{1}{2}r\pi)$, which is numerically less than or equal to $A\omega^r$. Hence the last term in Equ. (6) cannot numerically exceed $A\omega^r h^r/r!$ If the function has a number of sinusoidal components, the last term in Equ. (6) similarly cannot exceed $(h^r/r!)$ times the sum of the values of $A\omega^r$ for each of the components, and only high-frequency components will contribute appreciably if r is moderate or large. It is therefore reasonably easy to set an upper limit to the value of h which can safely be used when a given number of terms of Equ. (6) is taken to approximate to a function which is oscillating but has no components at frequencies above a given value say $\omega/2\pi$. The main usefulness of Equ. (6), however, is in cases where the first two or three terms are an adequate representation of the function under discussion over a relatively short range. When representation is required over a relatively wide range, it is more satisfactory to tabulate (or determine experimentally) a sufficient number of equally-spaced values of the function under discussion, and interpolate between them as explained in the first part of this article.

OBITUARY

Stephen Butterworth, O.B.E., who recently died at the age of 73 was on the Admiralty scientific staff from 1921 until his retirement in 1945. Although much of his work has been outside the radio field, he made noteworthy contributions to it in the earlier days.

In the Twenties he took a prominent part in the development of low-loss inductors, but his most important work was on "The Apparent Demodulation of a Weak Station by a Stronger One" and "The Theory of Filter Amplifiers".

The latter paper, published in 1930, is still widely quoted and by it he achieved the fame of having his name commonly associated with a type of filter response. The "Butterworth Filter" and the "Butterworth-type of response" are phrases widely used in modern filter literature.

Low-Loss Structures In Waveguides

EXPERIMENTAL EVALUATION OF EQUIVALENT CIRCUIT PARAMETERS

By M. F. McKenna, Ph.D., B.Sc.*

SUMMARY. *The relative variations of electric-field intensity inside a rectangular waveguide at certain positions in front of a low-loss structure when terminated in a variable reactance are shown to give information leading to the evaluation of the parameters of the equivalent network of the structure. The experimental procedure to be followed for determining the parameters of simple obstacle structures is also discussed.*

Consider a waveguide propagating its lowest mode and let it contain a single obstacle structure of low-loss. The obstacle in the waveguide may be considered as a reactive four-terminal network in a transmission line whose loss may be considered negligibly small. If a variable reactance is placed beyond the obstacle, taking the form of a section of the same waveguide terminated in a short-circuiting plunger, the standing-wave pattern produced by the obstacle will have nodes of zero field strength. A change of reactance, corresponding to the movement of the plunger, will shift the standing-wave pattern and the variation of electric-field intensity at certain points in front of the obstacle can be conveniently related to the plunger movement and the parameters of the equivalent network of the obstacle.

The theory which follows can be applied to any loss-less line system provided it contains loss-less structures and is developed for one propagating its lowest mode. It is only as a matter of convenience that potentials and currents are used in place of electric and magnetic field quantities.

Theory

Consider a high-frequency source connected to a loss-less line as shown in Fig. 1 and let it be represented by a constant-current generator of strength I and of admittance Y_g. The low-loss structure under consideration is assumed to have a T or π equivalence, its output terminals are connected to a variable reactance which is produced by a variable short-circuited section of line of length L and also of characteristic admittance Y_0. The potential difference at any point along the line distant z from the input terminals of the equivalent network can be found from the line equations and is,

$$V = \frac{I.e^{-j\beta L_1}}{(Y_0 + Y_g)} \cdot \left\{ \frac{e^{j\beta z} + \rho_t e^{-j\beta z}}{1 - \rho_t \cdot \rho_g e^{-2j\beta L_1}} \right\} \quad \ldots \quad \ldots \quad (1)$$

where ρ_g is the reflection coefficient of the generator; viz., $(Y_0 - Y_g)/(Y_0 + Y_g)$, and ρ_t is the reflection coefficient as presented by the input terminals of the network. ρ_t will depend on the parameters of the network and the position of the short circuit. Assuming that the generator can be matched to the line (i.e., $Y_g = Y_0$) thus making $\rho_g = 0$, then

List of Symbols

V	Potential difference
I	Electric current
Z_0	Characteristic impedance
Y_0	Characteristic admittance ($1/Z_0$)
X	Reactance
x	Normalized reactance, X/Z_0
B	Susceptance
b	Normalized susceptance, B/Y_0
ρ	Reflection coefficient
ϕ	Phase angle of the reflection coefficient
λ	Wavelength in free space
β	Phase shift constant
λ_g	Wavelength in rectangular waveguide

$$V = \frac{I}{2Y_0} e^{-j\beta L_1} \left(e^{j\beta z} + \rho_t e^{-j\beta z}\right) \quad \ldots \quad \ldots \quad \ldots \quad (2)$$

Since the input impedance of the network, when terminated in a reactance, is always reactive the magnitude of ρ_t is always unity. If the phase angle of ρ_t is assumed to be ϕ, the square of the magnitude of the voltage at any point along the line is, from (2)

$$|V|^2 = \frac{I^2}{Y_0^2} \cdot \cos^2 (\beta z - \phi/2) \quad \ldots \quad \ldots \quad \ldots \quad (3)$$

For $z = n\lambda/2$, where n is an integer,

$$|V_1|^2 = \frac{I^2}{2\,Y_0^2} \cdot (1 + \cos \phi) \quad \ldots \quad \ldots \quad \ldots \quad (4)$$

and, $z = (2n + 1)\lambda/4$

$$|V_2|^2 = \frac{I^2}{2\,Y_0^2} \cdot (1 - \cos \phi) \quad \ldots \quad \ldots \quad \ldots \quad (5)$$

The value of ϕ will depend on the parameters of the network and also upon L. Typical variations of $|V_1|^2$ and $|V_2|^2$ with L are shown in Fig. 2. At points P and Q, $|V|^2$ will have a value of $I^2/8Y_0^2$ and they may be considered as 'half-power' points. The values of ϕ at some of the principal points of interest are given as follows. At R and S, $\phi = 0$; at P, $\phi = \pi/2$; at Q, $\phi = -\pi/2$; at M, $\phi = \pi$ and at T, $\phi = -\pi$. If the volt-

* *Formerly Royal Naval College, Greenwich. Now at A.T.E. School of Electronics, Liverpool.*

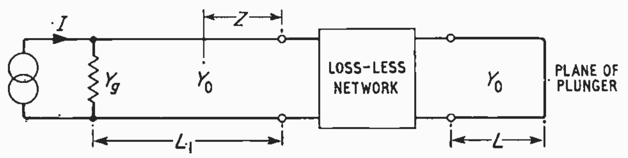


Fig. 1. *H.F. source connected to a loss-less line*

age variation at a point $z = n\lambda/2$ or $z = (2n + 1)\lambda/4$ can be observed when L is varied, values of ϕ can be obtained which will allow the parameters of the network to be calculated.

To determine the parameters of the network consider two general forms which it is likely to take, see Fig. 3. Since the network is assumed loss-less, the parameters will be wholly reactive and may be considered to have values normalized with respect to the characteristic impedance of the line. Assuming a T network as in Fig. 3(a), the impedance at the terminals 1, 2 when the output terminals 3, 4 are terminated in a reactance $jZ_0 \cdot \tan \beta L$ is reactive and is,

$$X = j\left\{x_1 + \frac{(x_3 + \tan \beta L)x_2}{x_2 + x_3 + \tan \beta L}\right\} Z_0 \quad \ldots \quad \ldots \quad (6)$$

If a loss-less line is terminated in a reactance X, the phase angle of the reflection coefficient is given by $\phi = 2 \cot^{-1} X/Z_0$. Substituting for ϕ the appropriate values of angle given by the salient points on the curves of Fig. 2, the parameters of the T-network are, in normalized values,

$$\left.\begin{aligned} x_2{}^2 &= \frac{2 \,.\, (\tan \beta l_3 - \tan \beta l_2)\,(\tan \beta l_3 - \tan \beta l_1)}{(\tan \beta l_2 - \tan \beta l_1)} \\ x_1 &= \frac{2 \,.\, \tan \beta l_3 - (\tan \beta l_1 + \tan \beta l_2)}{(\tan \beta l_1 - \tan \beta l_2)} - x_2 \\ \text{and } x_3 &= -\tan \beta l_3 - x_2. \end{aligned}\right\} \quad (7)$$

If the structure is to be represented by a π-network as shown in Fig. 3(b), the admittance between the terminals 1, 2 when the output terminals 3, 4 are terminated in a susceptance $-jY_0 \cot \beta L$ is susceptive and is,

$$B = -j\left\{b_2 + \frac{b_1\,(b_3 - \cot \beta L)}{b_1 + b_3 - \cot \beta L}\right\} Y_0 \quad \ldots \quad (8)$$

Since the phase angle of the reflection coefficient is $\phi = 2 \tan^{-1} B/Y_0$ and as, in the case of the π-network, the appropriate values of ϕ are given at the salient points on the curves of Fig. 2, the parameters in terms of normalized susceptances are,

$$\left.\begin{aligned} b_1{}^2 &= \frac{2(\cot \beta l_4 - \cot \beta l_2)\,(\cot \beta l_4 - \cot \beta l_1)}{(\cot \beta l_1 - \cot \beta l_2)} \\ b_2 &= \frac{2 \,.\, \cot \beta l_4 - (\cot \beta l_1 + \cot \beta l_2)}{(\cot \beta l_1 - \cot \beta l_2)} - b_1 \\ \text{and } b_3 &= \cot \beta l_4 - b_1 \end{aligned}\right\} \quad \ldots \quad (9)$$

The ambiguity of sign for x_2 and b_2 may be resolved in many cases with a foreknowledge of the kind of obstacle being used. For symmetrical networks $x_1 = x_3$ and $b_2 = b_3$ so that the expressions given in equations (7) and (9) reduce to simpler forms. By measuring the appropriate values of L at the salient points on the V^2–L curve, the parameters of the network can be evaluated according to equations (7) and (9). Although the theory applies only to loss-less lines and structures it may also be used where the loss is quite small and, in particular, to short lengths of waveguides containing metallic obstacle structures. If the mode of propagation through the waveguide is its lowest H or E mode, the obstacle structure may be represented as a four-terminal network the parameters being reactive and normalized with respect to the characteristic impedance of the waveguide. The variations in the magnitude of the electric field in front of the obstacle taken at suitable points along the middle line of the waveguide will be similar to those of V for the line. The points concerned are assumed to be sufficiently remote from the obstacle so that the evanescent-mode content is negligibly small and that the transverse electric-field variation is the same as for the dominant or propagating mode. A standing-wave detector can be used to record the field variations at points $n\lambda_g/2$ or $(2n + 1)\lambda_g/4$ from the chosen input terminals of the obstacle.

Experimental Procedure and Results

A standard microwave bench complete with component parts and a section of waveguide containing the obstacle structure is all that is required for the measurement of the equivalent network parameters. If the standing-wave detector, used to measure the field variations, is connected to a low-resistance recording instrument, the response may be considered very nearly square law.

To produce the variable reactance beyond the obstacle a short-circuiting plunger is used. Having suitably positioned the standing-wave detector from the input terminals of the obstacle the variation in its current ($\propto |V|^2$) can then be plotted against the movement of the plunger (L). It is advisable to keep the probe penetration of the detector as small as possible and to check that its loading is also small. This may be done by examining the detector response curve over a convenient range of plunger movement when the obstacle is not present in the waveguide. If there is appreciable loading, the curve will be distinctly asymmetrical.

Care should be taken to provide adequate attenuation between source and load so as to minimize frequency pulling which is likely to occur when the plunger is moved. A check to ensure that the source is matched

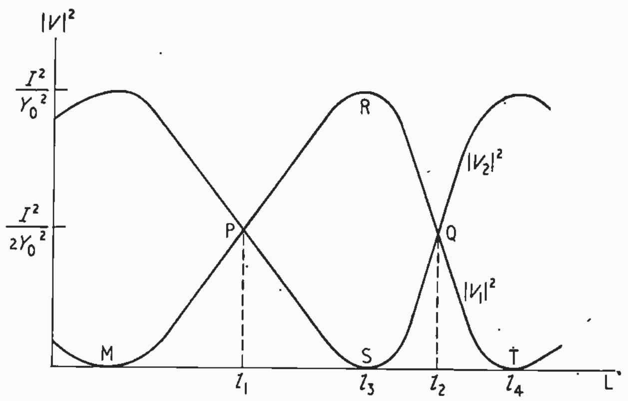


Fig. 2. *The points P and Q are 'half-power' points*

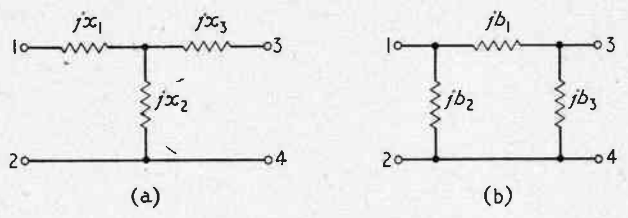


Fig. 3. *Two forms of equivalent network*

to the waveguide should also be made. A technique for matching the source to the waveguide has already been described by Parr[1].

The positioning of the standing-wave detector can be done experimentally, if necessary, by moving it until the field patterns, corresponding to $|V_1|^2$ and $|V_2|^2$ in the line case, intersect at the 'half-power points'. Under these conditions the position of the probe of the detector is directly related to the electrical axis of symmetry of the obstacle. For those obstacles which have physical symmetry, the physical and electrical axes of symmetry will be coincident.

To test the efficacy of this method a series of measurements was made on thin metal wires forming inductive posts in a rectangular waveguide at a free space wavelength, λ, of the order of 3·2 cm. The H_{01} mode propagating in the waveguide had a wavelength of approximately 4·5 cm. The reason for choosing inductive posts was that they could be made easily and accurately positioned in the waveguide. Experimental results for small diameter posts ($0 \cdot 0023\ \lambda_g$) showed that the series arms of the equivalent T-network had negligibly small values compared with the shunt ones. As a check on the performance of the equipment, measured values of the equivalent network could be used to calculate the angle of the reflection coefficient of the structure and plunger. By using equations (4) or (5) a graph of relative field intensity could then be drawn and compared with that obtained experimentally.

For metal posts up to $0 \cdot 035\ \lambda_g$ in diameter, the experimental results compared favourably with the theoretical values given in the "Waveguide Handbook"[2] and, in general, agreement between theory and experiment for the shunt components was of the order of $\pm 5\%$. For larger diameter posts, however, the experimental results were susceptible to large errors due, principally, to the loss of the system; the nodes of the electric field no longer being zero.

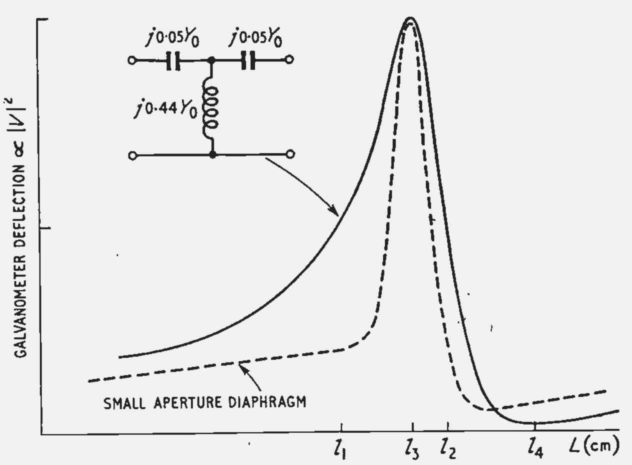


Fig. 4. *Response curve for an asymmetrical inductive diaphragm and the equivalent circuit*

Measurements made on thin inductive and capacitive diaphragms also showed reasonable agreement with theoretical values and, when these values were not available, a not unfavourable comparison was obtained with a more precise method of measurement described by Marcuvitz[3]. A typical response curve for an asymmetrical inductive diaphragm is shown in Fig. 4, where it will be observed that the minimum value is not quite zero. For diaphragms of smaller aperture size a typical response curve might be like that as shown by the dotted curve of Fig. 4.

A method of the kind just described has the limitation that it cannot be used successfully with obstacles producing large reflections. It has, however, been used to confirm the presence of higher mode coupling between adjacent obstacles in a rectangular waveguide and to determine the change in the equivalent circuit parameters of the obstacles when placed in close proximity to each other[4].

An experimental method of this type can be used with reasonable accuracy provided the generator can be kept matched to the waveguide, the probe penetration made small and frequency pulling of the source not great. The use of a well-designed ferrite isolator would permit an even smaller probe penetration, at the same time providing adequate isolation of the source. Experience has shown also that it is important to check the exact position of the equivalent plane of short circuit of the plunger. Any misalignment of the waveguide at the flanges can also produce an error in the final result.

Conclusions

The principal conclusion which can be drawn from an experiment of this kind is that the salient points on the relative field-intensity curves can be readily obtained thus enabling rapid evaluation of the equivalent-circuit parameters of the waveguide structure to be made. Experience has shown that although high accuracy is unlikely, satisfactory results can be obtained provided the precautions, outlined in the previous section, are observed. Experimental results indicate that the method is best suited for an obstacle which causes small reflection from itself.

Acknowledgements

Acknowledgements are made to Prof. Willis Jackson, F.R.S., under whose guidance this work has been carried out, and to Prof. G. Nicholson for providing the necessary facilities. Acknowledgements are also made to those colleagues with whom this paper has been discussed.

REFERENCES

1 "Matching Discontinuities in Waveguides," J. C. Parr, *Wireless Engineer* October 1953, Vol. 30.
2 "Waveguide Handbook," Vol. 10, Section 5.11, p. 257. M.I.T. Radiation Laboratory Series (McGraw-Hill).
3 "On the Representation and Measurement of Waveguide Discontinuities," N. Marcuwitz, *Proc. Inst. Radio Engrs*, June 1948, Vol. 36.
4 Thesis entitled "An Investigation of the Impedance Characteristics of Certain Discontinuities in Waveguides," M. F. McKenna, University of London 1955.

Selection of Matched Components from Random Samples

By D. P. C. Thackeray, B.Sc., A.Inst.P.*

SUMMARY. *Some problems in component selection are outlined, with especial reference to the selection of transistors from random samples, the selection of such samples from stocks, and the stocking of quantities which make such procedures possible. The methods are briefly illustrated by the example of a d.c. transistor amplifier, temperature and gain stabilized. An analogy is drawn between such procedures and those involved in the selection of personnel.*

Executives are finding it increasingly useful to base their decisions on the calculated risks associated with the adoption of a given procedure. In purely administrative matters this in no way absolves the executive from injudicious assessment of individual factors affecting the risks. In many cases, too, action is taken on a business decision if the probability of success is greater than 0·5. In matters of science and engineering, higher probabilities are usually demanded, even as great as unity; i.e., a certainty. Correspondingly, the calculations may be based more upon arithmetic than upon logic, since accountable quantities and qualities of things are usually involved. In what follows, to illustrate this, examples are drawn from an entirely fictitious pattern of component stocking and selection. Since these seem to be appropriate to transistor usage, a genuine illustration is then drawn from this field.

Stocking-Sampling-Group Selection Pattern

It affords considerable simplification of the general problem to introduce initial reservations. To this end it is as well to consider explicitly what common features a component stock possesses. It is clear that the manufacturer is responsible for much initial selection; e.g., at the purchasing stage components are identifiable entities, characterized not only by physical distinctions which distinguish the resistor from the capacitor, etc., but also by classification into electrical properties within well-defined tolerances. One cannot, however, necessarily assume that there is an entirely rectangular distribution of values of a given parameter within such a tolerance group. From the point of view of matching components for this parameter, such an assumption makes for easier handling of the calculations; and since in matching problems it gives the least optimistic answer, it has the advantage of adding a reserve or safety factor.

Unless one is interested in components at the production stage, it is therefore reasonable in such cases to adopt the simplification of rectangular distribution within the stated tolerance limits, or suspected limits. Since tolerances range from the $\pm$ 1% of the resistance of the better high-stability resistors, to factors of as much as 3 : 1 in the I'_{c0} of junction transistors, and the percentage stabilities of such different components may also vary as widely, it may also be convenient to consider as a useful parameter the quotient of these quantities. This new quantity appears as the significant number of different values of the same parameter that lie within the given tolerance limits. Thus, if a $\pm$ 10% tolerance resistor has a stability of $\pm$ 1%, there are only 10/1 significantly different groups to be extracted from a random sample.

If now a pattern of sampling from stock and matching from samples can be established for the use of a particular component, it becomes possible not only to predict suitable stocking quantities but also to guide matchers in the extraction of suitable samples.

Transistor Selection Problem

To develop the method, suppose that a demand exists for a group of four transistors matched to a $\pm$5% I'_{c0} stability limit from a sample containing a rectangular distribution of this parameter of $\pm$ 50%. Here there can be only 50/5 = 10 significantly different groups to sort the sample into. It would be possible, occasionally, to find a particularly awkward sample of thirty which distributed three transistors into each of these groups. With the addition of a single extra transistor to the sample it would, however, be impossible that at least one group should not contain the required four. Thus, the estimate of the sample required to meet this selection demand is bounded by the lower limit of three which gives zero probability (impossibility), and the upper limit of thirty-one which gives unity probability (certainty), of finding at least one suitable group of four.

If the demand is likely to be repeated, it is only necessary to restore the sample, now depleted by the removal of the first four, to its original number, by the addition of four more from stock. In this case, it is likely that the minimum stocks held would be related to the minimum certainty quantity of thirty-one, while the rate of stock replenishment above this number would be related to the expected demands. This allows addition-

* *Research Laboratory for the Physics and Chemistry of Solids, Department of Physics, University of Cambridge,* NOW AT *Vickers Group Research Establishment.*

ally that unexpected demands may often be satisfied also, since it can be expected that matched groups of four may sometimes be discovered in greater profusion than would be predicted by conditions of certainty. If this extra facility is undesirable or unnecessary, or if the demand is occasional, of low priority, or alternative to some other demand, to name a few possibilities, then it becomes necessary to allot to the probability of finding a group of four a value less than one. The calculation of the sample quantity for this probability must be considered next.

Selection Probabilities Less than Unity

Consider an algebraic version of the problem outlined above, where it is desired to select a group of x transistors, matched to the stability limit in I'_{c0} from a sample of n transistors of given tolerance in this parameter, with rectangular distribution of parameter values within the tolerance limits. Suppose there could be only M significant groups, as developed above. A method is: When x is smaller than $n/2$,

1. Write down all possible selections of $x - 1$, $x - 2$, . . . 2, 1, 0 transistors, with M terms in each selection and the sum of each selection being n.

E.g., for $n = 20$, $M = 10$ and $x = 4$ a typical selection could be: 3 3 3 3 3 2 2 1 0 0.

2. Evaluate the number of permutations of each selection.

E.g., for the numerical selection above there are:

$\frac{10\,!}{5\,!\,2\,!\,2\,!\,1\,!} = A$ (say) permutations*, since there are 10 terms altogether comprising 5 threes, 2 twos, 2 zeros and 1 one.

3. Evaluate the probability of each selection occurring.

E.g., for the numerical selection above the probability is:

$$\frac{20\,!}{10^{20}\ (3\,!)^5\ (2\,!)^2\ (1\,!)^1\ (0\,!)^2} = B \text{ (say)*}$$

4. The product AB now gives the probability of the particular selection appearing in any of its permutations. Hence summing all such products for the selections written down in (1) above, denoted algebraically as ΣAB, affords a value for the probability of appearance of any one of these selections appearing in any one of its permutations.

5. However, the selections written down in (1) are, since their terms are each smaller than x, those which do *not* satisfy the selection requirements. Hence ΣAB is the probability of appearance of selections which will *not* afford x matched transistors. Conveniently, since the required x will either be afforded or not be afforded, ΣAB may now be subtracted from unity, to give the probability, P, of appearance of selections which will afford x matched transistors; i.e.,

$$P = 1 - \Sigma AB$$

On occasions when x is larger than $n/2$ this artifice may be dispensed with, as the determination of successful selections will involve less arithmetic; i.e., step (1) will be to write down selections of

$n - 1, n - 2, \ldots x + 1, x$ transistors, instead.

This has been expanded in greater detail in the Appendix, both to show that the calculation is algebraically possible and for the convenience of possible users. Results are plotted in Fig. 1, of probability P against sample number n, for the particular numerical problem considered above. It can be seen that the points already established ($n = 3$ and $n = 31$) are accompanied by others giving the following probabilities:

n	P
3	0
10	0·13
15	0·48
20	0·87
25	0·99
31	1.0

These points have been joined by a smooth line in order to facilitate the derivation, by interpolation, of intermediate points. The most striking features of the curve are the small changes in probability for ranges $n = 0$ to $n = 10$, and $n = 20$ to $n = 30$, and the rapid change in the range $n = 10$ to $n = 20$. Thus in this particular problem a probability of 0·9 can be assured by taking samples only two-thirds the size of that assuring certainty, while a five-sixths sample affords 0·99 probability. Thus considerable savings in stock may sometimes be possible with very small accompanying risks.

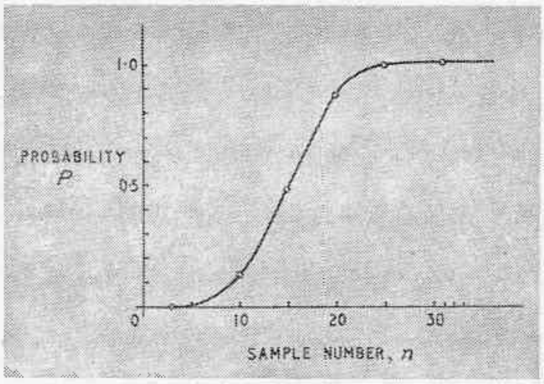


Fig. 1. *A smoothed plot of the probability, P, of finding at least four components matched in a particular parameter, when the sample, of n components, may contain components having any one of ten distinct values of this parameter. The steep rise in P between n = 10 and n = 20 should be noted, as this affords high values of P, well below the certainty (P = 1) value for n, of* 31

Other Applications

That such a solution is by no means limited to one particular field may be established by considering an analogous situation in an entirely unrelated field.

Consider a pool of unskilled labour from which it is customary to withdraw platoons of workers, for particular jobs, normally on the basis of skilled judgment and previous experience of individual capabilities. Four men are unpredictably required for level carriage of some object at shoulder height. A variation of this parameter

* Cf. "Higher Algebra", Hall & Knight, p. 402.

of one-tenth the normal limits for the whole group is acceptable. The personnel officer is required to give a spot decision on how many men should be paraded for selection. Clearly the answer is again:

thirty-one for a certainty,
twenty-five for a probability of 0·99, etc.;

but previous experience of such problems would afford realization that the chances were still quite high at only twenty men, a decision on which would allow the other eleven to pursue some more profitable occupation.

Transistor D.C. Amplifier

Opportunity for a practical test of the above method occurred when it was desired to build the direct-coupled amplifier of Fig. 2. The transistor pairs T_1T_2 and T_3T_4 need to be matched principally for I'_{c0}, and it is advisable, where possible, that T_1T_2 be matched for V_{be}, at $I_b = 0$. Considering only the former condition, a certainty is achieved for selection of a matched pair, when ten different values are possible, by taking a sample of eleven. For two matched pairs, a sample of thirteen is needed. High probabilities for one, two, and three pairs are afforded by seven, nine and eleven transistors respectively (much less than the certainty samples of eleven, thirteen and fifteen) as the following table shows:

n	P 1 pair	2 pairs	3 pairs
11	1	~1	0·94
9	~1	0·94	0·66
7	0·94	0·66	0·185
6	0·85	—	—
5	0·7	0·2	0
3	0·28	0	—
1	0	—	—

Experimentally a sample of nine was investigated, being the total stock of a particular type available locally. Two matched pairs were found without difficulty (though only two); the pairs which more closely had similar V_{be}, at $I_b = 0$, were used as T_1T_2, while the other pair became T_3T_4. From the remaining five transistors the two having highest α' were employed as T_5 and T_6. This seems to be a reasonable utilization (two-thirds) for a sample not affording certainty.

It may be added that this method of stabilization against temperature changes (after Shea) proved as effective as anticipated. After a preliminary warm-up of a few minutes, both short-circuit and open-circuit zeros were held for long periods without adjustment. Stability of gain was ensured by adequate negative feedback. It was checked that random selection of transistors produced intolerable thermal drifts in the zeros under the same conditions of operation. Substitution of a different make of transistor, selected by the same methods, produced a similarly effective amplifier.

Acknowledgements

The author tenders grateful thanks to Miss G. Vaisey, of New Hall, Cambridge, for developing a rigorous proof of the methods outlined above, and for the arithmetic leading to Fig. 1; to Mr. G. Hodgson for experimental assistance; and to Messrs. D. Q. Fuller and G. Roman, of Pye Industrial Electronics, Ltd., for a stimulating discussion and the loan of samples of their products.

Conclusion

It has been shown that the matching of components, as well as ancillary and analogous procedures, is susceptible to simple mathematical analysis. One such method is detailed, and its use illustrated by the need for selecting transistors in matched fours. In addition, a set of two matched pairs, for a particular direct-coupled amplifier circuit, is selected from a sample offering a probability of success of less than unity.

APPENDIX

To determine the probability of finding at least x identical objects amongst a total of n objects of M different kinds.

The total possible number of ways, T, in which n objects may be sorted into M different groups is given by

$$T = M^n$$

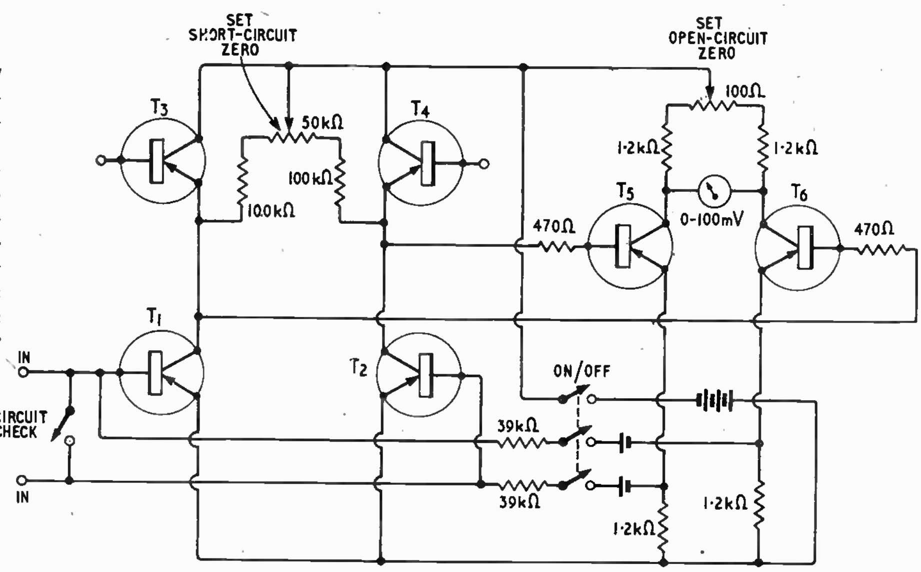


Fig. 2. *A circuit diagram of a direct-coupled transistor amplifier, selection of transistors for which is used as an illustration of the methods described in the text. The transistors T_3 T_4, which appear to function as collector loads for the input stage, when suitably matched reduce zero drifts due to temperature variations. The amplifier, designed as part of a high-temperature pyrometer utilizing the two-colour method, is intended to measure the output currents from two similar barrier-layer photocells. The gain and working points are stabilized by negative feedback*

A fraction, P, of these ways will meet the specified requirements, while a fraction $1 - P$ will not. For x smaller than $n/2$ it is simpler to determine $1 - P$ than to determine P directly. The severe approach described in the text above may be skirted by summing all distributions which do not meet the requirements, and dividing this sum, S, by T, to obtain the required quantity $1 - P$. The method is:

1. Write down all possible selections (S_1, S_2, etc., distributions) of $x - 1, x - 2, x - 3, \ldots 2, 1, 0$ objects, for the conditions that there shall be M terms in each selection, and the sum of each selection shall be n.

2. Determine the group permutations O_1, O_2, etc., possible for each selection. The interchanging of groups would normally afford $M!$ permutations.

However, suppose that in any one (S_1 distributions) of these selections there are:

p groups each containing a objects
q groups each containing b objects
. . . .
. . . .
w groups each containing 0 objects

where $p + q + \ldots + \ldots + \ldots + w = M$

and $pa + qb + \ldots + \ldots + \ldots + w0 = n$

Then, since no importance has been assigned to which objects fall into any particular group,

the interchanging of groups each containing a objects, and
the interchanging of groups each containing b objects, and
. . . .
. . . .
the interchanging of groups each containing w objects (affording $p!$, $q!$, . . . $w!$ permutations respectively), produces no significant redistribution. Hence the total $M!$ needs to be reduced by division successively by $p!$, $q!$, . . ., $w!$. I.e.,

$$O_1 = \frac{M!}{p!q! \ldots w!}$$

3. Determine the object permutations, Q_1, Q_2, etc., possible for each selection. Interchanging of objects would normally afford $n!$ permutations. However, since no importance has been assigned to the order of the objects within the groups, interchanging of objects falling within any group ($a!$, $b!$, etc., permutations) produces no significant redistribution.

Hence the number of different object permutations Q_1 available for distribution in O_1 ways is obtained by division of $n!$,

by $a!$ —— p times
$b!$ —— q times, etc.; i.e.,

$$Q_1 = \frac{n!}{(a!)^p \; (b!)^q \ldots (0!)^w} \text{ etc.}$$

4. The number of significantly different distributions S_1 is given by the product of the group permutations O_1, multiplied by the object permutations Q_1; i.e.,

$$S_1 = O_1 Q_1 = \frac{M!n!}{p!q! \ldots (a!)^p \; (b!)^q \ldots}$$

If all such distributions S_1, S_2, etc., are summed together, the total, S, is that of the number of unsuccessful distributions possible,

$$S = S_1 + S_2 + \ldots, \text{ etc.,}$$
$$= Q_1 O_1 + Q_2 O_2 + \ldots, \text{ etc.}$$

If S be divided by T, as suggested above, the result is $1 - P$, whence

$$P = 1 - S/T$$
$$= 1 - \frac{1}{M^n}\left[\left(\frac{M!\,n!}{p!q! \ldots (a!)^p \,(b!)^q \ldots}\right) + \text{etc.}\right]$$

Relative Speeds of Telegraphic Codes

By D. A. Bell, Ph.D., M.I.E.E.* and T. C. Duggan, B.Sc.†

SUMMARY. *In contrast to codes for machine telegraphy, which usually have all symbols of equal length for all characters, there are other telegraphic codes such as Morse code in which the lengths of symbols vary inversely as the anticipated frequencies of occurrence of the characters. The effective speed is then a function of the language of the text to be communicated.*

Codes in common use either employ spacing elements between characters, which considerably reduces speed, or rely on accurate synchronization between transmitter and receiver. There are other codes, the so-called minimum-redundancy codes, which eliminate the synchronizing problem. They result in a greater average length per character, so that they are slower unless they can be statistically weighted for a particular language. In English language the ratio of frequencies of different characters is not sufficiently great to give a large advantage from the use of symbols of unequal length. The extension to using single symbols for common words gives negligible improvement.

The comparison of speeds of telegraphic codes requires a careful definition of the basis of comparison if a unique answer is to be achieved; one can, for example, find it stated in one handbook that 5-unit code is faster than Morse in the ratio 8 : 5, while another handbook states that for a given speed the bandwidth required for a start-stop printing telegraph is one third greater than that required for Morse. Part of the ambiguity is due to the need for some means of synchronizing in 5-unit code when it is used on a start/stop basis, but the major difficulty is that the characters in Morse code are of unequal lengths, having been in fact designed to approximate to the condition that the length of character is inversely proportional to its frequency of occurrence in the English language.‡

* *Electrical Engineering Department, University of Birmingham.*
† *Formerly Electrical Engineering Department, University of Birmingham*

‡ The differences between the language used in North America and that used in the United Kingdom do not appear to be statistically significant.

Calling each minimum unit of time a 'digit', so that a character in synchronous 5-unit code contains five digits, the Morse *dot* counts as one digit, the *dash* as three digits, and the space between dots and dashes within a character as one digit (e.g., the Morse A, · —, is five digits long). On this basis the (Continental)§ Morse alphabet averages 8·23 digits per letter, though the symbols for numerals are much longer. For random collections of letters, therefore, Morse appears on this basis to be slower than continuous 5-unit code in the ratio of about 5 : 8. In fact, however, it is even worse, since gaps of 3-digit length must be provided between Morse characters, and none are assumed between characters in continuous 5-unit code: Morse therefore appears to be worse in the ratio 11·23 : 5. But, if the text to be transmitted is in *English language*, where the letter E is the commonest character, etc., the weighted average of net length of character in Morse is reduced to 5·96 digits per character, or 8·96 digits per character with the inter-character space. Since all characters in 5-unit code are of the same length, weighting the alphabet for English language has no effect; but if the system is worked start-stop, instead of synchronously, the length becomes 7½ digits per character which is more nearly comparable with the 9 digits gross of Morse with English-language weighting.

The Design of Optimum Codes

A code can only be 'optimum' in terms of some specified criterion, and the diversity of existing codes is largely a reflection of the diversity of criteria adopted by their inventors. Morse's original code, as quoted by Cherry[2], involved five different elements: dot, short dash, long dash, short space and long space, apart from intervals between characters and between words. It therefore required operators with a fairly good sense of timing to distinguish between elements of different lengths; but with the additional factor that the commonest letters were given the simplest combinations, it tended to give the *minimum number of movements of the key* when transmitting English text. For example, Morse's L consisted of a single long dash, in place of the present code's four elements, and his letters O, R, C, Y, J, Z using long interval spaces employed 2, 3, 3, 4, 4, 4 elements compared with the modern version having 3, 3, 4, 4, 4, 4; in fact Morse's code used slightly fewer elements per character because the elements were selected from a more numerous set. The reduction of the number of lengths of element to two only calls for less skill from the operator, and may be regarded as a sacrifice of minimum muscular effort (i.e., number of keying operations) in order to combat whatever form of 'noise' may tend to prevent discrimination between different lengths of time.

The relation between length of symbol and letter of the alphabet in Morse's original code was based on the quantities of different letters stocked in a printer's fount of type. But a more careful estimate of the relative frequencies of letters in English texts[3] leads to a slightly different weighting. Using the same Morse symbols as present-day (Continental) code, a slightly more efficient system for English language could be constructed as shown in Table 1, under the heading 'Optimum Letter'. With English-language weighting this modified code would average 5·56 digits per letter (net) as against 6·02 for the existing form, and of course it is not suggested that it would be worth while departing from the existing standard for the sake of this small improvement. It is noticeable in Table 1 that the *weighted length* of characters is at a maximum from about the fourth to the eighth, and is still significant as far as the twentieth, so it cannot be said that the weighted length is governed by the symbols allocated to the few commonest letters. Western European languages are sufficiently alike for Morse code to be suitable for all of them. For example, the mean length of a Continental Morse character is 5·69 digits if the language is French or 6·19 digits in Spanish, instead of 6·02 in English.

The great defect of Morse code is that by using two kinds of mark signal (dot and dash) as its basic elements it requires the addition of inter-element spaces which in principle serve only to define the dots and dashes and themselves convey no extra information. This is avoided in 5-unit code, where 'marks' and 'spaces' are both signal elements, but a certain degree of either synchronism or ability to distinguish lengths is implied, since a 'mark' of two or more digits' duration must be recognized as the juxtaposition of individual mark elements. It is on this basis that 5-unit code is necessarily a little faster than Morse with its average of 6 digits per character; and since 5-unit code achieves this without resort to statistical weighting of lengths of characters it

TABLE 1

Morse Symbol	Length Digits	Morse Letter	Letter Frequency	Weighted Length	Optimum Letter	Weighted Length
·	1	E	0·131	0·131	E	0·131
—	3	T	0·105	0·315	T	0·315
· ·	3	I	0·063	0·189	A	0·246
· —	5	A	0·082	0·410	O	0·400
— ·	5	N	0·071	0·355	N	0·355
· · ·	5	S	0·061	0·305	R	0·340
· — ·	7	R	0·068	0·476	I	0·441
— —	7	M	0·025	0·175	S	0·427
· · · ·	7	H	0·053	0·371	H	0·371
— · ·	7	D	0·038	0·266	D	0·266
· · —	7	U	0·025	0·175	L	0·238
· · — ·	9	F	0·029	0·261	F	0·261
— · · ·	9	B	0·014	0·126	C	0·252
— — ·	9	G	0·020	0·180	M	0·225
— · —	9	K	0·004	0·036	U	0·225
· — · ·	9	L	0·034	0·306	G	0·180
· · · —	9	V	0·009	0·081	Y	0·180
· — —	9	W	0·015	0·135	P	0·180
— · — ·	11	C	0·028	0·308	W	0·165
— — —	11	O	0·080	0·880	B	0·154
· — — ·	11	P	0·020	0·220	V	0·099
— · · —	11	X	0·002	0·022	K	0·044
— — · ·	11	Z	0·001	0·011	X	0·022
· — — —	13	J	0·001	0·013	J	0·013
— — · —	13	Q	0·001	0·013	Q	0·013
— · — —	13	Y	0·020	0·260	Z	0·013
Total:	214		1·000	6·020		5·556

§ This is the code built up of dots and dashes which is generally adopted in Europe, and known in U.S.A. as the 'continental' telegraph code. Morse code there refers to a slightly different version in which two different lengths of dash are used and long spaces within characters as well as dots. See Reference (1).

remains faster for *any language*, including text which has been so ciphered as to equalize approximately the letter probabilities, for which Morse would require an average of 8·23 digits per letter.

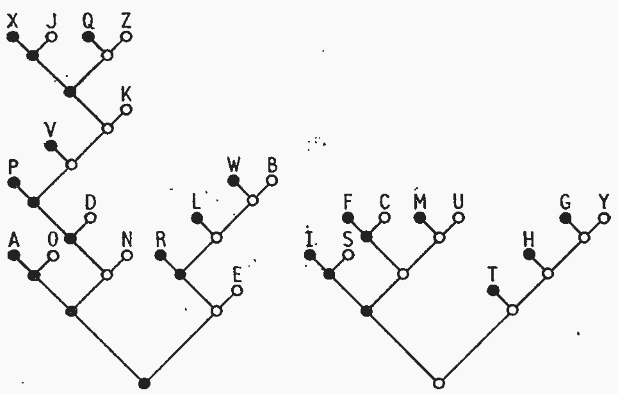
The need for synchronizing in a code using consecutive signal elements of equal length can be avoided if the code is so constructed that each character is represented by a unique group of elements and no character is represented by a group which forms the start of another group. If, in addition, the longest groups are assigned to the characters which occur least frequently, the code is of the type sometimes known as *Shannon-Fano* or minimum-redundancy. Although the Morse code conforms reasonably to the second characteristic, it in no wise satisfies the first. For example, the single dot of the letter E is the start of twelve other characters, and the dot-dash of A is the start of five, while the dash-dot of N is also the start of five others.

Minimum-Redundancy Code

The method of constructing a minimum-redundancy code has been described by Huffman[4]. Provided that no individual signal is represented by a sequence of digits which is also the *first part of* the sequence representing another signal, it is possible to transmit a succession of such signals without interposing either spaces or synchronizing signals. It is, however, implied that the start of the transmission can be accurately identified; and that the rate of sending digits is known with sufficient accuracy to distinguish between such groups as 0 0 0 1 1 and 0 0 1 which qualitatively are both represented by a 'step' waveform.

In principle an asynchronous code of this type would be constructed with a different group of digits for each message in the agreed ensemble of messages available for use in the particular communication channel. However, there are not many communication systems in which the number of possible messages is so restricted as to make this practicable. If one limited the idea to that of giving a code character to each word, one would be faced with 34,400 words in the Concise Oxford Dictionary and several thousand in any simplified language such as basic English. It is likely that the units of the ensemble would in practice be taken to be the letters of the alphabet. The lengths of individual

Fig. 1. '*Tree*' *diagram*



groups can then be arranged in the same way as discussed above for Morse code, but no use is then made of the fact that some *words* are common in a language and others rare. The example described by Huffman (loc. cit.) is a code for an ensemble of 13 messages, but the authors have constructed a code for 26 characters with probability weightings corresponding to letter frequencies in the English language. This code is listed in Table 2, but the logic behind it is perhaps best appreciated from the 'tree' diagram of Fig. 1. Here the black dots represent 'mark' and the circles 'space' (or digits 1 and 0) and, since the letters are placed at the ends of individual spurs of the tree, it is automatically established that the complete sequence of digits representing one letter cannot be the commencement of any other sequence used in the system. The longest combinations are allotted to the rarest letters by the following process (which is the pictorial representation of the method described by Huffman). The two rarest letters (Z and Q) are given the digits 0 and 1, forming the ends of two spurs. The joint probability of these is greater

TABLE 2

Shannon-Fano Code in Binary Digits for 26-letter Alphabet and English Language.

A	1 1 1 1	N	1 1 0 0
B	1 0 1 0 0 0	O	1 1 1 0
C	0 1 0 1 0	P	1 1 0 1 1 1
D	1 1 0 1 0	Q	1 1 0 1 1 0 0 1 0 1
E	1 0 0	R	1 0 1 1
F	0 1 0 1 1	S	0 1 1 0
G	0 0 0 0 1	T	0 0 1
H	0 0 0 1	U	0 1 0 0 0
I	0 1 1 1	V	1 1 0 1 1 0 1
J	1 1 0 1 1 0 0 1 1 0	W	1 0 1 0 0 1
K	1 1 0 1 1 0 0 0	X	1 1 0 1 1 0 0 1 1 1
L	1 0 1 0 1	Y	0 0 0 0 0
M	0 1 0 0 1	Z	1 1 0 1 1 0 0 1 0 0

than the probability of either X or J, so the latter terminate another pair of spurs, having a 1 at their junction in contrast to the 0 at the junction of the Q and Z paths. All four together have a probability comparable with K which is attached to a new spur at the appropriate level, and so on. The diagram is drawn as two separate trees, since there is no sequential link which is common to both digits 0 and 1 in the first place in the sequence.

The rather complicated coding of Fig. 1 leads to a straight average length of 5·65 digits per character, and an English-language weighted average of 4·16 digits per character, an advantage over 5-unit code which is clearly not sufficient to justify the complication. It has also been pointed out to the authors by Mr. G. R. Mansfield that an arbitrary division of the alphabet between some characters of four digits and some of five would give an unweighted mean length of less than five digits. (If the 16 possible 4-digit combinations were used for the first 16 letters in column 3 of Table 1 and the 10 remaining letters were given 5-digit combinations, the weighted mean length in English would be 4·18 digits per letter. It must be remembered, however, that

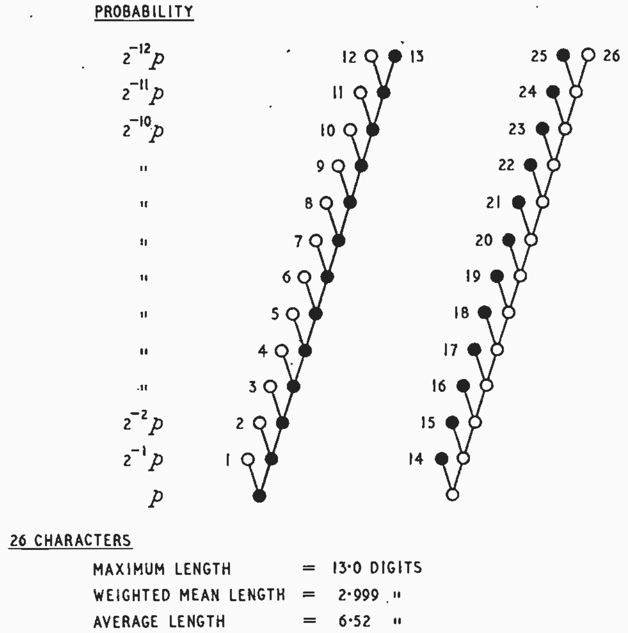


Fig. 2. *A pair of single-stemmed 'trees'*

such a code would not be minimum-redundancy and would hence involve the problem of synchronization.) The reason for the disappointingly small advantage from statistical weighting is that although the letter frequencies appear very unequal on an arithmetic scale, the range is nothing like sufficient for the geometric progression implied in this coding system: this is the cause of the somewhat irregular and 'bushy' structure of the 'tree' in Fig. 1, for according to Pratt's table[3] the range of letter-probabilities in English is from 0·131 for E to 0·0077 for Z, or $1 \cdot 7 \times 10^2 : 1$. If one had a set in which the relative probabilities of successive pairs of messages decreased by a factor of two, it could be represented by a pair of single-stemmed trees as sketched in Fig. 2. Here the number of digits in the character occupying the nth spur on either tree is $n + 1$ and its probability 2^{-n}. The weighted mean length of character is $\Sigma(n + 1)\ 2^{-n}$. If the summation is taken to infinity, the weighted mean length is precisely two digits per character but, in order to accommodate 13 letters on each tree, the relative probabilities of first and last would have to be in the ratio of 2^{13} or about $8 \times 10^4 : 1$ instead of $1 \cdot 7 \times 10^2 : 1$. It is therefore concluded that it is not worth while developing a weighted coding system for the alphabet.

Word Coding

It would however be possible to extend a coding system such as is shown in Fig. 1 by allotting single symbols to some of the commoner words, in addition to the 26 symbols for the letters of the alphabet. Dewey[5] has estimated that there are 10 words which each form more than 1% of the word content of English as shown in Table 3. But these words are all short and therefore the proportion of the letters they account for in a passage in English language is less than their proportion of the words and, in order to find the equivalent letter frequency for single symbols representing these words, one must find the average length of a word. One of the authors has published elsewhere[6] an analysis of the relative proportions of words of different lengths in the three-quarters of English texts which are made up of 1,000 commonly used words; and on this basis the average length of a word is 3·5 letters.

The remaining quarter of the text will consist mainly of longer words (since these are the less common words) so that in round figures the average length of a word may be 4 letters or even 5 as is conventionally assumed. Taking the figure of 4 letters average per word, the equivalent letter-frequency of the symbols representing the common words of the text is given in Table 3, third column. The equivalent letter-frequency is found by dividing the word-frequency by average number of letters per word. If those of the more common words having significant equivalent letter-frequencies (greater than 0·5%) are included in the code the number of characters will now be 32; these are the 26 letters of the alphabet and the six words 'the', 'of', 'and', 'to', 'a' and 'in'.

The letter frequencies in Table 1 must now be re-assessed so that the separate letters of these words are not included in the assessment of overall letter-frequency. Since these 6 words contain all of the most frequent letters the effect of this re-assessment will be to compress slightly the range of frequencies of the characters in the code—this is a process which has already been shown to be undesirable for the development of a weighted coding system.

The six words included in the code make up about 20% only of the total words in a text and a smaller proportion of the letters so that although the coding of the words as single characters will involve fewer digits than the coding of the separate letters in the word, the weighted mean length of a single character will probably not be much smaller than in the original code, and may even be longer owing to the extension of the code to 32 characters.

Against this, however, fewer characters will need to be sent for a given message so that, even if the mean length of code per character is slightly larger, the total number of digits sent might be significantly smaller than in the original code.

The proposed code was constructed and showed a

TABLE 3

Word	% Occurrence	Equivalent letter frequency. %
the	7·31	1·83
of	4·00	1·00
and	3·280	0·82
to	2·924	0·73
a	2·120	0·53
in	2·116	0·53
that	1·345	0·34
it	1·216	0·30
is	1·213	0·30
I	1·155	0·29

weighted mean length of 4·42 digits per character compared with 4·16 of the original code; i.e., an increase of about 6·25%. The number of characters in a message is however reduced by 7·55% so the new code is approximately 2% faster. This advantage does not justify the complication of using the code.

Conclusion

For English and other similar languages the Morse code is not much slower than 5-unit code worked on a start/stop basis. The application of modern principles to the construction of more elaborate English-weighted codes leads to codes which have no need of synchronizing signals and require less than 5 digits per character. But the ratio of the frequencies of occurrence of different letters is not great enough to take full advantage of a statistically-weighted code, and the benefit obtained is not commensurate with the complexity of the decoding apparatus which would be required.

Acknowledgements

One of the authors, T. C. Duggan, was in receipt of a D.S.I.R. grant when this work was commenced.

REFERENCES

[1] "Standard Handbook for Electrical Engineers". McGraw-Hill Book Co., 6th Edn, 1933.
[2] E. C. Cherry, "A History of the Theory of Information", *Proc. Inst. Elect. Engrs* 1951, Vol. 98, Part III, P. 383.
[3] F. Pratt, "Secret and Urgent", Blue Ribbon Books, 1939.
[4] David A. Huffman, "A Method for the Construction of Minimum-Redundancy Codes", *Proc. Inst. Radio Engrs* 1952, Vol. 40, p. 1098.
[5] G. Dewey, "Relative Frequency of English Speech Sounds", Harvard, 1923.
[6] D. A. Bell, "Information Theory and its Engineering Applications", 2nd Edn, Pitman, London, 1956, Appendix 2.

Correspondence

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

Brune's Theorem

Sir,—I agree entirely with Mr. S. R. Deards that Brune's work, in correlating the properties of a function of a complex variable with those of the variable itself, with particular reference to functions for realizable networks, is of the highest importance. It is respectfully pointed out, however, that Mr. Deards is mistaken in thinking that my observation was based on a misunderstanding of Brune's theorem.

The term "positive real part" is commonplace, with reference to the component U of a complex quantity $U + jV$; and it is moreover well known, in terms of the steady-state variable $j\omega$ at least, that the real part of the driving-point immittance (as distinct from transfer immittance) must be positive in the case of a passive network *that is known to be physically realizable.*

The correlation between the properties of p and those of $F(p)$, which is contained in Brune's theorem but which was not the subject of my comment, has a much deeper significance; it provides an elegant mechanism for the *synthesis* of a realizable passive network. It is therefore unfortunate that a term such as "positive real", which is subject to commonplace and simple associations, should be used to embrace the far-reaching implications of this correlation. Would not a term such as "realizability criterion" be more distinctive, as an alternative for the test of "positive reality"?

I have a high regard for David Tuttle's book, as my review implies; but I am opposed to glamourization in technical writing, and the comment to which Mr. Deards has responded was prompted primarily by that consideration. It should perhaps be added that the wider concept of "positive reality", as defined by Brune and referred to by Mr. Deards, is fully dealt with by the author.

10th November 1958. F.E.R.

New System of Units

Sir,—The interest in units and dimensions evoked by Quantum in the October issue, as well as the present confusion in the variety of units has led to the consideration of an entirely new system giving the common units sizes convenient in electronics and atomics. The fundamental definitions are:

C_0 = 1 metre per newsec
Z_0 = 1 newohm per square

where C_0 is the velocity of electromagnetic waves in free space and Z_0 is the free space impedance. It will be seen that the new unit of length has been chosen to be the metre and the new unit of time is the newsec given by:

1 newsec = c^{-1} seconds
and 1 newmetre = 1 metre

where c is the numerical value of the velocity of light in m.k.s. units. As the new unit of power is chosen to be the watt, the units of current and potential must be treated symmetrically. Thus:

1 newohm = $|Z_0|$ ohms $\simeq$ 377 ohms
1 newwatt = 1 watt
1 newvolt = $|Z_0|^{\frac{1}{2}}$ volts $\simeq$ 19·4 volts
1 newamp = $|Z_0|^{-\frac{1}{2}}$ amp $\simeq \frac{1}{19 \cdot 4}$ amp

and charge,

1 newcoulomb = 1 newamp newsec = $|Z_0|^{-\frac{1}{2}} c^{-1}$ coulombs.

The permeability and permittivity of free space are given numerically by

$\mu_0 = 1$
$\kappa_0 = 1$

And the new units of inductance and capacitance become more practical than the old 'practical' units, thus:

$$1 \text{ newhenry} = \frac{|Z_0|}{c} \text{ henrys} \simeq 1 \cdot 26\ \mu\text{H}$$

$$1 \text{ newfarad} = \frac{1}{|Z_0| c} \text{ farads} \simeq 8 \cdot 85\ \mu\mu\text{F}$$

TABLE OF UNITS

1 New unit	=	n old units
1 Newsecond	=	3·33 × 10^{-9} seconds
1 Newmetre	=	1 metre
1 Newwatt	=	1 watt
1 Newmass	=	3·71 × 10^{-26} kilogrammes
1 Newjoule	=	3·33 × 10^{-9} joules
1 Newforce	=	3·33 × 10^{-9} newtons
1 Newohm	=	3·77 × 10^{2} ohms
1 Newvolt	=	19·42 volts
1 Newamp	=	5·15 × 10^{-2} amp
1 Newcoulomb	=	1·72 × 10^{-10} coulombs
1 Newfarad	=	8·85 × 10^{-12} farads
1 Newhenry	=	1·26 × 10^{-6} henrys
1 Newgauss	=	6·47 × 10^{-4} gauss

From the watt the new unit of energy may be defined as that energy which is expended when working at the rate of one watt for one newsecond thus:

1 newjoule = c^{-1} joules

Hence the new unit of force, called the newforce for euphonic reasons in preference to newnewton, is given by:

1 newforce = c^{-1} newtons

and the new unit of mass is given by:

1 newmass = c^{-3} kg

This unit is not so inconvenient as might be supposed since it represents the mass of about 22 protons. It should be noted that the newjoule is the energy produced by the complete annihilation of one newmass. ($E = mc^2$)

The usual definitions of electrostatics are easily derived, thus the force between two charges is given by:

$F = \frac{q_1 q_2}{\kappa\, 4\pi\, d^2}$ newforces, where q_1, q_2 are measured in newcoulombs and d in metres.

Similarly the force between two lengths of wire carrying currents is:

$F = \frac{\mu i_1 i_2 l}{2\,\pi\, d}$ newforces, where i_1, i_2 are measured in newamps and l and d in metres. It will be seen that a factor 4π appears in the case involving spherical symmetry, and 2π in the case involving axial symmetry. Other formulae are derived as easily in electrostatics or in current electricity.

Although the new system has been used in work on microwaves and high-frequency circuitry where it has proved convenient it is presented here as a consistent system of units for the first time.

It is realized that although C_0 and Z_0 are fundamental properties of space the other dimensions used are not, the watt and metre being chosen for convenience. A system of units could, no doubt, be based on C_0, Z_0, h and d_0, where h is Planck's constant and d_0 almost any other fundamental property; e.g., the mean density of the universe.

A table of new units in terms of practical units is included.

Horwood Orchard, Church Road, P. W. Smith.
North Hayling, Hants. O. Nourse.
6th November 1958.

New Books

Engineering Electromagnetics

By Prof. William H. Hayt, Jr. Pp. 328 + xii. McGraw-Hill Book Co. Ltd., 95 Farringdon Street, London, E.C.4. Price 63s.

The practical outlook of an engineer, and the experienced insight of a teacher who knows the pace at which the average good student can progress, make this presentation of orthodox electromagnetic theory much more of a teaching course than a physicist's treatise. The presentation of vector analysis, for example, is developed during the course of the book. Divergence appears in Chapter 3, in connection with Gauss' Law; Gradient in the following chapter; and Curl with the general vector theorems in Chapter 8 on the magnetic field. The physics books, from Maxwell's "Treatise" onwards, concentrate a brief summary of vector analysis either at the beginning or in an appendix, and are a tough proposition for anyone who has not met mathematics at this level before. Prof. Hayt, while rightly saying that mathematics must be taught by mathematicians, explains the principles so clearly, and illustrates their applications so well, that the student who has worked through the book should be well equipped with vector analysis as a tool for further work; the author, on his own admission, stands pretty well convicted of being a mathematician in this respect. There is an account of experimental methods of field plotting, and the iteration and relaxation methods, and two chapters deal with applications of Maxwell's equations. The final chapter, on charged particles in electromagnetic fields, takes the discussion as far as the incidence of the special theory of relativity, which again is explained as the argument develops. One point in this last chapter made me wonder—the introduction, for the sake of symmetry, of a hypothetical "magnetic charge", the isolated magnetic pole. This is "something" which experiences a force in a moving electric field, but not in a stationary one; but if symmetry with electric charge is its justification is not the parallel between div **E** and div **B** enough to equate it to zero ?

The book is excellently written, with a fluent style, an undercurrent of humour, stern exhortations to stick at the sums, and plentiful drill examples in the text with answers given in a cryptic form so that they can't be fiddled backwards and all have to be done before you know that any one is right. Numerous references, with brief comments on the works cited, are given at the chapter-ends, with exercises of a varied and ingenious type. One, for example, asked for a critical review of the way a certain topic was dealt with in the references. It is difficult for anyone who is not himself an engineer to assess the book in relation to student courses in this country, but it can be recommended unreservedly as a first-rate example of the technique of exposition. G.R.N.

Atmospheric Explorations

Edited by Henry G. Houghton. Pp. 125 + x. Chapman & Hall Ltd., 37 Essex Street, London, W.C.2. Price 52s.

The five papers included in this volume were presented at the Benjamin Franklin Memorial Symposium of the American Academy of Arts and Sciences, which was held in 1956 to commemorate the two hundred and fiftieth anniversary of the birth of Franklin. The papers are not specifically concerned with his work, but describe recent important developments in several fields of atmospheric physics: four of them, however, are on subjects in which he himself made considerable contributions to knowledge.

Atmospheric electricity is the central theme of the first three papers, a field of study with which Franklin's name is particularly associated. The electrification of cloud and raindrops is discussed by Ross Gunn: this is a subject in which, up to only a few years ago, it was thought that progress would be very slow in view of the apparent complexity of the problem. Great progress has in fact been made recently at the United States Weather Bureau, and it seems that the surprisingly simple concept that raindrops and cloud droplets are under bombardment, in a statistical manner, by charged cloud particles and ions proves very fruitful in the description of the complex electrical characteristics of these drops.

The second paper, contributed by Joachim P. Kuettner, deals with the formation of electric charges in thunderstorms, and shows how many of Franklin's early ideas still hold true. It appears likely that there is a close relation between charge generation and the development of solid precipitation in the supercooled region of a thundercloud. Modern theories of the charge segregation, which leads to the formation of a vertical dipole in a mature thundercloud, are described. Further development of the theme of atmospheric electricity occurs in the next paper, in which Leonard P. Loeb discusses the positive streamer spark in air in relation to the lightning stroke. His aim is to show, amongst other things, how the results of research on the characteristics of the positive streamer in controlled electric sparks in the laboratory can be used to account for the mechanism of the charge drainage from a cloud in the lightning process—a matter hitherto rather shrouded in obscurity—although this is only one facet of the whole complex phenomenon. It is evident from reading these two papers that much still remains to be understood about the true nature of lightning displays, despite the admittedly considerable progress made since Franklin's first experiment with his kite string some two hundred years ago.

Meteorological phenomena in the upper atmosphere form the subject of the fourth paper, which is by Harry Wexler. Although Franklin is probably best known for his investigations of atmospheric electricity, he also made important improvements in meteorological instruments and studied other atmospheric features, including the horizontal movement of storms. Wexler's paper is concerned largely with the study of the vertical propagation of atmospheric disturbances; and while he suggests that there appears to be more evidence for the upward propagation of tropospheric storms to the upper atmosphere than there is for a reverse direction of movement, he adds that the subject still awaits the clarification which might be supplied only by another Franklin.

The final paper, by Henry G. Booker, is in a different category from the rest, and strictly bears no relation to any of the subjects in which Franklin was interested. The topic is the phenomena of radio scattering in the ionosphere, and neither radio waves nor the ionosphere were known in Franklin's time. However, as a student of the atmosphere, he would certainly have been interested in the matters discussed by Professor Booker had he been alive to-day.

Nine scattering processes in the ionosphere are described and their interpretation considered. Whether all of these processes can be explained in terms of a single underlying phenomenon is not yet known, but Booker suggests that if any one such phenomenon exists it can scarcely be other than atmospheric turbulence; and, while others may strongly hold somewhat different views on some aspects of the problem, none can deny the fruitfulness of Booker's theories.

As might have been expected from the authors, each with a world-wide reputation in the relevant field, these five papers present an authoritative and admirably concise account of the present state of knowledge in the subjects discussed. The material is in all cases attractively presented, with many helpful illustrations, and the result is a worthy tribute to the memory of Franklin. This book may be strongly recommended to all interested in the physics of the atmosphere. J.A.S.

Principles of Noise

By J. J. Freeman. Pp. 299 + x. Chapman & Hall Ltd., 37 Essex Street, London, W.C.2 (for John Wiley). Price 74s.

This book has both the merits and the defects of a work designed for teaching students. The merits are that it guides the reader into the subject at a fairly gentle pace, using careful explanation of every step and providing examples by which the reader can test his grasp of each step before proceeding to the next; and the main disadvantage is that the author has included one or two chapters such as those on "The measurement of direct voltage" and "Target noise" which read like rather elaborate class-room exercises in the applications of noise theory.

It has been said that there is a very good *calculus* of probabilities but only dubious *theories* of probability. This book appears to have the statistician's approach to the calculus, both in using the term *covariance* where many would use *correlation* and in the thoroughness with which it discusses the multivariate gaussian distribution. But its handling of the fundamentals of probability is open to question where it appears to treat *ensemble* as synonymous with *population* and almost appears to define the latter as "an infinite ensemble of hypothetical events" (page 42). On pp. 215–216 the author does well to discard the usual implicit assumption that an error distribution is always gaussian (or "normal"); but will the reader who has no previous experience of probability theory realize (a) that this is how the Tshebysheff lemma comes to be invoked and (b) that there are occasions which justify using the rather tighter limit specified by Camp and Meidell or sometimes even the gaussian distribution?

In spite of these criticisms the first three chapters, which are concerned with statistical techniques and the properties of statistical functions, will provide some useful ideas for anyone teaching in this field. The range covered by the rest of the book may be described very briefly as physical sources of noise, equivalent circuits and noise factor, the effect of noise on the measurement of a steady quantity, detection of sinusoidal signals in noise, and target noise in radar. In these topics the book should succeed in the object set out by the publishers, namely to bring the reader to the point of being able to use the specialist literature. D.A.B.

"Wireless World" Diary 1959

Pp. 80 of reference material, plus diary pages of a week to an opening. Published by T. J. & J. Smith in conjunction with *Wireless World*. Iliffe & Sons Ltd., Dorset House, Stamford Street, London, S.E.1. Price: Leather 6s. 3d.; rexine 4s. 6d.; postage 4d.

Automatic Control: Principles and Practice

By Werner G. Holzbock. Pp. 258 + vii. Chapman & Hall Ltd., 37 Essex Street, London, W.C.2. Price 60s.

Contains chapters on the following subjects: The Automatic Control System; Static Characteristics; Step Function Response of a Process; Step Function Response and Adjustments of Controller; Frequency Response; Mechanical Components; Electrical Components; Balances and Computing Circuits; Measuring Elements; Controllers; Final Control Elements; Control Systems; Industrial Applications.

Television Annual for 1959

Edited by Kenneth Baily. Pp. 160. Odhams Press Ltd., Long Acre, London, W.C.2. Price 10s. 6d.

A First Course in Television

By "Decibel". Pp. 149 + ix. Sir Isaac Pitman & Sons Ltd., Parker Street, Kingsway, London, W.C.2. Price 15s.

ELECTRONICS AND MEDICINE

The Council of the I.E.E. has instituted a Medical Electronics Discussion Group to provide a forum in which electronic engineers can meet members of the medical profession to discuss problems in which they have a common interest. The Group will hold regular meetings, and any person interested in the activities of the Group should send his name and address to the Secretary of the Institution of Electrical Engineers, Savoy Place, London, W.C.2.

MEETINGS

I.E.E.

10th December. "Bridging the Atlantic", by A. H. Mumford, O.B.E., B.Sc.(Eng.).

12th December. "The Teaching of Mathematics to Engineers", discussion to be opened at 6 o'clock by M. Bridger.

15th December. "The Acoustic Design of Talks Studios and Listening Rooms", by C. L. S. Gilford, M.Sc.

16th December. "Modern Control Techniques on the Railways", discussion to be opened by W. J. Webb, B.Sc. and L. A. Ginger.

These meetings will be held at the Institution of Electrical Engineers, Savoy Place, Victoria Embankment, London, W.C.2, and will commence at 5.30, *except for the meeting on 12th December.*

Brit. I.R.E.

12th December. Technical Films.

17th December. "A Vidicon Camera for Industrial Colour Television", by I. J. P. James, B.Sc.

These meetings will be held at 6.30 *at the London School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, W.C.1.*

STANDARD-FREQUENCY TRANSMISSIONS

(Communication from the National Physical Laboratory)

Deviations from nominal frequency for October* 1958

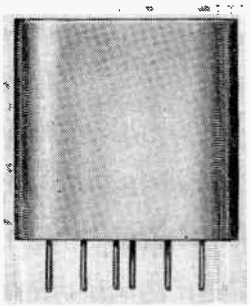
Date 1958 October	MSF 60 kc/s 2030 G.M.T. Parts in 10^9	Droitwich 200 kc/s 1030 G.M.T. Parts in 10^8
1	N.M.	− 2
2	N.M.	− 2
3	N.M.	− 2
4	− 2	N.M.
5	− 2	N.M.
6	− 2	− 1
7	− 2	− 1
8	− 1	− 1
9	− 2	− 1
10	− 1	− 1
11	− 1	N.M.
12	− 1	N.M.
13	− 1	0
14	− 1	0
15	− 1	+ 1
16	− 1	+ 1
17	− 1	+ 1
18	− 1	N.M.
19	− 1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

* *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

Sub-Miniature Relay

A sub-miniature relay, designated Series 335, has been designed by Magnetic Devices Ltd. and can be either a.c. or d.c. operated. The makers claim that because of its small size (it weighs only $\frac{1}{3}$ oz. and has dimensions of 0·78 in. wide × 0·35 in. thick × 1·03 in. high) it should be extremely suitable for use



in equipments where size and weight are of the utmost importance.

It has a balanced armature, and the 2-pole changeover contacts are rated at 2 A at 28 V d.c. or 110 V a.c. (with a non-inductive load); the minimum contact pressure is given as 10 gm and the contact bounce is stated to be negligible.

Hermetically sealed in a 'tinned' brass container, the relay is available with standard coil windings to suit a variety of common operating voltages. Coil resistances are up to 5 kΩ.

Magnetic Devices Ltd.,
Exning Road, Newmarket, Suffolk.

Audio-Frequency Spectrometer

This instrument has been designed basically for the frequency analysis of complex signals, such as the ones encountered in noise and vibration measurements. It may, however, also be used as

an r.m.s.-reading valve voltmeter and for the harmonic analysis of electrical signals.

Designated Type 2110, it comprises a high-gain low-noise amplifier with 30 fixed $\frac{1}{3}$-octave band-pass filters for analysis of the frequency spectrum over the range of 35–32,000 c/s. A linear network and four standardized weighting networks for sound measurements are included.

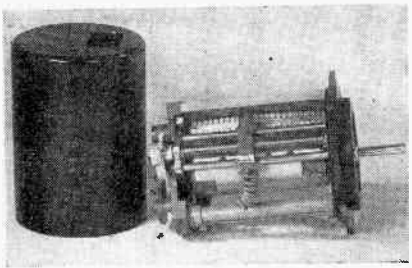
When used as a valve voltmeter, the frequency response is said to be linear from 2–35,000 c/s.

Provision is made for connecting the instrument to the makers' Level Recorder 2304, enabling complete frequency–amplitude diagrams to be recorded automatically on pre-printed frequency-calibrated recording paper in a time claimed to be less than 20 seconds.

B & K Laboratories Ltd.,
4 Tilney Street, Park Lane, London, W.1.

Precision Potentiometer

This component provides a compact means of achieving precise voltage division



proportional to the angular position of a shaft.

Fed with a constant voltage, it could give a signal proportional to shaft rotation in an analogue computer. It could be geared to a dial or a counter and used in a manual or self-balancing potentiometer or bridge circuit.

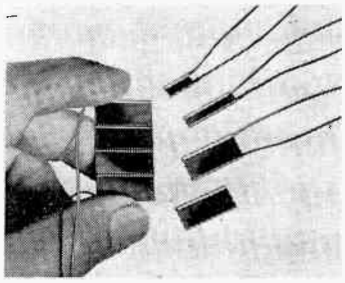
The rotating mandrel is helically wound with 50 turns of silver palladium wire specially tested for uniformity. The gold-alloy wiper is spring-loaded radially towards the wire on the mandrel. All contacts are tarnish free. It is carried along the mandrel on slides by a lead screw geared to the mandrel and parallel to its axis. The slides and lead screw are mounted on a balanced frame, pivoted about the axis of the mandrel and spring-loaded against a cam which advances the wiper along the wire by a few degrees. The initial shape of the cam is that required to compensate for the load on the potentiometer, as specified by the customer. Adjustments are made on test to correct for manufacturing errors including non-uniformity of the wire. The standard cam is for a load of 250 kΩ and zero input impedance, but other combinations can be corrected by suitable cams.

It has a linear accuracy of 0·008%, a rating of 0·5 W, a torque of less than 150 gm cm, and a life expectancy of more than 5,000 sweeps at 60 r.p.m. The potentiometer resistance can be up to 1,000 Ω.

Sperry Gyroscope Co. Ltd.,
Great West Road, Brentford, Middx.

Silicon Solar Cells

These cells are claimed to be capable of converting more than 10% of the radiant energy falling on their surface. Their high efficiency and rugged construction are said to



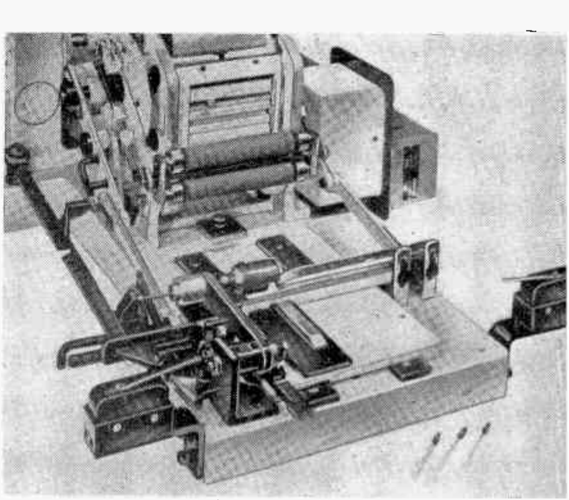
be due mainly to new alloying techniques which permanently bond the contact to the silicon wafer, making the contact an integral part of the cell itself, while still allowing the soldering of individual cells.

Rectangular in shape, the cells are obtainable with or without colour-coded pigtail leads, in sizes of 0·5 cm × 1 cm, 0·5 cm × 2 cm, and 1 cm × 2 cm.

International Rectifier Corpn.,
El Segunda, California, U.S.A.

Transistor Printing Machine

A machine designed for printing on transistors has been produced by Rejafix Ltd.



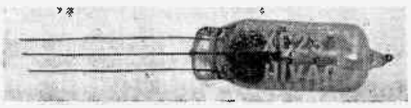
The makers state that this power-driven model, Type EIA/TPR, will prove an invaluable asset to firms engaged in transistor production.

The transistors, which are hand-fed into the microswitch-operated machine, are automatically printed and ejected after printing. It is claimed that outputs of the order of 1,500 prints per hour can be achieved, and that the changeover of information to be printed is a quick and simple process.

Rejafix Ltd.,
81-83 *Fulham High Street,*
*London, S.W.*6.

Cold Cathode Triode

A new sub-miniature cold-cathode valve, measuring 4·8 cm long and 1·6 cm in diameter, has been produced by Hivac Ltd. Called the XC23, it is claimed to have a maximum continuous cathode-current rating of 7·5 mA, a minimum anode breakdown voltage of 200 V, a nominal anode maintaining voltage of 67·5 V, and a



nominal trigger breakdown voltage of 70 V.

Hivac Ltd.,
Stonefield Way, Victoria Road, South Ruislip, Middx.

Vibration Strain Gauges

Two new types of vibration strain gauges have been produced by Technical Ceramics Ltd. Available either as expander or bender elements, the gauges can be used in a wide variety of applications for the determination and analysis of dynamic strain.

The expander gauge, as illustrated on the left, consists of a strip of piezoelectric ceramic, silvered and polarized across the thickness dimensions, with the lower silvering carried round to the top to facilitate electrical connection. The elements are said to have extremely high sensitivities, of the order of several hundred times those obtainable with wire strain gauges.

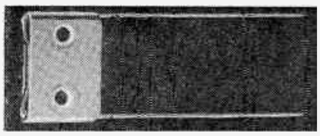
The bender gauge consists of a sandwich of thin piezoelectric ceramic and brass foil, responding to a bending movement. These gauges are intended for mounting at a point of maximum bending, and are claimed to be capable of producing an output of more than 1 V with a deflection of 0·001 in.

In addition to the use of these ceramic gauges as vibration pick-ups, they may also be used to generate vibrations in a structure by applying an alternating voltage to the transducer.

Technical Ceramics Ltd.,
Towcester, Northamptonshire.

Photocells

A new type of photoconductive cell, designed primarily for high-speed infra-red spectroscopy, has been announced by



Mullard. The cell, type ORP10, has an uncooled indium antimonide element enclosed in a flat protective case, with two flying leads for connection. The sensitive area is a narrow rectangular strip measuring 0·6 cm × 0·05 cm, and the overall dimensions are 1·2 cm × 1·7 cm × 0·15 cm.

Since the cell is comparatively insensitive to visible wavelengths, its performance is expressed in terms of the ratio of signal-to-noise voltage produced across the cell by a known quantity of interrupted monochromatic radiation. At a wavelength of 6 microns, with a direct current of 50 mA through the cell, the ratio of signal-to-noise voltage for an ambient temperature of 20 °C is stated to be greater than 72. However, the cell is claimed to be sensitive to infra-red radiations of wavelengths up to 8 microns.

Other points from the makers' data are given below:

Minimum detectable power: Less than 0·004 μW at 6 microns wavelength and bandwidth of 1 c/s.
Time constant: Less than 1 μsec.
Maximum direct current: 100 mA.
Cell resistance: 75 Ω.
Maximum case temperature: 70 °C.

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

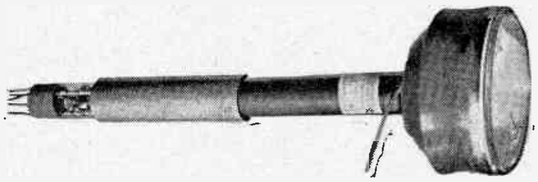
Micro-Spot Cathode-Ray Tube

Claimed to be the only one of its type in the world, this new Ferranti micro-spot cathode-ray tube, designated 5/71CM, is said to be capable of resolving 5,000 lines.

Measuring 5 in. across, the tube has been developed for airborne applications such as aerial mapping. While the tube is primarily intended for the display or photography of repetitive information, single transients may be photographed at writing speeds which are limited by the scan-coil requirements.

The spot-size diameter is stated to be less than 0·001 in.; this high resolution is attributed to the use of a very fine screen and a new design of electron gun using two focusing elements, one of which is electromagnetic and external to the tube, while the other is electrostatic and of fixed focal length.

The tube has an optical flat face with a non-darkening glass and a short cylindrical bulb, coated (except over the screen



surface) with a thick layer of plastic resin, enabling it to be operated under adverse atmospheric conditions; viz., 30 kV at 75,000 ft. without danger of e.h.t. breakdown. No tube socket is required as the leads to the rear end of the tube are encapsulated in a way which does not hinder the tube from being mounted easily in its focus and scanning assembly.

The standard phosphor used in the tube has green fluorescence with an afterglow to 1/*e* within 10 μsec. Tubes with a blue fluorescence can also be supplied.

The makers can provide scanning and focus coils specially designed for this tube, together with a small alignment magnet which is clamped to the neck of the tube in the region of the cathode.

Ferranti Ltd.,
Electronics Dept., Hollinwood, Manchester, Lancs.

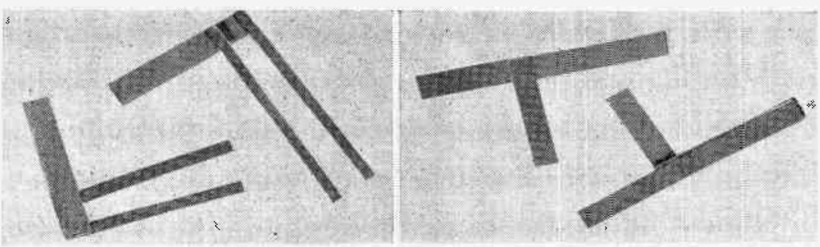
E.H.T. Power Supply

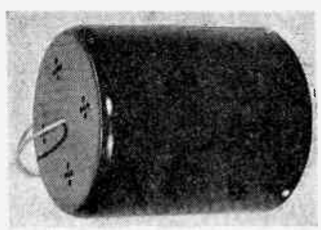
A light, compact and fully-screened e.h.t. power supply for providing an output of 1·5–15 kV d.c., where normal h.t. and l.t. supplies are available, has been produced by Hivolt Ltd.

The unit, which uses epoxy-moulded high-voltage components throughout, can be supplied to give either a fixed or continuously-variable output.

Provision is made for mounting the unit on an instrument chassis.

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





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

534.15 : 538.56 **3663**

Proposed Massless Remote Vibration Pickup.—C. Stewart. (*J. acoust. Soc. Amer.*, July 1958, Vol. 30, No. 7, pp. 644–645.) The method proposed is to transmit a narrow beam of microwave energy to the vibrating surface and detect the resulting phase modulation in the reflected wave. It is estimated that displacement sensitivities below a micron could be obtained using a 20-kW klystron transmitter. The method is also applicable to soil impedance measurements.

534.2 **3664**

Propagation of Plane Waves of Finite Amplitude.—Z. A. Gol'dberg. (*Akust. Zh.*, Oct.–Dec. 1957, Vol. 3, No. 4, pp. 322–328.) A discontinuity criterion is given for propagation in a viscous thermally conducting medium, and absorption coefficient formulae are derived.

534.2-14 **3665**

Diffraction and Radiation of Acoustic Waves in Liquids and Gases: Part 1.—M. D. Khaskind. (*Akust. Zh.*, Oct.–Dec. 1957, Vol. 3, No. 4, pp. 348–359.) General theory of hydrodynamic forces.

534.2-14 : 534.5 **3666**

The Phenomenon of Amplitude Modulation in Acoustic Combination Waves.—G. D. Mikhaĭlov. (*Akust. Zh.*, Oct.–Dec. 1957, Vol. 3, No. 4, pp. 376–378.) Extension of theoretical treatment noted earlier (1 of 1957), and a note of experimental results obtained using a quartz transducer operating simultaneously at 1·0 and 1·5 Mc/s.

534.2-8 : 541.135 **3667**

Effect of Pressure on Ultrasonic Relaxation in Electrolytes.—E. H. Carnevale & T. A. Litovitz. (*J. acoust. Soc. Amer.*, July 1958, Vol. 30, No. 7, pp. 610–613.) Measurements of ultrasonic absorption and velocity, made on aqueous solutions of NH_3 at pressures up to 2 030 kg/cm², show that the absorption decreases and the relaxation frequency increases as pressure is raised.

534.231 **3668**

Axially Symmetric Acoustic Streaming at a Resonator.—P. N. Kubanskiĭ. (*Akust. Zh.*, Oct.–Dec. 1957, Vol. 3, No. 4, pp. 337–341.)

534.231-8 : 534.26 **3669**

Diffraction Effects in the Ultrasonic Field of a Piston Source.—R. Bass. (*J. acoust. Soc. Amer.*, July 1958, Vol. 30, No. 7, pp. 602–605.) A new formula representing apparent attenuation due to diffraction is developed, using the relation defined by Williams (1546 of 1951). Results of measurements made at 1 and 3 Mc/s using a pulse technique confirm the theory qualitatively.

534.26 + 621.396.812.3 **3670**

Influence of the Directivity of a Receiving Unit on the Average Intensity of a Signal Received as a result of Scattering.—V. A. Zverev. (*Akust. Zh.*, Oct.–Dec. 1957, Vol. 3, No. 4, pp. 329–336.) A general expression is derived for the average intensity as a function of scattering angle, and its application to particular cases is noted, including that of a highly directional receiver.

534.6 + 621.317.3.029.6 **3671**

Experiments on cm Waves in Analogy with Acoustic Techniques made in Göttingen.—E. Meyer. (*J. acoust. Soc. Amer.*, July 1958, Vol. 30, No. 7, pp. 624–632.) Measurement techniques in the two fields are compared, with particular emphasis on the use of reverberation chambers. The design and performance of absorbing structures of both resonant and nonresonant types is discussed.

534.613 **3672**

Torques due to Acoustical Radiation Pressure.—G. Maidanik. (*J. acoust. Soc. Amer.*, July 1958, Vol. 30, No. 7, pp. 620–623.) A general expression is derived and applied to plane waves incident in an arbitrary direction, and to 'rigid' plane disks of arbitrary shape.

534.613 **3673**

Acoustic Radiation Force.—H. Olsen, H. Wergeland & P. J. Westervelt. (*J. acoust. Soc. Amer.*, July 1958, Vol. 30, No. 7, pp. 633–634.) Supplementary notes to 2316 of 1957 (Westervelt) and 1611 of June (Olsen et al.) are given, including a formula for the force on an arbitrary scatterer, which is derived without making any assumptions about the scatterer.

534.84 : 621.396.712.3 **3674**

The Large Auditorium of the Hessischer Rundfunk.—H. Schreiber. (*Rundfunktech. Mitt.*, Feb. 1958, Vol. 2, No. 1, pp. 29–34.) Details of the acoustic design and treatment of the hall are given, as well as a description of the lighting system and control-room equipment.

534.861 **3675**

Analysis and Measurement of Programme Levels.—(*B.B.C. Engng Div. Monographs*, March 1958, No. 16, pp. 5–31.)

Part 1—Investigation of Extreme Values of Sound Pressure.—D. E. L. Shorter & W. I. Manson (pp. 5–14). Correction, *ibid.*, Aug. 1958, No. 20, p. 23.

Part 2—A Description of an Optical Instrument for Monitoring Sound Signals. —E. R. Wigan (pp. 15–31).

534.88 **3676**

Electronic Sector Scanning.—D. G. Tucker, V. G. Welsby & R. Kendell. (*J. Brit. Instn Radio Engrs*, Aug. 1958, Vol. 18, No. 8, pp. 465–484.) A method is described of providing a rapid scan of an acoustic beam over a sector many times the beam width. The output of each element of a linear array or transducer is changed in frequency by a double-balanced modulator so that phase is retained. The outputs are then combined in a delay line, the ends of which are connected to a double-beam oscillograph giving bearing information over a sector for a continuous frequency sweep. The design of the modulators, delay line, and the choice of sector width are discussed together with display arrangements.

621.395.614 : 534.6-8 **3677**

Miniature Piezoelectric Ultrasonic Receivers.—E. V. Romanenko. (*Akust. Zh.*, Oct.–Dec. 1957, Vol. 3, No. 4, pp. 342–347.) Description of the manufacture and calibration of small $BaTiO_3$ receivers with a 0·2-mm detector element. Sensitivity is 0·004–0·007 μV/b over a frequency range of 1–10 Mc/s.

AERIALS AND TRANSMISSION LINES

621.372.2 **3678**

Miniature Delay Lines.—R. Gerharz. (*Electronic Radio Engr*, Oct. 1958, Vol. 35, No. 10, pp. 371–373.) The construction, which is described briefly, allows lines weighing 50 g and having a volume of 80 cm³ to be made. Propagation constants for seven experimental lines varied from 0·64 to 0·84. Pulse frequencies from about 5 to 39 Mc/s were obtained.

621.372.2 + 621.372.8] : 537.226 **3679**

Diffraction of Surface Waves by a Semi-infinite Dielectric Slab.—C. M. Angulo. (*Trans. Inst. Radio Engrs*, Jan. 1957, Vol. AP-5, No. 1, pp. 100–109. Abstract, *Proc. Inst. Radio Engrs*, May 1957, Vol. 45, No. 5, p. 716.)

621.372.8 : 621.396.65 **3680**

Microwave Aspects of Waveguides for Long-Distance Transmission.—A. E. Karbowiak. (*Proc. Instn elect. Engrs*, Part C, Sept. 1958, Vol. 105, No. 8, pp. 360–369.) Problems associated with long-range communication systems are discussed, and the circular waveguide excited in the H_{01} mode is shown to be most suitable. The problem of unintentional bends due to ground contours, etc., is analysed in detail and design criteria are established in terms of the surface impedance. Practical methods for obtaining the desired impedance are considered, including the use of surface dielectric coatings and helical waveguides.

621.372.8.001.2 **3681**

Normal-Modes Methods for Boundary-Excited Waveguides.—J. Van Bladel. (*Z. angew. Math. Phys.*, 25th July 1958, Vol. 9a, No. 2, pp. 193–202.)

621.372.821 **3682**

Shielded Coupled-Strip Transmission Line.—S. B. Cohn. (*Trans. Inst. Radio Engrs*, Oct. 1955, Vol. MTT-3, No. 5, pp. 29–38. Abstract, *Proc. Inst. Radio Engrs*, Feb. 1956, Vol. 44, No. 2, p. 276.)

621.372.823 **3683**

Effect of Ellipticity on Dominant-Mode Axial Ratio in Nominally Circular Waveguides.—P. I. Sandsmark. (*Trans. Inst. Radio Engrs*, Oct. 1955, Vol. MTT-3, No. 5, pp. 15–20. Abstract, *Proc. Inst. Radio Engrs*, Feb. 1956, Vol. 44, No. 2, p. 276.)

621.372.825 **3684**

The Design of Ridged Waveguides.—S. Hopper. (*Trans. Inst. Radio Engrs*, Oct. 1955, Vol. MTT-3, No. 5, pp. 20–29.) Practical design curves for single- and double-ridged waveguides are given.

621.372.831.25 **3685**

Step-Twist Waveguide Components. —H. A. Wheeler & H. Schwiebert. (*Trans. Inst. Radio Engrs*, Oct. 1955, Vol. MTT-3, No. 5, pp. 44–52. Abstract, *Proc. Inst. Radio Engrs*, Feb. 1956, Vol. 44, No. 2, p. 276.)

621.372.832.43 **3686**

Intrinsic Directional Coupler using Elliptical Coupling Apertures.—J. Figanier & E. A. Ash. (*Proc. Instn elect. Engrs*, Part C, Sept. 1958, Vol. 105, No. 8, pp. 432–437.) A coupler with a single elliptical hole in the broad face of a rectangular waveguide is analysed. A filter coupler using two such apertures is also examined. See also 1065 of April (Coale).

621.396.67 **3687**

A Generalized Form of the Aerial Reciprocity Theorem.—J. Brown. (*Proc. Instn elect. Engrs*, Part C, Sept. 1958, Vol. 105, No. 8, pp. 472–475.) "The reciprocity theorem which relates the transmission and reception properties of an aerial is extended to give information on the phase and amplitude of the signal received by the aerial for an incident plane wave of any polarization. The paper includes a rigorous proof based on the Lorentz reciprocity theorem for electromagnetic fields." See 3689.

621.396.67 : 621.315.668.2 **3688**

Steel Masts and Towers for the Danish Radio and Television Broadcasting Systems.—I. G. Hannemann, B. J. Rambøll & I. Mogensen. (*Teleteknik, Copenhagen, English Edn*, 1958, Vol. 2, No. 1, pp. 1–12.) Revised and extended version of 1736 of 1952 (Hannemann & Rambøll).

621.396.67.012.12 **3689**

A Theoretical Analysis of some Errors in Aerial Measurements.—J. Brown. (*Proc. Instn elect. Engrs*, Part C, Sept. 1958, Vol. 105, No. 8, pp. 343–351.) The reciprocity theorem is used to derive an expression for the power received by one aerial as a result of transmission from a second similar aerial at any distance from the first. Under conditions of aerial measurements the size of the receiving aerial can influence the errors in measured radiation patterns and power gains. The errors differ from those predicted by diffraction theory.

621.396.674.3.011.21 **3690**

Measured Self-Impedance of a Dipole Antenna near a Conducting Cylinder of Elliptical Cross-Section.—T. Y. Wong. (*Canad. J. Phys.*, July 1958, Vol. 36, No. 7, pp. 855–857.)

621.396.677 : 523.164 **3691**

A New Type of Pencil-Beam Aerial for Radio Astronomy.—J. H. Blythe. (*Mon. Not. R. astr. Soc.*, 1957, Vol. 117, No. 6, pp. 644–651.) In the interferometric technique described, a long narrow aperture and a small moving aerial are used at 38 Mc/s, and phase-switch records obtained at a number of different spacings are combined to give an effective beam width of 2·2°. Limitations are discussed. For results see 3792 below.

621.396.677.3 **3692**

Optimum Stacking Spacing in Antenna Arrays.—H. W. Kasper. (*QST*, April 1958, Vol. 42, No. 4, pp. 40–43.) Principles are outlined and general design information given in graphical form, relating spacing to source beam width.

621.396.677.5 **3693**

Loop Antenna Measurements.—P. A. Kennedy. (*Trans. Inst. Radio Engrs*, Oct. 1956, Vol. AP-4, No. 4, pp. 610–618. Abstract, *Proc. Inst. Radio Engrs*, April 1957, Vol. 45, No. 4, p. 571.)

621.396.677.6 : 621.396.93 **3694**

The Effect of Mutual Impedance on the Spacing Error of an Eight-Element Adcock.—Travers. (See 3827.)

621.396.677.71 **3695**

Circularly Polarized Slot Radiators. —A. J. Simmons. (*Trans. Inst. Radio Engrs*, Jan. 1957, Vol. AP-5, No. 1, pp. 31–36. Abstract, *Proc. Inst. Radio Engrs*, May 1957, Vol. 45, No. 5, p. 715.)

621.396.677.71 **3696**

Radiation Characteristics with Power Gain for Slots on a Sphere.—Y. Mushiake & R. E. Webster. (*Trans. Inst. Radio Engrs*, Jan. 1957, Vol. AP-5, No. 1, pp. 47–55. Abstract, *Proc. Inst. Radio Engrs*, May 1957, Vol. 45, No. 5, p. 715.)

621.396.677.71 **3697**

Cylindrical Radio Waves.—S. Sensiper. (*Trans. Inst. Radio Engrs*, Jan. 1957, Vol. AP-5, No. 1, pp. 56–70. Abstract, *Proc. Inst. Radio Engrs*, May 1957, Vol. 45, No. 5, p. 715.)

621.396.677.73 **3698**

Circularly Polarized Biconical Horns.—C. Goatley & F. D. Green. (*Trans. Inst. Radio Engrs*, Oct. 1956, Vol. AP-4, No. 4, pp. 592–596. Abstract, *Proc. Inst. Radio Engrs*, April 1957, Vol. 45, No. 4, p. 570.)

621.396.677.8 **3699**

Phase Centres of Microwave Antennas.—D. Carter. (*Trans. Inst. Radio Engrs*, Oct. 1956, Vol. AP-4, No. 4, pp. 597–600. Abstract, *Proc. Inst. Radio Engrs*, April 1957, Vol. 45, No. 4, p. 570.)

621.396.677.83.095 **3700**

Radiation by Disks and Conical Structures.—A. Leitner & C. P. Wells. (*Trans. Inst. Radio Engrs*, Oct. 1956, Vol. AP-4, No. 4, pp. 637–640. Abstract, *Proc. Inst. Radio Engrs*, April 1957, Vol. 45, No. 4, p. 571.)

621.396.677.833.2 **3701**

The Image Method of Beam Shaping.—P. T. Hutchison. (*Trans. Inst. Radio Engrs*, Oct. 1956, Vol. AP-4, No. 4, pp. 604–609. Abstract, *Proc. Inst. Radio Engrs*, April 1957, Vol. 45, No. 4, pp. 570–571.)

621.396.677.85 **3702**

Measured Phase Distribution in the Image Space of a Microwave Lens.—G. W. Farnell. (*Canad. J. Phys.*, July 1958, Vol. 36, No. 7, pp. 935–943.) Contours of constant phase at 3·2 cm λ are shown for a solid-dielectric aberration-free lens; extra detail is given near certain phase singularities which occur. Agreement is obtained with scalar diffraction theory. See also 29 of January (Bachynski & Bekefi).

621.396.677.85 **3703**

A Design Procedure for Dielectric Microwave Lenses of Large Aperture Ratio and Large Scanning Angle.—F. S. Holt & A. Mayer. (*Trans. Inst. Radio Engrs*, Jan. 1957, Vol. AP-5, No. 1, pp. 25–30. Abstract, *Proc. Inst. Radio Engrs*, May 1957, Vol. 45, No. 5, p. 715.)

621.396.677.85 : 537.226 **3704**

The Fields Associated with an Interface between Free Space and an Artificial Dielectric.—J. Brown & J. S. Seeley. (*Proc. Instn elect. Engrs*, Part C, Sept. 1958, Vol. 105, No. 8, pp. 465–471.) An approximate solution is obtained for the metal-strip dielectric in terms of evanescent waves inside the dielectric and in free space. Measured values for an equivalent circuit agree with the calculated values. See also 1367 of 1955 (Brown & Jackson).

AUTOMATIC COMPUTERS

681.142 **3705**

Short-Cut Multiplication and Division in Automatic Binary Digital Computers.—M. Lehman. (*Proc. Instn elect. Engrs*, Part B, Sept. 1958, Vol. 105, No. 23, pp. 496–504.) A modified short-cut process is proposed and the application of such procedures to restoring or non-restoring division techniques is discussed.

681.142 **3706**

A Full Binary Adder employing Two Negative-Resistance Diodes.—J. W. Horton & A. G. Anderson. (*IBM J. Res. Develop.*, July 1958, Vol. 2, No. 3, pp. 223–231.) This adder provides outputs which are virtually in coincidence with the input signal. A full adder is described using positive-gap diodes of the type described by Reeves & Cooke (3772 of 1955) which operate with 20-mμs pulses.

681.142 **3707**

TRADIC: the First Phase.—J. R. Harris. (*Bell Lab. Rec.*, Sept. 1958, Vol. 36, No. 9, pp. 330–334.) A general report is given of the equipment which was designed and built to test the feasibility of airborne digital computers using transistors.

681.142 **3708**

An Analogue-Computer Study of the Transient Behaviour and Stability Characteristics of Serial-Type Digital Data Systems.—O. I. Elgerd. (*Commun. & Electronics*, July 1958, No. 37, pp. 358–366.) The transient characteristics of sampled-data computer systems incorporating a holding circuit are examined, with particular emphasis on the transient response to a standard input step-function.

681.142 **3709**

Transistorized Analogue-Digital Converter.—W. B. Towles. (*Electronics*, 1st Aug. 1958, Vol. 31, No. 31, pp. 90–93.) The analogue/digital converter described has a power consumption of less than 4 W, and codes input signals up to 5 V at a maximum sampling rate of 5 000 inputs/s with errors not exceeding 0·5 %; the output is at the rate of 100 000 digits/s. The volume of the unit is 160 in³.

681.142 **3710**

A Direct-Reading Printed-Circuit Commutator for Analogue-to-Digital Data Conversion.—C. A. Walton. (*IBM J. Res. Develop.*, July 1958, Vol. 2, No. 3, pp. 178–192.) The disk-type commutator described supplies the digital signal required for output equipment operation without the need for supplementary coding or additional translation circuitry to remove ambiguities.

681.142 : 621-52 **3711**

Function Tables in Digital Control Computers.—E. J. Schubert. (*Commun. & Electronics*, July 1958, No. 37, pp. 316–319.) Stored function tables, with appropriate interpolation techniques, can be used with advantage in digital control computers where there are limitations on space and computing time, e.g. the control loop of servo systems.

681.142 : 621.318.134 : 621.318.57 **3712**

A Load-Sharing Matrix Switch.—G. Constantine, Jr. (*IBM J. Res. Develop.*, July 1958, Vol. 2, No. 3, pp. 205–211.) A matrix-switch winding pattern has been developed which allows the power from several pulse generators to be combined in a single high-power pulse to drive a computer core-type storage system. This pulse may be directed into one of a group of outputs; an example with 16 outputs is given.

CIRCUITS AND CIRCUIT ELEMENTS

621.3.049-181.4 : 621.318.5 **3713**

Miniaturization Design Techniques.—J. S. Zimmer. (*Electronic Equipm. Engng*, July 1958, Vol. 6, No. 7, pp. 37–38.) The construction of an e.m. relay is described as an example.

621.3.049.75 **3714**

Reliable Printed Wiring without Hole Pads.—G. F. Leyonmark. (*Electronic Equipm. Engng*, July 1958, Vol. 6, No. 7, pp. 43–45.) A 'plated-hole' technique is described.

621.314.2 : 621.372.45 **3715**

An Electronic Transformer.—T. G. Clark. (*Electronic Engng*, Sept. 1958, Vol. 30, No. 367, pp. 545–548.) The anode-follower circuit is used as a transformer in a cable system where signals are distributed from a master generator to a number of separate displays. The load on the source is negligible, the voltage transformation is independent of the impedance transformation, both being controllable, the cable may be matched if necessary, and the system bandwidth is inversely proportional to the cable length.

621.316.825 **3716**

Large-Signal Behaviour of Directly Heated Thermistors.—S. Ekelöf, N. Björk & R. Davidson. (*Acta polyt., Stockholm*, 1957, No. 216, 31 pp.; *Chalmers tek. Högsk. Handl.*, 1957, No. 185.) Part 3 of a study of thermistor circuits. Part 1: 3481 of 1954 (Ekelöf & Kihlberg); Part 2: *Chalmers tek. Högsk. Handl.*, 1955, No. 169 (Björk & Davidson).

621.316.825 : 621.375.4 **3717**

Temperature Compensating Networks.—H. D. Polishuk. (*Electronic Radio Engr*, Oct. 1958, Vol. 35, No. 10, pp. 373–377.) "A generalized analytical design procedure is proposed for the realization of two typical temperature-compensating bias networks, employing thermistors, for class-B push-pull transistor amplifiers. A set of simple relations is derived for evaluating the network component values, and restrictions are indicated on the choice of appropriate thermistors."

621.318.4 **3718**

The Spherical Coil as an Inductor, Shield, or Antenna.—H. A. Wheeler. (*Proc. Inst. Radio Engrs*, Sept. 1958, Vol. 46, No. 9, pp. 1595–1602.) The coil is a single-layer winding of constant axial pitch on a spherical surface. Its properties can be expressed by simple formulae, and can be used to evaluate the shielding effect of a closed nonmagnetic metal shell. Resonance effects are studied.

621.318.435 **3719**

Applications of Nonlinear Magnetics.—H. F. Storm. (*Commun. & Electronics*, July 1958, No. 37, pp. 380–388.) It is shown how saturable-core reactors may be used in such applications as counters, timers, voltage and current references, frequency multipliers, firing circuits for thyratrons and ignitrons, pulse-shaping circuits for magnetrons, rectifying circuits, bistable flip-flops, frequency detectors, and square-wave oscillators. 82 references.

621.318.57 **3720**

Minimization of Components in Electronic Switching Circuits.—T. J. Beatson. (*Commun. & Electronics*, July 1958, No. 37, pp. 283–291. Discussion.) The details are given of a method, using Boolean functions, for designing switching circuits using a minimum number of diodes or transistors.

621.318.57 **3721**

Some Comments on Minimum Triggering Signals.—J. L. Dautremont, Jr. (*Proc. Inst. Radio Engrs*, Sept. 1958, Vol. 46, No. 9, pp. 1654–1655.) A theorem on the energy transfer characteristics of a linear network is proved. See also 1994 of July (Beattie).

621.372 : 621.376.3 **3722**

The Response of a Network to a Frequency-Modulated Input Voltage.—J. W. Head and C. G. Mayo. (*Proc. Instn elect. Engrs*, Part C, Sept. 1958, Vol. 105, No. 8, pp. 509–512.) Mathematical treatment illustrating the relative simplicity of the method of operational calculus.

621.372.011.1 **3723**

An Exact Theory of *N*-Component Steady-State Operators for Linear Circuits.—A. J. O. Cruickshank. (*Proc. Instn elect. Engrs*, Part C, Sept. 1958, Vol. 105, No. 8, pp. 513–518.) See also 1997 of July.

621.372.2 **3724**

Unstable Linear Systems and the Minimum Phase Condition.—P. E. Pfeiffer. (*J. Franklin Inst.*, April 1958, Vol. 265, No. 4, pp. 291–301.) The relations between transfer functions for unstable systems and the class of minimum-phase transfer functions are examined.

621.372.41 : 621.318.424 **3725**

The Limits of the Regions of Stability of the Normal State in certain Ferroresonant Circuits.—M. Panet. (*C. R. Acad. Sci., Paris*, 6th Jan. 1958, Vol. 246, No. 1, pp. 85–87.) The unequal voltage distribution between the two identical resonance circuits referred to in 1350 of May is explained by periodic variations in coil inductance.

621.372.45 **3726**

Multi-gain Representation for a Single-Valued Nonlinearity with Several Inputs, and the Evaluation of their Equivalent Gains by a Cursor Method.—M. J. Somerville & D. P. Atherton. (*Proc. Instn elect. Engrs*, Part C, Sept. 1958, Vol. 105, No. 8, pp. 537–549.)

621.372.5 **3727**

Radio Engineering Use of the Cayley-Klein Model of Three-Dimensional Hyperbolic Space.—E. F. Bolinder. (*Proc. Inst. Radio Engrs*, Sept. 1958, Vol. 46, No. 9, pp. 1650–1651.) Applications to the solution of network problems are outlined. See also 3768 of 1957.

621.372.5 **3728**

Some Optimum Four-Terminal Networks having Given Input and Output Shunt Capacitances.—O. P. D. Cutteridge. (*Proc. Instn elect. Engrs*, Part C, Sept. 1958, Vol. 105, No. 8, pp. 398–403.)

621.372.5 : 621.376.23 : 621.396.822 **3729**

Optimum Network Functions for the Sampling of Signals in Noise.—H. S. Heaps & M. R. McKay. (*Proc. Instn elect. Engrs*, Part C, Sept. 1958, Vol. 105, No. 8, pp. 438–443. Discussion, p. 443.) Transfer functions are calculated for networks which maximize (*a*) the ratio between the average amplitude of *n* successive samples of the output signal and the r.m.s. output noise, and (*b*) a continuous sample of the output.

621.372.57 **3730**

Active Band-Pass Filter has Sharp Cut-Off.—J. R. MacDonald. (*Electronics*, 15th Aug. 1958, Vol. 31, No. 33, pp. 84–87.) An adjustable *RC* a.f. filter having Butterworth attenuation characteristics and 42 dB/octave cut-off slope is described. Outputs of 50 V r.m.s. can be obtained without appreciable harmonic distortion. The dynamic range exceeds 100 dB.

621.373.4.072.9 **3731**

On the Discrimination of a Synchronized Oscillator against Interference Accompanying the Synchronizing Signal.—R. Spence & A. R. Boothroyd. (*Proc. Instn elect. Engrs*, Part C, Sept. 1958, Vol. 105, No. 8, pp. 519–526.) The response of the oscillator to an interfering signal is investigated when the interference component of the oscillator output is small. The response is found to be linear, and the discrimination is expressed analytically. The experimental results are in good agreement with theory.

621.373.43 **3732**

Simplified Design of Pulse-Forming Networks.—K. H. Recorr. (*Electronics*, 1st Aug. 1958, Vol. 31, No. 31, p. 94.) The network consists of a five-section capacitive circuit and a single-layer continuously-wound tapped solenoid.

621.373.52 : 621.318.57 **3733**

Designing Transistor Circuits—Switching Dynamics.—R. B. Hurley. (*Electronic Equipm. Engng*, July 1958, Vol. 6, No. 7, pp. 30–34.) Equivalent-circuit data for determining overall response time are tabulated for basic transistor switches with an applied input step for the underdriven condition. The overdriven case is also considered. See also 2667 of September.

621.373.52 : 621.395.43 **3734**

Transistor Pulse Generators for Time-Division Multiplex.—K. W. Cattermole. (*Proc. Instn elect. Engrs*, Part B, Sept. 1958, Vol. 105, No. 23, pp. 471–479. Discussion, pp. 479–482.) "Point-contact transistor circuits to generate pulses in the microsecond range are described, together with means of frequency-dividing and interlacing pulse trains and their application to time-division operation of telephone transmission and switching systems."

621.374.32 **3735**

Build-Up of Large Signals with Elimination of Reflections in Magnetostrictive Storage Lines by means of Multicoil Transducers.—D. Maeder. (*Helv. phys. Acta*, 15th Aug. 1957, Vol. 30, No. 4, pp. 347–352. In German, with English summary.) An ultrasonic storage delay line using 12 transducer coils and a stainless-steel wire 18 m long has a capacity of 300 decimal places. See 69 of January.

621.375.1.012 **3736**

Amplifier Delay Charts.—J. B. Harrington. (*Electronics*, 15th Aug. 1958, Vol. 31, No. 33, pp. 88–90.) The time delay in various types of amplifier due to the network phase shift can be determined from the series of charts given if the amplifier bandwidth and number of stages are known.

621.375.13 : 621-52 **3737**

Relating the Nyquist Plot to the Root-Locus Plot.—W. G. Johnston. (*J. Electronics Control*, July 1958, Vol. 5, No. 1, pp. 89–96.)

621.375.3 : 621.318.57 : 621.314.7 **3738**

High-Efficiency Push-Pull Magnetic Amplifiers with Transistors as Switched Rectifiers.—A. G. Milnes. (*Commun. & Electronics*, July 1958, No. 37, pp. 327–330. Discussion, pp. 330–331.) Various circuits are considered in which the efficiencies exceed 50 %. They are particularly suitable where the available power supply is limited.

621.375.4 : 538.632 **3739**

A Simple Transistor Amplifier for Energizing a Hall Multiplier.—D. J. Lloyd. (*Electronic Engng*, Sept. 1958, Vol. 30, No. 367, pp. 560–561.)

621.375.4.018.7 **3740**

Nonlinear Distortion in Transistor Amplifiers at Low Signal Levels and Low Frequencies.—N. I. Meyer. (*Proc. Instn elect. Engrs*, Part C, Sept. 1958, Vol. 105, No. 8, pp. 550–552.) Discussion on 2392 of 1957.

621.375.4.029.5 : 621.397.6 **3741**

Transistor Video Amplifiers.—P. B. Helsdon. (*Marconi Rev.*, 2nd Quarter 1958, Vol. 21, No. 129, pp. 56–75.) The principles of design of iterated video amplifiers using transistors are discussed in terms of a simplified hybrid-π equivalent circuit. The design and performance of an experimental television video distribution amplifier are described.

621.375.9 : 538.569.4 **3742**

Polarization of a Molecular Beam by an Alternating Field with Variable Amplitude and Phase.—Lyubimov & Khokhlov. (See 3781.)

621.375.9 : 538.569.4 **3743**

Nonlinear Effects of the Interaction of Resonance Fields in the Molecular Generator and Amplifier.—V. M. Kontorovich & A. M. Prokhorov. (*Zh. eksp. teor. Fiz.*, Dec. 1957, Vol. 33, No. 6 (12), pp. 1428–1430.) Analysis of a molecular oscillator with an auxiliary field [see 402 of 1956 (Basov & Prokhorov)], based on the polarizability of a quantum system situated in two resonance fields. Such a system can operate at two frequencies which depend on the amplitude as well as the frequency of the auxiliary field.

621.375.9 : 538.569.4.029.6 **3744**

Susceptibility of the Three-Level Maser.—A. M. Clogston. (*Phys. Chem. Solids*, 1958, Vol. 4, No. 4, pp. 271–277.) The susceptibility presented to a radiation field of frequency $(E_3 - E_2)/h$ by the paramagnetic material is calculated. The effect of the cavity reaction at the frequency $(E_2 - E_1)/h$ is considered. The line shape is shown to be drastically altered for large-amplitude driving fields.

621.375.9 : 538.569.4.029.6 : 621.396.822 **3745**

Noise in Maser Amplifiers—Theory and Experiment.—J. P. Gordon & L. D. White. (*Proc. Inst. Radio Engrs*, Sept. 1958, Vol. 46, No. 9, pp. 1588–1594.) The theoretical treatment is based on an equivalent microwave circuit. The effective input noise temperature of a reflection-type NH_3 beam maser was found experimentally to be 80° K, which is in agreement with theory. An upper limit of 20° K for the 'beam temperature' was deduced. See also 737 of March.

621.375.9.029.6 : 538.569.4 : 538.221 **3746**

Quantum Analogue of the Ferromagnetic Microwave Amplifier.—H. Suhl. (*Phys. Chem. Solids*, 1958, Vol. 4, No. 4, pp. 278–282.) "Certain resemblances between the modes of operation of the three-level maser and the ferromagnetic microwave amplifier are shown to be superficial by constructing a quantum-mechanical model of the latter device. It is shown that while establishment of a negative temperature for two levels is essential in the three-level maser, it is inessential in the analogue of the ferromagnetic amplifier, which in essence depends only on the time-varying part of the density matrix." See also 3076 of 1957.

621.375.9.029.6 : 538.569.4 : 538.221 **3747**

Phase Dependence of a Ferromagnetic Microwave Amplifier.—W. L. Whirry & F. B. Wang. (*Proc. Inst. Radio Engrs*, Sept. 1958, Vol. 46, No. 9, pp. 1657–1658.) The phase-dependent operation of an amplifier using polycrystalline yttrium garnet is shown experimentally.

621.375.9.029.6 : 621.372.413 **3748**

Minimum Noise Figure of a Parametric Amplifier.—H. Heffner & G. Wade. (*J. appl. Phys.*, Aug. 1958, Vol. 29, No. 8, p. 1262.) With the aid of a circulator the noise figure may be made to approach the minimum value ω_p/ω_2, where ω_p is the pumping and ω_2 the output frequency.

621.375.9.029.63 : 621.3.011.23 **3749**

A Low-Noise Nonlinear-Reactance Travelling-Wave Amplifier.—R. S. Engelbrecht. (*Proc. Inst. Radio Engrs*, Sept. 1958, Vol. 46, No. 9, p. 1655.) Results obtained with an experimental model for 380 Mc/s using nonlinear capacitances are given. See also 2035 of July (Tien & Suhl).

621.376.223 **3750**

A Rectifier Modulator with Stable Low Carrier-Leak.—E. Hands. (*Proc. Instn elect. Engrs*, Part C, Sept. 1958, Vol. 105, No. 8, pp. 381–390.) The action of a constant-current ring modulator in which the input transformer is replaced by high-impedance valve circuits is analysed in detail. The theoretical analysis is confirmed experimentally using a 3-kc/s carrier frequency. Stable carrier-leak levels more than 90 dB below the carrier current from each source are possible.

621.376.5 : 621.372.632 **3751**

Pulse Modulation Transmitted through a Linearly Modulated Transit-Time Device.—V. Met. (*Proc. Inst. Radio Engrs*, Sept. 1958, Vol. 46, No. 9, pp. 1656–1657.) A discussion of basic principles with reference to the serrodyne device [1366 of 1957 (Cumming)], and their application to frequency shifting, computers, pulse duplexing and a multiple reflex-pulse amplifier.

GENERAL PHYSICS

53.081.6 **3752**

New Physical Constants from Dimensional Analysis.—A. T. Gresky. (*J. Franklin Inst.*, Feb. 1958, Vol. 265, No. 2, pp. 85–95.) Three quantities are formulated which represent constants of astronomy and classical mechanics and of submicroscopic physics, and which correlate phenomena in electromagnetic, quantum and classical physics.

530.112 : 530.12 : 531.18 **3753**

The Special Theory of Relativity and the Ether.—A. Metz. (*C. R. Acad. Sci., Paris*, 16th Dec. 1957, Vol. 245, No. 25, pp. 2197–2198.) Datzeff's theory (1381 of May) is held to be quite untenable.

530.12 : 535.13 **3754**

Spherically Symmetric Solution of the General Relativity Equations taking the Tensor of Born-Infeld Electromagnetic Theory as Energy-Momentum Tensor.—J. Lameau. (*C. R. Acad. Sci., Paris*, 16th Dec. 1957, Vol. 245, No. 25, pp. 2208–2210.)

537.122 **3755**

Theoretical Problem Posed by an Extended Model of the Electron and the Proton.—E. J. Sternglass. (*C. R. Acad. Sci., Paris*, 3rd March 1958, Vol. 246, No. 9, pp. 1386–1389.) Arguments about the stability and relativistic properties of elementary particles taken as extended sources of e.m. fields are considered.

537.311.1 **3756**

The Physical Interpretation of Mean Free Path and the Integral Method.—P. J. Price. (*IBM J. Res. Developm.*, July 1958, Vol. 2, No. 3, pp. 200–203.) An extension of previous theoretical work on electron transport in solids. See 90 of January and *ibid.*, July 1957, Vol. 1, No. 3, pp. 239–248.

537.311.1 **3757**

Generalization of the Variation Principle in the Theory of Electrical Conductivity.—V. Glaser & B. Jakšic. (*Nuovo Cim.*, 16th Jan. 1958, Vol. 7, No. 2, pp. 259–262. In English.)

537.311.62 **3758**

Theory of the Anomalous Skin Effect in Normal and Superconducting Metals.—D. C. Mattis & J. Bardeen. (*Phys. Rev.*, 15th July 1958, Vol. 111, No. 2, pp. 412–417.) The current density in a normal metal in which the electric field varies over a mean free path is derived from a quantum approach in which use is made of the density matrix in the presence of scattering centres but in the absence of the field. The method is applied to superconductors.

537.311.62 : 538.63 **3759**

Anomalous Skin Effect in a Magnetic Field.—D. C. Mattis & G. Dresselhaus. (*Phys. Rev.*, 15th July 1958, Vol. 111, No. 2, pp. 403–411.) A classical and quantum mechanical derivation of cyclotron resonance in metals is given. The quantum derivation yields the same result as the classical calculation except in the limit of low quantum numbers or high magnetic fields.

537.52 **3760**

Noise and Electron Temperatures of some Cold-Cathode Argon Discharges.—E. W. Collings. (*J. appl. Phys.*, Aug. 1958, Vol. 29, No. 8, pp. 1215–1219.) Noise temperatures at 3 kMc/s were compared with the corresponding electron temperatures for the positive columns of some cold-cathode discharges in A; they were found to be in close agreement. The discharges gave reproducible results and are recommended for use as noise standards.

537.525 : 538.69 **3761**

The Townsend Discharge in a Coaxial Diode with Axial Magnetic Field.—P. A. Redhead. (*Canad. J. Phys.*, March 1958, Vol. 36, No. 3, pp. 255–270.) An approximate theory of the striking characteristics of coaxial cylinders in an axial magnetic field, taking into account the effects of elastic collisions of the electrons. Measurements in the pressure range 10^{-3}–10^{-9} mm Hg are in general agreement with the theory.

537.533 **3762**

The Fresnel Biprism in Electron Optics; Influence of the Size of the Source; Effect of a Periodic Voltage Applied to the Wire of the Biprism.—J. Faget, J. Ferré & C. Fert. (*C. R. Acad. Sci., Paris*, 3rd March 1958, Vol. 246, No. 9, pp. 1404–1407.) See 1393 of 1957 (Faget & Fert).

537.533.7 : 538.561 **3763**

Contribution to the Theory of Transition Radiation.—G. M. Garibyan. (*Zh. eksp. teor. Fiz.*, Dec. 1957, Vol. 33, No. 6 (12), pp. 1403–1410.) The transition radiation and Cherenkov radiation produced when a charged particle moves in succession through two media of different dielectric and magnetic properties are considered. The cases in which one medium is a vacuum are discussed in detail. See also 3829 of 1957 (Pafomov).

537.56 **3764**

Apparatus for Producing Plasma Beams.—E. R. Harrison & R. H. Dawton. (*J. Electronics Control*, July 1958, Vol. 5, No. 1, pp. 29–32.) A brief account is given of simple apparatus and experiments conducted with it.

537.56 **3765**

Effect of Electron Exchange on the Dispersion Relation of Plasma Oscillations.—H. Kanazawa & S. Tani. (*Progr. theor. Phys.*, Feb. 1958, Vol. 19, No. 2, pp. 153–158.) The dispersion relation is derived from a canonical transformation slightly different from that of Bohm & Pines (1375 of 1954). A correction factor is introduced for electron exchange effects but agreement between theory and experiment is not thereby improved.

537.581 **3766**

Model for the Surface Potential Barrier and the Periodic Deviations in the Schottky Effect.—P. H. Cutler & J. J. Gibbons. (*Phys. Rev.*, 15th July 1958, Vol. 111, No. 2, pp. 394–402.) The model is based on the quantum-mechanical calculation by Bardeen (*ibid.*, 1st May 1936, Vol. 49, No. 9, pp. 653–663) on the form of the potential at the surface of a sodium-like metal and the analysis of Sachs & Dexter (*J. appl. Phys.*, Dec. 1950, Vol. 21, No. 12, pp. 1304–1308) on the quantum limits of the image-face theory. The periodic deviations are recalculated and results compared with previous theory and experiment.

538.114 **3767**

Remarks on Spin-Wave Theory for the Ferromagnetic Exchange Problem.—I. Mannari. (*Progr. theor. Phys.*, Feb. 1958, Vol. 19, No. 2, pp. 201–213.) A theory is developed which is essentially equivalent to the Bloch-Bethe-Van Kranendonk formalism [see 2025 of 1956 (Van Kranendonk)]. Thermodynamic properties below the Curie point are fully treated.

538.311 : 621.318.4 **3768**

The Production of Very Homogeneous Axially Symmetric Magnetic Fields.—H. Primas & H. H. Günthard. (*Helv. phys. Acta*, 15th Aug. 1957, Vol. 30, No. 4, pp. 331–346. In German.) Inhomogeneity in the magnetic field between two pole pieces is due to irregularity in the pole piece and to boundary effects which may be reduced by 'current shims' in the form of compensating coils.

538.312 **3769**

Electromagnetic Energy Transfer.—P. Hammond. (*Proc. Instn elect. Engrs*, Part C, Sept. 1958, Vol. 105, No. 8, pp. 352–358. Discussion, p. 359.) "Methods of calculating and measuring the flow of electromagnetic energy are compared and contrasted. The differences between the low-frequency and high-frequency approaches to energy flow problems are discussed and suggestions are made to ease the difficulties in the way of students and teachers faced with these apparently irreconcilable differences."

538.56.029.6 : 538.615 **3770**

Microwave Zeeman Effect and Theory of Complex Spectra.—F. R. Innes & C. W. Ufford. (*Phys. Rev.*, 1st July 1958, Vol. 111, No. 1, pp. 194–202.)

538.566 : 535.32 **3771**

Dispersion.—(*Wireless World*, Oct. 1958, Vol. 64, No. 10, pp. 502–506.) The effect is discussed in terms of group and phase velocities, and applied to waveguides, cables, circuits and the ionosphere.

538.566 : 535.42] + 534.26 **3772**

The Effect of Fluctuations on the Diffraction Patterns of a Focusing System.—L. A. Chernov. (*Akust. Zh.*, Oct.–Dec. 1957, Vol. 3, No. 4, pp. 360–365.) General formulae are derived for the average distribution of intensity and the distribution of fluctuations in a diffraction pattern when fluctuations are present in the incident wave. Limiting cases of large and small fluctuations are considered.

538.566 : 535.42 **3773**

Transmission Characteristics of Inclined Wire Gratings.—O. J. Snow. (*Trans. Inst. Radio Engrs*, Oct. 1956, Vol. AP-4, No. 4, pp. 650–654. Abstract, *Proc. Inst. Radio Engrs*, April 1957, Vol. 45, No. 4, p. 571.)

538.566 : 535.42 **3774**

On Resonance in Infinite Gratings of Cylinders.—S. N. Karp & J. Radlow. (*Trans. Inst. Radio Engrs*, Oct. 1956, Vol. AP-4, No. 4, pp. 654–661. Abstract, *Proc. Inst. Radio Engrs*, April 1957, Vol. 45, No. 4, p. 571.)

538.566 : [535.43 + 535.312 **3775**

On Scattering and Reflection of Electromagnetic Waves by Rough Surfaces.—V. Twersky. (*Trans. Inst. Radio Engrs*, Jan. 1957, Vol. AP-5, No. 1, pp. 81–90. Abstract, *Proc. Inst. Radio Engrs*, May 1957, Vol. 45, No. 5, p. 716.)

538.566.029.6 : 535.42 **3776**

Diffraction of Microwaves by Tandem Slits.—L. R. Alldredge. (*Trans. Inst. Radio Engrs*, Oct. 1956, Vol. AP-4, No. 4, pp. 640–649. Abstract, *Proc. Inst. Radio Engrs*, April 1957, Vol. 45, No. 4, p. 571.)

538.569 : 539.2 **3777**

Induced and Spontaneous Emission in a Coherent Field.—I. R. Senitzky. (*Phys. Rev.*, 1st July 1958, Vol. 111, No. 1, pp. 3–11.) The resonant interaction between a coherently oscillating radiation field and a number of similar atomic systems coupled to the field through their electric dipole moments is analysed quantum-mechanically. Distinction is drawn between coherent and incoherent parts of the energy. Terms corresponding to induced and spontaneous emission are identified, and it is shown that the latter includes both coherent and incoherent components. Special situations related to masers and to the coherence of spontaneous radiation are discussed.

538.569.4 **3778**

Theory of Cyclotron Resonance.—E. A. Kaner. (*Zh. eksp. teor. Fiz.*, Dec. 1957, Vol. 33, No. 6 (12), pp. 1472–1476.) Treatment of cyclotron resonance in a metal in an inclined magnetic field and in a parallel magnetic field with arbitrary electron reflection.

538.569.4 **3779**

Theory of Cyclotron Resonance in Metals.—E. A. Kaner & M. Ya. Azbel'. (*Zh. eksp. teor. Fiz.*, Dec. 1957, Vol. 33, No. 6 (12), pp. 1461–1471.) An investigation of the influence of field strength and temperature on the surface impedance of a metal in r.f. and constant magnetic fields parallel to the surface.

538.569.4 : 537.311.62 **3780**

The Skin Effect and Ferromagnetic Resonance.—V. L. Gurevich. (*Zh. eksp. teor. Fiz.*, Dec. 1957, Vol. 33, No. 6 (12), pp. 1497–1504.) Mathematical analysis of normal and anomalous skin effect in metals under conditions of ferromagnetic resonance.

538.569.4 : 621.375.9 **3781**

Polarization of a Molecular Beam by an Alternating Field with Variable Amplitude and Phase.—G. P. Lyubimov & R. V. Khokhlov. (*Zh. eksp. teor. Fiz.*, Dec. 1957, Vol. 33, No. 6 (12), pp. 1396–1402.) Equations are derived and an exact solution is given for the case when the frequency of the applied field is the same as that of the molecular transition. Approximate solutions are obtained for slow and rapid variations in the amplitude and frequency of the field during the time of transit of the molecular beam through the resonator cavity.

538.569.4.029.6 **3782**

Measurement of Microwave Absorption in Binary Gaseous Mixtures.—G. Boudouris & D. Ilias. (*C. R. Acad. Sci., Paris*, 3rd March 1958, Vol. 246, No. 9, pp. 1407–1410.)

538.569.4.029.6 **3783**

Absorption and Refraction of some Polar Gases as a Function of Pressure at Microwave Frequencies.—A. Battaglia, F. Bruin & A. Gozzini. (*Nuovo Cim.*, 1st Jan. 1958, Vol. 7, No. 1, pp. 87–94. In English.)

538.569.4.029.6 : 535.33.08 **3784**

Optical Detection of Hyperfine Transitions of Caesium Atoms.—F. Diamand, J. M. Legendre & T. Skalinski. (*C. R. Acad. Sci., Paris*, 6th Jan. 1958, Vol. 246, No. 1, pp. 90–92.) Report of measurements made at frequencies of 9205·3 Mc/s and 9179·8 Mc/s to detect hyperfine Zeeman transitions in Cs.

538.569.4.029.6 : 535.343.4 **3785**

Microwave Apparatus for the Measurement of the Refraction, Dispersion and Absorption of Gases at Relatively High Pressure.—A. Battaglia, F. Bruin & A. Gozzini. (*Nuovo Cim.*, 1st Jan. 1958, Vol. 7, No. 1, pp. 1–9. In English.)

538.569.4.029.64/.65 : 535.343.4 **3786**

A Microwave Spectrometer for the Study of Free Radicals.—I. R. Hurle & T. M. Sugden. (*J. sci. Instrum.*, Sept. 1958, Vol. 35, No. 9, pp. 319–323.) Description of apparatus suitable for the study of short-lived molecules in the gas phase, and operating in the frequency range 20–70 kMc/s.

538.569.4.08 **3787**

Micromodulator—a Device for Measuring the Intensities of Microwave Absorption Lines.—R. D. Mattuck & M. W. P. Strandberg. (*Rev. sci. Instrum.*, Aug. 1958, Vol. 29, No. 8, pp. 717–721.) By means of a small electromagnet and power supply, a free electron resonance is utilized to provide a standard comparison line at any frequency up to 40 kMc/s.

GEOPHYSICAL AND EXTRATERRESTRIAL PHENOMENA

523.15 **3788**

On Force-Free Magnetic Fields.—S. Chandrasekhar & L. Woltjer. (*Proc. nat. Acad. Sci.*, 15th April 1958, Vol. 44, No. 4, pp. 285–289.) The assumption that the Lorentz force vanishes in cosmic magnetic fields which occur in regions of low density is discussed.

523.164 **3789**

Observations of Discrete Radio Sources at a Frequency of 500 Mc/s.—R. G. Conway. (*Mon. Not. R. astr. Soc.*, 1957, Vol. 117, No. 6, pp. 692–697.) An interferometer system with long integration times is used to determine the flux densities of eleven sources relative to Cygnus A.

523.164 **3790**

The Spectra of Radio Stars.—G. R. Whitfield. (*Mon. Not. R. astr. Soc.*, 1957, Vol. 117, No. 6, pp. 680–691.) By considering all available measurements on the flux density of Cassiopeia A, it is concluded that its spectrum obeys a simple power law. Using this law, the spectra and spectral indices of 31 radio stars are derived, including Cygnus A, Virgo A and Taurus A.

523.164 **3791**

On the Nature of the Cygnus-X Radio Source as derived from Observations in the Continuum and at the Hydrogen-Line Frequency.—R. D. Davies. (*Mon. Not. R. astr. Soc.*, 1957, Vol. 117, No. 6, pp. 663–679.)

523.164 **3792**

Results of a Survey of Galactic Radiation at 38 Mc/s.—J. H. Blythe. (*Mon. Not. R. astr. Soc.*, 1957, Vol. 117, No. 6, pp. 652–662.) The results, covering most of the sky north of $-20°$, are presented in the form of a contour map together with a list of reliably observed sources and H II regions with their features.

523.164 : 621.396.677 **3793**

A New Type of Pencil-Beam Aerial for Radio Astronomy.—Blythe. (See 3691.)

523.164 : 621.396.677.3 **3794**

A Theoretical Study of Errors in Radio-Interferometer-Type Measurements Attributable to Inhomogeneities of the Medium.—G. J. Simmons. (*Trans. Inst. Radio Engrs*, Dec. 1957, Vol. TRC-3, No. 3, pp. 2–5. Abstract, *Proc. Inst. Radio Engrs*, April 1958, Vol. 46, No. 4, p. 805.)

523.164.32 **3795**

Duration and Bandwidth of Short-Lived Transients in Solar Noise.—T. de Groot. (*Nature, Lond.*, 14th June 1958, Vol. 181, No. 4624, pp. 1676–1677.) Histograms of single-frequency measurements made at 400 Mc/s and a table of results for a two-channel receiver covering the band 394–406 Mc/s are given. See also 439 of February.

523.5 : 621.396.11 **3796**

The Variation of Ionization along a Meteor Trail.—J. S. Greenhow & E. L. Neufeld. (*Mon. Not. R. astr. Soc.*, 1957, Vol. 117, No. 4, pp. 359–369.) Results are described of investigations, using two spaced receivers to observe radio echoes from faint meteor trails. The mean ionization curve is much shorter than predicted by present theory and the rise to maximum electron density more rapid than expected.

523.5 : 621.396.822 **3797**

Radio Noise from Meteors.—G. S. Hawkins. (*Nature, Lond.*, 7th June 1958, Vol. 181, No. 4623, p. 1610.) A note of attempts made in U.S.A. to detect meteor noise at frequencies of 1 c/s, 30 Mc/s, 218 Mc/s and 475 Mc/s. No emission from meteors was detected. It is concluded that the efficiency of conversion of the kinetic energy of meteors to radio energy is less than 10^{-16} per unit bandwidth.

523.5 : 621.396.96 **3798**

Analysis of Meteoric Body Doppler Radar Records taken during a Geminid Shower Period.—M. S. Rao. (*Canad. J. Phys.*, July 1958, Vol. 36, No. 7, pp. 840–854.) The prevailing-wind speed in the 80–100-km region has been determined using a c.w. Doppler radar and three-station pulsed radars operating simultaneously at about 30 Mc/s. The body Doppler frequency and its fluctuations indicate a wind speed of 54 m/s and a turbulence scale of about 1 km on the night of 10th/11th December 1948.

523.745 : 523.165 **3799**

A Cosmic-Ray Increase Related to Solar Activity.—J. Katzman. (*Canad. J. Phys.*, July 1958, Vol. 36, No. 7, pp. 807–814.) A large increase in cosmic-ray activity, measured with telescopes of small solid angle, was observed to accompany a sustained increase in the F_2 layer critical frequency during the period September 1956–February 1957.

523.75 : 535.334 **3800**

Temperatures and Electron Densities in Flares as derived from Spectroscopic Data.—J. T. Jefferies. (*Mon. Not. R. astr. Soc.*, 1957, Vol. 117, No. 5, pp. 493–504.)

523.752 **3801**

Type IV Emissions and the Origin of Cosmic Rays Associated with Chromospheric Eruptions.—A. Boischot & J. F. Denisse. (*C. R. Acad. Sci., Paris*, 16th Dec. 1957, Vol. 245, No. 25, pp. 2194–2197.) See also 2437 of 1957 (Boischot).

550.38 **3802**

The Origin and Maintenance of Geomagnetism, its Secular Variation and its Inversions.—A. Dauvillier. (*C. R. Acad. Sci., Paris*, 3rd March 1958, Vol. 246, No. 9, pp. 1354–1356.)

550.389.2 : 629.19 **3803**

Orbital Behaviour of Earth Satellites.—R. E. Roberson. (*J. Franklin Inst.*, Sept. & Oct. 1957, Vol. 264, Nos. 3 & 4, pp. 181–202 & 269–285.) Sources of perturbation are considered with particular attention to the effect of the oblateness of the earth, for which an analysis is developed, and recent contributions are reviewed.

550.389.2 : 629.19 **3804**

Radio Doppler Measurements on the Russian Satellites at the National Standards Laboratory.—G. J. A. Cassidy. (*Proc. Instn Radio Engrs, Aust.*, March 1958, Vol. 19, No. 3, pp. 105–109.) From observations made on the 40-Mc/s transmission at one station, values for the period and other orbit parameters were deduced using simple methods.

550.389.2 : 629.19 **3805**

Sputnik I's Last Days in Orbit.—J. D. Kraus & E. E. Dreese. (*Proc. Inst. Radio Engrs*, Sept. 1958, Vol. 46, No. 9, pp. 1580–1587.) The satellite was tracked by using a c.w. reflection technique [see 1724 of June (Kraus)], and was found to break up in a complex manner over a period of days. Possible break-up mechanisms are suggested.

550.389.2 : 629.19 **3806**

Effect of Air Drag on the Orbit of the Russian Earth Satellite 1957β: Comparison of Theory and Observation.—D. G. King-Hele & D. C. M. Leslie. (*Nature, Lond.*, 28th June 1958, Vol. 181, No. 4626, pp. 1761–1763.)

550.389.2 : 629.19 **3807**

Measurement of Cosmic Radiation on the Sputnik.—S. N. Vernov, N. L. Grigorov, Yu. I. Logachev & A. E. Chudakov. (*Dokl. Ak. Nauk S.S.S.R.*, 21st June 1958, Vol. 120, No. 6, pp. 1231–1233.) Preliminary results obtained by means of two independent recording instruments located in the second artificial earth satellite are shown graphically. A 3-min 50% increase in intensity was recorded on 7th November 1957 above latitude 58°N.

550.389.2 : 629.19 **3808**

Radio Scintillations of Satellite 1958α.—O. B. Slee. (*Nature, Lond.*, 7th June 1958, Vol. 181, No. 4623, pp. 1610–1612.) Graphical recordings of the 108-Mc/s signal from satellite 1958α are reproduced. The scintillations observed are correlated with scintillations of cosmic r.f. sources recorded during the same period. Results indicate that the ionospheric irregularities responsible for the scintillations must lie below 350 km.

Corresponding recordings from satellite 1958γ show significantly less scintillation activity at perigee (185 km) than on preceding and following days.

550.389.2 : 629.19 : 551.510.535 **3809**

Some Effects of the Fine Structure of the Ionosphere on Transmission Received from the Russian Earth Satellite 1958δ.—F. A. Kitchen & W. R. R. Joy. (*Nature, Lond.*, 28th June 1958, Vol. 181, No. 4626, pp. 1759–1761.) Anomalies in Doppler observations of the satellite are discussed. It appears practicable to make a detailed study of the lower boundary of the F region by an analysis of Doppler frequency discontinuities in conjunction with accurately known orbit parameters.

550.389.2 : 629.19 : 551.510.535 **3810**

On the Results of the Electron-Concentration Determinations in the External Region of the Ionosphere made on the Basis of Radio Signals from the First Sputnik.—Ya. L. Al'pert, F. F. Dobryakova, E. F. Chudesenko & B. S. Shapiro. (*Dokl. Ak. Nauk S.S.S.R.*, 1st June 1958, Vol. 120, No. 4, pp. 743–746.) Brief description of the method of observation of 40-Mc/s radio signals from the satellite to determine the exact time of its 'rising' and 'setting'. Calculated values of electron density range from $1 \cdot 8 \times 10^6$ electrons/cm³ at 320 km to 10^2 electrons/cm³ at 3 050 km.

551.510.535 **3811**

Rocket Measurements of Electron Concentration in the Ionosphere by means of an Ultra-Short-Wave Dispersion Interferometer.—K. I. Gringauz. (*Dokl. Ak. Nauk S.S.S.R.*, 21st June 1958, Vol. 120, No. 6, pp. 1234–1237.) Investigations have been carried out since 1954 at heights up to 473 km using rockets equipped with transmitters operating at 48 and 144 Mc/s. Signals were recorded at the ground by two different oscillographic methods. Results indicate that the true height of F-layer reflections is 50–150 km lower than the effective height recorded by an ionospheric sounder.

551.510.535 **3812**

Apparent Saturation in F_2 Layer.—T. W. Bennington. (*Wireless World*, Oct. 1958, Vol. 64, No. 10, pp. 472–473.) At sunspot numbers near 100, there is a departure from the linear relation with F_2-layer critical frequency which is attributed to a combination of high sunspot numbers and local summer daytime conditions.

551.510.535 **3813**

Horizontal Ionospheric Drifts in the F_2 Region at Equatorial Latitudes.—B. R. Rao & E. B. Rao. (*Nature, Lond.*, 7th June 1958, Vol. 181, No. 4623, pp. 1612–1613.) Systematic measurements of F_2 drift made at Waltair, India, by the spaced-receiver method from February 1956 to January 1958 are analysed. The 24-h E-W component (80–90 m/s) is invariably higher than the N-S component (65–75 m/s). The prediction of phase reversal of F_2 drift at a latitude of 35° is confirmed. See also 2090 of July (Purslow) and 3818 below.

551.510.535 : 523.72 **3814**

Similarities in the Characteristics of Solar Radiation at λ 10·7 cm and in the Far Ultraviolet.—C. M. Minnis & G. H. Bazzard. (*Nature, Lond.*, 28th June 1958, Vol. 181, No. 4626, p. 1796.) Values of the activity index Ch_E, based on E-layer data for Slough, have been correlated for a ten-year period with the monthly mean value Φ of solar r.f. noise flux measured at Ottawa. The close correlation found ($r_{max} = 0 \cdot 99$), and results of an analysis of eclipse data [3437 of November (Minnis)], support the conclusion of Denisse & Kundu (1758 of 1957).

551.510.535 : 550.385 **3815**

Equatorial Spread-F and Magnetic Activity.—A. J. Lyon, N. J. Skinner & R. W. Wright. (*Nature, Lond.*, 21st June 1958, Vol. 181, No. 4625, pp. 1724–1725.) Analysis of data for Ibadan, Nigeria, for the years 1956 and 1957 shows that the incidence of spread-F on international quiet days is higher than that on international disturbed days.

551.510.535 : 621.396.11 **3816**

Diurnal Variation of Deviative Absorption in the F_2 Region of the Ionosphere.—S. K. Sharma. (*Indian J. Phys.*, June 1958, Vol. 32, No. 6, pp. 297–298.) Note of absorption measurements near the critical frequency. Daytime reduction of deviative absorption is ascribed to thermal expansion of the F_2 layer.

551.510.535 : 621.396.11 **3817**

Anomalous Variation of Total Absorption of Radio Waves Reflected from the F_2 Region of the Ionosphere around Midday.—S. K. Sharma. (*Proc. phys. Soc.*, June 1958, Vol. 71, No. 462, pp. 1007–1010.) Observations made at Banaras, using frequencies higher than F_1-layer critical frequency, show two maxima, one before and the other after local noon. The first maximum has been attributed to thermal expansion of the F_2 region, the effect of which is normally observed before midday; the second coincides with the usual maximum of total absorption observed at lower frequencies after midday.

551.510.535 : 621.396.812.3 **3818**

Investigation of Horizontal Drifts in the E Region of the Ionosphere in Relation to Random Fading of Radio Waves.—B. R. Rao & M. S. Rao. (*J. Brit. Instn Radio Engrs*, Aug. 1958, Vol. 18, No. 8, pp. 493–495.) Measurements of E-region wind velocities V and frequency of fading N were made at 2·3 and 2·8 Mc/s. The linear relation $V = 1 \cdot 86 \; N\lambda$, which is in agreement with theory, is deduced.

551.594.223 **3819**

Ball Lightning and Thermonuclear Reactions.—A. Dauvillier. (*C. R. Acad. Sci., Paris*, 16th Dec. 1957, Vol. 245, No. 25, pp. 2155–2156.) It is suggested that ball lightning is formed by radiocarbon 14, due to the action on atmospheric nitrogen of thermal neutrons liberated by lightning discharges. See also 2957 of 1955 (Kapitsa).

551.594.5 **3820**

Height Distribution of the Red Auroral Line in Polar Aurorae.—L. Harang. (*Geofys. Publ.*, Jan. 1958, Vol. 20, No. 5, 9 pp.) Luminosity curves along vertical cross-sections of auroral forms recorded by means of a photoelectric photometer are analysed.

551.594.5 : 621.396.96 **3821**

Some Observations of Aurora using a Low-Power Frequency-Modulated Radar.—C. Collins. (*Canad. J. Phys.*, July 1958, Vol. 36, No. 7, pp. 926–934.) An experimental c.w. radar is described which provides information on range and radial motion of auroral echoes. A histogram of the range distribution of echoes from reflecting areas north of Ottawa shows a maximum at 650–750 km.

551.594.6 **3822**

Polarization of Atmospherics.—F. Horner: S. R. Khastgir. (*Nature, Lond.*, 14th June 1958, Vol. 181, No. 4624, pp. 1678–1680.) Comment on 2420 of August and author's reply.

551.594.6 **3823**

'Whistlers' in the Antarctic.—L. H. Martin. (*Nature, Lond.*, 28th June 1958, Vol. 181, No. 4626, pp. 1796–1797.) Observations made from 15th–30th April 1958, at Scott Base showed considerable activity including 'bonks', 'tweeks', long and short whistlers and periods of strong 'sferics' but no dawn chorus. It is probable that the whistlers are propagated from lower-latitude regions, first along the appropriate magnetic flux line, and then by ionospheric reflection.

551.594.6 : 621.3.087.4/.5 **3824**

Automatic Recorder of the Waveforms of Atmospherics.—B. A. P. Tantry. (*Indian J. Phys.*, June 1958, Vol. 32, No. 6, pp. 267–275.) Description, with circuit diagrams, of component units of film-type recording equipment in operation since 1952 and of similar design to that described earlier [679 of 1952 (Clarke & Mortimer)].

523.164 **3825**

The Exploration of Space by Radio. [Book Review]—R. H. Brown & A. C. B. Lovell. Publishers: Chapman & Hall, London, 1957, 207 pp., 35s. (*Nature, Lond.*, 7th June 1958, Vol. 181, No. 4623, pp. 1562–1563.) A detailed review of different branches of the subject.

LOCATION AND AIDS TO NAVIGATION

534.88 **3826**

Electronic Sector Scanning.—Tucker, Welsby & Kendell. (See 3676.)

621.396.93 : 621.396.677.6 **3827**

The Effect of Mutual Impedance on the Spacing Error of an Eight-Element Adcock.—D. N. Travers. (*Trans. Inst. Radio Engrs*, Jan. 1957, Vol. AP-5, No. 1, pp. 36–39. Abstract, *Proc. Inst. Radio Engrs*, May 1957, Vol. 45, No. 5, p. 715.) See also 1423 of 1956.

621.396.93(083.71) **3828**

I.R.E. Standards on Radio Aids to Navigation: Definitions of Terms, 1954.—(*Proc. Inst. Radio Engrs*, Sept. 1958, Vol. 46, No. 9, p. 1645.) A correction to standard 54 I.R.E. 12.S1 (1350 of 1955).

621.396.933 **3829**

Radio Navigation and Pilotage Facilities of the Danish Aircraft Control Area.—K. Svenningsen. (*Teleteknik, Copenhagen, English Edn*, 1958, Vol. 2, No. 1, pp. 12–22.) English version of 1668 of 1955.

621.396.933.2 **3830**

Recording Techniques for H.F. Direction Finding.—C. W. McLeish. (*Electronic Radio Engr*, Oct. 1958, Vol. 35, No. 10, pp. 386–390.) Methods are described for reducing the information given by d.f. equipment to a form which can be easily assimilated. The alternatives discussed are pen-recording of bearing/time and the photographic reproduction of the bearing/amplitude distribution functions. In both cases, records can be produced simultaneously from two direction finders and this facilitates comparisons.

621.396.96 **3831**

Investigation of Extended Over-Water Ranges of Low-Sited Radar.—F. A. Sabransky. (*J. Met.*, June 1958, Vol. 15, No. 3, pp. 303–308.) The increase in range of radars due to surface-based superrefractive layers has been studied to verify predictions of extended coverage.

621.396.96 : 621.396.11 **3832**

A Study of Radar Elevation-Angle Errors due to Atmospheric Refraction.—B. M. Fannin & K. H. Jehn. (*Trans. Inst. Radio Engrs*, Jan. 1957, Vol. AP-5, No. 1, pp. 71–77. Abstract, *Proc. Inst. Radio Engrs*, May 1957, Vol. 45, No. 5, pp. 715–716.)

621.396.96 : 621.396.822 **3833**

A Proposed Technique for the Improvement of Range Determination with Noise Radar.—H. Hochstadt. (*Proc. Inst. Radio Engrs*, Sept. 1958, Vol. 46, No. 9, p. 1652.) Comment on paper by R. Bourret (*ibid.*, Dec. 1957, Vol. 45, No. 12, p. 1744).

621.396.962.3.029.65 **3834**

8-mm High-Definition Radar.—J. Verstraten & J. M. G. Seppen. (*Tijdschr. ned. Radiogenoot.*, Jan. 1958, Vol. 23, No. 1, pp. 17–32.) The information capacity of an 8-mm-λ pulsed system is considered and a description is given of equipment and operational results.

621.396.969.34 : 621.396.933.2 **3835**

Radar Beacon System Performance.—S. Thaler & D. L. Ashcroft. (*Trans. Inst. Radio Engrs*, June 1957, Vol. ANE-4, No. 2, pp. 65–71.) A system of ground radar beacon interrogators and airborne beacon transponders in a circular area of approximately 200 miles radius is considered with special reference to undesirable mutual interactions.

MATERIALS AND SUBSIDIARY TECHNIQUES

53 : 061.6(494) **3836**

Report of the Meeting of the Swiss Physical Society.—(*Helv. phys. Acta*, 15th Aug. 1957, Vol. 30, No. 4, pp. 221–296.) The text is given of the following papers included among those read at a meeting held at Brunnen on 4th–5th May 1957.

(*a*) A Relation between the Structure of Semiconductors and Atomic Properties.—E. Mooser & W. B. Pearson (pp. 222–223, in German).

(*b*) Magnetic Susceptibility of Liquid Selenium and Tellurium.—G. Busch & O. Vogt (pp. 224–227, in German).

(*c*) Hall Effect of Bismuth as a Function of Magnetic Induction.—R. Jaggi (pp. 228–230, in German).

(*d*) Critical Magnetic Fields of Superconducting Vanadium.—G. Busch & J. Müller (pp. 230–233, in German).

(*e*) Hall Effect in Fe_3Al Alloy.—J. P. Jan (pp. 233–235, in French).

(*f*) Photoconductivity of Zinc Oxide with Ohmic and Blocking Contacts.—H. J. Gerritsen, W. Ruppel & A. Rose (pp. 235–238, in German).

(*g*) Maximum Performance of Photoconductors.—A. Rose (pp. 242–244). See also 768 of 1956.

(*h*) Blackening of ZnS and CdS Single Crystals by Light.—W. J. Merz (pp. 244–246, in German).

(*i*) A New Type of Radio Spectrograph for the Observation of Electron Resonance in the Region of Metric and Decimetric Waves.—J. P. Borel & C. Manus (pp. 254–257, in French).

(*j*) Stability of NH_3 Frequency Standards.—J. Bonanomi, J. De Prins, J. Herrmann & P. Kartaschoff (pp. 288–290, in French).

(*k*) High-Resolution Microwave Spectrograph.—J. Bonanomi, J. De Prins, J. Herrmann & P. Kartaschoff (pp. 290–292, in German).

(*l*) A High-Frequency Ion Source with Low Power Requirements.—M. Bloom, A. Rytz & H. Staub (pp. 292–296, in German).

531.788.7 **3837**

Operation of an Inverted-Magnetron Gauge in the Pressure Range 10^{-3} to 10^{-12} mm Hg.—J. P. Hobson & P. A. Redhead. (*Canad. J. Phys.*, March 1958, Vol. 36, No. 3, pp. 271–288.) Description of a cold-cathode ionization gauge with axial magnetic field and radial electric field. See also 3761 above.

535.215 **3838**

On the Theory of Photoemission.—P. Görlich & H. Hora. (*Optik, Stuttgart*, Feb./March 1958, Vol. 15, Nos. 2/3, pp. 116–126.) The distinction between two different types of photoemission from metals is clarified. Phenomenological theory for Cs_3Sb is applied to measured photoemission in the far ultraviolet region; close agreement is found and generalizations of the principle are discussed. See also 798 of March (Methfessel).

535.215 **3839**

Optical Absorption and Photoemission of Barium and Strontium Oxides, Sulphides, Selenides, and Tellurides.—R. J. Zollweg. (*Phys. Rev.*, 1st July 1958, Vol. 111, No. 1, pp. 113–119.) Considerable structure is observed at the intrinsic optical absorption edge of annealed films of BaO, BaS, BaSe, BaTe, SrO, SrS, SrSe and SrTe at −160°C. An estimate is made from photoemission measurements of the energy separation between the top of the valence band and the vacuum level.

535.215 **3840**

Optical Transmission and Photoconductive and Photovoltaic Effects in Activated and Unactivated Single Crystals of ZnS.—G. Cheroff & S. P. Keller. (*Phys. Rev.*, 1st July 1958, Vol. 111, No. 1, pp. 98–102.)

535.215 : 546.482.21 : 537.312.8 **3841**

Magnetoresistance Effect in Cadmium Sulphide.—S. Tamaka & T. Masumi. (*J. phys. Soc. Japan*, March 1958, Vol. 13, No. 3, p. 314.)

535.37 **3842**

Radiationless Recombination in Phosphors.—L. Bess. (*Phys. Rev.*, 1st July 1958, Vol. 111, No. 1, pp. 129–132.) "An Auger-type process is proposed for a possible means of nonradiative annihilation of free holes at electron traps in phosphors. A rough calculation is made of the cross-section for the process, and some of the consequences are considered qualitatively."

535.37 **3843**

Two Kinds of Manganese Luminescence Centres in the Cadmium-Lithium Orthosilicate Phase.—V. V. Osiko. (*Dokl. Ak. Nauk S.S.S.R.*, 21st July 1958, Vol. 121, No. 3, pp. 507–510.) Investigation showed a luminescence spectrum with two maxima in the wavelength regions 514 and 615 mμ and varying with the molarity ratio of CdO/Li_2O.

535.37 : 537.226 **3844**

Two Distinct Types of Photodielectric Effect in Cadmium Sulphide. — R. Freymann, E. Grillot, M. Hagene & J. Le Bot. (*C. R. Acad. Sci., Paris*, 16th Dec. 1957, Vol. 245, No. 25, pp. 2261–2264.) CdS when pure or activated with Ag or Cu shows an unusual type of absorption when illuminated at 4°K and then heated in darkness to about 250°K.

535.37 : 546.41-31 : 535.215 **3845**

Photoconductivity of Calcium Oxide.—J. Janin & L. Cotton. (*C. R. Acad. Sci., Paris*, 10th March 1958, Vol. 246, No. 10, pp. 1536–1538.) The photoconductivity induced by irradiation at certain wavelengths in pure CaO and CaO activated by Pb, Mn, (Pb+Mn) and (Pb+Sm) has been investigated experimentally using voltages up to 210 V. See also 729 of 1955 (Crozet & Janin).

535.37 : 546.472.21 **3846**

Radiative Energy Transfer in ZnS.—R. E. Halsted, E. F. Apple & J. S. Prener. (*Phys. Rev. Lett.*, 15th Aug. 1958, Vol. 1, No. 4, pp. 134–136.) Absorption and emission spectra are identified with specific impurities, and support an explanation in terms of hole transitions.

535.37 : 546.472.21 **3847**

Exhaustion Barriers in Zinc Sulphide.—G. F. Alfrey & K. N. R. Taylor. (*Helv. phys. Acta*, 1st July 1957, Vol. 30, Nos. 2/3, pp. 206–208.) "The nature of the exhaustion barrier at a metallic contact to a ZnS crystal is considered in the light of the evidence of electroluminescence and of the effect of electric fields on the scintillations produced by alpha particles. The evidence suggests that the donor states whose depletion gives rise to the barrier are concentrated at a single energy level, rather than distributed through the forbidden band." See also 781 of 1956.

535.376 : 537.226 **3848**

Electroluminescence from the Surface Layer of $BaTiO_3$, $SrTiO_3$, and Associated Materials.—G. G. Harman. (*Phys. Rev.*, 1st July 1958, Vol. 111, No. 1, pp. 27-33.) It is shown that light emission resulting from h.f. excitation is due to a high r.f. field across a thin surface barrier. An efficiency of the order of 10^{-8}% was obtained. A model involving field emission from the metal electrode into the crystal surface layer is proposed.

537.226/.228.2 : 546.431.824-31 **3849**

Inquiry into the Electrostriction Equation of Barium Titanate Ceramic.—K. Masuzawa, Y. Tomita & T. Yamaguchi. (*Rep. elect. Commun. Lab., Japan*, April 1958, Vol. 6, No. 4, pp. 105–108.) The relation between the applied polarization and strain in a $BaTiO_3$ ceramic is investigated.

537.226/.228.1 : 546.431.824-31 **3850**

Elastic and Piezoelectric Coefficients of Single-Crystal Barium Titanate.—D. Berlincourt & H. Jaffe. (*Phys. Rev.*, 1st July 1958, Vol. 111, No. 1, pp. 143–148.) Mechanical resonance and antiresonance frequencies were measured at temperatures from −50°C to +150°C. A complete set of elastic, piezoelectric, and dielectric constants of the tetragonal modification at 25°C is obtained. The elastic compliances show deviation from cubic symmetry. Measurements in the orthorhombic state show longitudinal compliance four times higher than in the tetragonal state.

537.226/.227 : 538.569.4 **3851**

Paramagnetic Resonance of Fe^{3+} in $SrTiO_3$ Single Crystals.—K. A. Müller. (*Helv. phys. Acta*, 2nd June 1958, Vol. 31, No. 3, pp. 173–204. In German.) 58 references.

537.226 : 621.319.2 **3852**

On the Making of Electrets and Measurement of the Changes of Dielectric Constant of a Polarized Electret-Forming Material with Time.—T. C. Bhadra. (*Indian J. Phys.*, June 1958, Vol. 32, No. 6, pp. 281–296.) More detailed account of measurements reported earlier [3627 of 1955 (Chatterjee & Bhadra)].

537.226 : 621.396.677.85 **3853**

The Fields Associated with an Interface between Free Space and an Artificial Dielectric.—Brown & Seeley. (See 3704.)

537.227 **3854**

Ferroelectricity in Diglycine Nitrate $(NH_2CH_2COOH)_2.HNO_3$.—R. Pepinsky, K. Vedam, S. Hoshino & Y. Okaya. (*Phys. Rev.*, 15th July 1958, Vol. 111, No. 2, pp. 430–432.)

537.227 **3855**

Ferroelectric Properties of Glycine Sulphate.—L. Taurel, E. Pourel & F. Thomassin. (*C. R. Acad. Sci., Paris*, 6th Jan. 1958, Vol. 246, No. 1, pp. 70–72.) See also 1105 of 1957 (Matthias et al.).

537.227 **3856**

Ferroelectricity of $NaNH_4$-Tartrate.—Y. Takagi & Y. Makita. (*J. phys. Soc. Japan*, March 1958, Vol. 13, No. 3, pp. 272–277.) Below the transition point, 190°K, a crystal plate shows domain structure if viewed under a polarizing microscope parallel to the *b* axis; shearing stress will reverse the polarization. The spontaneous value is 0·21 $\mu C/cm^2$ at 92°K, and is probably constant below the transition temperature.

537.227 : 546.431.824-31 : 621.318.57 **3857**

Ultrasonic Measurement of Polarization Switching Processes in Barium Titanate Single Crystal.—K. Husimi & K. Kataoka. (*J. appl. Phys.*, Aug. 1958, Vol. 29, No. 8, pp. 1247–1251.) A non-destructive piezoelectric method for studying the polarization of ferroelectric crystals is applied to study polarization switching in $BaTiO_3$ single crystals. Three polarization processes are believed to exist, one of these being very slow. Switching-time results are considered in the light of the above experiments. See also 147 of January (Zen'iti et al.).

537.227 : 621.318.57 **3858**

Polarization Reversal in Triglycine Sulphate Crystal.—K. Zen'iti, K. Husimi & K. Kataoka. (*J. phys. Soc. Japan*, June 1958, Vol. 13, No. 6, p. 661.)

537.311.3 : 534.23 : 538.6 **3859**

Acoustomagnetoelectric Effects in Metal and Semiconductor Filaments.—G. G. E. Low. (*Proc. phys. Soc.*, 1st June 1958, Vol. 71, No. 462, pp. 965–972.) The interaction of a magnetic field and a compressional acoustic wave, travelling in a conducting medium, is considered. Assuming charge neutrality, expressions for the electric current densities and fields in filamentary specimens are derived, and applied in particular to semiconductors. Second-order effects are discussed.

537.311.3 : 537.534.9 **3860**

Application of the Ion Bombardment Cleaning Method to Titanium, Germanium, Silicon and Nickel as Determined by Low-Energy Electron Diffraction.—H. E. Farnsworth, R. E. Schlier, T. H. George & R. M. Burger. (*J. appl. Phys.*, Aug. 1958, Vol. 29, No. 8, pp. 1150–1161.)

537.311.33 **3861**

Carrier Mobilities in InP, GaAs, and AlSb.—F. J. Reid & R. K. Willardson. (*J. Electronics Control*, July 1958, Vol. 5, No. 1, pp. 54–61.) Measurements of carrier mobilities in single crystals have been made as a function of impurity concentration and temperature. Scattering of charge carriers at 300°K suggests lattice mobilities of 11 500 cm^2/V.sec for electrons in GaAs, 6 600 cm^2/V.sec for electrons in InP and 450 cm^2/V.sec for holes in AlSb.

537.311.33 **3862**

Effect of Electron-Electron Scattering on Hall Mobility of Electrons in *n* Semiconductors.—M. S. Sodha & P. C. Eastman. (*Progr. theor. Phys.*, March 1958, Vol. 19, No. 3, pp. 344–346.) A Hall-mobility/drift-mobility ratio of 1·18 is obtained if account is taken of electron-electron scattering.

537.311.33 **3863**

Recombination at Two-Level Traps in Semiconductors.—M. Bernard. (*J. Electronics Control*, July 1958, Vol. 5, No. 1, pp. 15–18. In French.) The statistics of recombination of excess carriers is examined in the case of a flaw common to two non-independent levels in the forbidden energy gap. Two examples given refer to carrier lifetime with low-level injection, and carrier generation rate in the space-charge zone of a *p-n* junction. See also 2124 of July (Sah & Shockley).

537.311.33 **3864**

The Electrical Conductivity of *p*-Type Semiconductors in the Case of Chemisorption of Atoms and Radicals.—I. A. Miasnikov. (*Dokl. Ak. Nauk S.S.S.R.*, 21st June 1958, Vol. 120, No. 6, pp. 1298–1301.) Experimental investigation of the effect of chemisorption on the conductivity of ZnO or TiO_2 in the presence of H_2, N_2 or alcoholic vapours.

537.311.33 **3865**

Electrical Conduction via Slow Surface States on Semiconductors.—H. Statz & G. A. de Mars. (*Phys. Rev.*, 1st July 1958, Vol. 111, No. 1, pp. 169–182.) Steady-state and transient conductance of inversion layers created by acetone vapour on silicon *n-p-n* bars were investigated. The interpretation gives strong evidence that the charge in the outer surface states can move in an electric field. The mobility of the charge is of the order of $10^{-3}cm^2$/V.sec for thick films and becomes progressively smaller for thinner films. It is found that inversion layers created by mobile charges may be unstable for certain applied voltages.

537.311.33 **3866**

Preventing Conductivity Fluctuations during Growth of a Semiconducting Crystal.—W. G. Pfann, J. N. Hobstetter & G. S. Indig. (*J. appl. Phys.*, Aug. 1958, Vol. 29, No. 8, pp. 1238–1240.) Fluctuations in the electrical conductivity of an extrinsic semiconductor can be eliminated by adding to the melt a critical concentration of a suitable donor or acceptor.

537.311.33 : 53.08 : 536.62 **3867**

Construction of a Microcalorimeter for Investigations on Semiconductors. —D. Blet-Talbot. (*C. R. Acad. Sci., Paris*, 16th Dec. 1957, Vol. 245, No. 25, pp. 2224–2227.) Theoretically determined values of sensitivity and time constant of the calorimeter are respectively $0 \cdot 024 \mu V/\mu W$ and 11 s.

537.311.33 : 541.135 : 621.375.9 **3868**

Amplification in an Electrolyte.—(*Engineering, Lond.*, 30th May 1958, Vol. 185, No. 4812, p. 696.) Note on an experimental device described by J. F. Dewald which consists of a hexagonal rod-shaped crystal of pure ZnO immersed in a highly conducting electrolyte. Gains exceeding 15 dB at 1 kc/s have been obtained.

537.311.33 : 546.26-1 **3869**

Electronic Structure and Diamagnetism of Graphite.—S. Mase. (*J. phys. Soc. Japan*, June 1958, Vol. 13, No. 6, pp. 563–573.)

537.311.33 : [546.28 + 546.289 **3870**

Radiation Damage in Ge and Si Detected by Carrier Lifetime Changes: Damage Thresholds.—J. J. Loferski & P. Rappaport. (*Phys. Rev.*, 15th July 1958, Vol. 111, No. 2, pp. 432–439.) Minority carrier lifetime, τ, is shown to be more sensitive by a factor of 10^4 to radiation-induced defects than the conductivity. Both direct measurements of τ and evaluation of dependent parameters are described. The thresholds for production of Frenkel defects were found. Analysis shows how the radiation-induced energy levels and the relative minority-carrier capture cross-sections can be determined experimentally. Comparisons are made with theory.

537.311.33 : 546.28 **3871**

Temperature Dependence of Carrier Lifetime in Silicon.—D. J. Sandiford. (*Proc. phys. Soc.*, 1st June 1958, Vol. 71, No. 462, pp. 1002–1006.) Experimental results and theory may be reconciled on the assumption that the capture probabilities of the recombination centres are temperature dependent, and that the energy levels of the centres lie $0 \cdot 45 \pm 0 \cdot 05$ eV above the valence band.

537.311.33 : 546.28 **3872**

Absorption Spectrum of Bismuth-Doped Silicon.—H. J. Hrostowski & R. H. Kaiser. (*Phys. Chem. Solids*, 1958, Vol. 4, No. 4, pp. 315–317.)

537.311.33 : 546.28 **3873**

Work Function and Sorption Properties of Silicon Crystals.—J. A. Dillon, Jr, & H. E. Farnsworth. (*J. appl. Phys.*, Aug. 1958, Vol. 29, No. 8, pp. 1195–1202.) The work functions of Si single crystals were found for various samples of floating-zone and non-floating-zone Si. Differences are noted between radiation-quenched and annealed specimens. The effects of exposure to oxygen, hydrogen, and nitrogen, and of heating in high vacuum were measured.

537.311.33 : [546.28 + 546.289] : 538.63 **3874**

Interpretation of Magnetoconductivity in *n*-Type Germanium and Silicon. —R. W. Keyes. (*Phys. Rev.*, 1st July 1958, Vol. 111, No. 1, pp. 34–35.) The phenomenological magnetoconductance coefficients of a cubic crystal are expressed in terms of the single-valley magnetoconductance constants, for energy bands consisting of [111] or [100] valleys. The 'symmetry conditions' for magnetoconductance are found to depend on the vanishing in the principal axis directions of the longitudinal magnetoconductance coefficients of a single valley.

537.311.33 : 546.289 **3875**

Electrical Properties of Clean Germanium Surfaces.—G. A. Barnes & P. C. Banbury. (*Proc. phys. Soc.*, 1st June 1958, Vol. 71, No. 462, pp. 1020–1021.) A preliminary report is given of studies of field effect and photoconductance, using a technique in which specimens, electrodes and fracturing equipment are contained in envelopes under pressures of the order of 10^{-10} mm Hg.

537.311.33 : 546.289 **3876**

Dislocation Etch Pits in Germanium. —W. Bardsley, R. L. Bell & B. W. Straughan. (*J Electronics Control*, July 1958, Vol. 5, No. 1, pp. 19–28.) From an examination of the shape of CP4 etch pits on {111} faces, azimuth but not declination of a dislocation line may be derived. Observations of azimuth and trace direction have been used to identify the direction of dislocation lines in some crystals.

537.311.33 : 546.289 **3877**

Low-Level Absorption in Germanium. —T. S. Moss & T. D. H. Hawkins. (*Phys. Rev. Lett.*, 15th Aug. 1958, Vol. 1, No. 4, pp. 129–130.) Absorption coefficients as low as 10^{-5} cm^{-1} were observed at photon energy levels down to $0 \cdot 56$ eV.

537.311.33 : 546.289 **3878**

Absorption of Light by Electron-Hole Pairs Liberated by the Photoelectric Effect in a Single Crystal of Germanium. —F. Desvignes. (*C. R. Acad. Sci., Paris*, 24th March 1958, Vol. 246, No. 12, pp. 1824–1827.) A beam of light of wavelength above the photoelectric threshold and of constant intensity inpinges directly on a slab of Ge which is also obliquely illuminated by a modulated beam of light from another source. The transmission factor of the material is correspondingly modulated.

537.311.33 : 546.289 **3879**

Nonradiative Recombination of Electrons at Impurity Centres in *n*-Type Germanium.—V. A. Kovarskiĭ. (*Zh. eksp. teor. Fiz.*, Dec. 1957, Vol. 33, No. 6 (12), pp. 1445–1453.) Theoretical treatment of nonradiative recombination at liquid-helium temperatures. The interaction between an electron and acoustic vibrations of the lattice is taken into account by successive diagonalization of the original Hamiltonian by a unitary transformation [see e.g. 3557 of 1955 (Kubo & Toyozawa)].

537.311.33 : 546.289 **3880**

Precipitation of Cu in Ge: Part 2—Supersaturation Effects.—A. G. Tweet. (*Phys. Rev.*, 1st July 1958, Vol. 111, No. 1, pp. 57–66.) Further investigation of precipitation rates indicating the occurrence of nucleation at sites other than dislocations. See 3191 of 1957.

537.311.33 : 546.289 **3881**

Precipitation of Cu in Ge: Part 3—Quench Effects in Nearly Perfect Crystals.—A. G. Tweet. (*Phys. Rev.*, 1st July 1958, Vol. 111, No. 1, pp. 67–71.) Part 2: 3880 above.

537.311.33 : 546.289 **3882**

Measurement of Germanium Surface States by Pulsed Channel Effect.—G. Rupprecht. (*Phys. Rev.*, 1st July 1958, Vol. 111, No. 1, pp. 75–81.) Densities, cross-sections, and activation energies of several fast Ge surface states are inferred from low-temperature conductivity relaxations in a thin diffused surface layer. The results indicate the existence of an electron trap $0 \cdot 24$ eV from the conduction band and two hole traps $0 \cdot 17$ eV and $0 \cdot 22$ eV from the valence band.

537.311.33 : 546.289 **3883**

Anisotropy of Hot Electrons in *n*-Type Germanium.—W. Sasaki, M. Shibuya & K. Mizuguchi. (*J. phys. Soc. Japan*, May 1958, Vol. 13, No. 5, pp. 456–460.) The e.m.f. perpendicular to the current flow in *n*-type Ge has been measured and compared with theoretical values. This effect is attributed to anisotropic conduction due to ellipsoidal energy surfaces.

537.311.33 : 546.289 : 535.215 **3884**

Large-Signal Surface Photovoltage Studies with Germanium.—E. O. Johnson. (*Phys. Rev.*, 1st July 1958, Vol. 111, No. 1, pp. 153–166.) The studies were carried out over a wide range of excess-carrier densities. Ambient-induced inversion and accumulation layer surfaces were studied on *p*-type and *n*-type Ge. The results agree with the theory that considers the surface space charge, but neglects charge changes in fast surface states.

537.311.33 : 546.289 : 538.63 **3885**

Phonon-Drag Thermomagnetic Effects in *n*-Type Germanium: Part 1—General Survey.—C. Herring, T. H. Geballe & J. E. Kunzler. (*Phys. Rev.*, 1st July 1958, Vol. 111, No. 1, pp. 36–57.) Experimental investigation of the Nernst field and thermoelectric power for single-crystal *n*-type Ge over a wide range of temperature, for various orientations and with fields up to 18 000 G. Both effects are dominated by 'phonon drag' at low temperatures. The results can be explained by a model which assigns to each ellipsoidal energy shell in crystal-momentum space an anisotropic phonon-drag Peltier tensor with principal components in the high- and low-mass directions.

537.311.33 : 546.289.221 **3886**

Electrical and Optical Properties of GeS.—T. Yabumoto. (*J. phys. Soc. Japan*, June 1958, Vol. 13, No. 6, pp. 559–562.) GeS was purified by recrystallization in an atmosphere of ammonia gas. Measurements were made of dark conductivity, optical absorption, photoconductivity and thermoelectric force.

537.311.33 : 546.3-1'289'28 **3887**

Mobility in Electrons in Germanium-Silicon Alloys.—M. Glicksman. (*Phys. Rev.*, 1st July 1958, Vol. 111, No. 1, pp.

125–128.) The scattering of electrons in the alloys (with compositions varying from 0 to 30 atomic % Si) includes a contribution from scattering by the disorder present which depends on the composition as $[\alpha(1-\alpha)]^{-1}$ where α is the mole-fraction of the minority component. The disorder scattering mobility varies as $T^{-0 \cdot 8}$.

537.311.33 : 546.482.21 **3888**

Ohmic Probe Contacts to CdS Crystals.—Y. T. Sihvonen & D. R. Boyd. (*J. appl. Phys.*, Aug. 1958, Vol. 29, No. 8, pp. 1143–1145.) Wire probe contacts are found to be diodic upon first touching CdS, but can be permanently changed from diodic to ohmic by the passage of a moderately intense electric current pulse. This result was obtained for ten metals, and it is postulated that the current pulse punctures the exhaustion barrier thereby permitting electrons to tunnel more freely and in greater numbers. See also 3197 of 1957 (Walker & Lambert).

537.311.33 : 546.49.241 **3889**

Electrical Properties of Mercury Telluride.—R. O. Carlson. (*Phys. Rev.*, 15th July 1958, Vol. 111, No. 2, pp. 476–478.) Preparation of polycrystalline samples is described. The compound has a band gap of $\approx 0 \cdot 02$ eV and a large mobility ratio. The magneto-Hall effect suggests a complicated conduction band. Zn acts as a donor impurity and Cu as an acceptor impurity.

537.311.33 : 546.681.19 **3890**

Effective Mass of Electrons in Gallium Arsenide.—L. C. Barcus, A. Perlmutter & J. Callaway. (*Phys. Rev.*, 1st July 1958, Vol. 111, No. 1, pp. 167–168.) "The effective mass of electrons in a sample of *n*-type gallium arsenide has been measured by determining the reflectivity in the infrared. The value obtained, $(0 \cdot 043 \pm 0 \cdot 005)m_0$, supports the hypothesis that the minimum of the conduction band is at the centre of the Brillouin zone."

537.311.33 : 546.681.19 **3891**

Optical Absorption in *p*-Type Gallium Arsenide.—R. Braunstein & L. Magid. (*Phys. Rev.*, 15th July 1958, Vol. 11, No. 2, pp. 480–481.) A number of absorption bands have been observed on the low-energy side of the intrinsic absorption edge. The main features of the spectra can be explained in terms of hole transitions between different branches of the valence band.

537.311.33 : 546.682.19 **3892**

Temperature Dependence of Optical Absorption in *p*-Type Indium Arsenide.—F. Matossi & F. Stern. (*Phys. Rev.*, 15th July 1958, Vol. 111, No. 2, pp. 472–475.) Observed and calculated absorption characteristics are compared. The position and magnitude of the absorption peak change approximately as predicted, using a model in which absorption is attributed to transitions between the light- and heavy-hole bands.

537.311.33 : 546.873.241 : 536.21 **3893**

Heat Conduction in Bismuth Telluride.—H. J. Goldsmid. (*Proc. phys. Soc.*, 1st July 1958, Vol. 72, No. 463, pp. 17–26.) The calculated electronic component of the thermal conductivity, for *p*-type material, agrees with experimental results, assuming the lattice thermal conductivity to be independent of the electrical conductivity. Agreement has also been obtained for non-halogen-doped *n*-type Bi_2Te_3, but not for halogen-doped material, due to the high effective scattering cross-section, for phonons, of halogen atoms. See also 2449 of 1956.

537.311.33 : 546.873.241 : 537.324 **3894**

The Performance of Bismuth Telluride Thermojunctions.—H. J. Goldsmid, A. R. Sheard & D. A. Wright. (*Brit. J. appl. Phys.*, Sept. 1958, Vol. 9, No. 9, pp. 365–370.) The thermoelectric properties of *n*-type and *p*-type thermojunctions have been measured between 150° and 300° K, and a figure-of-merit calculated. This is highest for material with a conductivity of 1 000 Ω^{-1} cm^{-1} with current parallel to the cleavage planes.

537.311.33 : 548.32 **3895**

The Isomorphism of Type $A^{III}B^{V}$ Compounds.—W. Köster & W. Ulrich. (*Z. Metallkde*, July 1958, Vol. 49, No. 7, pp. 365–367.)

537.311.33 : 548.5 **3896**

Floating Crucible Technique for Growing Uniformly Doped Crystals.—W. F. Leverton. (*J. appl. Phys.*, Aug. 1958, Vol. 29, No. 8, pp. 1241–1244.) A simple modification of the Czochralski technique permits the growing of large Ge single crystals of uniform resistivity. Each crystal is grown from an inner crucible floating in the Ge melt; the liquid volume in this crucible is constant and the impurity concentration gradient is eliminated. The application of the technique to the growing of uniform Si crystals is discussed.

537.311.33 : 621.396.822 **3897**

Semiconductor Noise as a Queuing Problem.—D. A. Bell. (*Proc. phys. Soc.*, 1st July 1958, Vol. 72, No. 463, pp. 27–32.) A power spectrum whose intensity appears to increase without limit as the frequency is decreased can be explained by considering the rate at which carriers leave the conduction band to be the result of a queuing problem rather than a relaxation problem. See also 818 of 1956.

538.22 **3898**

A Thermodynamic Theory of 'Weak' Ferromagnetism of Antiferromagnetics.—I. Dzyaloshinsky. (*Phys. Chem. Solids*, 1958, Vol. 4, No. 4, pp. 241–255.) English version of 2475 of August.

538.22 **3899**

Measurement of the Magnetothermal Effect of MnAs.—A. J. P. Meyer & P. Taglang. (*C. R. Acad. Sci., Paris*, 24th March 1958, Vol. 246, No. 12, pp. 1820–1822.) Measurements made on powdered material in a field of 26 250 Oe at temperatures from 20° to 180°C are shown graphically.

538.22 : 538.569.4 **3900**

Absorption Lines in the Antiferromagnetic States of $MnCl_2.4H_2O$ and $MnBr_2.4H_2O$.—I. Tsujikawa. (*J. phys. Soc. Japan*, March 1958, Vol. 13, No. 3, pp. 315–316.)

538.221 **3901**

A Ferromagnetic Dynamical Equation.—H. B. Callen. (*Phys. Chem. Solids*, 1958, Vol. 4, No. 4, pp. 256–270.) A general form of ferromagnetic dynamical equation with three parameters having quantum-mechanical significance is discussed. An explicit rotational dynamical equation is obtained for a special case, and may serve to explain qualitatively certain observed size and shape effects.

538.221 **3902**

Magnetization Mechanism and Domain Structure of Multi-domain Particles.—H. Amar. (*Phys. Rev.*, 1st July 1958, Vol. 111, No. 1, pp. 149–153.) "The free energy of a two-domain cube of iron is considered with and without an applied magnetic field. It is shown that the two-domain configuration may exist only beyond a critical size (200 Å), that the wall characteristics are size-dependent and that their values are substantially different from the values assumed in bulk material."

538.221 **3903**

A Semi-empirical Equation for the Initial Susceptibility of Homogeneous Ferromagnetic Alloys.—E. W. Lee & R. C. Jackson. (*Proc. phys. Soc.*, 1st July 1958, Vol. 72, No. 463, pp. 130–134.)

538.221 **3904**

The Approach to Saturation as $1/H^2$ for Polycrystalline Ferromagnetic Materials.—H. Danan. (*C. R. Acad. Sci., Paris*, 24th March 1958, Vol. 246, No. 12, pp. 1822–1824.)

538.221 **3905**

Investigation of the Variation of the Magnetization of Pure Polycrystalline Iron and Nickel near Saturation Point.—H. Danan. (*C. R. Acad. Sci., Paris*, 6th Jan. 1958, Vol. 246, No. 1, pp. 73–76.)

538.221 **3906**

Measurement of the Gyromagnetic Ratio of Very Pure Nickel.—A. J. P. Meyer. (*C. R. Acad. Sci., Paris*, 10th March 1958, Vol. 246, No. 10, pp. 1517–1519.)

538.221 : 539.23 **3907**

Thin Ferromagnetic Layers. Magnetic Properties deduced from Investigations of the Conductivity of Thin Layers of Nickel.—A. Colombani & G. Goureaux. (*C. R. Acad. Sci., Paris*, 31st March 1958, Vol. 246, No. 13, pp. 1979–1983.)

538.221 : 621.318.124 **3908**

Effects of some Additionals for the Magnetic Properties of Ba and Sr Oxide Magnets.—H. Kojima. (*Sci. Rep. Res. Inst. Tohoku Univ., Ser. A*, April 1958, Vol. 10, No. 2, pp. 175–182.)

538.221 : 621.318.13.017.31 **3909**

Eddy-Current Losses in Thin Ferromagnetic Sheets.—E. W. Lee. (*Proc. Instn elect. Engrs*, Part C, Sept. 1958, Vol. 105, No. 8, pp. 337–342.) In very weak fields, observed eddy-current losses are greater than those theoretically predicted. It is suggested that the classical calculation of eddy-current loss is invalid when the distance between domain walls becomes comparable with the sheet thickness. See also 508 of 1957 (Aspden).

538.221 : 621.318.134 **3910**

Elementary Domains on the {100} Planes of Nickel Ferrite Crystals and on the (0001) Plane of Barium Ferrite Crystals.—M. Paulus. (*C. R. Acad. Sci., Paris*, 16th Dec. 1957, Vol. 245, No. 25, pp. 2227–2230.) Photograph of powder patterns are shown and discussed. See also 3210 of 1957 (Pearson).

538.221 : 621.318.134 **3911**

Phase Equilibria in the Ferrite Region of the System Manganese-Iron-Oxygen.—M. W. Shafer. (*IBM J. Res. Developm.*, July 1958, Vol. 2, No. 3, pp. 193–199.)

538.221 : 621.318.134 **3912**

Galvanomagnetic Properties of Manganese Ferrite.—K. P. Belov & E. V. Talalaeva. (*Zh. eksp. teor. Fiz.*, Dec. 1957, Vol. 33, No. 6 (12), pp. 1517–1519.)

538.221 : 621.318.134 **3913**

A Richter-Type Magnetic Loss in Yttrium-Iron Garnet.—H. Sekizawa, S. Iida & T. Miyadai. (*J. phys. Soc. Japan*, June 1958, Vol. 13, No. 6, p. 658.) A magnetic loss observed in ferrites containing ferrous ions is attributed to electron diffusion. A similar loss has been observed in Y-Fe garnet. The peak-loss frequency varies with temperature and peaks do not appear after heating in air to 380°C.

538.221 : 621.318.57 **3914**

Effect of a Transverse Field on Switching Rates of Magnetic Memory Cores.—T. D. Rossing & S. M. Rubens. (*J. appl. Phys.*, Aug. 1958, Vol. 29, No. 8, pp. 1245–1247.) A transverse magnetic field applied at the same time as a remagnetizing pulse facilitates the magnetization of a ferromagnetic material, and provides an improved method of writing into a magnetic-core storage system.

621.315.61 : 537.529 **3915**

Dielectric Breakdown in Solids.—J. J. O'Dwyer. (*Advances Phys.*, July 1958, Vol. 7, No. 27, pp. 349–394.) Various theories of breakdown in dielectric solids are reviewed and compared with the results of experimental work. Over 40 references.

621.315.616.9 **3916**

New Protectants for Polyethylene.—F. H. Winslow. (*Bell Lab. Rec.*, Sept. 1958, Vol. 36, No. 9, pp. 319–322.) A combination of carbon black and sulphur compounds offers the best protection against oxidation by heat and light.

621.315.616.96 : 537.311.31 : 621.372.56.029.6 **3917**

Casting Lossy Microwave Parts in Resin aids Design Work.—A. Staniforth & K. A. Steele. (*Canad. Electronics Engng*, May 1958, Vol. 2, No. 5, pp. 16–20.) Attenuation characteristics of iron-powder filler in casting resins are shown. The use of this material for lossy microwave components in transmission lines is noted.

621.318.1 **3918**

Materials used in Radio and Electronic Engineering: Part 5—Magnetic Materials.—(*J. Brit. Instn Radio Engrs*, Aug. 1958, Vol. 18, No. 8, pp. 449–464.) A survey including tabulated information of properties and applications of different types, together with British standards and over 50 references. For earlier parts see 1419 of 1955, and 501 & 2828 of 1956.

MATHEMATICS

517.949 **3919**

Contribution on the Method of Difference Equations.—J. Hersch. (*Z. angew. Math. Phys.*, 25th July 1958, Vol. 9a, No. 2, pp. 129–180. In French.) Detailed treatment of linear difference equations and certain of their applications noted earlier (975 and 1623 of 1957).

518.5 : 517.512.2 **3920**

A Calculator for Numerical Fourier Synthesis.—V. Timbrell. (*J. sci. Instrum.*, Sept. 1958, Vol. 35, No. 9, pp. 313–318.) A method of Fourier synthesis using a mechanical calculator is ten times faster than customary methods using three-figure tables, and accuracy is about the same. An instrument of simple construction for handling 15 harmonics is described.

519.2 : 621.396.822 **3921**

A Systematic Approach to a Class of Problems in the Theory of Noise and Other Random Phenomena.—(*Trans. Inst. Radio Engrs*, March 1957, Vol. IT-3, No. 1, pp. 32–43. Abstract, *Proc. Inst. Radio Engrs*, Aug. 1957, Vol. 45, No. 8, p. 1165.)

Part 1—D. A. Darling & A. J. F. Siegert (pp. 32–37).

Part 2—Examples.—A. J. F. Siegert (pp. 38–43).

519.283 : 621.391 **3922**

Linear Least-Squares Smoothing and Prediction, with Applications.—S. Darlington. (*Bell Syst. tech. J.*, Sept. 1958, Vol. 37, No. 5, pp. 1221–1294.) Techniques based on concepts in circuit theory, are developed explicitly for time series which are continuous and statistically stationary. Functions of time are replaced by functions of frequency representing their transforms. Mathematical complications are avoided by restricting statistical ensembles to those which have rational power spectra. General techniques are developed for specific problems including signal detection, diversity reception and network synthesis.

MEASUREMENTS AND TEST GEAR

621.3.018.41(083.74) : 529.786.525.35 **3923**

Frequency of Caesium in terms of Ephemeris Time.—W. Markowitz, R. G. Hall, L. Essen & J. V. L. Parry. (*Phys. Rev. Lett.*, 1st Aug. 1958, Vol. 1, No. 3, pp. 105–107.) Description of the conversion of the frequency of Cs resonance, based on the second of U.T.2, to the frequency expressed in terms of ephemeris time, using observations of the moon. See also 3195 of October.

621.317.3.029.6 : 534.6 **3924**

Experiments in cm Waves in Analogy with Acoustic Techniques made in Göttingen.—Meyer. (See 3671.)

621.317.33 **3925**

Dynamic-Conductance Meter.—M. R. Barber & A. G. Bogle. (*Electronic Radio Engr*, Oct. 1958, Vol. 35, No. 10, pp. 392–394.) The instrument gives a direct indication of the dynamic conductance of a resonant circuit at frequencies up to 1·5 Mc/s. It makes use of the properties of a transitron-connected pentode.

621.317.34 **3926**

Measurements of Impedance and Attenuation of a Cable through an Arbitrary Loss-Free Junction.—J. Allison & F. A. Benson. (*Proc. Instn elect. Engrs*, Part B, Sept. 1958, Vol. 105, No. 23, pp. 487–495.) Various methods are discussed and their usefulness and accuracy compared.

621.317.342 **3927**

How to Measure Midfrequency Phase Shift.—A. Nirenburg. (*Electronics*, 29th Aug. 1958, Vol. 31, No. 35, pp. 46–47.) A comparison method for the range 5–50 Mc/s, using double mixing and a c.r. oscilloscope, is described.

621.317.373.029.64 **3928**

Phase-Shift at Microwave Frequencies.—M. H. N. Potok. (*Electronic Radio Engr*, Oct. 1958, Vol. 35, No. 10, pp. 382–386.) "Phase-shift through waveguide arbitrary lossless networks can be measured by the application of the nodal shift method. Measurements on filters in the 4-kMc/s range agree well with calculations."

621.317.443 : 621.318.5 **3929**

A Permeameter Controller for Magnetic Measurements.—M. J. Swan. (*J. sci. Instrum.*, Sept. 1958, Vol. 35, No. 9, pp. 344–346.) Description of a semi-automatic system for the cyclical switching of the main and compensating magnetization currents of the N.P.L. permeameter, using relay-operated mercury switches.

621.317.62 **3930**

Measurement of Magnetization Curves in High Pulsed Magnetic Fields.—I. S. Jacobs & P. E. Lawrence. (*Rev. sci. Instrum.*, Aug. 1958, Vol. 29, No. 8, pp. 713–714.)

621.317.7 **3931**

Scientific Electrical Measuring Instruments.—F. C. Widdis. (*Proc. Instn elect. Engrs*, Part B, Sept. 1958, Vol. 105, No. 23, pp. 415–424.) A progress review. The types of apparatus discussed include semiconductor and nuclear devices, a.c. bridges, electronic instruments and apparatus for measuring non-electrical quantities. 77 references.

621.317.7 **3932**

Industrial Electrical Measuring Instruments.—F. R. Axworthy. (*Proc. Instn elect. Engrs*, Part B, Sept. 1958, Vol. 105, No. 23, pp. 404–414.) A review of the progress made in design, construction and measuring techniques. 41 references.

621.317.7 : 621.396.82 **3933**

Radio Interference : Part 4—Measuring Equipment.—Macpherson. (See 3964.)

621.317.725 : 621.385 **3934**

Automatic Range Selector for Electronic Voltmeter.—M. Hoberman. (*Electronics*, 1st Aug. 1958, Vol. 31, No. 31, pp. 84–85.)

621.317.761 **3935**

High-Precision Frequency Meter with Linear Response.—G. Giralt. (*C. R. Acad. Sci., Paris*, 6th Jan. 1958, Vol. 246, No. 1, pp. 77–79.) The apparatus which includes a relaxation oscillator [see 983 of March (Lagasse et al.)] can be used as frequency meter and discriminator. It has been applied to measure frequencies between 42·5 and 52·5 c/s.

OTHER APPLICATIONS OF RADIO AND ELECTRONICS

612.14 : 621.375.4 **3936**

Transistor Unit monitors Blood Pressure.—O. Z. Roy & J. R. Charbonneau. (*Electronics*, 15th Aug. 1958, Vol. 31, No. 33, pp. 82–83.)

621.362 : 621.385.2 **3937**

Analysis and Experimental Results of a Diode Configuration of a Novel Thermoelectron Engine.—Hatsopoulos & Kaye. (See 4024.)

621.384.622.2 **3938**

On Travelling-Wave Electron Accelerators Incorporating their Source of High-Frequency Energy.—R. Warnecke, H. Leboutet & G. Vincent. (*C. R. Acad. Sci., Paris*, 3rd March 1958, Vol. 246, No. 9, pp. 1399–1401.) Two designs of linear electron accelerator are outlined in which the delay line is common to both electron accelerator and h.f. generator. The latter can be a carcinotron, or a travelling-wave amplifier operating as an oscillator by virtue of the reaction across the circuit.

621.384.622.2 **3939**

A New Type of Linear Electron Accelerator Incorporating a High-Frequency Generator.—H. Leboutet, G. Vincent & R. Warnecke. (*C. R. Acad. Sci., Paris*, 10th March 1958, Vol. 246, No. 10, pp. 1519–1522.) The properties of periodic delay lines and their application to the apparatus outlined in 3938 above are considered, and details of the apparatus are given.

621.385.833 **3940**

Asymmetric Electron Lenses.—P. Durandeau, C. Fert & P. Tardieu. (*C. R. Acad. Sci., Paris*, 6th Jan. 1958, Vol. 246, No. 1, pp. 79–81.) See also 3621 of 1957 (Durandeau & Fert).

621.385.833 **3941**

An Unconventional Electron Lens.—G. D. Archard. (*Proc. phys. Soc.*, 1st July 1958, Vol. 72, No. 463, pp. 135–137.) Methods of removing spherical aberration are discussed, and a new electrode arrangement proposed for this purpose is analysed.

621.385.833 **3942**

The Electron-Optical Action of an Annular Aperture Lens.—L. A. Harris. (*Proc. Inst. Radio Engrs*, Sept. 1958, Vol. 46, No. 9, pp. 1655–1656.)

621.385.833 **3943**

Optical Properties of a Doublet formed by Two Strongly Convergent Magnetic Lenses.—A. Septier. (*C. R. Acad. Sci., Paris*, 24th March 1958, Vol. 246, No. 12, pp. 1835–1838.)

621.385.833 **3944**

The Electron Microscopy of Crystal Lattices.—J. W. Menter. (*Advances Phys.*, July 1958, Vol. 7, No. 27, pp. 299–348, 29 plates.) A review of the present development of the electron microscope and of direct and indirect methods of studying molecular detail and crystal lattices. Over 100 references.

621.385.833 **3945**

Use of a Strong-Focusing Doublet in Electron Microscopy.—A. Septier. (*C. R. Acad. Sci., Paris*, 31st March 1958, Vol. 246, No. 13, pp. 1983–1985.)

621.387.4 : 621.374.32 **3946**

Analysis of Pulse Pile-Up Effects in a Pulse-Counting System.—R. H. Frazier. (*J. Franklin Inst.*, Sept. 1957, Vol. 264, No. 3, pp. 203–233.) An analysis of the rate of spurious counts due to background radiation.

621.385.833 + 537.533.72 **3947**

Electron Microscopy : Proceedings of the Stockholm Conference, September 1956. [Book Review]—F. S. Sjöstrand & J. Rhodin (Eds). Publishers : Almqvist & Wiksell, Stockholm, and Academic Press, New York, 1957, 355 pp., 85 Sw. kr. (*Nature, Lond.*, 14th June 1958, Vol. 181, No. 4624, pp. 1626–1627.)

PROPAGATION OF WAVES

621.396.11 **3948**

Line-of-Sight Wave Propagation in a Randomly Inhomogeneous Medium.—B. M. Fannin. (*Trans. Inst. Radio Engrs*, Oct. 1956, Vol. AP-4, No. 4, pp. 661–665. Abstract, *Proc. Inst. Radio Engrs*, April 1957, Vol. 45, No. 4, p. 571.)

621.396.11 **3949**

The Use of Equivalent Secondary Sources in the Theory of Ground-Wave Propagation over an Inhomogeneous Earth.—Z. Godziński. (*Proc. Instn elect. Engrs*, Part C, Sept. 1958, Vol. 105, No. 8, pp. 448–464.) The actual field is shown to be the superposition of the fields generated by the primary source and by secondary sources distributed along the path. The analysis is discussed in detail when the paths may be regarded as plane, and when they extend into the diffraction zone. The influence of ground conductivity at transmitting and receiving sites is also discussed. 31 references.

621.396.11 **3950**

Ray Theory vs Normal-Mode Theory in Wave Propagation Problems.—L. G. McCracken. (*Trans. Inst. Radio Engrs*, Jan. 1957, Vol. AP-5, No. 1, pp. 137–140. Abstract, *Proc. Inst. Radio Engrs*, May 1957, Vol. 45, No. 5, p. 716.)

621.396.11 **3951**

Universal Curves for the Vertical-Polarization Reflection Coefficient.—G. P. Ohman. (*Trans. Inst. Radio Engrs*, Jan. 1957, Vol. AP-5, No. 1, pp. 140–142. Abstract, *Proc. Inst. Radio Engrs*, May 1957, Vol. 45, No. 5, p. 716.)

621.396.11 : 551.510.535 **3952**

[Communications on] **28 Mc/s (10·7 m) between Spain and Argentine and Uruguay.**—R. Gea Sacasa. (*Rev. Telecomunicacion, Madrid*, March 1958, Vol. 12, No. 51, pp. 16–24.) Critical comparison of I.F.R.B. predictions with those obtained by Gea's method, on the basis of amateur reception reports.

621.396.11.029.6 **3953**

Theory of the Scintillation Fading of Microwaves.—O. Tukizi. (*Trans. Inst. Radio Engrs*, Jan. 1957, Vol. AP-5, No. 1, pp. 130–136. Abstract, *Proc. Inst. Radio Engrs*, May 1957, Vol. 45, No. 5, p. 716.)

621.396.11.029.6 **3954**

Refraction Anomalies in Airborne Propagation.—M. S. Wong. (*Proc. Inst. Radio Engrs*, Sept. 1958, Vol. 46, No. 9, pp. 1628–1638.) The anomalies are investigated by analogue computation of ray tracings, using a differential analyser. Results are used to explain large spatial field variations and radio ducting, and comparisons with field-strength data are made. Radar angular and range errors under certain conditions are deduced.

621.396.11.029.62 **3955**

Reflection of an Electromagnetic Wave by an Atmospheric Layer presenting a Variation of Refractive Index.—F. du Castel, P. Misme & J. Voge. (*C. R. Acad. Sci., Paris*, 24th March 1958, Vol. 246, No. 12, pp. 1838–1840.) The calculations given in 3956 below may be generalized by an analysis applicable to any layer with a variation having a Fourier transform.

621.396.11.029.62 **3956**

Contribution of Partial Atmospheric Reflections to the Explanation of the Field Received at Great Distances.—F. du Castel & P. Misme. (*C. R. Acad. Sci., Paris*, 6th Jan. 1958, Vol. 246, No. 1, pp. 82–84.) Attenuation at 1 m λ relative to transmission in free space has been calculated for distances of 200–600 km on the assumption that the atmosphere has randomly distributed reflecting strata.

621.396.11.029.64 **3957**

Diffraction by Smooth Cylindrical Mountains.—H. E. J. Neugebauer & M. P. Bachynski. (*Proc. Inst. Radio Engrs*, Sept. 1958, Vol. 46, No. 9, pp. 1619–1627.) A new Fresnel theory is compared with the results of model experiments at K-band frequencies. Other theories are also discussed.

RECEPTION

621.376.23 **3958**

Automatic Bias Control for a Threshold Detector.—J. Dugundji & E. Ackerlind. (*Trans. Inst. Radio Engrs*, March 1957, Vol. IT-3, No. 1, pp. 65–70. Abstract, *Proc. Inst. Radio Engrs*, Aug. 1957, Vol. 45, No. 8, pp. 1165–1166.)

621.376.23 : 621.396.822 **3959**

The Output Signal-to-Noise Ratio of Correlation Detectors.—P. E. Green, Jr. (*Trans. Inst. Radio Engrs*, March 1957, Vol. IT-3, No. 1, pp. 10–18. Abstract, *Proc. Inst. Radio Engrs*, Aug. 1957, Vol. 45, No. 8, p. 1165.)

621.376.23 : 621.396.822 : 621.372.5 **3960**

Optimum Network Functions for the Sampling of Signals in Noise.—Heaps & McKay. (See 3729.)

621.396.621.5-519 **3961**

Stable Receiving Circuits for Remote Control.—S. J. Neshyba & F. E. Brooks, Jr. (*Electronics*, 1st Aug. 1958, Vol. 31, No. 31, pp. 74–76.) "Analysis of single-stage super-regenerative receivers employed in remote-controlled applications shows that with self-quenching circuits, optimum performance is obtained when the receiver is in a weak oscillatory state and an incoming signal causes oscillation every third quench cycle. Vacuum-tubes exhibit low sensitivity to impulse noise, wide dynamic range and high gain."

621.396.81/.82 **3962**

Error Probabilities for Binary Symmetric Ideal Reception through Nonselective Slow Fading and Noise.—G. L. Turin. (*Proc. Inst. Radio Engrs*, Sept. 1958, Vol. 46, No. 9, pp. 1603–1619.) A theoretical treatment of the selection by an ideal receiver of one of two waveforms transmitted through a channel, subject to fading and contaminated by Gaussian noise. Conclusions relating to system design are applied to binary frequency-shift keyed systems.

621.396.812.3 + 534.26 **3963**

Influence of the Directivity of a Receiving Unit on the Average Intensity of a Signal Received as a result of Scattering.—Zverev. (See 3670.)

621.396.82 : 621.317.7 **3964**

Radio Interference: Part 4—Measuring Equipment.—A. Macpherson. (*P.O. elect. Engrs' J.*, July 1958, Vol. 51, Part 2, pp. 115–119.) The general principles and technical requirements of an interference measuring set are discussed and brief descriptions are given of apparatus in use. Part 3: 3624 of November (Dilworth).

STATIONS AND COMMUNICATION SYSTEMS

621.376.53 : 621.395.4 **3965**

Efficiency and Reciprocity in Pulse-Amplitude Modulation.—(*Proc. Instn elect. Engrs*, Part B, Sept. 1958, Vol. 105, No. 23, pp. 449–470. Discussion, pp. 479–482.)

Part 1—Principles.—K. W. Cattermole (pp. 449–462).

Part 2—Testing and Applications.—J. C. Price (pp. 463–470).

A method of converting a l.f. signal into a modulated pulse train and back again, with low power loss, provides multiple communication on a two-wire basis without amplifiers. Theoretical and practical aspects are discussed; transmission with an overall loss of about 2 dB can be achieved.

621.376.55 **3966**

A Study of a Pulse-Phase-Modulation Installation.—R. Kaenel, H. Pfyffer & H. E. Weber. (*Tech. Mitt. PTT*, 1st Jan. 1958, Vol. 36, No. 1, pp. 1–12.) A comparison of the p.p.m. system with other modulation systems, and a description of a model installation for four telephony channels.

621.391 **3967**

On the Estimation in the Presence of Noise of the Impulse Response of a Random, Linear Filter.—G. L. Turin. (*Trans. Inst. Radio Engrs*, March 1957, Vol. IT-3, No. 1, pp. 5–10. Abstract, *Proc. Inst. Radio Engrs*, Aug. 1957, Vol. 45, No. 8, p. 1165.)

621.391 **3968**

On the Capacity of a Noisy Continuous Channel.—S. Muroga. (*Trans. Inst. Radio Engrs*, March 1957, Vol. IT-3, No. 1, pp. 44–51. Abstract, *Proc. Inst. Radio Engrs*, Aug. 1957, Vol. 45, No. 8, p. 1165.)

621.391 **3969**

Merit Criteria for Communication Systems.—A. Hauptschein & L. S. Schwartz. (*Trans. Inst. Radio Engrs*, March 1957, Vol. IT-3, No. 1, pp. 52–55. Abstract, *Proc. Inst. Radio Engrs*, Aug. 1957, Vol. 45, No. 8, p. 1165.)

621.391 : 621.376.56 **3970**

Noise-Reducing Codes for Pulse-Code Modulation.—J. E. Flood. (*Proc. Instn elect. Engrs*, Part C, Sept. 1958, Vol. 105, No. 8, pp. 391–397. Discussion, p. 397.) A discussion of methods of improving the signal/noise ratio of p.c.m. systems by making the more significant digits less liable to error than the less significant ones. Systems using pulses of varying height and length are compared.

621.391 : 621.376.56 **3971**

The Rate of Transmission of Information in Pulse-Code-Modulation Systems.—A. R. Billings. (*Proc. Instn elect. Engrs*, Part C, Sept. 1958, Vol. 105, No. 8, pp. 444–447.) A general expression is derived for the maximum rate of communication of information when the interfering noise has a Gaussian amplitude distribution. The cases of binary and tertiary coding are dealt with in detail.

621.391 (083.7) **3972**

I.R.E. Standards on Information Theory: Definitions of Terms, 1958.—(*Proc. Inst. Radio Engrs*, Sept. 1958, Vol. 46, No. 9, pp. 1646–1648.) Standard 58 I.R.E. 11.S1.

621.395.4 : 621.318.5 **3973**

Selective Signalling and Switching for the SAGE System.—H. J. Michael. (*Bell Lab. Rec.*, Sept. 1958, Vol. 36, No. 9, pp. 335–339.) An outline of the telephone circuits within the system.

621.395.4 : 621.318.5 **3974**

Automatic Line-Switching for L3 Carriers.—E. C. Thompson. (*Bell Lab. Rec.*, Sept. 1958, Vol. 36, No. 9, pp. 340–343.) Techniques are outlined for bypassing faulty sections of line.

621.395.4 : 621.318.57 **3975**

Experimental Electronic Telephone Switching System.—(*Bell Syst. tech. J.*, Sept. 1958, Vol. 37, No. 5, pp. 1091–1220.) The system described in the following papers includes a stored program, a network employing gas-diode crosspoints, time-division common control and large-capacity photographic and barrier-grid valve storage systems.

(*a*) An Experimental Switching System using New Electronic Techniques.—A. E. Joel, Jr (pp. 1091–1124).

(*b*) Semiconductor Circuit Design Philosophy for the Central Control of an Electronic Switching System.—B. J. Yokelson, W. B. Cagle & M. D. Underwood (pp. 1125–1160).

(*c*) Fundamental Concepts in the Design of the Flying-Spot Store.—C. W. Hoover, Jr, R. E. Staehler & R. W. Ketchledge (pp. 1161–1194).

(*d*) A High-Speed Barrier-Grid Store.—T. S. Greenwood & R. E. Staehler (pp. 1195–1220).

621.395.43 : 621.373.52 **3976**

Transistor Pulse Generators for Time-Division Multiplex.—Cattermole. (See 3734.)

621.396.3 : 621.396.43 : 523.5 **3977**

Meteor Bursts provide Communications Path.—B. M. Sifford & W. R. Vincent. (*Electronics*, 29th Aug. 1958, Vol. 31, No. 35, pp. 42–45.) Details are given of the equipment used in the radio link previously described [1549 of May (Vincent et al.)].

621.396.3 : 621.396.43 : 523.5 **3978**

Storage Capacity in Meteor-Burst Communication Systems.—W. A. Helbig. (*Proc. Inst. Radio Engrs*, Sept. 1958, Vol. 46, No. 9, pp. 1649–1650.) A method differing from that of Campbell (907 of March) is used to derive the storage capacity.

621.396.41 **3979**

Multichannel U.H.F. Radio Telephone Equipment.—J. Fieguth. (*Proc. Instn Radio Engrs, Aust.*, Feb. 1958, Vol. 19, No. 2, pp. 43–53.) Recently developed f.m. equipment, operating in the 900-Mc/s band, is described. It can be used for up to 36 telephone channels, and performance figures show that C.C.I.F. standards are met.

621.396.65 : 621.372.8 **3980**

Microwave Aspects of Waveguides for Long - Distance Transmission.—Karbowiak. (See 3680.)

621.396.712.2/.3 **3981**

The B.B.C.'s Mark II Mobile Studio and Control Room for the Sound Broadcasting Service.—L. E. H. O'Neill. (*B.B.C. Engng Div. Monographs*, Aug. 1958, No. 20, pp. 5–23.)

621.396.712.3 : 534.84 **3982**

The Large Auditorium of the Hessischer Rundfunk.—Schreiber. (See 3674.)

621.396.933.42 **3983**

Single-Sideband Aircraft Communication.—G. L. Grisdale. (*Wireless World*, Oct. 1958, Vol. 64, No. 10, pp. 460–465.) S.s.b. and d.s.b. systems are compared with reference to long-distance aeronautical communications, and the advantages of the former are described together with the technical problems involved in its introduction to civil air routes.

SUBSIDIARY APPARATUS

621-526 **3984**

Transistors Reduce Relay Servo Size.—S. Shenfeld. (*Electronics*, 15th Aug. 1958, Vol. 31, No. 33, pp. 73–75.)

621.311.6.072.2 : 621.314.6 **3985**

New-Type Constant-Voltage Rectifier.—Y. Imamizu, M. Take & Y. Suzuki. (*Rep. elect. Commun. Lab., Japan*, April 1958, Vol. 6, No. 4, pp. 116–129.) A constant-voltage supply for use as a floating-battery power source is described; its output rating is 50 V at 150 A.

621.316.542.2 : 621.398 **3986**

A High-Speed Rotary Switch and some Applications. — M. Lowenberg. (*Electronic Engng*, Sept. 1958, Vol. 30, No. 367, pp. 524–527.) The general requirements of high-speed switches are discussed with particular reference to applications in information sampling systems. Details and applications of a rotary switch permitting rotational speeds of up to 200 rev/min are described.

621.316.721/.722 : 621.314.7 **3987**

The Principle of Stabilization of Constant-Impedance Devices and its Application to a Transistor Power Supply.—É. Cassignol. (*C. R. Acad. Sci., Paris*, 3rd March 1958, Vol. 246, No. 9, pp. 1401–1404.) The useful operating range of a shunt-type voltage regulator is expressed in terms of a utilization coefficient. General relations derived are applied to a two-transistor circuit of the type described earlier [3642 of November (Cassignol & Giralt)] particularly suitable for stabilization of valve heater supplies.

TELEVISION AND PHOTOTELEGRAPHY

621.397.5 **3988**

Australian Television.—(*Proc. Instn Radio Engrs, Aust.*, March 1958, Vol. 19, No. 3, pp. 122–124.) Definition of the revised technical standards issued on 4th Nov. 1957.

621.397.5 : 623 **3989**

Military Uses of Television.—(*J. Soc. Mot. Pict. Telev. Engrs*, July 1958, Vol. 67, No. 7, pp. 441–479.) The text is given of 10 papers, most of which were read at the Convention of the Society of Motion Picture and Television Engineers held in Philadelphia, October 1957.

(*a*) Pickup-Tube Performance with Slow Scanning Rates.—C. T. Shelton & H. W. Stewart (pp. 441–451).

(*b*) Development of the Thin Cathode-Ray Tube.—W. R. Aiken (pp. 452–455). See also 977 of March.

(*c*) Development and Applications of Transparent Cathode-Ray Screens.—C. Feldman (pp. 455–460).

(*d*) Television for Parade Control and Field Exercises.—H. Dakin, F. L. Martin, P. A. J. Bue & J. R. Smith (pp. 461–463).

(*e*) Technical and Production Problems in Military Television Recordings.—N. Gray (pp. 463–464).

(*f*) Army Television Research and Development.—W. A. Huber & R. B. Le Vino (pp. 465–469).

(*g*) Television for Use under Rugged Environmental Conditions.—J. P. Day & F. R. Pike (pp. 470–472).

(*h*) Television Viewing of Rocket Engine Tests.—J. P. Mitchell (pp. 473–474).

(*i*) Some Aspects of the Application of Television to the Tracking of Guided Missiles.—H. L. Roberts (pp. 475–477).

(*j*) Airborne Closed-Loop Television System.—A. F. Flacco (pp. 477–479).

621.397.6 **3990**

Efficiency-Diode Scanning Circuits.—K. G. Beauchamp. (*Electronic Engng*, Aug. & Sept. 1958, Vol. 30, Nos. 366 & 367, pp. 490–497 & 549–556.) Various types of efficiency-diode circuit are examined theoretically, and the influence of valve characteristics on the series circuit is investigated for various operating modes. Both valve and saturated-reactor methods of controlling scan linearity are described and a 'differential method' of controlling scan width is outlined. A complete scanning circuit with provision for deriving the e.h.t. supply for the c.r. tube is given.

621.397.6 : 621.314.7 **3991**

The Application of Transistors in Video-Frequency Techniques.—H. Fix. (*Rundfunktech. Mitt.*, Feb. 1958, Vol. 2, No. 1, pp. 10–17.) Circuit and performance details of portable television camera equipment incorporating transistors are given.

621.397.6 : 621.396.65 : 621.317.799 **3992**

A Pulse-and-Bar Waveform Generator for Testing Television Links.—I. F. Macdiarmid & B. Phillips. (*Proc. Instn elect. Engrs*, Part B, Sept. 1958, Vol. 105, No. 23, pp. 440–448.) Details are given of the design of a test-signal generator which, at the line-frequency repetition rate, produces a composite waveform consisting of a sine-squared pulse, a smoothed-bar pulse and a normal line-synchronizing pulse.

621.397.611 : 522.2 **3993**

Television Camera with Prolonged Storage Time for Televising Objects of Low Light Intensity particularly for Use in Television Astronomy.—P. Piepereit. (*Rundfunktech. Mitt.*, Feb. 1958, Vol. 2, No. 1, pp. 18–19.) Modifications to an image-orthicon circuit for increasing its photosensitivity and avoiding flicker are described.

621.397.611.2 **3994**

Transmission Characteristics of the Image - Orthicon Television Camera Tube at Extremely High Photocurrents.—R. Theile & F. Pilz. (*Rundfunktech. Mitt.*, Feb. 1958, Vol. 2, No. 1, pp. 1–9.) See also 603 of February. Good picture quality can be obtained with very high photocurrents and low storage time.

621.397.611.2 **3995**

The Influence of the Optical System of a Television Camera on the Frequency Response Characteristic of a Television System.—D. Frenzel. (*Rundfunktech. Mitt.*, Feb. 1958, Vol. 2, No. 1, pp. 20–28.)

621.397.62 : 621.396.665 **3996**

A.G.C. for Television Receivers.—R. H. Skinner. (*Wireless World*, Oct. 1958, Vol. 64, No. 10, pp. 486–490.) Two methods are described, using bias volts derived from the video signal at the grid of the synchronizing-pulse separator, and delay volts for the r.f. stage from the contrast control.

621.397.621.2 : 535.623 **3997**

Colour Selection with the Chromotron Tube.—L. W. Allen. (*Radio-Electronics*, April 1958, Vol. 29, No. 4, pp. 115–118.) The principle of operation and the circuitry of the single-gun three-colour Lawrence tube are described.

621.397.7 **3998**

B.B.C. Television Centre.—(*Wireless World*, Oct. 1958, Vol. 64, No. 10, pp. 484–

485.) Description, with perspective drawings and photographs, of the layout and special features of the White City centre due to be completed in 1961.

621.397.8 **3999**

The Relation between Picture Size, Viewing Distance and Picture Quality.—L. C. Jesty. (*Proc. Instn elect. Engrs*, Part B, Sept. 1958, Vol. 105, No. 23, pp. 425–434. Discussion, pp. 435–439.) A description of experiments to determine the preferred viewing distance for a number of different types and sizes of picture with different bandwidths, including 405-line and 625-line monochrome and 405-line colour television. The use of spot-wobble techniques is also investigated.

621.397.8 **4000**

Performance of U.H.F. and V.H.F. Transmitting and Receiving Equipment.—W. J. Morlock & W. O. Swinyard. (*Elect. Engng, N.Y.*, March 1958, Vol. 77, No. 3, pp. 226–231.) Survey of the problems investigated by Panels 1 and 2 of T.A.S.O. [see 3259 of October (Town)] to assist the F.C.C. in making frequency allocations.

621.397.8 : 621.396.822 **4001**

Visibility of Noise on Television Pictures.—R. Fatehchand. (*Nature, Lond.*, 28th June 1958, Vol. 181, No. 4626, p. 1797.) Note of an experiment demonstrating the increased visibility of 'quasi-triangular' noise (power per unit bandwidth increasing with frequency) when a sinusoidal signal is added at the grid of a video amplifier.

621.397.82 **4002**

Nonlinear Distortion in Television Transmission Lines.—J. Müller. (*Arch. elekt. Übertragung*, Dec. 1957, Vol. 11, No. 12, pp. 485–494.) Frequency-dependent nonlinear distortion in program lines and f.m. radio links is discussed with particular regard to the effect on the video signal and picture quality. Oscillograms obtained in measurements on a 4-kMc/s radio link are given.

VALVES AND THERMIONICS

621.314.63 **4003**

Analysis of Current Flow in a Planar Junction Diode at a High Forward Bias.—A. K. Jonscher. (*J. Electronics Control*, July 1958, Vol. 5, No. 1, pp. 1–14.) Using planar geometry, the general case of an asymmetric *p-n*-type diode is analysed, the impurity concentrations and widths on both sides being arbitrary. With certain assumptions, the current/voltage relation is $I^{\frac{1}{2}} = S(V - V_0)$, where S is expressed in terms of the physical parameters of the junction and V_0 is the equilibrium potential.

621.314.63 : 621.317.3 **4004**

Crystal Rectifiers in Measurement Technique.—H. Wucherer. (*Arch. tech. Messen*, Feb. 1958, No. 265, pp. 41–44.) Equivalent circuits and rectifier characteristics are summarized.

621.314.7 **4005**

A New Method of Voltage and Power Amplification at High Frequencies.—S. Teszner. (*C. R. Acad. Sci., Paris*, 6th Jan. 1958, Vol. 246, No. 1, pp. 72–73.) A note on the construction, characteristics and theory of the tecnetron. See 3657 of November (Aisberg).

621.314.7 **4006**

Variation with Temperature of the Cut-Off Frequency of Junction Transistors in the Common-Emitter Connection.—R. Birebent & R. Morelière. (*C. R. Acad. Sci., Paris*, 10th Feb. 1958, Vol. 246, No. 6, pp. 909–911.) Diffusion-type *p-n-p* junction transistors subjected to temperature variations in the range −20°C to +30°C showed a regular diminution of cut-off frequency with increase of temperature.

621.314.7 **4007**

The Measurement of the Operating Temperature of Transistors.—H. Beneking. (*Arch. elekt. Übertragung*, Dec. 1957, Vol. 11, No. 12, pp. 504–508.) The operation of the equipment described is based on the measurement of collector current with emitter and base terminals short-circuited.

621.314.7 **4008**

On Understanding Transistors.—K. C. Johnson. (*Wireless World*, Sept. & Oct. 1958, Vol. 64, Nos. 9 & 10, pp. 429–43 & 497–501.) L.f. and h.f. equivalent circuits, for junction transistors, are developed by comparison with the ideal thermionic valve. Semiconductor theory is included.

621.314.7 : 621.397.6 **4009**

The Application of Transistors in Video-Frequency Techniques.—Fix. (See 3991.)

621.383.2 **4010**

On the Random Character of Photon Absorption.—E. Baumgardt. (*C. R. Acad. Sci., Paris*, 16th Dec. 1957, Vol. 245, No. 25, pp. 2236–2238.) The random character of the absorption of photons by a SbCs photocathode is demonstrated experimentally.

621.385.029.6 **4011**

International Congress on Microwave Valves.—(*Le Vide*, July/Aug. 1957, Vol. 12, No. 70, pp. 229–370.) A further selection of papers presented at the Congress (see also 639 of February), including the following:

(*a*) Microwave Triode B-26 for 4 000-Mc/s Operation.—Y. Nakamura, T. Miwa & Y. Hasegawa (pp. 230–246, in French & English).

(*b*) A Magnetron Controlled by a Symmetrically Coupled TE_{011}-Mode Cavity.—J. Feinstein & R. J. Collier (pp. 247–254, in French & English).

(*c*) Magnetron: 8 mm, 40 kW, 12 W.—R. Juillerat & A. Regeffe (pp. 255–260).

(*d*) The Problem of Designing 'Turbators' (Magnetrons) for Communication Equipment.—H. Paul (pp. 261–268, in French & German).

(*e*) Reflex Klystron with a Wide Mechanical Tuning Range for the Millimetre Region.—E. D. Naumenko (pp. 269–272, in French & English).

(*f*) High-Power Travelling-Wave Valves Types O and M: Amplifiers and Oscillators.—P. Guénard & O. Doehler (pp. 273–277).

(*g*) Some New Circuits for High-Power Travelling-Wave Valves.—M. Chodorow & R. A. Craig (pp. 278–283, in French & English). See 3698 of 1957.

(*h*) Development of Travelling-Wave Amplifier Valves at Federal Telecommunication Laboratories.—A. G. Clavier, O. Boychenko & R. W. Wilmarth (pp. 284–293, in French & English).

(*i*) Travelling-Wave Valves Types 4W85 and 4W86 used in the Microwave Link Tokyo–Osaka.—S. Hayashi, K. Sato, D. Kobayashi & H. Nishio (pp. 294–300, in French & English).

(*j*) High-Gain and Medium-Power Travelling-Wave Valve Type ECL-1140.—K. Sato, D. Kobayashi, S. Hamada & Y. Uji (pp. 301–307, in French & English).

(*k*) Very-Low-Noise Travelling-Wave Valve.—E. W. Kinaman & M. Magid (pp. 308–317, in French & English).

(*l*) Millimetre Carcinotrons.—J. Laborderie, G. Vincent & T. Yeou (pp. 318–326).

(*m*) Contribution to the Design of Permanent Magnets with particular reference to Magnet Shapes for Travelling-Wave Valves.—L. Brück (pp. 327–335, in French & German).

(*n*) Ion Discharge Tubes in Microwave Techniques.—J. Lecorguillier (pp. 336–340).

(*o*) Oscillography and Beam Analysis at Microwave Frequencies.—H. Von Foerster, E. W. Ernst, O. T. Purl & M. Weinstein (pp. 341–351, in French & English).

(*p*) Technology of the Millimetre Region.—H. Piatti (pp. 352–355).

(*q*) Research and Development of Microwave Valves in Japan.—Y. Koike & Y. Nakamura (pp. 356–370, in French & English).

621.385.029.6 **4012**

Shunt Impedance of Klystron Cavities.—E. L. Ginzton & E. J. Nalos. (*Trans. Inst. Radio Engrs*, Oct. 1955, Vol. MTT-3, No. 5, pp. 4–7. Abstract, *Proc. Inst. Radio Engrs*, Feb. 1956, Vol. 44, No. 2, p. 275.)

621.385.029.6 **4013**

A.C. Operation of Magnetrons for Coherent Operation.—W. Schmidt. (*Elektronische Rundschau*, Jan. 1958, Vol. 12, No. 1, pp. 12–14.) The use of a.c. voltage supplies instead of d.c. is discussed and the relative advantages are tabulated.

621.385.029.6 **4014**

Focusing in High-Voltage Beam-Type Electron Devices.—S. V. Yadavalli. (*J. Electronics Control*, July 1958, Vol. 5, No. 1, pp. 65–87.) The paraxial electron trajectory equation, applicable at relativistic speeds, including the effects of self-magnetic field and space-charge of the beam, is derived. The equation is applied to problems of beam spreading, e.s. and magnetic lenses, Brillouin flow, and beam stability. Results are discussed in detail and practical applications are indicated.

621.385.029.6 **4015**

Analysis of Travelling-Wave Tubes with Tapered Velocity Parameter.—D. V. Geppert. (*Proc. Inst. Radio Engrs*, Sept. 1958, Vol. 46, No. 9, p. 1658.)

621.385.029.6 **4016**

Interaction within the Attenuator of a High-Power T.W.T.—D. E. T. F. Ashby, T. D. Cockhill, A. F. Hassell & R. O. Jenkins. (*J. Electronics Control*, July 1958, Vol. 5, No. 1, pp. 62–64.) An account is given of an unsuccessful attempt to cause interaction to take place in the attenuator of a travelling-wave valve at normal beam voltages. The method used was to vary the phase velocity in the two sections of the attenuator by varying the pitch of the helix. Conclusions are drawn.

621.385.029.6 : 621.3.032.53 : 666.1.037.5 **4017**

Sealed-In Connections with Improved Surfaces for Microwave Valves.—W. Düsing. (*Telefunken Ztg*, Dec. 1957, Vol. 30, No. 118, pp. 264–269. English summary, pp. 288–289.) Improved high-frequency conductivity and other advantages are obtained using disk-shaped connectors of Fe-Ni alloy which are silver-plated over a thin layer of gold and sealed with lead glass. The resulting improvement in the performance of disk-seal triodes is shown graphically.

621.385.032.21 **4018**

A Cathode Test utilizing Noise Measurements.—W. Dahlke & F. Dlouhy. (*Proc. Inst. Radio Engrs*, Sept. 1958, Vol. 46, No. 9, pp. 1639–1645.) Shot-noise effects are used as a sensitive measure of cathode quality. Test equipment and procedure are described.

621.385.032.213.13 **4019**

The Conductivity of Oxide Cathodes: Part 5—Functional Structure of the Cathode.—G. H. Metson. (*Proc. Instn elect. Engrs*, Part C, Sept. 1958, Vol. 105, No. 8, pp. 374–380.) The cathode is considered as a thin-film emitter covered by a porous oxide matrix. The thin-film emitter determines the total available emission, and the self-generated electron density within the matrix determines the potential rise between emitter and electron-exit boundary. See 2274 of July.

621.385.032.26 : 537.533 **4020**

Large Perturbations in Electron Beams from Shielded and Immersed Guns.—T. S. Chen. (*J. Electronics Control*, June 1958, Vol. 4, No. 6, pp. 523–538.) "Large perturbations in cylindrical beams from magnetically shielded and immersed guns are calculated by numerical integration of the electron dynamic equations. Contours of a particular beam from both types of electron gun are given, and the calculated contours in the shielded gun are compared with the experimental results obtained by Lawson (3790 of 1955). By the use of reduced variables, universal beam contours are prepared for determination of the profiles of other beams. The limit of applicability of the small-perturbation theory used in analysis of electron beams is evaluated."

621.385.1 **4021**

A Perturbation Analysis of the Equations for Electrostatic Space-Charge Flow and its Application to the Production of Hollow Beams from a Toroidal Cathode.—P. T. Kirstein. (*J. Electronics Control*, July 1958, Vol. 5, No. 1, pp. 33–53.)

621.385.1 **4022**

Grid Current in Electron Tubes.—E. Fairstein. (*Rev. sci. Instrum.*, June 1958, Vol. 29, No. 6, pp. 524–526.) In modern low-power receiving valves grid current is mainly due to photoelectric emission from the grid, caused by soft X rays produced at the plate. A simple formula is given for predicting this current from the operating conditions.

621.385.2 : 537.533 **4023**

Magnetic Constriction in Simple Diodes.—B. Meltzer. (*Nature, Lond.*, 10th May 1958, Vol. 181, No. 4619, pp. 1332–1333.) A note on the restriction which must be placed on cathode size for parallel flow to be approximately realizable. The ratio of radius to anode/cathode spacing must be considerably less than 29, 5·6 and 1·1 for diodes in which the maximum kinetic energy of the electrons is respectively one tenth, equal to, and ten times their rest energy. See also 3037 of October.

621.385.2 : 621.362 **4024**

Analysis and Experimental Results of a Diode Configuration of a Novel Thermoelectron Engine.—G. N. Hatsopoulos & J. Kaye. (*Proc. Inst. Radio Engrs*, Sept. 1958, Vol. 46, No. 9, pp. 1574–1579.) The engine is designed to convert heat into electrical work without use of moving mechanical parts. It depends on the transfer of electrons emitted with high initial velocity from a hot cathode to an anode, against a potential barrier. An efficiency of 12 % has been achieved in a model made to investigate the principles of operation. See also 3592 of November.

621.385.3.029.63 **4025**

Energy Balance in Disk-Seal Oscillators at Ultra High Frequencies.—M. R. Gavin & L. J. Herbst. (*Brit. J. appl. Phys.*, Sept. 1958, Vol. 9, No. 9, pp. 377–380.) Measurements on Type CV273 disk-seal triodes in the range 500–2 000 Mc/s showed that the input d.c. power could be accounted for by the a.c. output power and dissipation at the electrodes.

621.385.4 : 621.397.621 **4026**

Improving the Deflection Amplifier.—C. Droppa. (*Electronic Ind.*, May 1958, Vol. 17, No. 5, pp. 76–79.) A new Type-6FH6 valve has been developed for the horizontal-deflection amplifier in television receivers. The grid wires are supported at constant tension at exactly 90° to the vertical.

621.385.832 **4027**

The Optimum Design of Electrostatically Deflected Cathode-Ray Tubes.—H. Moss. (*J. Brit. Instn Radio Engrs*, Aug. 1958, Vol. 18, No. 8, pp. 485–491.) For a given spot size and beam current it is shown that defocusing is a minimum and deflection sensitivity is a maximum when (*a*) the electron gun is short so that the deflectors are mounted as far as possible from the screen, and (*b*) the deflectors are as large and sensitive as possible.

621.385.832 **4028**

Electron-Beam Tubes as Information Carriers.—F. Schröter. (*Telefunken Ztg*, Dec. 1957, Vol. 30, No. 118, pp. 251–263. English summary, p. 288.) Several electron-beam devices are described including deflection amplifiers, and storage-type and writing tubes.

621.387 : 621.396.822.029.63 **4029**

Helix-Coupled Gas-Tube Noise Sources.—K. W. F. Steward. (*Marconi Rev.*, 2nd Quarter 1958, Vol. 21, No. 129, pp. 43–55.) Design data are presented for noise sources in the frequency-range 300–1 450 Mc/s using the Type-CV1881 gas discharge tube. Curves are given for the input voltage s.w.r. and insertion loss as functions of frequency.

MISCELLANEOUS

061.3 : [621.38/.39+681.142] **4030**

Second Electronic Convention in Israel.—(*Bull. Res. Counc. Israel*, Nov. 1957, Vol. 6C, No. 1, pp. 77–83.) Summaries of papers presented at the convention held at Rehovot, 16th–17th June 1957.

061.4 : 621.396 **4031**

Farnborough, 1958.—(*Wireless World*, Oct. 1958, Vol. 64, No. 10, pp. 491–494.) Review of aviation electronics at the S.B.A.C. exhibition.

061.6 : 621.396 **4032**

The Radio Research Station, Slough.—(*Nature, Lond.*, 14th June 1958, Vol. 181, No. 4624, pp. 1642–1643.) A summary of the program of research in progress at the time of the open days, 20th–21st May 1958. See also 4086 of 1957.

621.3-71 **4033**

Liquid Cooling of Electronic Equipment.—E. N. Shaw. (*Electronic Engng*, Sept. 1958, Vol. 30, No. 367, pp. 516–523.) Experimental results are analysed showing the effectiveness of liquid cooling applied to miniaturized equipment. Built-in heat exchangers can remove 95% of the heat developed inside a pressurized container. See also 2311 of 1957.

ABSTRACTS AND REFERENCES INDEX

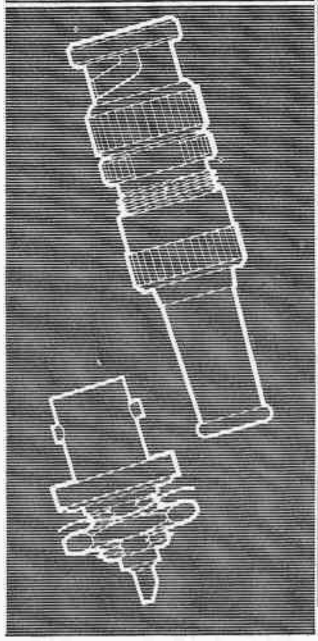
The Index to the Abstracts and References published throughout 1958 is in course of preparation and will be available with the March 1959 issue. As usual, a selected list of the journals scanned for abstracting, with publishers' addresses, will be included.

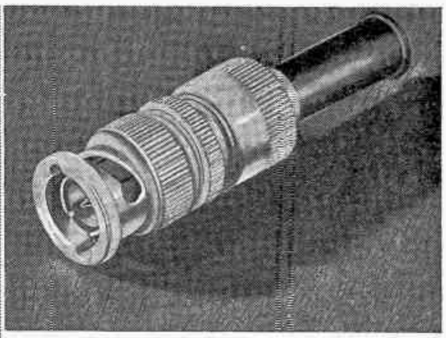
INDEX

Vol. 35 *New Series* — **Electronic & Radio Engineer** — **1958**

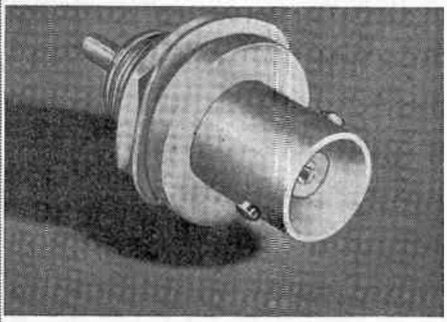
INDEX TO AUTHORS

THESE DIAGRAMS ARE ACTUAL SIZE





L.1331/FP FREE PLUG



L.1331/CS CHASSIS SOCKET

BNC CONNECTORS

This new range is designed for electronic V.H.F. applications, such as N.A.T.O. and Service equipment, laboratory use, etc.

The "Belling-Lee" connectors are interchangeable with their American counterparts, and have certain advantages. The improved cable grip action has been designed to hold the connector firmly on the end of the cable.

The five connectors at present in production consist of a free plug, a right-angled free plug, a free socket, a fixed socket, and a bulkhead adaptor (socket to socket) with P.T.F.E. insulation.

The nominal characteristic impedance throughout the range is 51 ohms, and these connectors can be used up to frequencies of at least 3,000 Mc/s. They are designed for use with "Uniradio" 43 cable and the standing wave radio introduced by the connector when it is used with this cable is less than the tolerance of the characteristic impedance of the cable itself.

Comet 4 carries 736 "Belling-Lee" components, comprising various types of fuses and fuse-holders

Voltage standing wave ratio: Measured up to 900 mc/s FP and FS less than 1.08 to 1, other types less than 1.2 to 1.

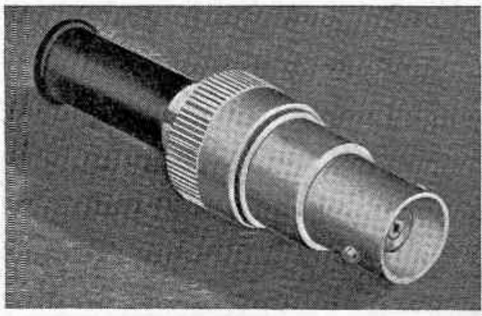
Min. and max. panel thickness: L.1352/BS (bulkhead adaptor not illustrated) min. $\frac{1}{16}$ in., max. $\frac{1}{8}$ in. L.1331/CS min. $\frac{1}{16}$ in., max. $\frac{3}{16}$ in.

Finish: Silver-plated.

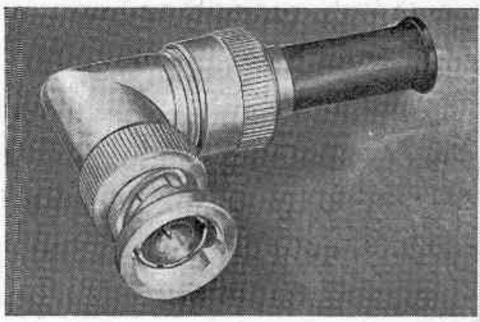
Weight:

BS	CS	FS	FP	RFP
27	10·5	15	22	26 grams
·95	·37	·52	·77	·92 oz.

Most "Belling-Lee" products are covered by patents or registered designs, or applications therefor.

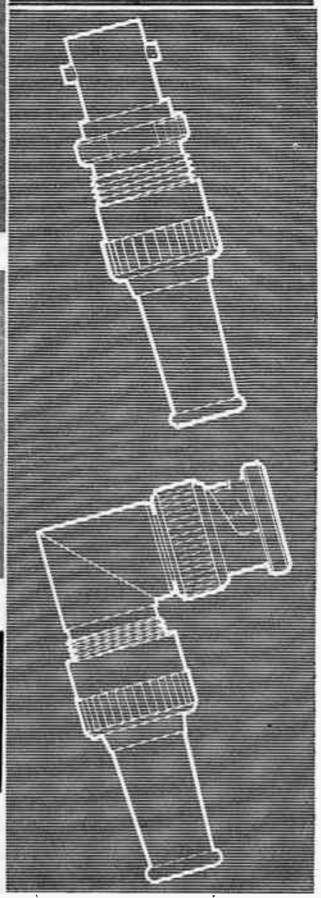


L.1331/FS FREE SOCKET



L.1331/RFP RIGHT-ANGLE FREE PLUG

THESE DIAGRAMS ARE ACTUAL SIZE



BELLING & LEE LTD

GREAT CAMBRIDGE ROAD, ENFIELD, MIDDX., ENGLAND

Telephone: Enfield 3322 · Telegrams: Radiobel, Enfield

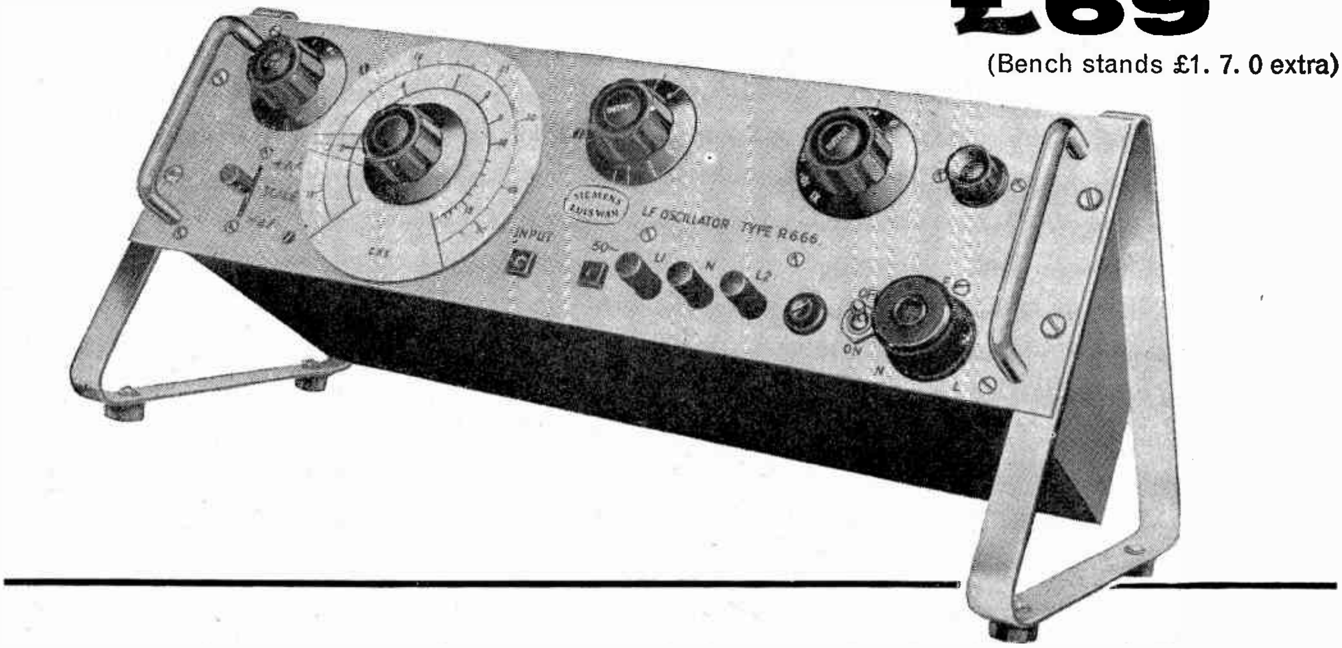
TERMINALS · PLUGS & SOCKETS · THERMAL DEVICES · FUSES · INTERFERENCE FILTERS · RECEIVING AERIALS

World Radio History

This low frequency oscillator costs only

£69

(Bench stands £1. 7. 0 extra)



This reasonably-priced low frequency oscillator is used extensively as a convenient source of signals down to 1·15 c.p.s. for the testing and calibration of vibration recorders servo systems etc.

BRIEF SPECIFICATION

TYPE	FREQUENCY RANGE	OUTPUT	INPUT	CONSTRUCTION
Resistance capacity, with automatic amplitude control effective over the whole frequency range.	1.15 c.p.s. to 5,500 c.p.s.	Sine wave 50 volts peak to peak, push-pull, with built-in attenuator.	200–250 volts, 40–60 c.p.s.	Standard 19″ rack mounting, but also suitable for bench use. Bench stands available.

NOTES: **An incremental switch is fitted. Provision is made for mixing other signals with the output.**

Immediate delivery from

SIEMENS EDISWAN

SIEMENS EDISON SWAN LIMITED • SPECIAL PRODUCTS DIVISION (PD 17)

An A.E.I. Company

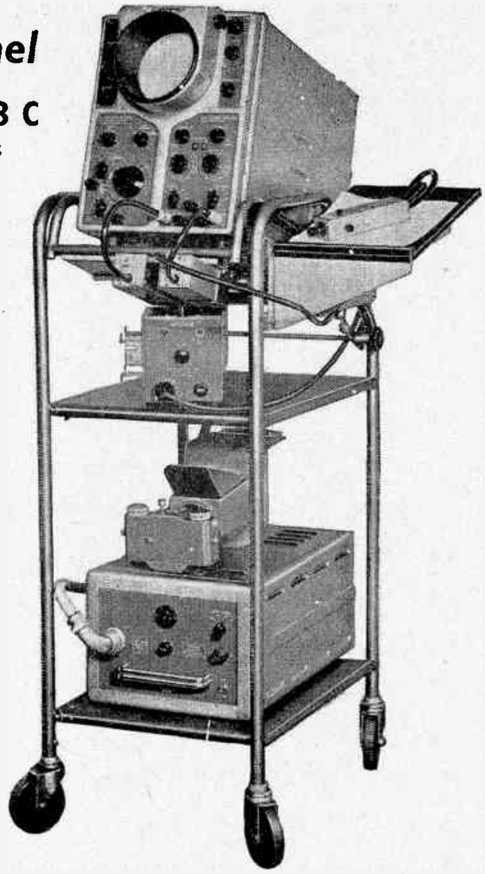
155 CHARING CROSS ROAD, LONDON, W.C.2. TELEPHONE: GERrard 8660. TELEGRAMS: SIESWAN, WESTCENT LONDON

CRC 17/14

AN IMPROVED WIDE BAND Two Channel

OSCILLOSCOPE

MODEL DE 103 C
—D.C. to 15 Mc/s
Rise time
24 musec.



As a result of developments in double gun C.R.T.'s we are now able to offer a considerably improved performance with a fine focus giving clear resolution of waveform details.

TIME BASE of constant linearity driving two sweeps with independent X shifts so that traces may be aligned for comparison with great accuracy.

Calibrated sweep times from 0.2 sec. to 0.6 μsec. per 10 cm. enabling time measurement within 2% accuracy.

Excellent synchronising facilities at high frequencies, under either repetitive or triggered conditions.

TWO CHANNEL AMPLIFIER covering DC to 15 Mc/s-3dB extending to 21 Mc/s at 6dB point—RISE TIME 24 musec.

Sensitivity—1 cm/120mV with linear swing exceeding 6 cms peak to peak in each channel.

Voltage calibrated AC or DC within 5% over a range of 100mV to 500 volts.

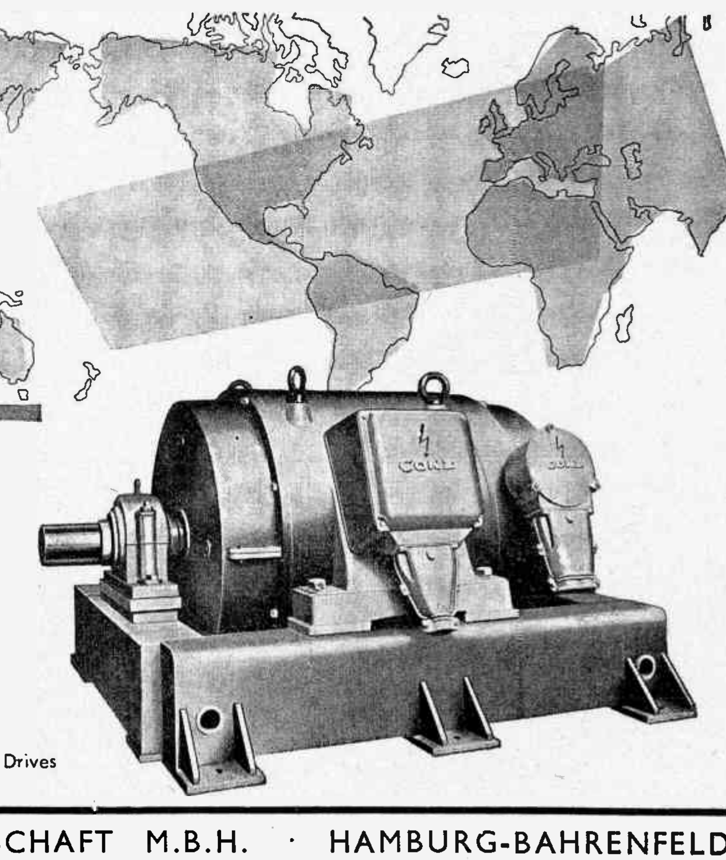
Having two channels which are free from interaction and which do not depend on beam switching techniques, the two displays may be aligned as desired in both axes, with confidence that their waveform details are strictly relative under either single stroke triggered or repetitive sweep conditions.

The new trolley mounting of this instrument has facilities for conveniently carrying accessories, such as signal delay lines, cathode follower probe and single shot camera. Note the useful writing desk attachment.

NAGARD LTD

In effect the instrument comprises two first class wide band C.R.O.'s combined in one unit.

18 AVENUE ROAD · BELMONT · SURREY · VIGILANT 9161-2



thousands of CONZ *electrical machines*

guarantee efficient service in all parts of the globe

Manufacturing Programme

Threephase Squirrelcage Motors up to 2500 kW
Threephase Slipring Motors up to 2500 kW
Threephase Generators up to 3600 kVA
D. C. Motors and Generators up to 2000 kW
Converters and Motor-Generator Sets of all kinds
Ward-Leonard Converters
Medium Frequency Converters up to 10 000 cps
Projects and Supply of Electronically and Magnetically Controlled Drives

CONZ ELEKTRICITÄTS-GESELLSCHAFT M.B.H. · HAMBURG-BAHRENFELD
PHONE: 89 68 61 · CABLES : CONZDYNAMO HAMBURG · TELEX : 021 1364

SOLARTRON

Precision instrumentation for very low frequencies

Described below are just three examples of Solartron precision V.L.F. instrumentation. These instruments, which together cover the frequency range 1 cycle in 3 hours to 11.1 Kc/s, form part of the comprehensive Solartron Dynamic Analysis range. They embody the latest design techniques and are built to the finest standards of electrical and mechanical engineering.

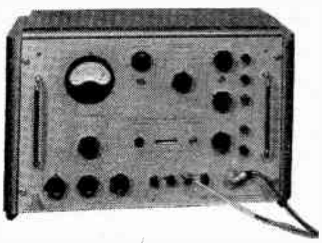
PROCESS RESPONSE ANALYSER JY 743

- **Systems analysis down to 3-hour period**
- **Rejects harmonic frequencies and noise**
- **Can be programmed remotely**

Giving direct indication of "in-phase" and "quadrature" components of a resolved test signal, the Solartron PRA is a vital aid to instrumentation of very low frequency systems—including nuclear reactor controllers, heat exchangers and heavy chemical plant. The PRA uses gated integration techniques to achieve a degree of measurement accuracy hitherto unobtainable at these very low frequencies.

The L.F. Decade Oscillator section (JO 744) has both 4-phase and 3-phase outputs, also triangular and squarewave outputs, the frequency accuracy being inside 1.5%, with amplitude stability better than 1% over the entire range. 'Prime', 'Start' and 'Hold' controls act on the oscillator below 10 c/s so that, at V.L.F., there is no "warm-up" time and any instantaneous value of the output waveform can be frozen for examination. These facilities can also be commanded externally, for example from a computer or simulator. The Resolved Components Indicator section has a maximum sensitivity of 3mV full-scale, with simultaneous analogue voltage outputs for digital conversion or for automatic X-Y plotting.

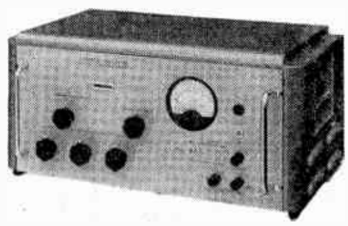
L.F. DECADE OSCILLATOR OS 103.2



The basic oscillator instrument of the world-renowned Solartron Transfer Function Analyser, now available in Series II form. The OS 103.2 provides a 4-phase output over the frequency range 0.01 c/s to 11.1 Kc/s; is amplitude stabilised and has continuous amplitude monitoring regardless of frequency. Harmonic distortion at the output is less than 1% and frequency accuracy inside 1.5%.

TWO-PHASE L.F. OSCILLATOR BO 567

Of similar decade design to the OS 103.2 Oscillator, the BO 567 has a restricted range of 0.1 c/s to 1110 c/s (in 0.1 and 1 c/s steps). This instrument also provides continuous amplitude monitoring, with phase outputs at 0° and 90°.



Have you had your copy of the new Solartron short form catalogue on Dynamic Analysis Instrumentation?

THE SOLARTRON ELECTRONIC GROUP LTD

THAMES DITTON · SURREY · ENGLAND · TEL: EMBerbrook 5522

H

NO REFERENCE VOLTAGE SOURCE *IS NEEDED WITH A* **DIRECT-READ-OFF**

ADJUSTABLE (Constant) VOLTAGE SUPPLY

With the new DEKAVO-100, setting and reading are absolute, on 3-decade calibrated "window-type" dials correct to ½ digit. 100-400 V. DC. 100mA.

Operated direct from 220-250v. AC-supplies the unit compensates for mains fluctuations at the rate 0.02% output variation per 10% input-volts change. Overload- or short-circuit protection is afforded by built-in current limiter. Extra low-volt DC or high-volt output up to 800v by running 2 units in series. Power output multiplied by 2 or more units in parallel retaining full regulation. AC-outputs at 3A for 4, 6.3, and 12v.

Ripple < 20μV/Volt • Accuracy = ±0·02% for ±10% input change

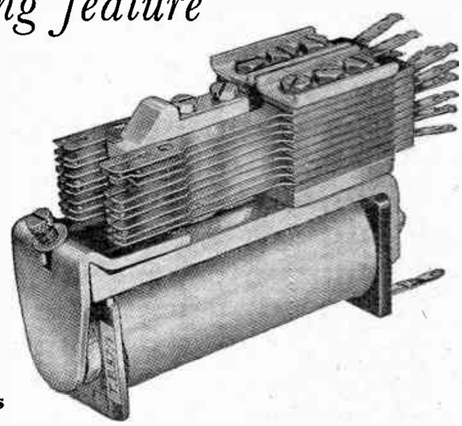
KYNMORE ENGINEERING CO LTD **19 BUCKINGHAM ST., LONDON, W.C.2**

Telegrams and Cables KYNMORE LONDON Telephone TRAfalgar 2371 (3 lines)

TMC TRADE MARK

REMANENT RELAYS

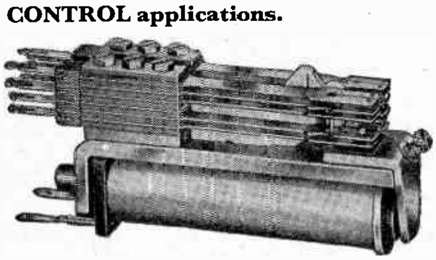
with a magnetic latching feature



TMC P.O. type 3000 and 600 relays are now available fitted with special "remanent" cores having a high order of retentivity, and will *latch-up* on receipt of a signal, remaining so, without power, until the core flux is cancelled. This is effected either by a current reversal in the operate winding, or by the use of a second release-winding. When latched-up the relays can withstand a high degree of shock and vibration.

The relays are available fitted with the usual range of coil windings and contact assemblies; the same operating conditions apply as for standard 3000 and 600 type relays.

TMC REMANENT RELAYS supersede the use of hold-on coils and contacts and are ideal for DIGIT STORE and REMOTE CONTROL applications.

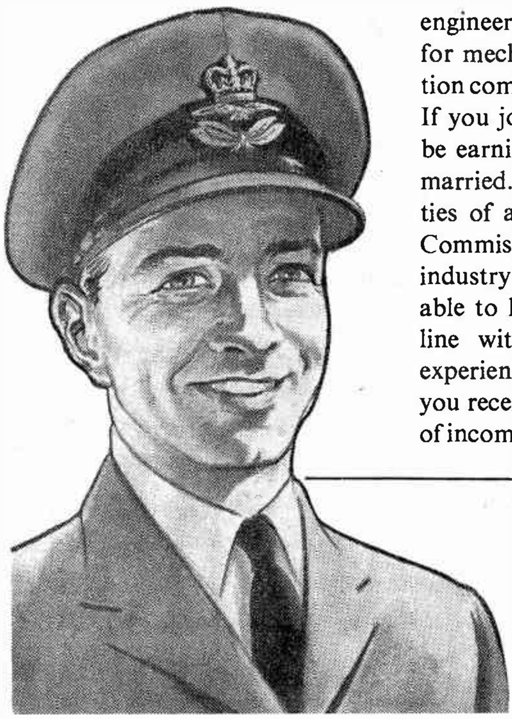


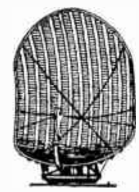
Write for technical data to:

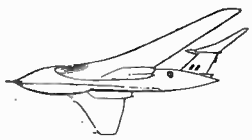
TELEPHONE MANUFACTURING CO LTD

Manufacturers of the Carpenter Polarized Relay

HOLLINGSWORTH WORKS, DULWICH, LONDON S.E.21
Telephone: GIPsy Hill 2211







Voltage Regulation

750 VA AUTOMATIC VOLTAGE REGULATOR

Type P881

- Output voltage controlled with ±1%
- Output adjustable between 195 and 260 volts
- Output remains constant over an input range of 80 volts
- Independent of normal variations in frequency, load and load power factor
- 3·2 Amperes continuous load current
- 12 volts per second compensating rate
- Internal and external automatic control and manual control
- Immediate delivery

The Equipment consists essentially of an air-cooled type auto-transformer, the ratio of which is varied by means of motor driven brushes. Automatic control is effected by two thyratron operated relays which switch the supplies to the reversible motor, the thyratrons being triggered by a voltage sensitive circuit.

A selector switch allows the output to be controlled either manually or from an external voltage. In the Manual position the automatic control is disconnected and the voltage raised or lowered by means of a spring loaded lever switch. In the External position the equipment may be controlled by a low value external signal to compensate for transformer or rectifier circuits having poor regulation.

Airmec

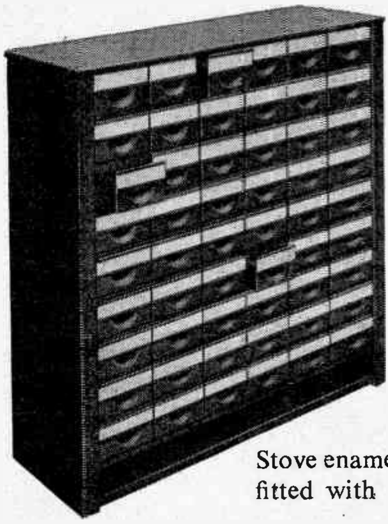
VOLTAGE REGULATORS

AIRMEC LIMITED · HIGH WYCOMBE · BUCKS

Telephone: High Wycombe 2060

FOR STORAGE OF SMALL PARTS, BOLTS, NUTS, SUNDRIES

WELCODIX



54/53 DRAWER UNIT

3ft. 6ins. high × 3ft. wide × 12ins. deep with 54 drawers 5ins × 3 ins. × $11\frac{1}{4}$ ins. each fitted with one adjustable divider, draw pull and card holder. Stove enamelled green. Cabinet fitted with flush sides.

Price £16.16.0 each

(Carriage 14/- each)

FULL LIST DRAWER UNITS & CLOTHES LOCKERS ON REQUEST

WELCODIX EQUIPMENT CO. LTD.

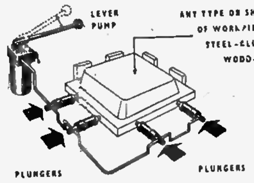
IRONBRIDGE. SALOP

Got CLAMPING Problems?

The BIGGEST TIME & MONEY SAVER in WORK CLAMPING is the

NEWTON Hydraulic **CLAMP SYSTEM**

No matter the type or shape of the workpiece the Newton Hydraulic Clamp System provides the quickest, simplest and safest method of work-holding while reducing production time and costs. Plungers can be used in groups of any number with simultaneous pressure of from 800 lb. to 4 tons. Maximum pressure with smallest plungers. Easily adaptable to any fixture design.



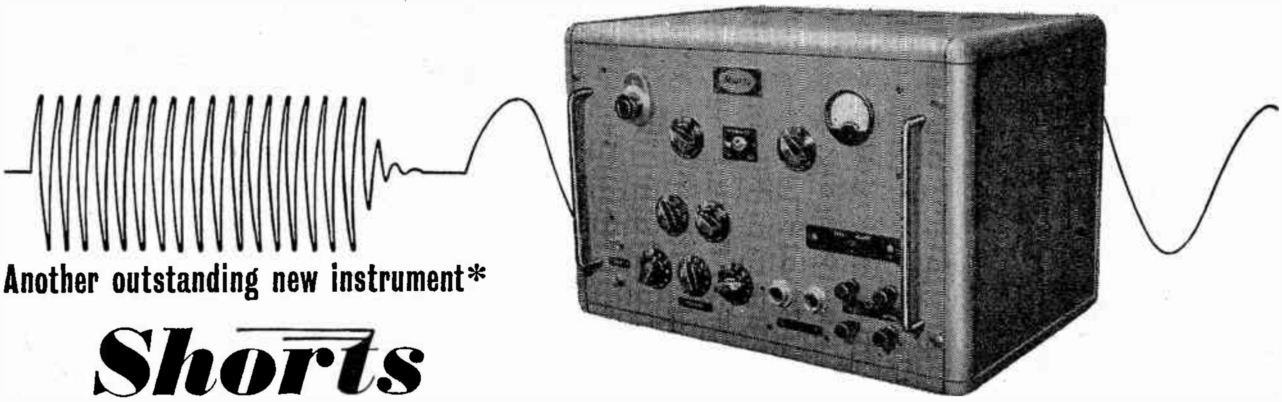
Write for fully illustrated technical booklet No. 243/J2.

POWER JACKS LIMITED

Maylands Ave · Hemel Hempstead

Telephone: Boxmoor 3800

Grams: 'Newsorber Hemel Hempstead'



Another outstanding new instrument*

Shorts

LOW-FREQUENCY DECADE OSCILLATOR

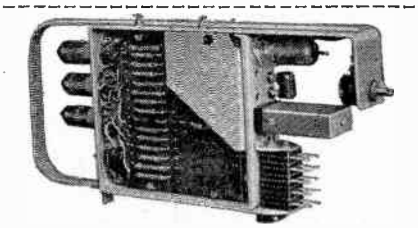
This oscillator has been designed for testing servo-mechanisms and electrical systems where inputs of extremely low distortion and accurate amplitude are essential. It employs three drift-corrected computing-type amplifiers to generate a sinusoidal oscillation in the range 0.01 to 110 c/s, according to the setting of the 3-decade frequency control. "Step" and "Ramp" functions may also be generated, and the total distortion is less than 0.5%.

*** By the same team that designed the Shorts General Purpose Analogue Computor**

All enquiries to:

SHORT BROTHERS & HARLAND LTD.

Computor Sales Department 208a Regent Street, W.I. REGent 8716



One of the three *printed circuit* drift-corrected plug-in amplifiers used in the Oscillator.

TMC CAPACITORS

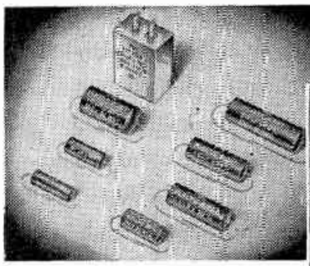
DESIGNED TO COMMUNICATIONS STANDARDS

. . . offer the Engineer

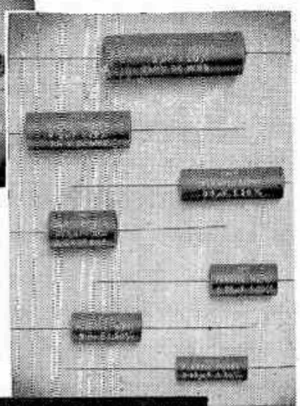
RELIABILITY +

TMC POLYSTYRENE capacitors have an insulation 50 times greater than Mica with comparable stability plus an attractive price advantage.

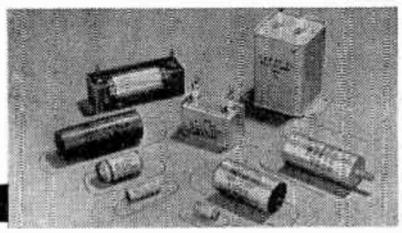
METALLIZED FILM



METALLIZED MELINEX



POLYSTYRENE

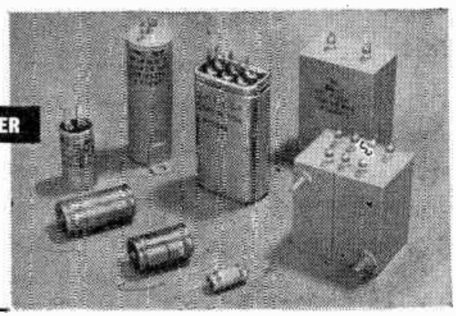


TMC METALLIZED MELINEX CAPACITORS

are a high grade successor to Metallized Paper, with smaller dimensions and an operational temperature range up to 150°C.

In addition to standard ranges of plastic film, precision paper and silvered mica capacitors, we also have many designs and ratings suitable for abnormal conditions and unusual locations.

METALLIZED PAPER



For full technical data write to:

COMPONENT SALES DIVISION

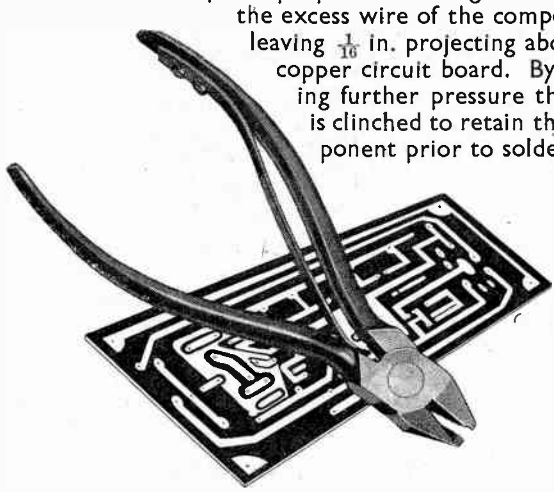
TELEPHONE MANUFACTURING CO LIMITED

CRAY WORKS · ST. MARY CRAY · ORPINGTON · KENT · Tel: ORPINGTON 26611

Wilkinsons Special Purpose Tools for the Radio, Electrical and Electronic Engineer

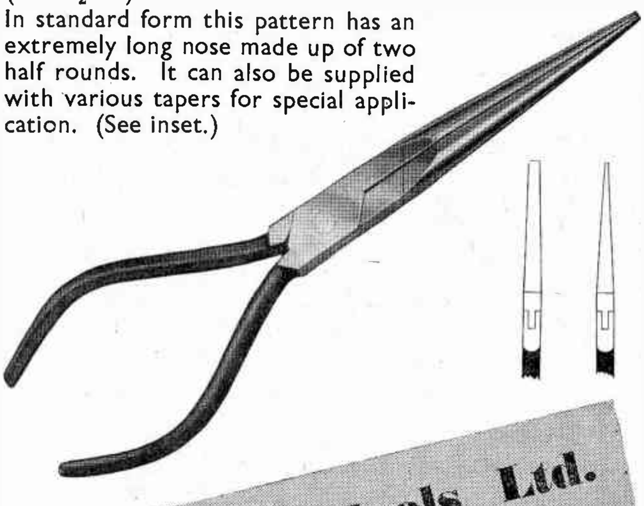
No. 11009 Cutting and clinching plier for printed circuits (size 5¼ in.).

A special purpose tool designed to cut off the excess wire of the components, leaving $\frac{1}{16}$ in. projecting above the copper circuit board. By exerting further pressure the wire is clinched to retain the component prior to soldering.



No. 23003 Long snipe nose plier G.P.O. wiring no. 3. (size 7½ in.).

In standard form this pattern has an extremely long nose made up of two half rounds. It can also be supplied with various tapers for special application. (See inset.)



Wilkinsons Tools Ltd.
(A member of the Staveley Coal & Iron Co. Ltd. Group)
Kerfoot Street, Warrington England

X55

Write today for a copy of our Special Purpose Tools catalogue No. S.157

Opportunities in U.S.A.

for

ENGINEERS & SCIENTISTS

Westinghouse Electric Corporation is seeking a few highly qualified and experienced engineers to work in their large vacuum tube plant and laboratory in the beautiful Finger Lakes district of New York State.

Work assignments will be either in the field of microwave tubes or electron image tube devices, but engineers and scientists who have demonstrated ability in any branch of free electron science are encouraged to apply. High academic qualifications in physics or electrical engineering are also required. Salaries will be commensurate with these attainments and equivalent to £3,000 to £5,000 p.a.

Selected candidates will be interviewed in London during the week of December 8 through December 15 at the Dorchester Hotel, Park Lane, London by Dr. Hilary Moss, English born Westinghouse fellow engineer. He will be able to discuss, from personal experience, all aspects of employment opportunities and migration to the U.S.

Applications accompanied by copies of, or references to, any relevant published work, should be sent to Dr. Hilary Moss at the Dorchester.

Westinghouse
ELECTRONIC TUBE DIVISION ELMIRA, NEW YORK.

PHILIPS RADIO AND TELEVISION DESIGN LABORATORIES (CROYDON, SURREY)

have a vacancy for a

MECHANICAL DESIGNER

This is a senior appointment, calling for a man with considerable design experience in the field of large scale production, preferably in the light electrical engineering industry. Some knowledge of the processes involved in the manufacture of wood cabinets and plastic mouldings is essential. The starting salary for this post will be in the region of £1,000 p.a.

Applicants should write for an Application Form quoting reference DD/R, to the Personnel Officer, Philips Croydon Works Limited, Commerce Way, Purley Way, Croydon, Surrey.

INSTRUCTORS required by **POSTS AND TELEGRAPHS DEPARTMENT, NIGERIA FEDERAL GOVERNMENT** on contract for one tour of 12/24 months in first instance. Commencing salary according to experience in scales set out below. Out allowance £60. Gratuity at rate of £150 a year. Free passages for officer and wife. Assistance towards children's passages and grant up to £150 annually towards maintenance in U.K. Liberal leave on full salary. Established Civil Servants' Pension Rights may be preserved.

INSTRUCTOR, GRADE I (M2C/42120/EO). Candidates, preferably under 40 years of age, should have had experience in the installation or maintenance of Multi-Channel radio telephone systems and be conversant with V.H.F. and F.M. techniques. They should have had at least three years' teaching experience and possess C. & C. certs. in Telecomms. Principles III and Radio III or equivalent. Salary scale (including Inducement Addition) £1,536, rising to £1,674 a year.

INSTRUCTOR, GRADE II (M2C/50237/EO). Candidates, preferably under 35 years of age, should possess C. & G. certs. or equivalent in Telecomms. subjects and have had recent teaching experience in Radio Communication. Salary scale (including Inducement Addition) £1,170, rising to £1,488 a year. Write to the Crown Agents, 4 Millbank, London, S.W.1. State age, name, in block letters, full qualifications and experience and quote reference shown against post applied for.

ELECTRONIC & RADIO ENGINEER

CLASSIFIED ADVERTISEMENTS

Advertisement Rates. *6d. per word, minimum charge 6/-, each paragraph charged separately. Remittances payable to Iliffe & Sons Ltd., Dorset House, Stamford St., S.E.1. Series discount of % 15 is allowed for 12 consecutive insertions.*

Box Numbers *are available at an additional charge of 2/- to defray cost of registration and postage. Replies should be addressed Box No. 0000, c/o "Electronic & Radio Engineer", Dorset House, Stamford Street, London, S.E.1.*

Semi-Display *advertisements with centralized lines £1/15/- per single column inch—no additional charge for Box Numbers. The Publishers are not responsible for clerical or printers' errors although every care is taken to avoid mistakes.*

Press date for the January 1959 issue is first post 18th December 1958

SITUATIONS VACANT

DIPLOMATIC WIRELESS SERVICE
Foreign Office

APPLICATIONS are invited from qualified candidates to fill, by competitive interview, the following posts:

1. Engineer/Technicians grades A & B and grades 1 & 2

RADIO Engineers are required for shift duties in Receiving and Transmitting Stations at home and abroad. Applicants should have experience in the maintenance of Communication Receivers and associated equipment and/or experience in the operation and maintenance of Telegraphy Transmitters and High Power Broadcast Transmitters and should have technical knowledge to the standard of the C & G Final in Telecommunications or the H.N.C. or show evidence of an equivalent standard of technical education. Grading according to qualifications and experience.

SALARY scales, grade A, £1,235-£1,464; grade B, £1,180-£1,325; grade 1, £974-£1,180; grade 2, £820 (at age 30 years)—£974. Adequate allowances paid whilst serving overseas and in most cases families may accompany husbands to posts abroad.

2. Engineer/Technicians, grade 3

RADIO Engineers required for shift duties in Receiving and Transmitting Stations at home and abroad. Applicants should have experience in the maintenance of Communication Receivers and associated equipment and/or experience in the operation and maintenance of Telegraphy Transmitters and High Power Broadcast Transmitters and should have technical knowledge to the standard of the C & G Intermediate in Telecommunications or its equivalent. Adequate allowances paid whilst serving overseas and in most cases families may accompany husbands to posts abroad.

3. CONTROL Room Engineers required for shift duties in the Radio Teleprinter Terminal in London. Applicants should have experience in the maintenance of Teleprinters, V.F. Telegraph and other line equipment, and have some knowledge of short wave Radio Propagation. They should have technical knowledge to the standard of the C & G Intermediate in Telecommunications or its equivalent.

4. CHARGE Hand Rigger required at a Radio Station in Buckinghamshire. Applicants must have experience in the erection of steel and wooden masts up to 150 ft. in height and the rigging of aerial wires and transmission lines.

SALARY scale, grade 3, £655 (at age 26 years) —£820. Candidates must be British subjects or citizens of the Irish Republic born within the Commonwealth or in the Irish Republic of parents born within these territories.

ALL first appointments are on a temporary basis with prospects of establishment. Candidates must be prepared to undergo a medical examination. The Department, which already employs a large number of ex-members of Royal Navy, Royal Signals, R.E.M.E. and the R.A.F., will welcome applications from qualified ex-service men who have served in Technical Units of H.M. Forces.

WRITE giving age, qualifications and experience to:

THE CHIEF ESTABLISHMENT OFFICER
DIPLOMATIC WIRELESS SERVICE,
FOREIGN OFFICE, LONDON, S.W.1. [1265

ELECTRONICS ENGINEER

COURTAULDS LIMITED require a Senior Electronics Engineer for the Experimental Department of their Engineering Division in Coventry. Applicants should possess a degree or equivalent academic qualification and should have had several years' industrial or research experience. The appointment is pensionable and will qualify for Co-partnership benefits.

Candidates should write for a detailed form of application to the Director of Personnel, Courtaulds Limited, 16 St. Martins-le-Grand, London, E.C.1, quoting reference number B.50. [1263

COMMONWEALTH OF AUSTRALIA
Commonwealth Scientific and Industrial Research Organization
Division of Radiophysics
FELLOWSHIP IN RADIO ASTRONOMY

THE Organization's Division of Radiophysics invites applications for a Fellowship in Radio Astronomy.

THE Division has its headquarters within the grounds of Sydney University and operates a number of powerful and unique radio telescopes at field stations located in the country-side around Sydney. The appointee will be expected to take part in an active research programme in some aspect of radio astronomy.

THE Fellowship is tenable at Sydney for a period of two years. Applicants should have had previous research experience in either radio astronomy or astronomy, and the salary offered will be determined in relation to qualifications and experience, but will be not less than £A1,400 p.a.

THE appointment will be conditional upon a satisfactory medical examination.

FARES to Australia, including those of wife and dependent family, will be provided by the Organization, and return fares to point of origin will be allowed at the end of the period of appointment in the case of an appointee who is not of Australian nationality. Details may be discussed with the undersigned.

APPLICATIONS quoting Appointment No. 780/194 should include full name, place, date and year of birth, nationality, marital state and present employment; details of academic training, qualifications, research experience, and published work (if any); the names of not more than four persons acquainted with the applicant's academic and professional standing, and reach the undersigned by the 31st December, 1958.

E. J. Drake
Chief Scientific Liaison Officer.
Australian Scientific Liaison Office,
Africa House,
Kingsway, W.C.2.
[1266

UNIVERSITY COLLEGE OF WALES
Aberystwyth

A Research Assistant is required in the Department of Physics for work on radio observation of artificial satellites. Sound knowledge of electronics and interest in radio propagation problems required. Salary in range £600-£700.

APPLICATIONS, as soon as possible, to the Registrar. [1267

ELECTRONICS Experimental Engineer required for nationally-known company manufacturing mechanical components for Radio, Television and Electronics Industries.

RESPONSIBILITIES include general research and experimental development of new products in conjunction with Design staff. Experience with electronic test equipment essential.

SALARY according to qualifications and experience. Pension scheme and canteen facilities.

APPLY to: Secretary, Carr Fastener Company Limited, Stapleford, Nottingham. [1261

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

SUBMARINE CABLES LIMITED
Erith, Kent
Experienced Telecommunication Engineers
required for
Design and Development of
Submerged Repeaters
and associated
Production Test Equipment
Components and Materials

VACANCIES exist for Engineers and Technical Assistants having University degree, H.N.C. or equivalent and post graduate experience.

APPLICANTS without such qualifications but with some years constructive telecommunication experience will be considered.

SALARIES offered will be appropriate to responsibility involved and to qualifications and experience.

APPLICATIONS should be made in the first place to: The Staff Officer, Telcon Works, Greenwich, S.E.10. [1262

UNIVERSITY COLLEGE OF SOUTH WALES AND MONMOUTHSHIRE

APPLICATIONS are invited from Electrical Engineers or Physicists for appointment as Lecturer in Electrical Engineering. Salary on the scale £900 by £50 to £1,350 by £75 to £1,650 per annum, with family allowances and superannuation. Starting salary according to qualifications and experience. The appointment will be effective from April 20th, 1959, or earlier. Single copies of applications, stating particulars of age, experience and qualifications, together with the names of three referees, should be sent before January 13th, 1959, to the Registrar, University College, Cathays Park, Cardiff, from whom further particulars may be obtained.

E. R. EVANS,
Registrar.
[1268

ELECTRO-ENCEPHALOGRAPHY RECORDIST, GRADE I

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

ELECTRICAL Engineer with knowledge of magnetism and electronics required for Technical Sales appointment concerned with the development of the use of magnets in instrument design. Post will involve travelling mainly in London and the Home Counties with possibly occasional visits to the Provinces. Age preferably between 25 and 32 years. Salary according to qualifications. Murex Ltd., Rainham, Essex. [1264

BATTERSEA COLLEGE OF TECHNOLOGY, London, S.W.11. Applications are invited from graduates of a British University for two Lectureships in Physics. Preference will be given to specialists in Experimental Microwave Physics or Theoretical Metal Physics. Experience in teaching and/or research essential. Salary: Men, £1,200 by £30 to £1,350, plus London allowance of £36-£48, women, slightly lower, rising to men's scale by 1961. Full particulars from the Clerk of the Governing Body, to whom applications should be sent as soon as possible. [1269

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

SITUATIONS VACANT

SIGNAL Technician required by Kenya Government Police Force on agreement for tour of 24-45 months in first instance with prospect of permanency. Commencing salary according tu age and experience in scale (including Inducement Pay) £813 rising to £1,341 a year. Outfit allowance £40. Free passages for officer and wife and assistance towards cost of children's passages. Liberal leave on full salary. Candidates, preferably not over 40 years of age, must have wide knowledge of installation, running and maintenance uf H.F. communication equipment, fixed and mobile V.H.F. equipment and installation and maintenance of ancillary equipment. Experience with V.H.F. multi-channel equipment, teleprinters or facsimile equipment 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/50288/EO. [1260

TANGANYIKA GOVERNMENT POLICE FORCE require an Assistant Engineer Grade I for one tour of 30/36 months in first instance. Salary scale (including inducement pay) £1,056 rising to £1,341 a year. Gratuity at rate of 13½ per cent of total substantive salary drawn. Free passages. Liberal leave on full salary. Candidates preferably not over 40 years of age, should be of good education and able to carry out complete installation of medium- and low-powered HF and VHF radio stations and low-power diesel and petrol generating sets. Also installation and erection of lattice masts. They should also be capable of running a small workshop and store and supervising work of junior staff. Experience in telephone and teleprinter practice in relation to HF and VHF systems advantageous. Write to the Crown Agents, 4 Millbank, London, S.W.1. State age, name in block letters, full qualifications and experience and quote M2C/50370/EO. [1259

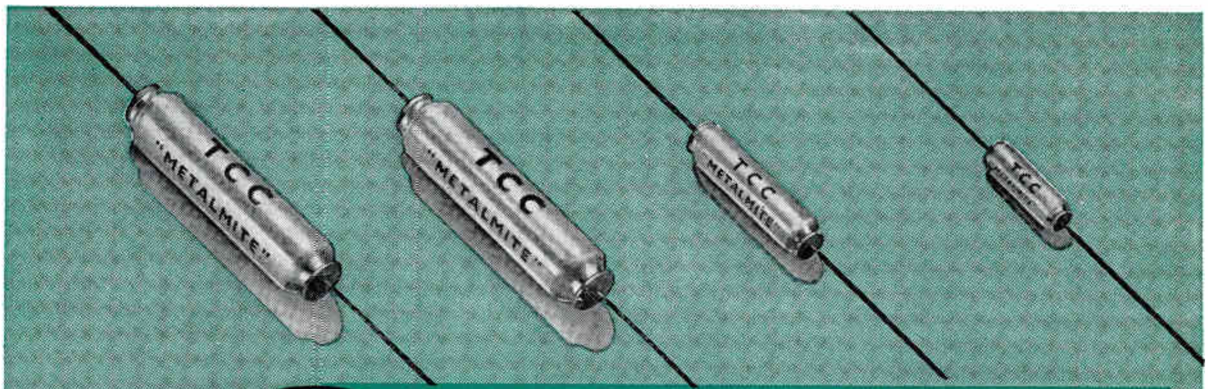
BOOKS, ETC.

"WIRELESS Servicing Manual" (9th Edition). By W. T. Cocking, M.I.E.E. A carefully revised edition of the handbook known since 1936 as an invaluable, comprehensive guide for radio servicemen and others. Completely up to date, it deals in a lucid practical way with the problems that arise in the repair, maintenance and adjustment of modern wireless receivers. All recent developments in receiving equipment have been incorporated and the servicing of frequency-modulated v.h.f. receivers—a development of great importance to all servicemen—is thoroughly covered in a completely new chapter. Here is a work of proven value to professional and amateur, written by a widely known authority on modern radio engineering. 17s. 6d. net from all booksellers. By post 18s. 8d. from The Publishing Dept., Iliffe & Sons, Ltd., Dorset House, Stamford Street, London, S.E.1.

"TELEVISION Engineering: Principles and Practice." Vol. III: Waveform Generation. 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. The third volume of a comprehensive work on the fundamentals of television theory and practice, written primarily for the instruction of B.B.C. Engineering Staff. This volume gives the application in television of sinusoidal, rectangular, sawtooth and parabolic waves and shows the mathematical relationship between them. The main body of the text is devoted to the fundamental principles of the circuits commonly used to generate such signals, the treatment being largely descriptive in nature and therefore less mathematical than that of the previous volume. The work is intended to provide a comprehensive survey of modern television principles and practice. 30s. net from leading booksellers. By post 31s. from Iliffe & Sons, Ltd., Dorset House, Stamford Street, London, S.E.1.

Index to Advertisers

Printed in Great Britain for the Publishers, Iliffe & Sons, Ltd., Dorset House, Stamford Street, London, S.E.1, by Gibbs & Bamforth, Ltd., St. Albans. Distributed in U.S.A. by Eastern News Company, 306 West 11th Street, New York, 14.



SUPER TROPICAL "METALMITES"

The T.C.C. "Metalmite" ranges of condensers set a new standard both for compactness and ability to withstand extreme tropical conditions: satisfactory insulation resistance is maintained after extensive tests at 100° C. and 100% humidity, thus conforming to the requirements of Government specification RCS. 131. "Metalmites" are suitable for use in miniature receivers and transmitters, hearing aids, and in the most compact types of portable equipment.

Their construction is of the well-proved T.C.C. technique of winding non-inductively layers of paper dielectric to each solid aluminium foil, all impregnated under vacuum, and finally hermetically sealed in aluminium tubes with synthetic rubber bungs. Plastic protective sleeving can be supplied if required.

Capacity tolerance ±25%
Temperature range −40°C. to +100°C.

SUPER TROPICAL "METALMITES"

Capacity μF.	Working Volts D.C.		Dimensions in inches		Type No.	List Price Each
	At 70°C.	At 100°C.	L.	D.		
·001	1,000	650	1 5/8	·34	CP49W	1/10
·002	1,000	650	1 5/8	·34	CP49W	1/10
·001	500	350	1	·2	CP30S	1/9
.005	500	350	1	·25	CP32S	1/10
·01	500	350	1	·34	CP33S	1/10
·05	500	350	1 5/8	7/16	CP37S	2/1
·01	350	175	1	·25	CP32N	1/8
·02	350	175	1	·34	CP33N	1/9
·05	350	175	1 3/8	3/8	CP35N	2/-
·1	200	100	1 5/8	3/8	CP36H	2/2
SUPER TROPICAL MINIATURE "METALMITES"						
·0002	500	350	11/16	·2	CP110S	2/-
·0003	500	350	11/16	·2	CP110S	2/-
·0005	500	350	11/16	·2	CP110S	2/-
·001	350	175	11/16	·2	CP110N	2/-
·002	350	175	11/16	·22	CP111N	2/-
·005	200	100	11/16	·22	CP111H	2/-
·01	200	100	11/16	·25	CP112H	2/-
·01	350	175	11/16	·34	CP113N	2/2

DETAILS OF COMPLETE RANGES AVAILABLE ON REQUEST

CONDENSER SPECIALISTS SINCE 1906

THE TELEGRAPH CONDENSER CO. LTD

RADIO DIVISION · North Acton · London W3 · Tel: ACOrn 0061

Reflectograph

NOW UNCONDITIONALLY GUARANTEED FOR 1 YEAR *

. . . INCLUDING VALVES!

Service on user's premises by factory trained engineers of Home Maintenance Ltd., an E.M.I. Company. Subsequent maintenance contracts available up to 20 years for a small annual fee.

PRICE **94** GNS

* *Subject only to misuse or neglect.*

- Variable speed between 8 and 3½ i.p.s.
- Neon lit stroboscope showing precise speeds of 7½ and 3¾ i.p.s.
- 3 separate heads, erase, record and playback.
- Tape/Input switch providing instant comparison between input signal and signal recorded on tape.
- Fast rewind, fast forward and "inching" lever control. Sound available if required.
- Peak level recording meter.
- Easy tape loading into straight slot.
- 8¼" reel capacity.
- Clock-type tape position indicator.
- 3 silent running Garrard motors.
- Tape drive lever, giving instant start and stop.
- Output socket to external speaker when used mutes internal speakers.
- 3 watts undistorted output.
- Output from playback pre-amplifier to feed external amplifier.
- 2 matched loudspeakers.
- Microphone, radio or pick-up input sockets.
- Off, playback and record push buttons, with safety latch.
- Bib tape splicer.
- Finished in luxan hide and pigskin colours.
- Provision for conversion to stereo.
- Complete with reel of tape; spare reel, splicing tape, 2 screened jack plugs.
- Record and playback characteristics of the amplifiers aligned to C.C.I.R. recommended specification.

FOR THE TECHNICAL MAN

Frequency Response
± 2 dB. 50-10,000 c/s.
± 3 dB. 45-12,000 c/s.

Signal to Noise Ratio
Better than −45 dB. (unweighted, including hum)

Output from Playback Preamplifier
200 mV. R.M.S.

Inputs to Record Amplifier
(High Impedance)
Microphone 1 mV } for max.
Radio or pickup 50-200 mV. } record level

"Wow" and "Flutter"
Better than 0.2% R.M.S.

EXPERT OPINION

P. Wilson, M.A., "The Gramophone"

This is without doubt the most versatile domestic tape recorder that I have had the pleasure of trying out, and the quality, both of its recording and its playback, is of exceptionally high standard. For quality of performance, then, I give the instrument full marks: I know of no better. For the construction I have nothing but praise. There is nothing flimsy about it either as a piece of mechanism or on the electronic side. It is a fine piece of engineering up to the highest British standards.

D. W. Aldous, M.Inst.E., M.B.K.S.

"The Gramophone Record Review"

The separate record and replay amplifiers make possible the direct monitoring from the tape during the actual recording and this facility is certainly a boon. There is no doubt whatever that when one has used this type of recorder one never wishes to return to the combined record/playback type of instrument. I have never heard better quality at 7½ in.p.s. from any tape recorder that has passed through my hands. The "Reflectograph" is a pedigree tape recorder of immaculate construction and impeccable performance.

James Moir, "Hi-Fi News"

Separate motors are used for capstan drive and both spools, all three motors being of Garrard manufacture. The overall impression after some months of use is that the machine is convenient and pleasant to handle, while the extra facilities make it very suitable for professional use.

MULTIMUSIC LTD., MAYLANDS AVENUE, HEMEL HEMPSTEAD, HERTS. TELEPHONE BOXMOOR 3636.