ELECTRONIC & RADIO ENGINEER

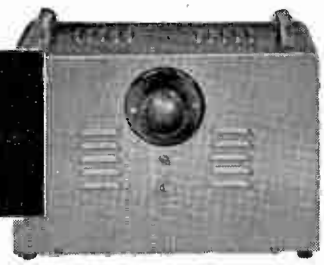
Incorporating **WIRELESS ENGINEER**

In this issue

Three shillings
and sixpence

APRIL 1957 Vol 34 *new series* No 4

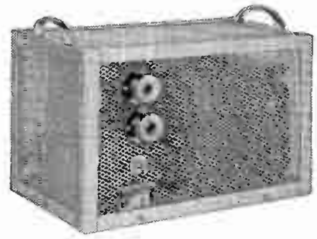
A-C AUTOMATIC VOLTAGE REGULATORS
39 BASIC TYPES IN 6 DESIGN SERIES



BMVR - 1725

WIDEST RANGE IN THE WORLD?

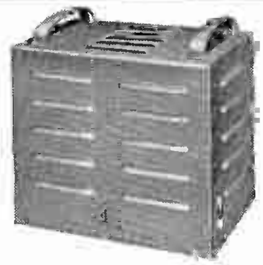
So far as we are aware, our range of A.C. Automatic Voltage Stabilisers is the largest in the World. We have a very wide range of standard models, single-phase patterns ranging from 200 VA to about 30 kVA (3-phase types up to about 90 kVA). There are 39 basic types, in six distinct design series, and all are available in standard form or as tropicalised instruments. We feel that on this account there can be few, if any requirements covering Stabilisers that we are not in a position to meet economically, efficiently and promptly.



BAVR - 1000 & BAVR - 1000-E

Here are very brief details of the six main series, in handy tabular form: cut this ad. out and use it as a Buying Guide; but please remember that if you do not see *exactly* what you require a written enquiry will probably reveal that we have a "special" to suit, or that the answer is under development. New stabilisers are regularly being added to our range. Several are at the very advanced development stage now—and we do design "specials". One such "special" (AM type 10D/20161) is illustrated (Illustrations not to scale). Nearly 100 have been supplied to Murphy Radio Ltd. for incorporation in equipment supplied by them to the Air Ministry for use on a chain of Radar Marker Beacons. 45 in slightly differing form are currently being made by us for the Air Ministry for another Radar Chain.

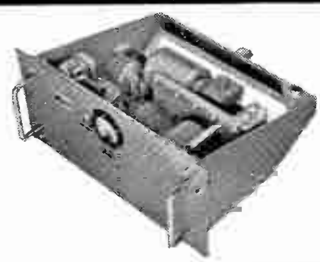
For complete data request our 20-Page Supplement Ref. V-549-S and its associated Special Price List, CLL Form VSP-56/16.



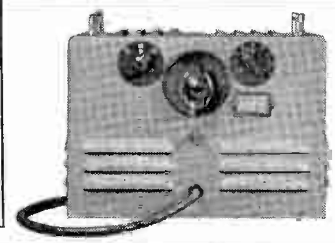
BMVR - 7000 - Series & TCVR - 7000 - Series

DESIGN SERIES	ASR	ATC	BAVR	BAVR-E	BMVR	TCVR
Input Voltage "Swing"	— 10% to + 5%	—20% to + 10%	— 10% to + 5%	— 10% to + 5%	Depends on power: typical is from — 19% to +8.5%	
Output Voltage Stability	± 2½%	± 5%	± 0.15%	± 0.15%	Usually ±0.5%	Usually ±0.5%
Change due to load (0-100%)	NEGLIGIBLE		±2.0%	±0.3%	NIL	NIL
Harmonics Generated	NIL	NIL	YES	YES	NIL	NIL
Response Speed	PRACTICALLY INSTANTANEOUS AVERAGING				I V/Sec.	40V/Sec.
	2-3 CYCLES		I CYCLE			
Power Ratings	1150VA 2300VA	575VA 1150VA	200VA 500VA 1000VA	200VA 500VA 1000VA	1600VA to 30kVA (18 models)	1600VA to 12kVA (11 models)
Basic Prices *	£24 to £34	£24 to £34	£50 to £79	£59 to £88	£75 to £237	£91 to £144

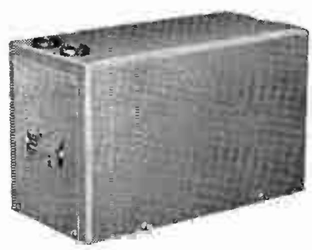
* From May 1st 1956, subject to 7½% increase.



BMVR - 2750 - S58 (AM Ref. 10D/20161)



BMVR - 2750/VV & TCVR - 2750/VV



ASR - 1150 & ATC - 575.

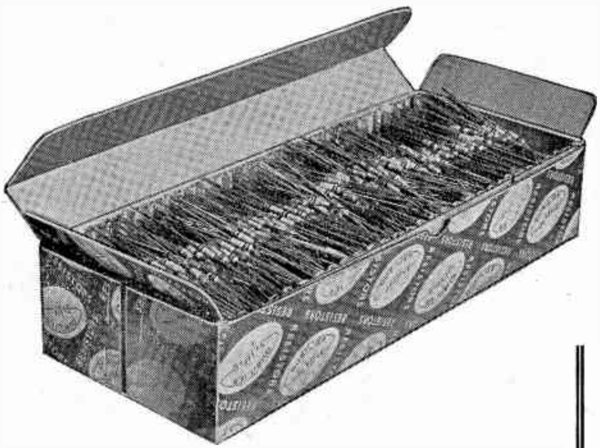
Claude Lyons Ltd.

STABILISER DIVISION

HODDESDON · ENGLAND · TEL: HODDESDON 3007 (4 LINES) · 'GRAMS: MINMETKEM, HODDESDON

No engineer can resist these NEW one watt resistors . . .

R.E.C.M.F. Exhibition
Grosvenor House
VISIT US ON STAND 46
9th to 11th April



RATINGS

1 watt at 70°C.
500 V.D.C. Max.

Range . . . . 270Ω—22MΩ
Tolerances ±5%, ±10%, ±20%
Dimensions $\frac{23}{32}''$ x $\frac{1}{4}''$ diameter

. . . because . .

- Type BTA are fully insulated
- Type BTA are much smaller
- Type BTA are available in Autopacks *
- Type BTA are manufactured with new production methods using new basic materials providing greater stability.
- Type BTA have special solder coated wire terminations for printed circuit applications.

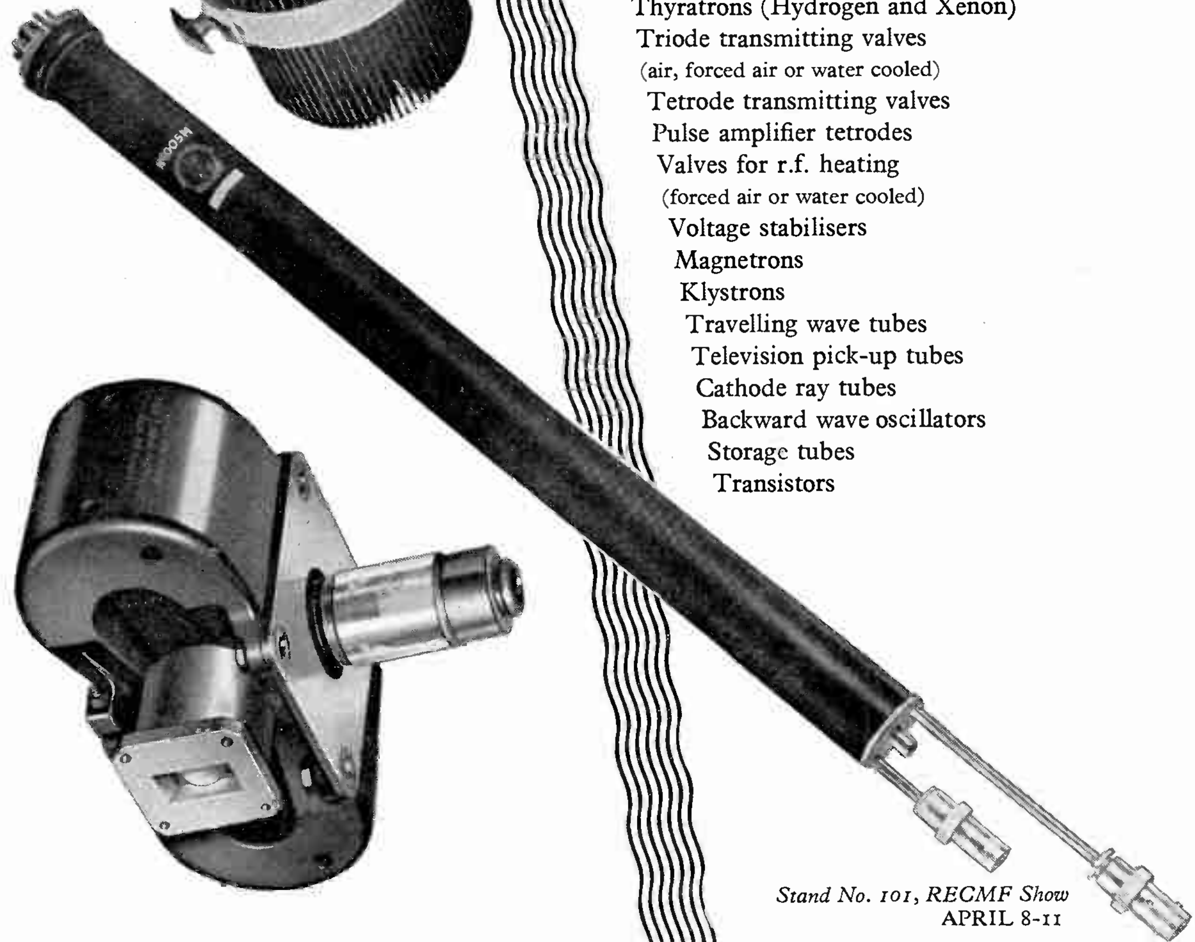
* DUBILIER AUTOPACKS—

designed primarily for loading hoppers for automatic feed systems, also solve the spiky problem of resistor storage. BTA Resistors are packed in boxes of 200 and 1000—all lined up with connecting wires dead straight, ready for immediate use—and taking up very little space in the process.

DUBILIER

DUBILIER CONDENSER CO. (1925) LTD.,
DUCON WORKS, VICTORIA RD., NORTH ACTON, LONDON, W.3
Telephone: ACOrn 2241
Telegrams: Hivoltcon, Wesphone, London.

DN 171



INTRODUCING THE NEW

NASHTON INSTRUMENT RANGE

Resistance

(5Ω to 500MΩ)

Capacitance

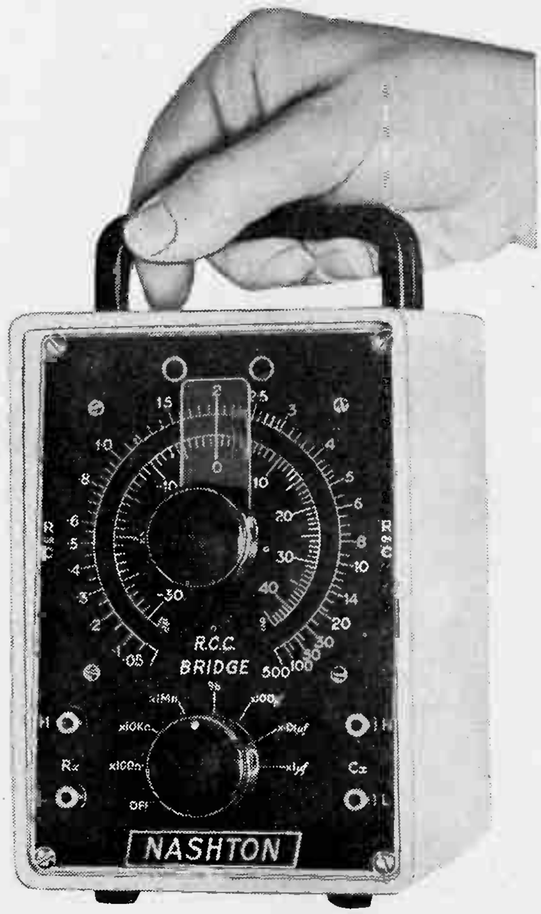
(5pF to 500μF)

Comparison

(—30% to +45%)

BRIDGE

(1% mid-scale;
$2\frac{1}{2}$% from 20Ω to 20MΩ)



The Nashton R.C.C. Bridge is the first of a new range of electrical test instruments by Nash & Thompson, the Company specially selected to carry out the R.C.S.C. approval testing for the Ministry of Supply. The R.C.C. Bridge is precision-built of high stability 1% components and incorporates a 0.1% linearity wire-wound cam-corrected balancing potentiometer.

Instruments in the new Nashton range, of which the R.C.C. Bridge is the first, will all be

**Accurate · Low-priced · Reliable
Compact**

WRITE TO:—

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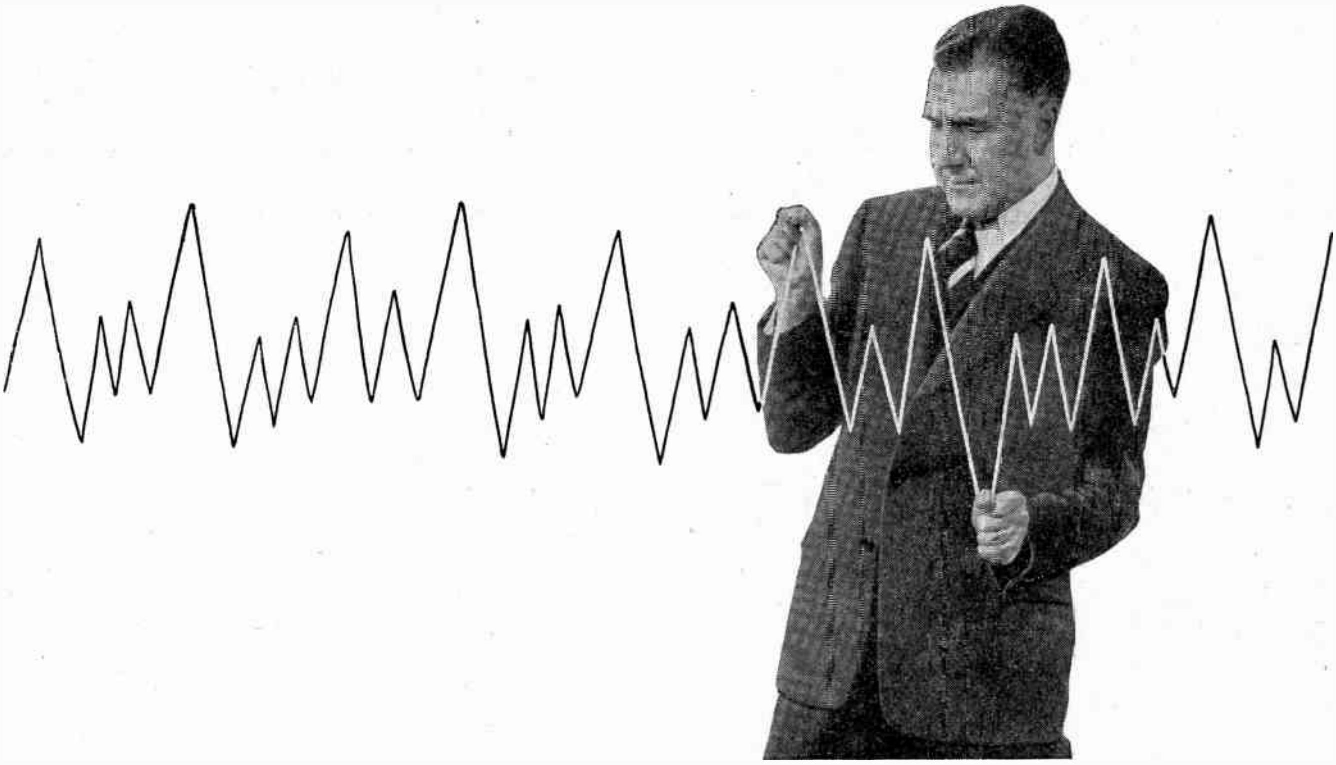
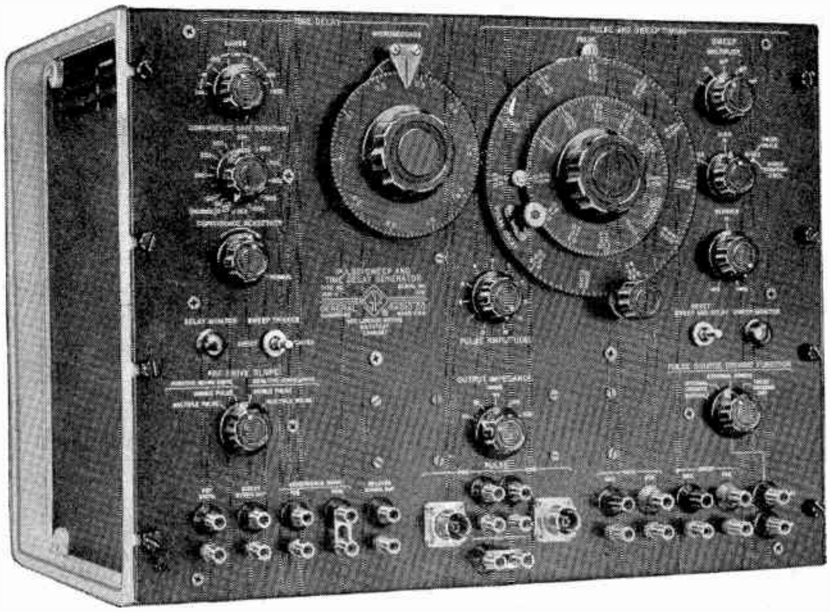
LIMITED

OAKCROFT ROAD · CHESSINGTON · SURREY · *Elmbridge 5252*

for inclusion in the NASHTON mailing list for information

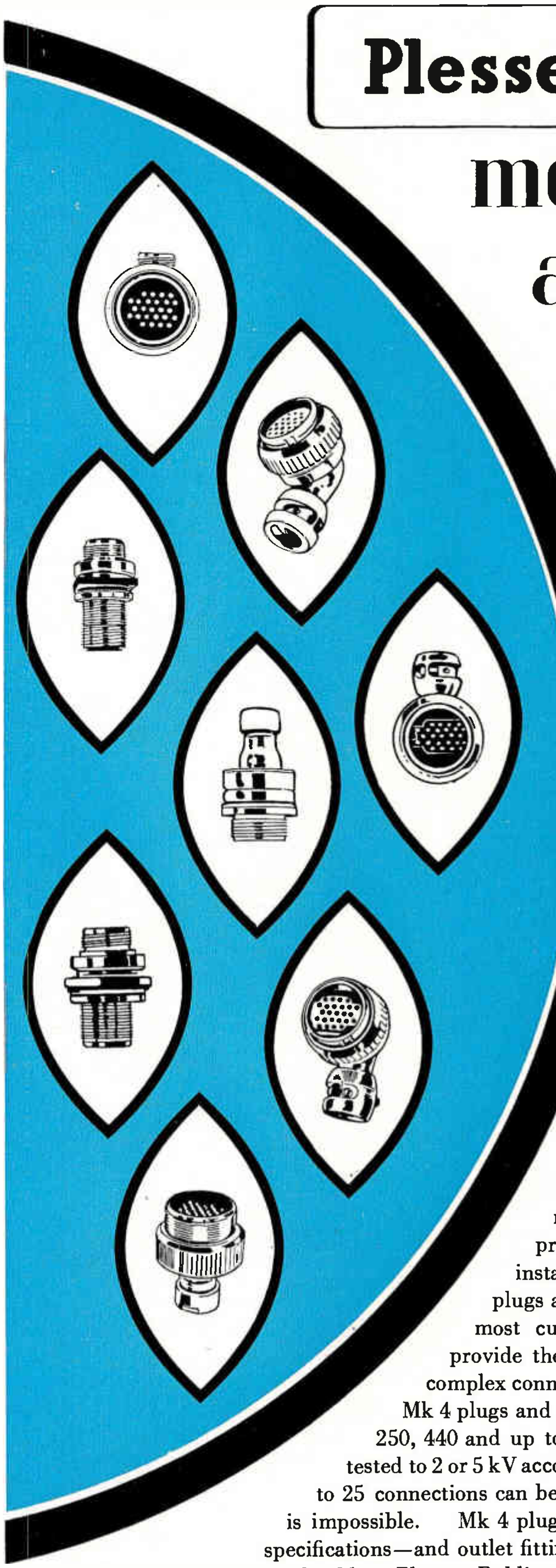
WHG/NT52

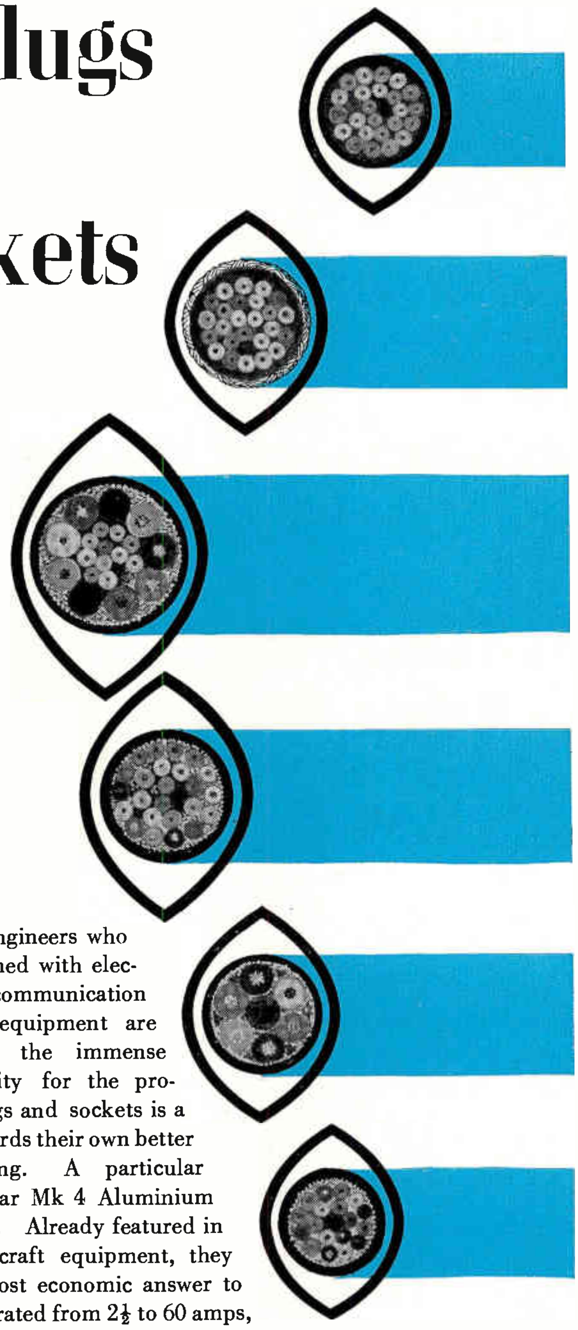





murphy

for most uses Plessey produces most plugs and sockets





Design Engineers who are concerned with electronics, communication and other equipment are finding that the immense Plessey capacity for the production of plugs and sockets is a major facility towards their own better production planning. A particular instance is the popular Mk 4 Aluminium plugs and sockets range. Already featured in most current British aircraft equipment, they provide the simplest and most economic answer to complex connection. Officially rated from 2½ to 60 amps, Mk 4 plugs and sockets have continuous working voltages of 250, 440 and up to 2 kV. They are fully pressurised and are tested to 2 or 5 kV according to type. Due to their compact nature, up to 25 connections can be accommodated within 1¼ sq. in. Mismating is impossible. Mk 4 plugs and sockets are fully approved to all official specifications—and outlet fittings are available to suit virtually every approved type of cable. Plessey Publication No. 863 sets out full technical details of this range. Please request a copy if the subject interests you.

AIRCRAFT & AUTOMOTIVE GROUP · WIRING & CONNECTOR DIVISION

THE PLESSEY COMPANY LIMITED · KEMBREY STREET · SWINDON · WILTSHIRE · TELEPHONE SWINDON 5461

PB8

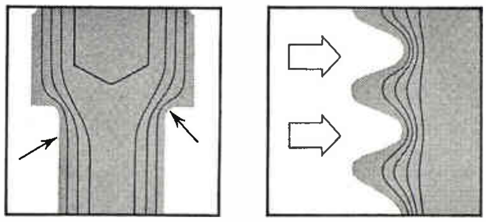
Let's see what UNBRAKO SOCKET SCREWS MEAN TO YOU

On the right we tell you, if you are interested, how we do it. Here we want to say what Unbrako screws mean to you. They mean safety. We all know the old rhyme about how the battle was lost for want of a horse shoe nail. In these mechanised days it is very much easier to lose a reputation because of the consequences of bolt failure. Unbrako screws mean new, lightweight designs that you dreamed about, because fewer, smaller Unbrako screws will take the strain, enabling you to make lighter, smaller joints. Unbrako screws mean economy, with fewer screws to the job, less drilling, less tapping, less labour. Unbrako screws mean better design, because no spanner clearance is necessary and screw spacing is determined by engineering considerations only. Unbrako screws mean greater efficiency, bigger business, more prosperity to you. And one of our technicians will be very happy to call, without obligation, to go into more detail.

UNBRAKO

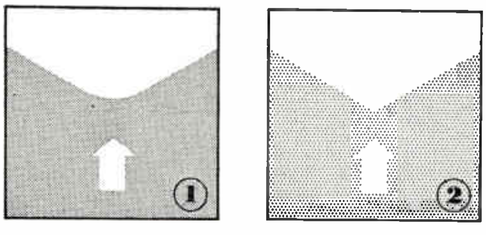
UNBRAKO SCREWS COST LESS THAN TROUBLE

Unbrako screws are made from their own special formula steels and carefully controlled through every stage of manufacture to produce the world's finest fastener. Better steel means that Unbrako can give you a deeper socket for greater wrench purchase, and greater wrench purchase means tighter screws, a safeguard against stress and vibration.

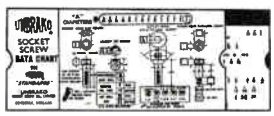


Most screw failures occur at the junction of the head and shank or at the thread root. Unbrako design and manufacture ensures maximum fatigue resistance at these vital points, giving you stronger, safer screws that will never let you down.

Unbrako develop fully formed threads with a radius instead of crack-inducing corners. The metal is compressed to a closely knit grain structure, the grain flow following the contours of the threads, reducing screw failure to a new minimum only possible with Unbrako—the world's finest screw.



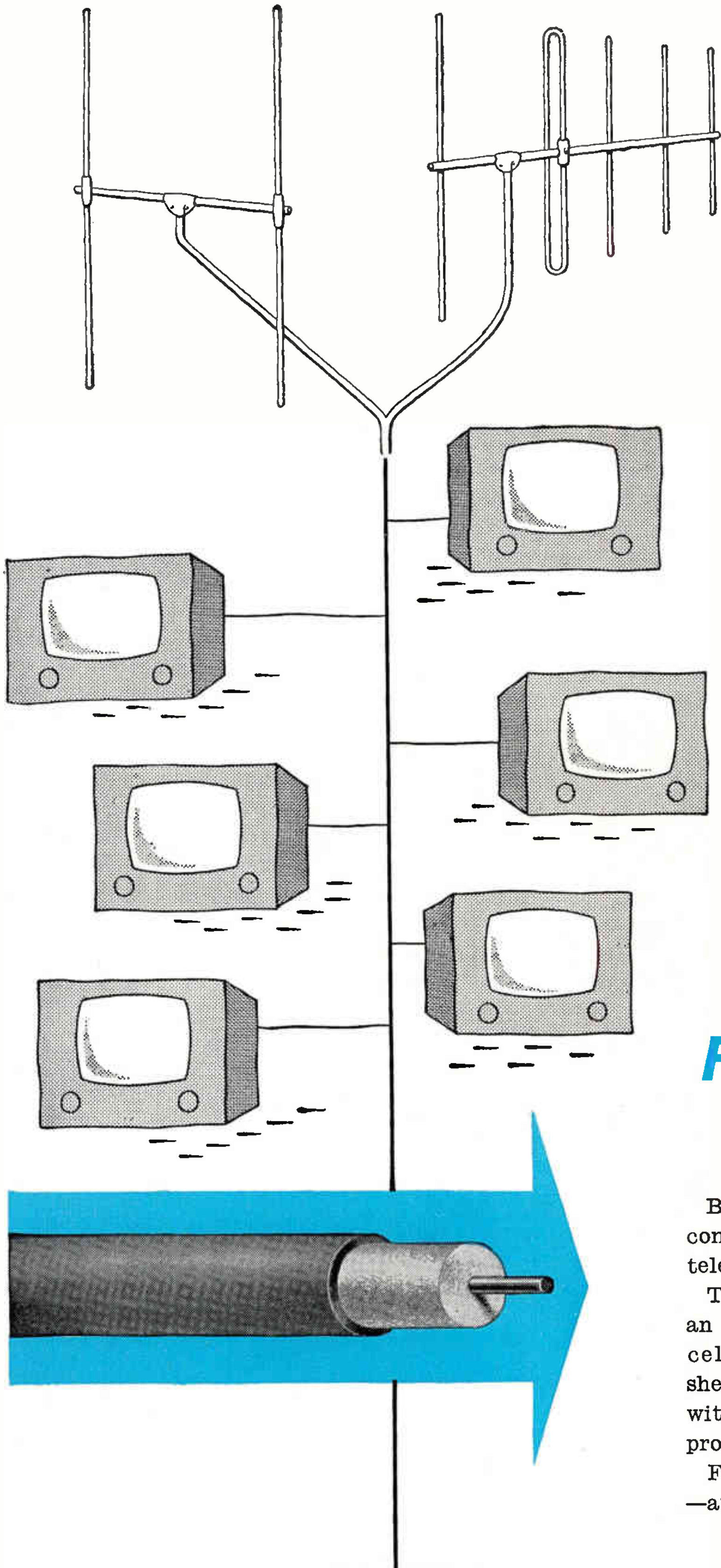
Another Unbrako safety refinement. The cone point on Unbrako Socket Screws has a radius, giving firmer seating (1) and precluding any possibility of the weakness to be found in pointed cones (2).

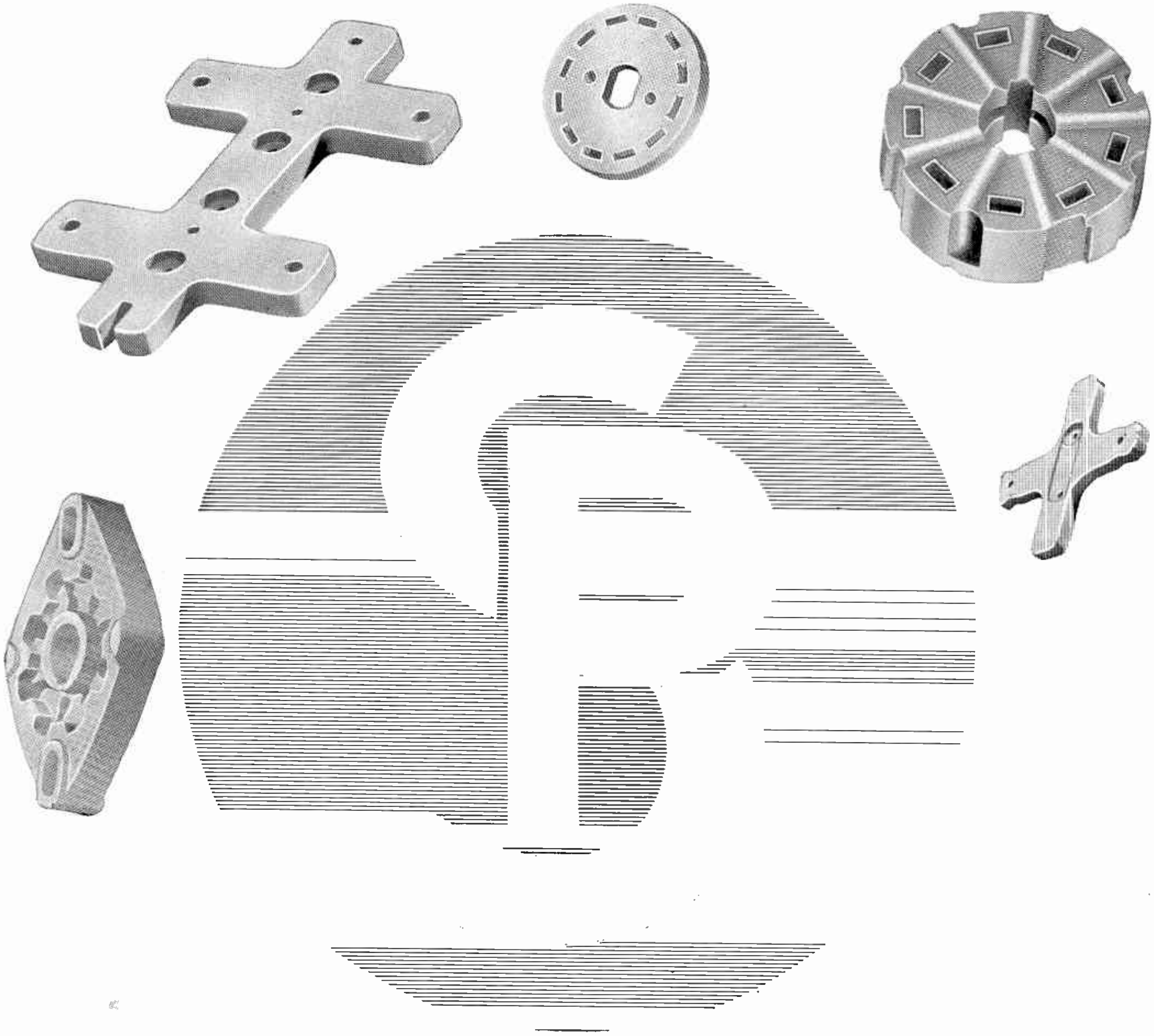


FREE DATA CHART

In the drawing office, in the toolroom or on production — you'll save valuable time and avoid costly guess-work with this free data chart, it cuts out all physical measurements or calculation.

UNBRAKO SOCKET SCREW CO. LTD. COVENTRY



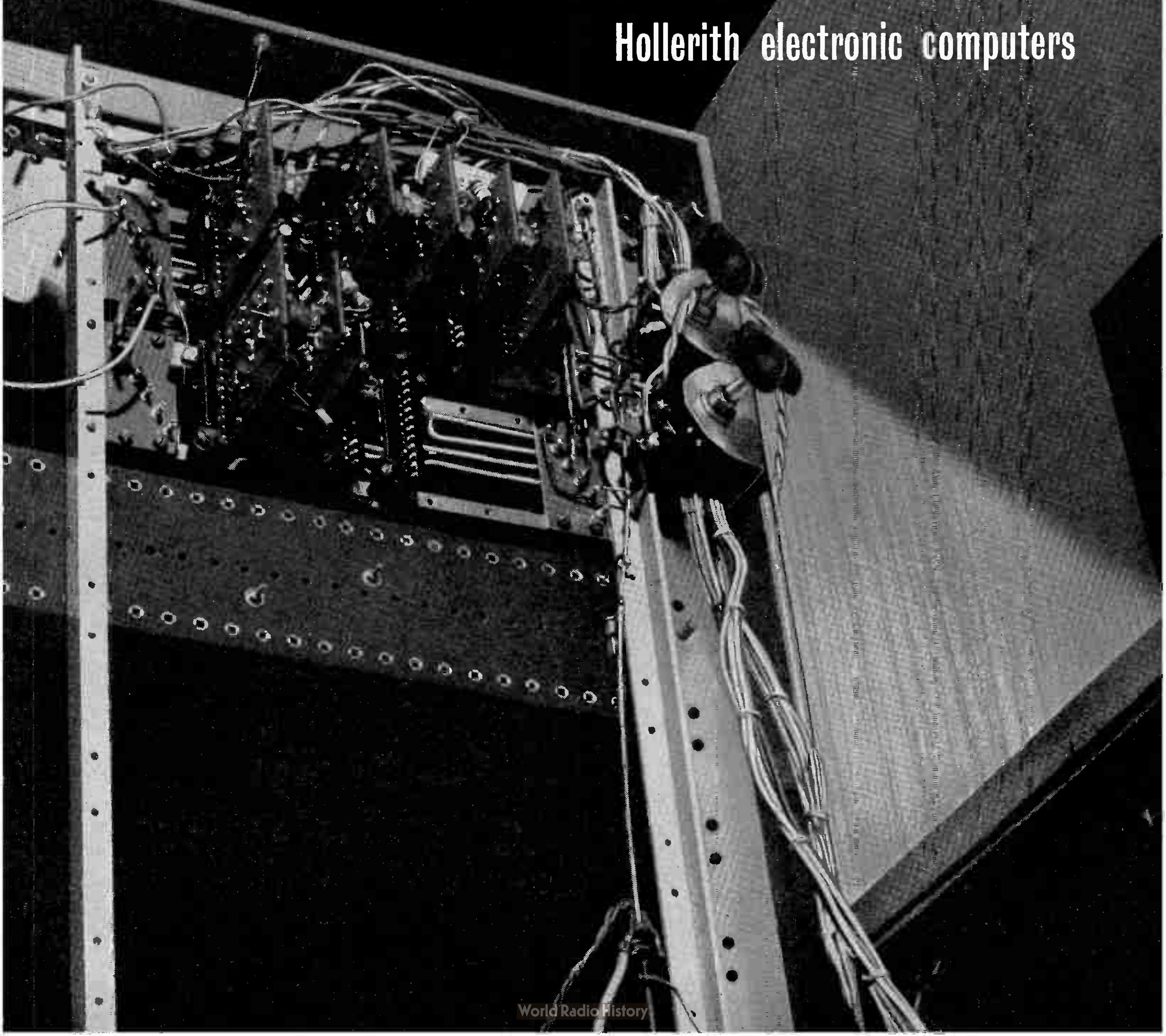


for radio cera ics

STEATITE & PORCELAIN PRODUCTS LTD.

Stourport-on-Severn, Worcestershire. Telephone: Stourport 2271. Telegrams: Steatain, Stourport

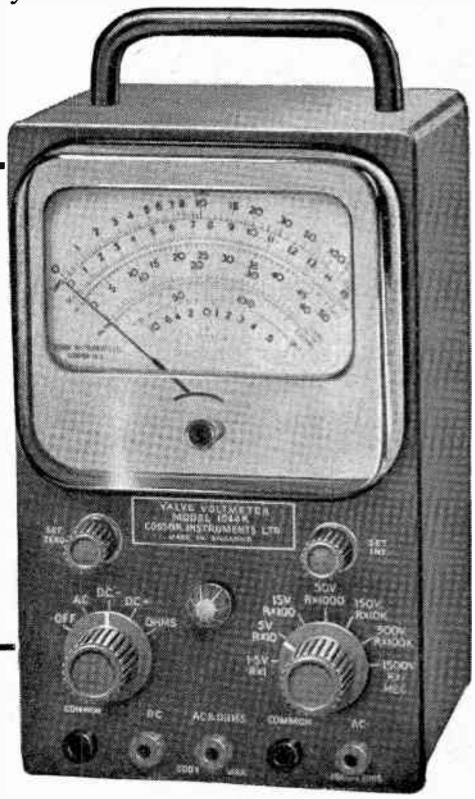
SP88



Cossor Kits

In laying down their programme for the design and production of a range of apparatus in Kit Form, Cossor Instruments Limited have chosen as their "opening pair" two most valuable items of test gear; a VALVE VOLTMETER and a single-beam cathode-ray OSCILLOSCOPE.

PRINTED CIRCUITS are utilised for built-in stability and reliability for both of these instruments. Bearing in mind the highly satisfactory specification/cost ratio of these instruments and being aware of the instructional value in building them, the Laboratory or Service Department Engineer will certainly place them high on his list of essential purchases.



Model 1044K Valve Voltmeter Kit

Brief Specification

D.C. Voltmeter 7 ranges: 1.5V-1,500V Full Scale

A.C. Voltmeter 7 r.m.s. ranges: 1.5V-1,500V Full Scale
7 peak-to-peak ranges: 4V-4000V Full Scale

Ohmeter 7 ranges: Allowing resistance measurement from 0.1 ohm-1,000 megohms.

Dimensions

Height 9½ in. (24 cm.)	Depth 4¾ in. (12 cm.)
Width 5 in. (12.7 cm.)	Weight 4½ lb. (2 kg.)

LIST PRICE £20

HIRE PURCHASE TERMS AVAILABLE

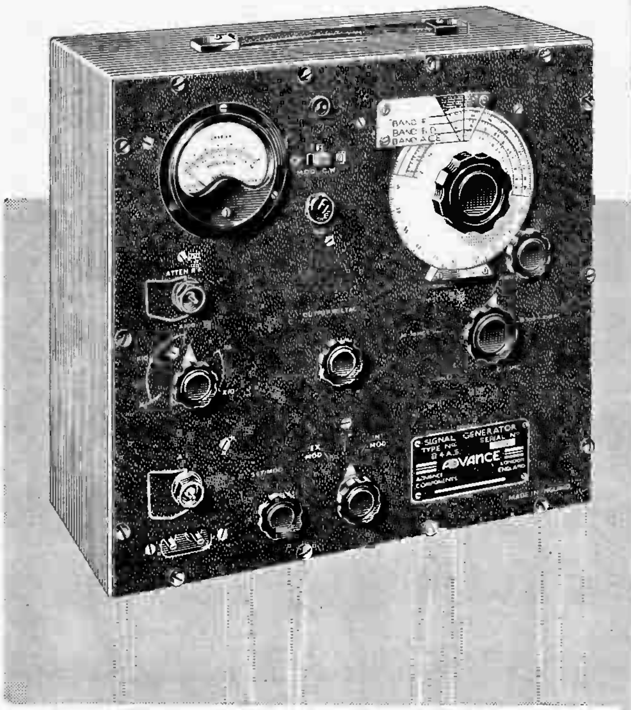
Please write for fully descriptive leaflets

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



MODEL A 100 kc/s—80 Mc/s in six bands

MODEL B 30 kc/s—30 Mc/s in six bands

Calibration accuracy of both models is ±1%

ADVANCE TYPE B4

Net price in U.K. £65

The Advance type B4 is a tried and proven generator which is essentially simple to use. One special feature is the accuracy of the R.F. output over the entire frequency range, achieved by the use of a crystal voltmeter and the subsequent elimination of all circuits having poor frequency characteristics.

Full technical details in Folder R38

Advance
signal generator

SEE THE RANGE OF ADVANCE INSTRUMENTS ON

STAND 934

7th to 17th May

I.E.A. EXHIBITION

GRAND HALL, OLYMPIA, LONDON, W.14

STAND 30

R.E.C.M.F. EXHIBITION

8th to 11th April

GROSVENOR HOUSE, LONDON, W.1

ADVANCE COMPONENTS LTD., ROEBUCK ROAD, HAINAULT, ILFORD, ESSEX TELEPHONE HAINAULT 4444

E·M·I

STROBOSCOPES

MULTISTROBE TYPE 1

—FOR STROBOSCOPIC ILLUMINATION OF LARGE AREAS

HIGH POWER stroboscope capable of illuminating one large area or several small areas simultaneously. The unit can operate up to four lamps as required, the flashing rate being controlled by a stable internal oscillator; provision is also made for triggering from external sources including photo-electric probes.
RANGE: 120-9000 R.P.M. (2-150 flashes per second).
COLOUR OF FLASH: Blue-white (Xenon gas).

GENERAL PURPOSE TYPE 4

Range 250-15,000 flashes per minute. Accuracy 5 % of scale reading. Duration of Flash 15 microseconds (approx.) Lamp Peak Axial Intensity 100,000 candle power at 1,500 F.P.M. Built-in synchronous reed for accurate spot frequency checks.

PRECISION TYPE 3c

Direct Reading 200-6,000 r.p.m. Accuracy 1 % full scale. Light intensity 100,000 candle power at 25 flashes per sec. The lamp may be detached from the body for remote working as shown. This model is available with modified specifications to cover special applications.

OTHER PRODUCTS

ELECTRONIC TACHOMETERS
PHOTO-ELECTRIC TRANSDUCERS
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ELECTRO-MAGNETIC VIBRATION GENERATORS WITH ASSOCIATED CONTROL EQUIPMENT
(UP TO 3,000 lbs. PEAK THRUST)

E.M.I. ELECTRONICS LTD.

INSTRUMENT DIVISION (Dept. 20D) · HAYES : MIDDLESEX : ENGLAND · Tel: SOUthall 2468 Ext. 475

EE73

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 34 NUMBER 4 APRIL 1957

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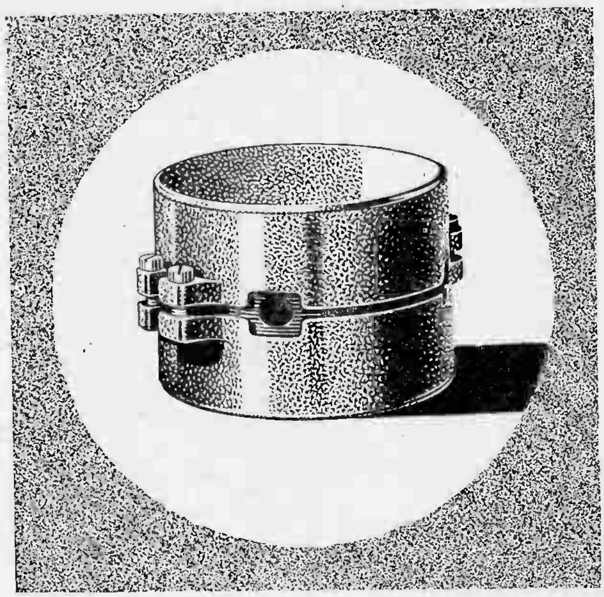
Canada and U.S.A. $7.50

PUBLISHED BY ILIFFE & SONS LTD. DORSET HOUSE STAMFORD STREET LONDON S.E.1
Telephone . Waterloo 3333 (60 lines) *Telegrams . Wirenger, Sedist, London*

BRANCH OFFICES AT BIRMINGHAM MANCHESTER GLASGOW

NEW
GRADE
OF
FERROXCUBE
RESULTS
IN

HIGHER EFFICIENCY POT CORES FOR AUDIO FREQUENCIES



Following the development of audio frequency grades of Ferroxcube, Mullard now introduce a series of 30mm pot cores with exceptionally low losses and high effective permeabilities.

Initial permeability μ_o of 1,400 with a loss of $\frac{\tan\delta}{\mu}$ of 2.5×10^{-6}.

The added advantages of simple construction and light weight make them specially suitable for use in cable splicing and audio frequency output transformers.

Designers requiring full technical details on this new series of high efficiency pot cores are invited to write to the address below.

Mullard

'Ticonal' permanent magnets
Magnadur ceramic magnets
Ferroxcube magnetic cores

MULLARD LTD., COMPONENT DIVISION, MULLARD HOUSE, TORRINGTON PLACE, W.C.1

MC256a

VOLUME 34 NUMBER 4

APRIL 1957

ELECTRONIC & RADIO ENGINEER

incorporating WIRELESS ENGINEER

Exhibitions

IN this issue, there appears a report of the Television Society's exhibition. This marks the opening of the exhibition season or, should we say, the close of the exhibition holiday? A glance at the list which we published in the February issue shows that, from March to October, only June is free from some exhibition in our field. There are actually three exhibitions in each of the months of March, April and May, and two each in July, August and September; in all, there are sixteen and this does not include those arranged by Institutions in conjunction with conventions and the like.

About one-half of them are ones which are, basically, electronic in nature. The exhibits are mainly in this field. The others are, primarily, more general exhibitions or are specialized ones in other fields; at these, electronics is subsidiary to the exhibition as a whole and the exhibits are designed to show its applications in other fields.

With such a large number of exhibitions, it is inevitable that much of the apparatus shown at one will reappear at another. From the point of view of reviewing exhibitions, therefore, it is clearly unsatisfactory to treat each as an independent entity. We are consequently grouping them as far as is practicable. The report which will appear in the May issue, for instance, will deal with four exhibitions together. We feel that only in this way can we present to readers an adequate account of the exhibits without a great deal of repetition.

We do not propose to deal here with the question of whether so many exhibitions are necessary or desirable. On the face of it, they would appear to be neither but the fact that they obtain support from industry is an argument against this superficial view.

Magnetic Amplifiers

PRINCIPLES, ADVANTAGES AND LIMITATIONS

The history of the magnetic amplifier is comparatively long. The device was used, before the valve, to modulate radio-telephone transmitters. With the general use of valves, the magnetic amplifier suffered something of an eclipse but, more recently, the advent of new magnetic materials and rectifiers has brought about a vast expansion in magnetic amplifier applications.

Advantages of Magnetic Amplifiers

The outstanding advantage of magnetic amplifiers over valve amplifiers is that of reliability. There is nothing to wear out and the actual components—coils, resistors and, perhaps, metal rectifiers—are few in number. The devices operate direct from an a.c. supply, without intermediate high-tension rectifiers, and their efficiency is high, often exceeding 90%. Physically, magnetic amplifiers are small and they can be made very robust. They are relatively insensitive to temperature changes and have no warming-up time.

It is these advantages which account for most of the uses of magnetic amplifiers. There are other applications, however, which make use of other features, in particular, the stability which can be achieved. Very low level inputs, of the order of a few micro-microwatts, can be amplified without serious drifts. Where the input is obtained from a low-resistance source, such as a thermocouple, the magnetic amplifier has advantages over the valve. It is possible to match the signal source to the magnetic amplifier so as to make the best use of the available signal power.

Disadvantages of Magnetic Amplifiers

In general, magnetic amplifiers have a slow response to signal changes. This is because the input impedance is inductive, and so has a time constant L/R, where R is the resistance of the signal winding and the signal source. If R is increased artificially by adding resistance, the speed of response is improved but, at the same time, the signal current is reduced. In any case, since control of a core is effected only once per cycle, the response time cannot be much less than $1/f$, however much the gain is reduced. An important recent advance in magnetic amplifiers (the Ramey amplifier) has made possible high power gains (1,000) with half-cycle response times, so that the speed of response is limited only by the supply frequency. In many cases, however, this limitation is an embarrassing one, since it is generally undesirable to have to generate high-frequency power for the benefit of the amplifier (possibly using valves in the process), instead of utilizing available a.c. mains. However, the available response times are often short compared with those of machines which have to be controlled, so that magnetic amplifiers are very suitable for servo systems.

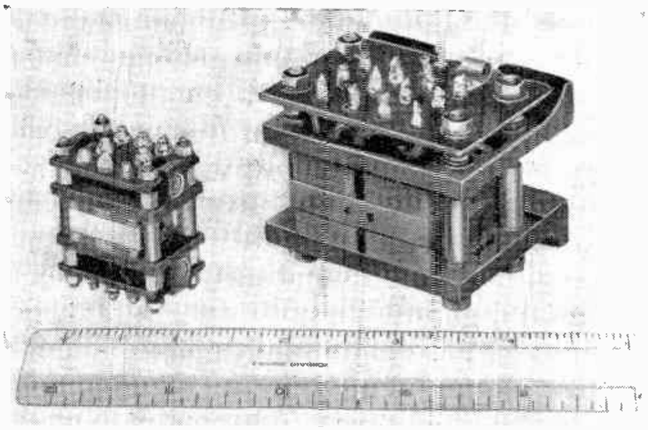
The weight of magnetic amplifiers may be embarrassing in some applications though, here again, reduction is possible by resorting to higher-frequency a.c. supplies. The cost of reactors is high compared with that of other components with similar power ratings.

Transistors, by virtue of their efficiency, small size and fast response are obviously the magnetic amplifier's biggest rival. However, until transistors are equally reliable, drift-free, able to handle large powers, and operate at higher temperatures, they will not be a serious threat to the magnetic amplifier in many applications. In any case, the two devices might profitably be combined in a single equipment. This has already been done to a limited extent.

The other device which competes with the magnetic amplifier is the thyratron. This is efficient and capable of handling high powers, but suffers from the usual disadvantages of thermionic valves. The two devices are sometimes used together.

Mode of Operation

The behaviour of an iron-cored inductor (usually referred to as a 'reactor' in literature on magnetic amplifiers) can be deduced from a study of the $B - H$ curve of the core material. However, the engineer works with volts and amperes rather than gauss and oersteds, and it is easier to think in terms of the more familiar units. In magnetic amplifiers, an alternating voltage (derived from the mains) is applied to a winding. The flux density (B) in the core surrounded by the winding then depends on the applied voltage. If a steady voltage is suddenly applied to such a winding, initially a large back e.m.f. is produced, and the current starts from zero, rising in value at a rate determined by the time-constant of the circuit. B is therefore a function of both the applied voltage and time and is, in fact, $\int_0^t V dt$. Another thing that happens in magnetic amplifiers is the application of d.c. signals to windings. The resulting ampere-



Typical transducers for positive-feedback magnetic amplifiers. (Ultra Electric Ltd.) That on the left can deliver an output of 0·5 *W, with a power gain of* 100,000, *while that on the right has a gain of* 125,000 *and an output of* 5 *W*

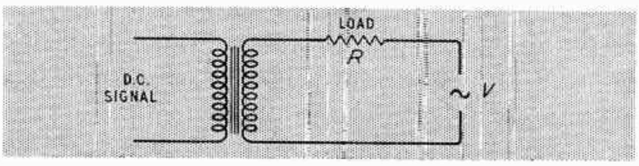


Fig. 1. *Elementary reactor circuit*

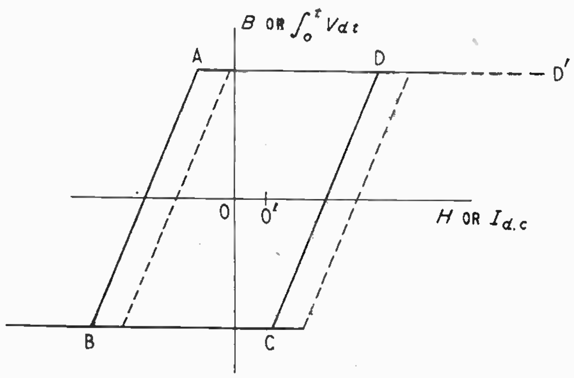


Fig. 2. *Core hysteresis loop. The dashed lines indicate the shift which occurs when a d.c. signal is applied*

turns are measured along the H axis of the $B - H$ curve. Current and voltage-time, therefore, correspond to H and B.

A further point which emerges from the above is that it is wrong to approach the subject of magnetic amplifiers with fixed ideas about which is the dependent variable in $B - H$ curves. In practice, the state of a core is determined by both the alternating energizing voltage and signal currents.

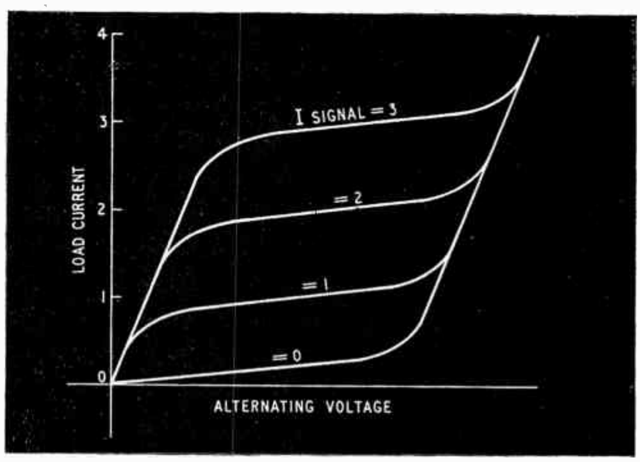
Magnetic amplifiers operate by virtue of the fact that the inductance of an iron-cored or ferrite-cored inductor can be varied by changing the magnetic state of the core by means of a signal current. The essentials of the device are shown in Fig. 1. Suppose the a.c. supply is adjusted so that with no d.c. signal the core just fails to saturate, then the load current, which depends on the series impedance of the load and the inductance of the appropriate winding on the 'reactor', can be made arbitrarily small by increasing the inductive reactance. This no-signal load current is termed the magnetizing current.

Suppose the core has the idealized $B - H$ characteristic of Fig. 2. With no d.c. signal, we apply an alternating voltage across the coil via the load such that the operating point moves round the loop ABCDA ; i.e., the core just reaches the threshold of saturation during each half-cycle. Under these conditions (core not saturated), the inductance is large and only the magnetizing current $V_{ac}/\omega L_{max}$ flows, ωL_{max} being much greater than the load resistance. If a d.c. signal current is applied such that the abscissa of the X axis is 00′, the combined effect of d.c. and a.c. sources is to cause the core to saturate during part of a positive half-cycle of energizing voltage. When this happens, the inductance of the winding is reduced abruptly and a current, given very nearly by V/R flows in the load R. An ideal core behaves, therefore, like a switch, opening and closing at times determined by the combined effect of energizing supply and signal current. In practice, the energizing voltage is fixed and the average load current is then approximately proportional to the signal current.

It will be clear from Fig. 1 that an alternating current flows in the signal circuit. If the signal source presents a low impedance, a large current may be induced by transformer action. One result will be to cause load power to be developed in the no-signal condition, so that the ratio of maximum to minimum load currents will be reduced. This is obviously undesirable, but can be avoided if a large inductance is put in series with the signal source. In many cases, this expedient is even less desirable, because the necessary choke is bulky and expensive, and the input time-constant is increased. A better method is to have two load windings in series opposition, so that the effect of load currents is cancelled in the signal winding. Either a three-limbed core with the signal winding on the centre limb and the load windings on the outside limbs, or two separate cores, may be employed.

Characteristic curves of such a device are shown in Fig. 3. These bear a close resemblance to valve or transistor characteristic curves. (The sharp rise of load

Fig. 3. *Amplifier characteristic curves*



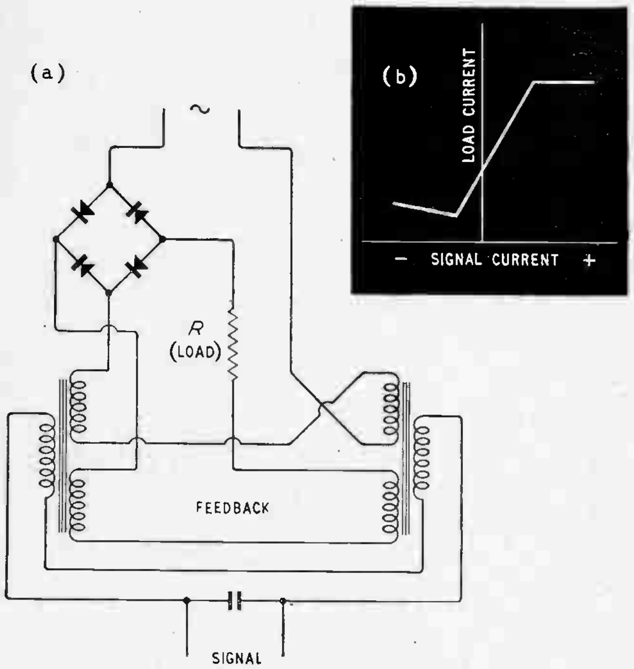


Fig. 4. *Practical amplifier circuit* (a) ; *relation between load and signal currents* (b)

current at the right is the result of the cores saturating without an input signal, and fixes the largest alternating voltage that may be used.) The ratio of signal turns to load turns in this reactor is unity. It can be seen that

$$\frac{\text{I signal}}{\text{I load}} = \frac{\text{N load}}{\text{N signal}}$$

Load lines can be drawn in the usual way. Provided the signal current is not great enough to cause 'bottoming', the output current is independent of the load resistance. On the face of it, it would seem that very high power gains could be obtained, since the d.c. signal need only create ampere-turns, and not input watts. In practice, however, signal windings have a finite resistance and the power gain is limited to 10 to 100. Where much larger gains are needed, positive feedback is used, part of the output being rectified and used to supplement the signal.

The circuit of a fairly simple magnetic amplifier is shown in Fig. 4 (a) and its input–output current curve in Fig. 4 (b). It will be seen that there is a substantial output current with no input. This is a consequence of the use of positive feedback, the mechanism being as follows. All the output current is rectified and passed through the feedback windings so as to increase the gain. In the absence of a signal, the magnetizing current flows, and this, too, is rectified and fed back, the resulting increased rectified current constituting the no-signal load-current. This can, if necessary, be reduced by passing a suitable d.c. bias through an additional winding. A negative input signal acts like such a bias, hence there is a minimum output for a certain value of input current.

The amount of feedback is governed by the ratio of feedback winding turns to load winding turns (β, say) and the effect of feedback on current gain is to multiply the latter by $1/(1-\beta)$, as in more familiar types of amplifier. Since magnetic amplifiers are stable devices, large amounts of positive feedback can be employed; less than 90% is considered small. The price paid for increased gain (which may be 10^6 to 10^7) is increased response time.

The purpose of the capacitor across the signal source in Fig. 4 (a) is to prevent even-harmonic currents from flowing in the signal circuit. Fundamental frequency e.m.fs cancel in the signal circuit because one of the load windings is reversed, equal and opposite voltages then being induced in the two signal windings, provided that the cores and windings are balanced.

Magnetic Modulators

An important application of magnetic amplifier principles is the second-harmonic type of 'amplifier', which is really a modulator. In this, a d.c. input gives rise to an a.c. output at twice the energizing frequency. It will be clear from a consideration of Fig. 2 that

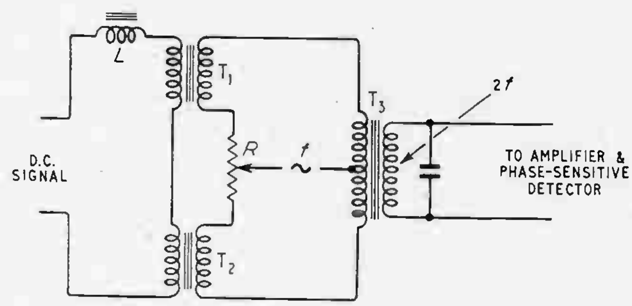


Fig. 5. *Second-harmonic magnetic amplifier*

reactors can give rise to harmonic currents. If the core of Fig. 2 is driven only by a pure sine-wave alternating voltage of large amplitude, saturation will occur on each peak. In a circuit like Fig. 1, with no d.c. signal, the load will receive a current with a symmetrical peaky waveform; i.e., containing odd harmonics of the supply frequency. If a d.c. signal is now applied, the energizing current will be assisted on one half-cycle and opposed on the next, so that the load current is now asymmetrical and contains even-harmonic components. The effect was used in the early days of radio transmission to multiply the frequency of the currents produced by high-frequency alternators, thus producing power at frequencies beyond the range of efficient mechanical generators.

The interest in second-harmonic magnetic amplifiers arises because of their stability, which is better than that of fundamental amplifiers by a factor of 10^2 to 10^4. Drifts in the second-harmonic type can be as small as 10^{-17} watt referred to the input.

Fig. 5 shows a suitable circuit. T_1 and T_2 are the reactors, energized at a frequency f. They are connected in a bridge circuit, R being a balancing potentiometer. The bridge output is via T_3, the secondary of which is tuned to $2f$. It is usually necessary to amplify the output, but this can readily be done in a valve amplifier the gain of which is stabilized by negative feedback. The choke L in series with the input prevents alternating currents from flowing through the signal source. The device is phase-sensitive, since the direction of the signal current determines whether the flux in T_1 or T_2 is aided or opposed during a particular half-cycle of f. A phase-sensitive detector is therefore employed, energized by power at $2f$ obtained by applying f to a frequency-doubling circuit.

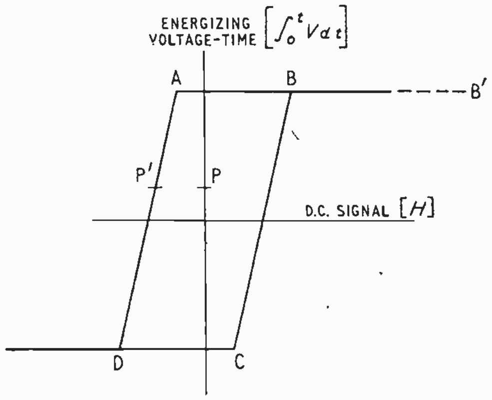
This type of magnetic amplifier can readily be made to perform as a magnetometer and, as such, has applications in automatic steering systems, control of the state of the cores then being effected by the earth's field.

High-Speed Magnetic Amplifiers

The response-time of a non-feedback magnetic amplifier is of the order of 10 cycles of the energizing frequency. Since the latter is commonly 50 c/s, the response is quite slow compared with that of other devices such as valves and even relays. A special type of amplifier with a short response time has been developed by Ramey. The essence of the device is the idea of 'setting' the magnetic state of a core during one half-cycle of the energizing frequency and resetting it during the next. Suppose a core with characteristics as shown in Fig. 6 has its working point set to point B during one half-cycle. Then, during the next half-cycle, the working point will move to D, then back to B in the next, and so on. In the Ramey amplifier, the core is initially set to B, but is reset to a point determined by the signal, say, to P′ during the next half-cycle. On the following 'set' half-cycle, the stored energy assists the energizing voltage, so that the core saturates (operating point on BB′) and a large current flows in the load.

It will be seen that, in order to effect control, the signal voltage must oppose the energizing voltage and so prevent the working point from being taken as far as D during reset half-cycles. The basic amplifier circuit is as Fig. 7, and operation is as follows.

Suppose that there is a conducting path through the signal source, but no signal. The balancing voltage is adjusted so that the core completely resets when D_1 conducts. The working point then moves round the loop ABCDA, being fully set and reset as D_2 and D_1 conduct. (D_2 conducts during 'plain' half-cycles, D_1 during 'black' half-cycles.) If a signal *voltage* of the polarity shown is applied, the signal and balancing voltages are opposed during the reset half-cycles when D_2 conducts. The voltage across the signal winding is then



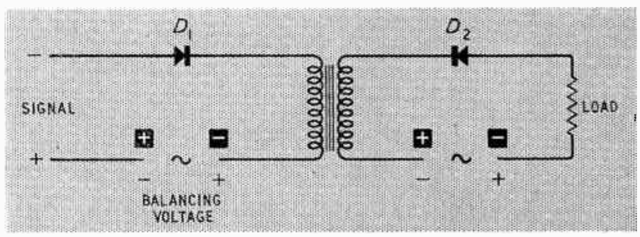


Fig. 6 (*left*). *Core conditions in Ramey amplifier*

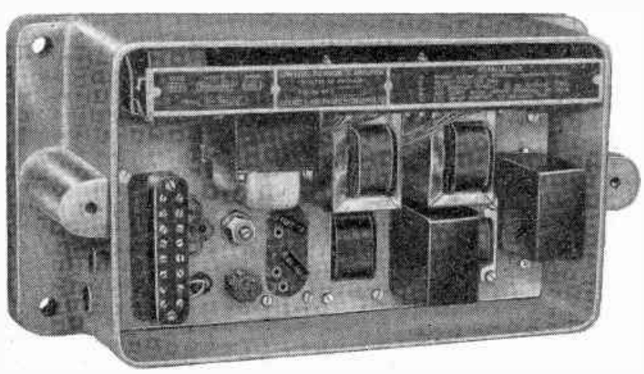
Fig. 7 (*above*). *Basic Ramey amplifier*

reduced, so that the core is not fully reset. It may, for instance, be reset to point P′ on Fig. 6, so that, when the energizing voltage falls to zero at the end of the reset half-cycle, the core working point is at P. On the next half-cycle, the core saturates and a substantial load current is taken.

Two important advantages of the circuit can now be seen. First, only one half-cycle need elapse between the application of a signal and the appearance of load current. Secondly, no signal current can flow during the half-cycle when D_1 is non-conducting and, on the next half-cycle, current flows *into* the signal circuit, since the balancing voltage exceeds the signal voltage. In other words, the device is voltage-operated and, in theory, the signal source need not supply power. In practice, some power is required, because neither the rectifier nor the reactor is perfect, and losses must be made up. The signal can be d.c. or half-wave rectified a.c. derived from the energizing source and suitably phased.

Against these advantages must be set the facts that current from the amplifier enters the signal circuit, that d.c. flows in the a.c. power circuit, and that rectifiers are essential. (Since rectifiers are less stable than reactors,

Low-level d.c. magnetic amplifier. Typical input 4 *mV in* 20 Ω, *output* 5 *mA in* 500 Ω. *Zero stability* 10^{-12} *W.* [*Courtesy, Elliott Bros. (London) Ltd.*]



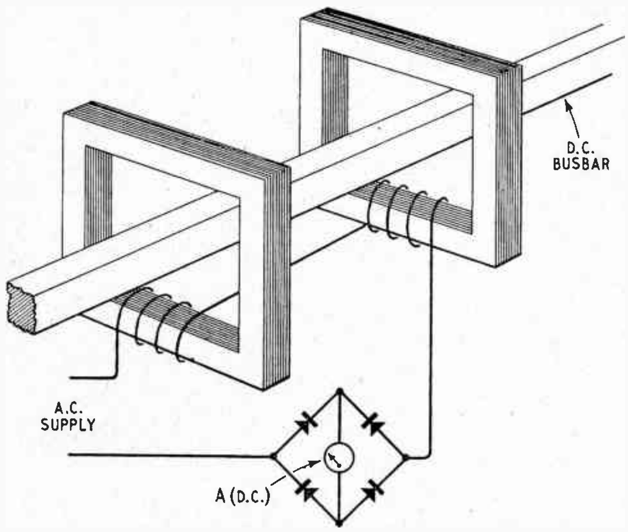


Fig. 8. *'D.C. transformer' for measurement of large direct currents*

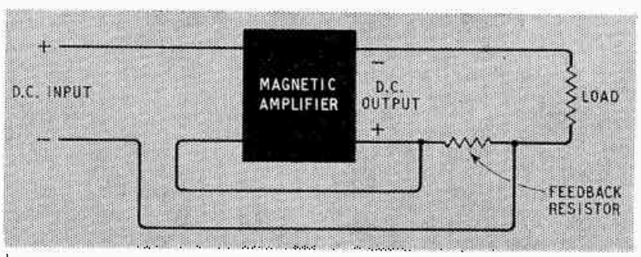
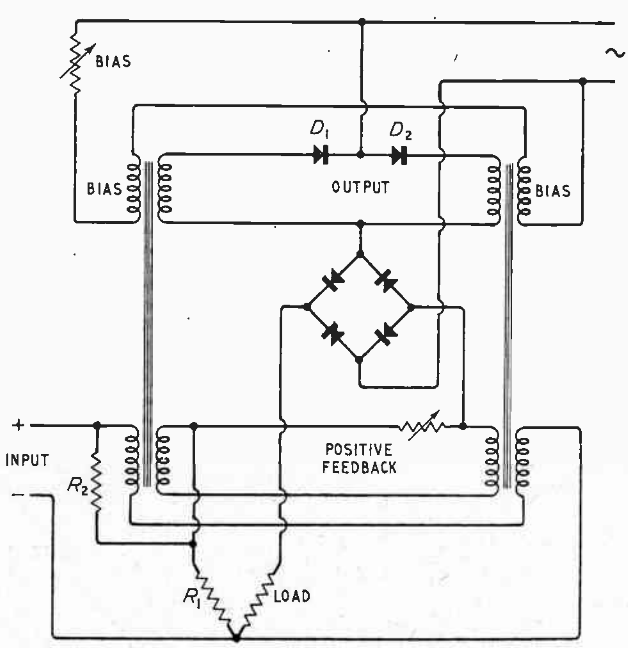


Fig. 9. *Negative-current feedback amplifier*

Fig. 10. *Magnetic amplifier employing mixed positive and negative feedback*



the circuit is not suitable for very low-level working.) More complicated circuits with fewer disadvantages are described in the literature.

Some Magnetic Amplifier Applications

Amplitude modulation of radio transmitters was mentioned above as an early application of the magnetic amplifier. It is now only of historical interest, but it is interesting to recall that the transmitters operated on low radio frequencies of a few tens of kc/s. This enabled the amplifier to be energized by the transmitter and, since the energizing frequency was many times greater than the highest audio frequency required, it was possible to obtain a sufficiently fast response. The actual modulating signal was derived from a carbon microphone, and so consisted of a steady direct current with an audio-frequency ripple superimposed. The direct current provided the bias necessary to avoid frequency doubling. Modulation was effected by variable absorption of power from the r.f. generator.

Simple saturable reactors of the type illustrated in Fig. 1 have been widely used for dimming lamps in theatres, etc. Advantages over direct control of lamp current by a rheostat are the smaller size of control devices (small variable resistors) and the greater efficiency obtainable. Such devices are not always thought of as magnetic amplifiers, but they are inasmuch as they permit the control of a large current by a small one.

An interesting application is to the measurement of large direct currents such as flow through d.c. busbars (Fig. 8). Here the busbar forms a single-turn control winding and, if the amplifier has characteristics like Fig. 3, the rectified output current is proportional to the control current. Given suitable core materials and construction, the value of the alternating voltage has little effect on the output current. The advantages of this system of measuring large direct currents are two-fold. First, the need for bulky and expensive shunts is eliminated and, secondly, there is no direct connection between the meter and the busbar, so that the system is safe even though the busbar is at a high potential above earth.

Most amplifiers make use of input signals in the form of electric currents. It is equally possible, however, to utilize a magnetic field as a signal. The field then assists or opposes the flux in a core exactly as a signal current does. The application of this principle to navigational aids has already been mentioned. In this case, it is the earth's field that constitutes the signal and, since the latter is weak, considerable amplification is necessary. If the signal originates from a powerful source of magnetic field close to the cores, a detectable output is available without further amplification. The principle has been applied to remote position-indicating devices. A magnet fixed to the moving part rotates inside the amplifier core, giving rise to an output which varies with the relative positions of the two. The amplitude of the output varies as the sine of the relative angle of core and magnet but, within the limitations imposed by this non-linearity, the device has the advantage of being robust, non-contacting, and mechanically simple.

The stability of magnetic amplifiers makes them useful in the measurement of small direct voltages. A disadvantage, however, is the low input resistance, which is normally the resistance of the signal windings. Negative current feedback can be applied so as to increase the input resistance. The arrangement used is shown in Fig. 9. If a substantial increase is to be obtained, the gain of the amplifier and the fraction of the rectified output fed back must be large. Fortunately, it is possible to increase the gain by applying positive feedback without affecting the input resistance. This will be clear from a consideration of Fig. 4 (a). Here, the positive feedback is applied to separate feedback windings. Since any coupling between these windings and the signal windings must be inductive, under steady-state conditions the feedback current can have no effect on the signal current.

The voltage developed across the feedback resistor of Fig. 9 opposes the input voltage and, in effect, cancels part of it. The requirement for complete cancellation (infinite input resistance) is that the gain inside the box should be infinite. Fortunately, the stability of the device is such that very large gains are possible, and the working input resistance may be anything up to 1,000 times the resistance of the signal windings. Even so, the input resistance is not large (a few kilohms) compared with that of valve amplifiers. However, an additional advantage is improved linearity. Such amplifiers are used in conjunction with thermo-couples, barrier-layer photocells, resistance thermometers, and bridges. It is usually necessary to back off the no-signal load current [Fig. 4 (b)] by means of a d.c. bias. The resulting amplifier then has signal, positive feedback, load, and bias windings, and rectifiers where appropriate and, consequently, appears complicated.

It is, of course, possible to reduce the input resistance by employing parallel-connected negative feedback. This is useful where currents, rather than voltages, have to be measured. The complete circuit of such an amplifier, which also incorporates means of reducing the complexity just referred to, is given in Fig. 10.

Here, a.c. bias is used, suitably phased so that the no-signal output is minimized. In practice, it is often necessary to include a reactive network in the bias circuit so that the load and bias currents can be kept in anti-phase.

The output current is rectified by the two half-wave rectifiers D_1, D_2, and the resulting pulses of d.c. are passed through the output windings in the correct sense to provide positive feedback. Thus, some positive feedback is obtained without extra windings and with a minimum number of rectifiers. Part of the full-wave rectified load current is passed through separate positive feedback windings which serve to provide fine control of feedback. These windings are shunted by a variable resistor which acts as a regeneration control.

The load current causes a voltage drop in R_1 which provides negative feedback via R_2. It will be seen that the signal and feedback voltages are series-aiding as far as the circuit through R_2 is concerned. Thus, a given signal voltage results in more input current in the feedback condition than in the non-feedback condition. In other words, the input resistance is decreased by the application of feedback. In the limit, when the amplifier loop gain is made to approach infinity, the input impedance approaches zero.

The vast majority of magnetic amplifiers are used in control systems of various kinds, including servo systems. The amplifier of Fig. 11, for example, is one stage of a three-stage magnetic amplifier for use in turbo-jet aircraft, where it forms part of an engine temperature-control system. The object is to allow the gas turbine to operate as near as is safely possible to its maximum rated temperature (the condition for maximum engine power). The control signals are produced by thermocouples at a level of about 10^{-14} watt.

In this application, which is typical, the reliability of the magnetic amplifier when subject to shock, acceleration, vibration and extremes of temperature and humidity is a decisive factor. The device is also made attractive for use in aircraft by the existence of suitable

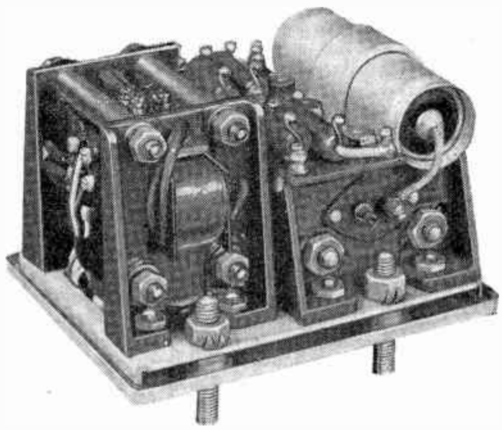


Fig. 11. *One stage of a three-stage amplifier for use in aircraft over a wide range of ambient temperatures.* [*Courtesy, Ultra Electric Ltd.*]

high-frequency power in the form of the aircraft's 400-c/s supply mains. (The size and weight of transductors can be reduced if the frequency is increased.) This type of amplifier will give its full specified performance (temperature control to within 9°C at up to 750°C) when the ambient temperature is −55°C to + 55°C, and it will go on operating, with reduced performance, at much higher temperatures.

In such applications, the magnetic amplifier has, at present, no serious rivals among electronic devices. The junction transistor is a potential rival in that it is compact, efficient, mechanically strong, and (probably) reliable. It has the additional advantages of light weight, a greater input resistance, and a higher speed of response. At present, the transistor's temperature limitations, and the rather restricted range of available types are sufficient to exclude it from this field, but if stable transistors capable of controlling adequate amounts of power become available, the heyday of the magnetic amplifier will be over. In less critical applications, the magnetic amplifier is at a disadvantage by reason of the lack of a standard range of transductors.

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A Phase-Sensitive Valve Voltmeter

DESIGN AND CHARACTERISTICS

By R. Kitai*

The instrument described was designed to measure the in-phase and quadrature components of a sine-wave voltage relative to a reference voltage of the same waveform and frequency. The frequency range of the instrument is 20 c/s to 40 kc/s, and the accuracy is within 1% of full-scale deflection when reading either in-phase or quadrature voltages.

The instrument has four ranges for the signal input voltage, full-scale reading on the meter being 1, 3, 10 or 30 volts r.m.s. The input resistance at the signal terminals exceeds 25 megohms. The reference voltage is required to lie in the range 4–16 volts r.m.s., the input resistance at the reference voltage terminals exceeding 2 megohms.

The indicating meter is of the centre-zero moving-coil type with linear scales, and the instrument has a switch which permits either in-phase or quadrature components of voltage to be indicated on it. In this way, positive and negative values of both components of a signal voltage are read, providing a direct measure of voltage in complex form without ambiguities of sign. The main applications of the instrument are as follows:

(a) Direct plotting of Nyquist loci (of particular value in high-speed servomechanisms).

(b) Measurement of impedance and transmission characteristics of amplifiers, networks, transmission lines, etc.

(c) Null indication in a.c. bridges. For this application, the instrument must be used in conjunction with a high-gain, low phase-shift amplifier.

The instrument is seen to be valuable for general laboratory use. It offers advantages over the oscilloscope for phase-angle measurement in that oscilloscope methods are inaccurate for phase angles greater than about 70° while phase-shifts inherent in normal oscilloscopes prohibit measurements over a wide frequency range. The author has also found the instrument very useful in demonstrating transmission-line characteristics in the students' laboratory. Previously, the vector-voltage distribution on an artificial transmission line had been obtained using the Larsen rectangular potentiometer. As a large number of readings is required, the potentiometer method is tedious; also accuracy is often impaired by frequency and current drift during the time required for measuring. The phase-sensitive voltmeter has reduced the time of measurement very considerably, with comparable accuracy.

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Fig. 1 (a). *Diagram of phase-sensitive circuit.*

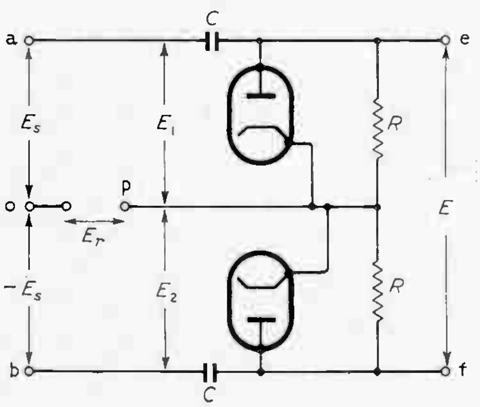
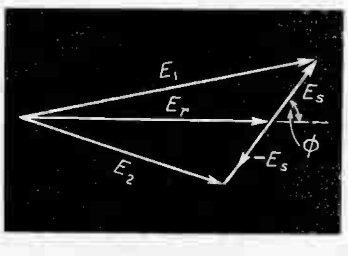


Fig. 1 (b). *Vector diagram of voltage relations.*



Principle of Operation

The phase-sensitive device is an adaption of the 'coherent' detector circuit. One form of this circuit is shown in Fig. 1 (a). The produce *CR* is assumed to be substantially greater than the periodic time of the voltages applied. A reference voltage E_r is applied to terminals 'po' and two antiphase signal voltages, each of magnitude E_s are applied to terminals 'ao' and 'bo' respectively. E_s and E_r are of the same frequency, and are out of phase by an angle ϕ.

In Fig. 1, the effective voltages applied to each diode and *CR* circuit are E_1 and E_2 respectively. Provided that E_r is substantially greater than E_s, the direct voltage E

between terminals 'ef' is very nearly 2 $E_s \cos \phi$.
If provision is made that E_r is shifted in phase by 90° leading, $E \approx 2\, E_s \sin \phi$.
Thus, both the in-phase and quadrature components of E_s relative to E_r can be obtained. In these two relations, of course, the peak value of E_s must be used.

A block diagram of the complete voltmeter is shown in Fig. 2 and a detailed circuit diagram, excluding the regulated power supply, is shown in Fig. 5. The following data is relevant to the design.

(i) *Magnitudes of Reference and Signal Voltages*

Referring to Fig. 1, the voltage vectors E_1 and E_2 are given by

$$E_1 = [E_r^2 + E_s^2 + 2E_rE_s \cos \phi]^{1/2},$$
$$E_2 = [E_r^2 + E_s^2 - 2E_rE_s \cos \phi]^{1/2}$$

Substituting

$$x = \frac{E_s}{E_r},\; k = \frac{2x}{1 + x^2},$$
$$E_1 = E_r \sqrt{1 + x^2}\sqrt{1 + k \cos \phi}$$
$$E_2 = E_r \sqrt{1 + x^2}\sqrt{1 - k \cos \phi}$$

Expanding the square-root terms containing angle ϕ in series form, and subtracting, we obtain—

$$E_1 - E_2 = E_r \sqrt{1 + x^2}\left[k \cos \phi + \frac{1}{8} k^3 \cos^3 \phi + \frac{35}{640} k^5 \cos^5 \phi + \ldots\right]$$
$$= E_r \left[\cos \phi \frac{2x}{\sqrt{1 + x^2}} + \cos^3 \phi \frac{x^3}{(1 + x^2)^{5/2}} + \frac{35}{20} \cos^5 \phi \frac{x^5}{(1 + x^2)^{9/2}} + \ldots\right]$$
$$= 2E_s \cos \phi \left[1 - \frac{x^2}{2}(1 - \cos^2 \phi) + \frac{x^4}{8}(3 - 10 \cos^2 \phi + 7 \cos^4 \phi) + \ldots\right]$$

As $\phi \rightarrow 0$, $E_1 - E_2 \rightarrow 2E_s$. For $x = 0 \cdot 1$, $E_1 - E_2$ deviates from $2E_s \cos \phi$ by nearly 1/2% as $\phi \rightarrow \pi/2$.

Considering the indicating meter, it is evident from the theory that if x is large and ϕ is near 90°, the pointer can read on-scale with very large error. Two precautions have been taken to avoid this condition; in designing the instrument, change of range switching is performed in the signal-input channel prior to the detector, and not in the d.c. valve-voltmeter section. Further, it is stipulated in the instructions for using the voltmeter that the position of the range-change switch must be such that both in-phase and quadrature components of the signal voltage can be read on scale. This restriction means that if one component of the voltage to be measured is very small, the range-change switch cannot be operated to give a greater deflection if the other component is thrown off-scale. The author has found that, with the closely-spaced range-change facilities and with a large meter scale, this is not an important limitation.

The value of x used in design is determined by the condition $\phi = \pi/4$. In-phase and quadrature readings are identical and the r.m.s. value of E_s is $\sqrt{2}$ times the meter reading. The lowest range of the instrument is 1 volt r.m.s. full-scale, so that the highest value of E_s of concern is $\sqrt{2}$ volts r.m.s. For this condition, if $x = 0 \cdot 1$ the reference voltage is $10\sqrt{2}$ volts r.m.s., and the maximum error is nearly 1/4% of full-scale deflection. A reference voltage of this magnitude can be handled by valve circuits supplied from a regulated source of

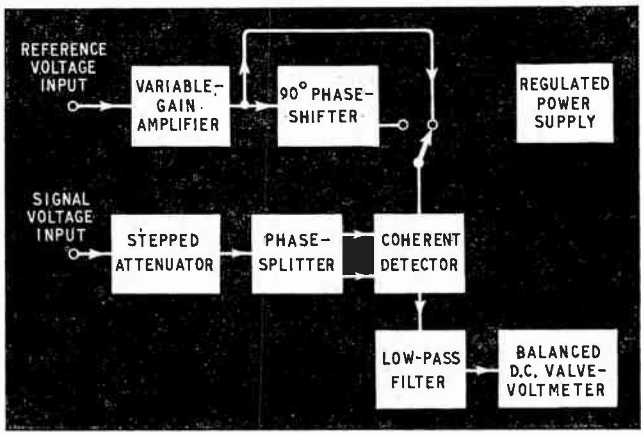


Fig. 2. *Block diagram of instrument*

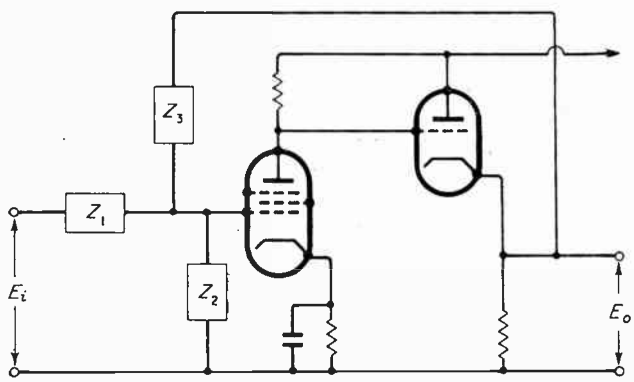


Fig. 3. *Feedback method of producing 90-degree phase-shift*

power, and the margin of x is such that E_r need not be set with precision. A reference voltage of about 15 volts r.m.s. is used.

(ii) *Permissible Phase-Shifts*

Assume that the phase angle between E_r and E_s at the input terminals is ϕ, and that a small additional phase-shift δ radians is introduced in the reference and signal channels prior to the detector. The in-phase reading on the meter will be—

$$E_s \cos (\phi + \delta) \approx E_s \cos \phi\, [1 - \delta \tan \phi]$$

and the quadrature reading will be

$$E_s \sin (\phi + \delta) \approx E_s \sin \phi\, [1 + \delta \cot \phi]$$

Thus as $\phi \rightarrow 0$ (or π) and with full-scale deflection for in-phase reading, the error in quadrature reading will be 100δ%. A similar situation holds for $\phi \rightarrow \pm \pi/2$. When $\phi = \pi/4$ one reading will be high and the other low by an amount 100δ%. For a maximum error of $0 \cdot 5$% of full-scale deflection due to this cause, $\delta = 17'$.

The analysis assumes that negligible phase-angle error is introduced in the 90° phase-shifter. This condition can be assumed, as discussed in (iv) below.

(iii) *Ref.rence-Voltage Amplifi.r*

The voltmeter is invariably used in conjuntion with a conventional audio-frequency oscillator, the reference voltage often being the oscillator output voltage. It was therefore considered unnecessary to accommodate a range of reference-voltage amplitudes beyond 4–16 volts. A single-stage degenerative amplifier is used, the gain of the circuit of valve V_{1a} (Fig. 5) being controlled by a variable cathode resistor. The phase-shift in the output of this stage is nearly 16′ at 40 kc/s, but this is compensated for by phase-shifts in the circuits of the first two valves in the signal channel, the extent of the compensation depending on the position of the range-change switch.

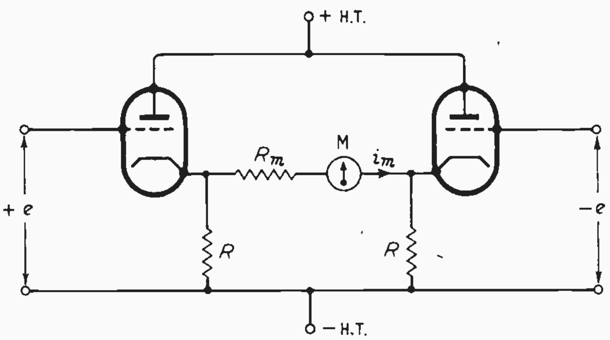


Fig. 4. *Balanced valve-voltmeter circuit*

Valve V_{1b} is a cathode-follower, and a fraction of its output voltage can be switched into the signal channel. Then, in setting the reference voltage, the amplifier gain control is adjusted to give full-scale deflection on the meter.

(iv) 90-*Degree Phase-Shifter*

Of the several types of phase-shifter in common use, that which would appear to be the most satisfactory is one which provides only slight variation in phase-shift but large variation in output voltage amplitude with variation in frequency[1]. Since the magnitude of E_r is of secondary importance, only a rough setting of phase-shifter controls would then be necessary.

The Miller integrator and the differentiator are of this type. The usual arrangement is shown in Fig. 3. The pentode amplifier provides high gain, and the cathode-follower permits external coupling at a low impedance level. The transfer characteristic of the circuit is—

$$\frac{E_0}{Ei} \approx -\frac{Z_3}{Z_1}\,\frac{1}{1+\frac{1}{A}\left[1+\frac{Z_3}{Z_1}+\frac{Z_3}{Z_2}\right]}$$

where A is the gain of the pentode and cathode-follower combination with Z_1 short-circuited and Z_3 disconnected. In the Miller integrator-invertor Z_3 is a capacitor and Z_1 a resistor, Z_3 being nearly equal in magnitude to Z_1 for unity overall gain. Neglecting the effect of the input impedance Z_2 of the pentode valve, the required value of A for unity overall gain and phase-shift in error by 17′ of 90° is 200 (this assumes zero phase-shift in the amplifier). Now a value of A exceeding this figure is easily obtained. In practice, however, the arrangement is found to be unsatisfactory. Using set components for Z_3 and Z_1 to provide unity overall gain at a high frequency, the gain of the stage increases with decrease in frequency so that low-frequency noise generated in the pentode as well as in previous stages are amplified substantially. Since the voltmeter section of the instrument is sensitive to very low frequencies the pointer of the indicating meter fluctuates erratically.

An alternative means of obtaining a 90° leading phase shift is to commence by using the circuit of Fig. 3 as an inverter, Z_3 and Z_1 being equal resistors. The circuit is then switched to become a differentiator-inverter with Z_1 capacitive and Z_3 resistive. While this arrangement does not amplify low-frequency noise, the phase-shift is critically dependent on the purity of the elements Z_3 and Z_1. In the differentiator circuit an undesirable resistive element is associated with the capacitor Z_3, this being the internal resistance of the previous stage. On attempting to obviate this difficulty by increasing the impedances of Z_3 and Z_1 a condition is soon reached where Z_2 commences to exercise a deleterious effect on the phase-shift.

A superior phase-shifter is of a type in which voltage amplitude is substantially independent of frequency, but the phase-shift is frequency sensitive. Such an arrangement is the circuit of valve V_{2a} in which a resistor and capacitor in series are connected across a phase splitter. A phase-shift of precisely 90° can be obtained using the following procedure:—

With the same fraction of in-phase reference voltage injected into the signal channel as in (iii) above, and with the phase-shifter in circuit, the phase-shifter capacitor and resistor controls are set to give zero deflection on the meter. The switched capacitors constitute a "coarse" control, frequency figures being marked on each side of the switch positions. A three-to-one frequency range is covered by the resistance control with some overlap at each end. In this arrangement, purity of the phase-shifter elements is of minor concern, and shunt capacitances in the phase-shifter output circuit are accounted for. The phase-splitting valve has a gain very near to unity so that, from a decoupling point of view, the circuit has an added advantage over phase-shifters employing high-gain amplifiers.

Valve V_{2b} (Fig. 5) is a cathode-follower which is directly coupled to the coherent detector so as to operate the valve-voltmeter section at a suitable quiescent condition.

(v) *Signal Channel*

Valve V_3 is a combined attenuator and phase-splitter, the output being fed to two cathode-follower valves V_4. The shunt-feed arrangement of the coherent detector enables the detector capacitors to be useful as d.c. blocking capacitors as well.

(vi) *Balanced Valve Voltmeter*

The conventional balanced valve voltmeter with degeneration is shown in Fig. 4. If unbalance voltages e are applied to each grid, the meter current is given by:

$$i_m\,[R_m\,(g_m + 1/R) + 2] \approx 2g_m e$$

where g_m is the mutual conductance of each valve. The requirements that i_m shall be substantially independent of variations in valve parameters are:

$$R \gg 1/g_m, \quad R_m \gg 2/g_m$$

These can be achieved using a sensitive meter movement with high-slope valves, and by restricting the voltage required for full-scale deflection to a high enough value.

The meter connections are taken from the diode anodes rather than from the cathodes of V_8 to provide increased source resistance in the overload state. With this protection, the meter current cannot exceed about twice full-scale value. Valves V_7 may be replaced by crystal diodes to afford even greater protection because of their lower forward resistance; however, care must be taken to ensure that their back resistances are sufficiently high so as not to affect on-scale readings.

Two separate meter scales are provided, reading 1–0–1 and 3–0–3 volts respectively.

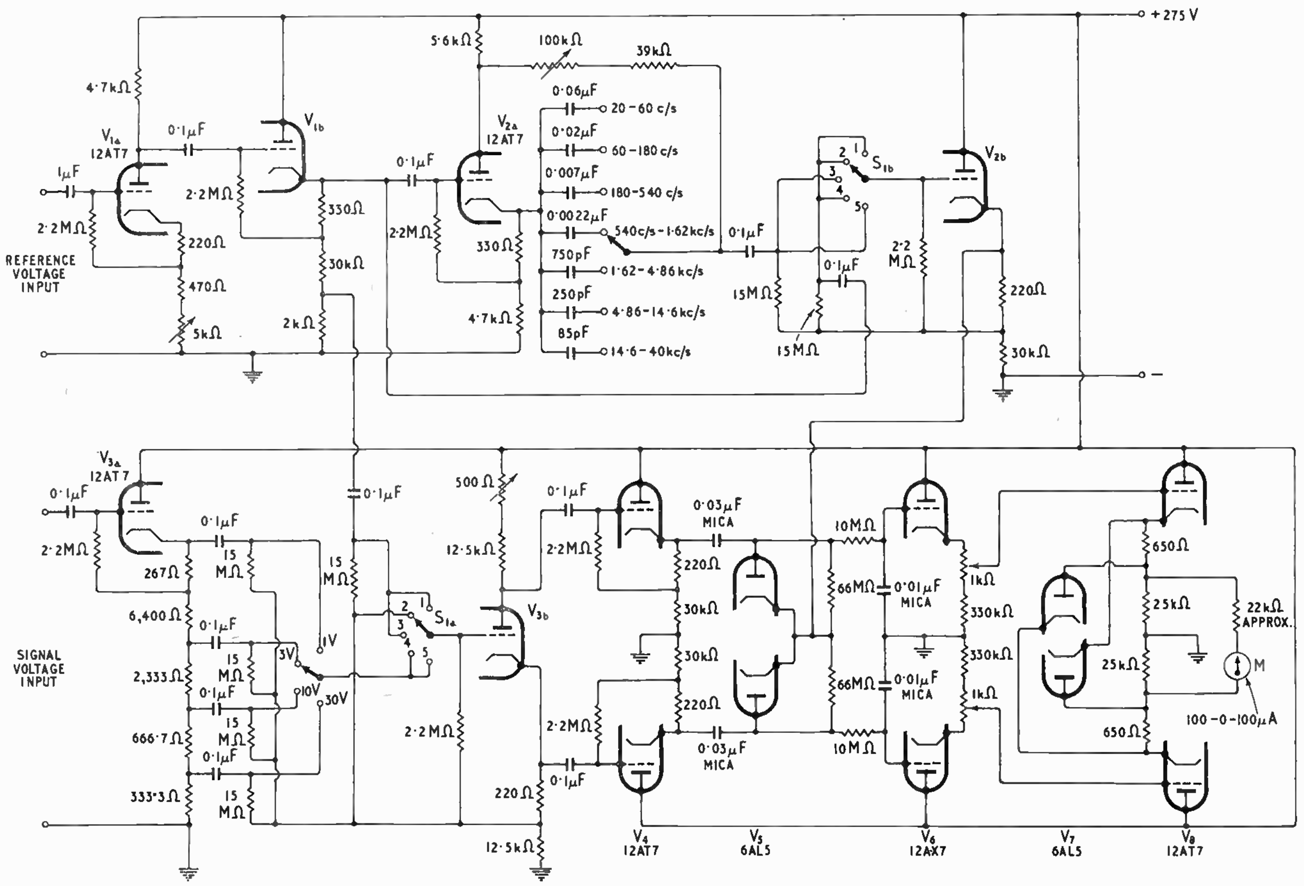


Fig. 5. *Schematic circuit of phase-sensitive voltmeter. The five potential-divider resistors in the cathode circuit of valve* V_{3a} *and the five resistors in the cathode circuit of valve* V_8 *are of precision-type*

The large currents passed by high-slope valves prohibit direct connection to the high-resistance coherent detector and filter circuits; accordingly, impedance-transformer valves V_6 are inserted. One potentiometer in the cathode circuits of V_6 is the voltmeter "set zero" control, the other being adjusted only when valves are replaced.

A further consequence of large current flow in valves V_8 is that the meter movement requires to be protected against overload. This is accomplished by valves V_7, the diodes having a bias of about 4 volts negative (in the quiescent state) by cathode currents in valves V_8.

(vii) *Power Supply*

The stringent phase-shift specifications prohibit the use of *RC* decoupling circuits; consequently, coupling between channels is avoided by using a regulated power supply having low internal impedance over the entire frequency range. A conventional supply delivering 60 milliamps at 275 volts d.c. with an internal impedance of near 2 ohms is satisfactory.

The heaters of all valves may be connected in parallel and operated at about 75 volts positive from a suitable potential divider in the high-tension supply circuit.

Adjustments and Operation

A double-pole, five-position switch S_1 controls adjusting and reading procedure. The following are the engraved markings on the switch, and a description of its operation :—

Position (1) 'Set V ref'. The in-phase reference voltage is fed to the coherent detector, and a portion of this voltage is also fed to the signal channel. The reference-voltage gain control is adjusted to give full-scale deflection on the meter.

Position (2) 'Set Zero'. The portion of the reference voltage fed to the signal channel is now removed and the valve voltmeter 'set zero' control is adjusted to give no meter deflection.

Position (3) 'Set Phase-Shifter'. The quadrature reference voltage is fed to the coherent detector and a portion of the in-phase reference voltage is fed to the signal channel. The phase-shifter capacitors and resistor are adjusted to give no meter deflection.

Position (4) 'Read in-phase'.

Position (5) 'Read quadrature'.

While adjusting the instrument, connections to the signal input terminals need not be removed.

Signal and reference channels require to be well isolated from each other. The switch contacts on S_{1b} require to be well removed from those on S_{1a}.

Acknowledgment

The author is grateful to Professor F. G. Heymann for several helpful suggestions.

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[1] M. J. Somerville, "An A.C. Potentiometer for Measurement of Amplitude and Phase", *Electronic Engineering*, 1956, Vol. 28, p. 308.

Transistor Impedance Matching

A NOTE ON A FUNDAMENTAL PROPERTY

By H. Paul Williams, Ph.D., A.M.I.E.E.*

In a large number of cases, transistor stages are required to operate with matched input and output impedances. The appropriate formulæ have been given by Wallace and Pietenpol[1] and by various other authors. Presented in the usual way, the equations are neither easy to memorize nor do they bring out the essence of the relationships.

In the course of using these formulæ, the writer came across a property of the matching impedances which does not seem to have been mentioned as yet in transistor literature. This property is that the product of the input and output impedances is, for practical purposes, the same for all three configurations. Expressed in symbols we have

$$R_{Gm}R_{Lm} = h_{11}/h_{22} \quad \ldots \quad (1)$$

where R_{Gm} = matched generator resistance.

R_{Lm} = matched load resistance.

h_{11} = input impedance with output s.c.

h_{22} = output admittance with input o.c.

Here, h_{11} and h_{22} are two of the hybrid parameters commonly used by manufacturers for their transistor data. It is immaterial whether the h parameters refer to the earthed base, emitter or collector configurations, provided the same configuration is used for both h_{11} and h_{22}.

In terms of the equivalent-T parameters we have:

$$R_{Gm}R_{Lm} = r_c[r_e + (1 - \alpha)\, r_b] \quad \ldots \quad (2)$$

where r_c = collector resistance.

r_e = emitter resistance.

r_b = base resistance.

α = current gain for earthed base.

The emitter resistance is $25/I_e$ ohms, where I_e is the emitter current in mA. Hence for an emitter bias of 1 mA, the product $R_{Gm}R_{Lm}$ will be some 30 to 40 times r_c. Since a common value for r_c is about 1 MΩ, the product will be of the order of 30 to 40 × 10^6.

The ratio of the matched impedances is given by the following simple formulæ.

(i) *Earthed Base*

$$\frac{R_{Gm}}{R_{Lm}} = h_{11}h_{22} + \alpha h_{12} = \frac{r_e + r_b}{r_c} \quad \ldots \quad (3)$$

(ii) *Earthed Emitter*

$$\frac{R'_{Gm}}{R'_{Lm}} = b(h_{11}h_{22} + \alpha h_{12}) = b\,\frac{(r_e + r_b)}{r_c} \quad \ldots \quad (4)$$

(iii) *Earthed Collector*

$$\frac{R''_{Gm}}{R''_{Lm}} = b \quad \ldots \quad (5)$$

In the above equations

$$b = \frac{\alpha}{1 - \alpha} \quad \ldots \quad (6)$$

These equations assume that r_c and $(1 - \alpha)r_c$ are much greater than r_e or r_b. These conditions are amply fulfilled by junction transistors.

* *Weapon Division, The Fairey Aviation Co. Ltd.*

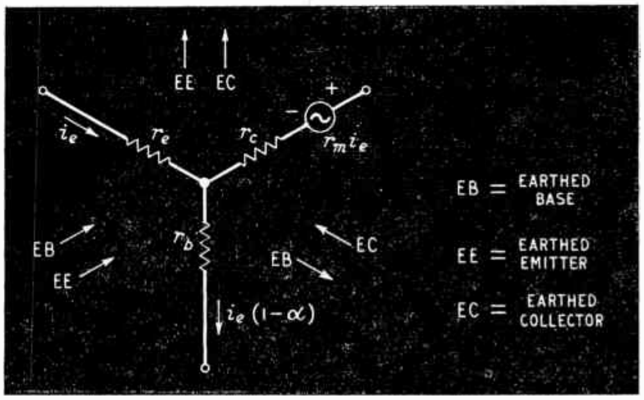


Fig. 1. *Equivalent-T network of transistor*

A further simplification has been made by writing b for $(b+1)$; this will only introduce errors of a few per cent.

Comparing equations (4) and (5) we see that if $b^2 = r_c/(r_e + r_b)$ then

$$\frac{R'_{Lm}}{R'_{Gm}} = \frac{R''_{Gm}}{R''_{Lm}}$$

i.e., the input and output impedances are interchanged.

When this is the case (and for junction transistors it is often at least approximately true) then earthed-emitter and earthed-collector stages can be cascaded without matching transformers.

Using equation (1) or (2) in conjunction with (3), (4) or (5) we can readily determine the appropriate matching impedances.

As an example, we may take the following typical values.

$$\alpha = 0{\cdot}975$$

$h_{11} = 37{\cdot}5$ ohms, $h_{12} = 0{\cdot}5 \times 10^{-3}$, $h_{22} = 10^{-6}$ mhos

i.e., $r_e = 25$ ohms, $r_b = 500$ ohms, $r_e = 1$ megohm.

Then we have:

$$R_{Gm}R_{Lm} = R'_{Gm}R'_{Lm} = R''_{Gm}R''_{Lm} = 37{\cdot}5 \times 10^6$$

The matched impedances values as obtained from equations (3) to (5) are set out in the table below.

	Generator/Load Resistance Ratio	Resistance in Ohms	
		Generator	Load
(i) Earthed Base ..	$\frac{1}{1,900}$	140	267,000
(ii) Earthed Emitter..	$\frac{1}{47}$	890	42,000
(iii) Earthed Collector	40	39,000	970

Making the same approximations as mentioned above, we can express the matched power gain G_m, as follows:

(*i*) *Earthed Base*

$$G_m = \frac{\alpha^2 r_c}{5r_e + (5 - 4\alpha)r_b} \quad \ldots \quad (7)$$

(*ii*) *Earthed Emitter*

$$G'_m = \frac{\alpha b r_c}{r_e + r_b}\left[1 + \sqrt{\left(1 + \frac{b r_e}{r_e + r_b}\right)}\right]^{-2} \quad \ldots \quad (8)$$

(iii) *Earthed Collector*

$$G''_m = b + 1 \quad \ldots \quad (9)$$

Equation (8) does not permit further simplification because br_e is of the same order as $(r_e + r_b)$. In most cases the bracketed term squared will have a value lying between 5 and 15, in which case comparison with (7) indicates that the power gain will be at least $b/10$ times greater for the earthed-emitter configuration.

In our example we have:

$G_m = 1{,}410$ i.e., 31·5 dB.
$G'_m = 10{,}100$ i.e., 40 dB.
$G''_m = 41$ i.e., 16 dB.

APPENDIX

Calculation of Product $R_{Gm}R_{Lm}$

Fig. 1 gives the equivalent-T network for a transistor and shows the input and output paths of these configurations by means of arrows. The open- and short-circuited impedances are given in the table below (assuming the same approximations as in the text). To avoid going outside the usual range of symbols, the short-circuited values will be expressed as admittances.

	R_{11}	$1/G_{11}$	R_{22}	$1/G_{22}$
(i) Earthed Base	r_e+r_b	$r_e+r_b(1-\alpha)$	r_c	$r_c\left(1-\frac{\alpha r_b}{r_e+r_b}\right)$
(ii) Earthed Emitter ..	r_c+r_b	$r_b+r_e(1+b)$	$r_c(1-\alpha)$	$r_c\left(1-\frac{\alpha r_b}{r_e+r_b}\right)$
(iii) Earthed Collector ..	r_c	$r_b+r_e(1+b)$	$r_c(1-\alpha)$	$r_e+(1-\alpha)r_b$

From the above Table we see that

$$\frac{R_{11}}{G_{22}} = \frac{R_{22}}{G_{11}} = r_c\left[r_e + (1-\alpha)\,r_b\right] \quad \ldots \quad (A.1)$$

in all three configurations.

Now the matched impedances are given by the square root of the product of the open- and short-circuited impedances; i.e.,

$$R_{Gm} = \sqrt{\frac{R_{11}}{G_{11}}} \quad \ldots \quad (A.2)$$

$$\text{and } R_{Lm} = \sqrt{\frac{R_{22}}{G_{22}}} \quad \ldots \quad (A.3)$$

Using equation (A.1) we find that the product of the matched impedances is

$$R_{Gm}R_{Lm} = \sqrt{\frac{R_{11}}{G_{22}} \cdot \frac{R_{22}}{G_{11}}}$$
$$= r_c[r_e + (1-\alpha)\,r_b] \quad \ldots \quad (A.4)$$

This is equation (2) of the main text.

If one remembers the principle and wishes to obtain equation (A.4) this can be done most easily by forming the product R_{22}/G_{11} for the earthed-base case. It is obvious that with the input open, the output impedance equals $(r_c + r_b)$ which, neglecting r_b, gives us $R_{22} = r_c$. Then $1/G_{11}$ is given by shorting the output, which leaves us with r_e plus r_b and r_c in parallel: the latter can be neglected, while r_b carries only $(1-\alpha)$ of the emitter current and hence $1/G_{11} = r_e + (1-\alpha)r_b$.

It will be noticed that in terms of hybrid parameters we have $R_{22} = 1/h_{22}$ and $1/G_{11} = h_{11}$, consequently $R_{22}/G_{11} = h_{11}/h_{22}$.

REFERENCE

[1] R. L. Wallace and W. J. Pietenpol, "Some Circuit Properties and Applications of n-p-n Transistors", *Proc. Inst. Radio Engrs*, July 1951, Vol. 39, p. 753.

LIGHT-WAVES AND PHOTONS

In his every-day work, the electronic engineer does not often become involved in the question, which is probably a meaningless one, of whether electromagnetic radiation is a wave motion or a stream of particles. He knows that it is sometimes necessary to treat it as one and sometimes as the other.

He does, however, sometimes come up against the matter when, for instance, he finds that a beam of electrons can be considered as having a wavelength! More often, he runs up against it in photoelectric devices where photons and quanta impose the need for using in some measure a particle theory of light.

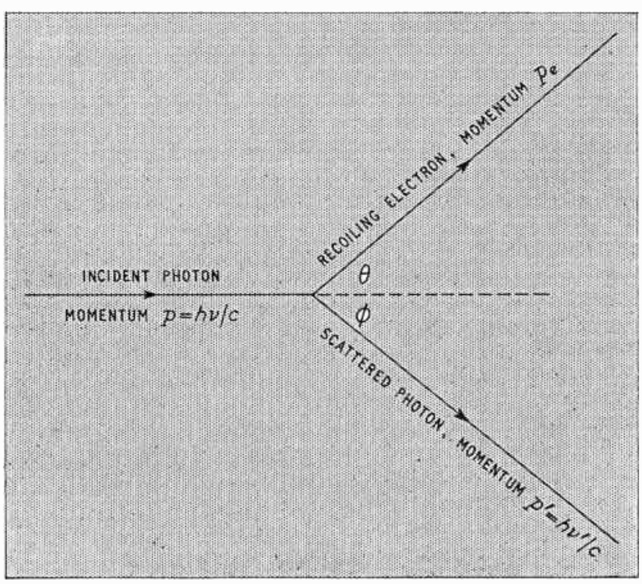
In their monumental "Principles and Applications of Physics", Bluh and Elders say that the really difficult concepts are those of classical physics, such as Ohm's law and the conservation laws, and that it is relatively easy to visualize the elementary particles of modern physics, meaning protons and neutrons, electrons and photons. Between ourselves, I think that this is an over-simplification, for I have found in so many pupils a deafness to the charms of Ohm's law which was not over-compensated by visual acuity in electronics.

Moreover, when some recent articles in *Nature* on experiments with photons set me trying to picture these light-particles in simple terms, I found that it was much more difficult than I expected. It is all very well to say that they obey Bose-Einstein statistics, to call them bosons familiarly as if you were a boson's mate, and talk of their unit spin. This is as helpful as telling somebody who wants to draw a cricket ball that there are six balls to an over and you tie the batsman down with off-spinners. The reason why it is hard to picture them may be that one just accepts photons when it is convenient to do so, and usually gets along quite nicely with radiation in terms of Maxwell's equations or their equivalent.

Fig. 1. *Illustrating the Compton Effect. The vector lines represent to scale the* momentum *of the incident and scattered photon, and the recoiling electron. Momentum is conserved, so that*

$p = p_e \cos\theta + p' \cos\phi$, *and* $p_e \sin\theta = p' \sin\phi$;

Also, energy is conserved so that $h\nu - h\nu'$ *equals the kinetic energy of the electron*



Electrons and such-like are much more clearly imaginable as particles. So much so that they are often featured prominently in the more highbrow kind of advertisement, as if familiarity with their looks could be taken for granted. The visualizing difficulty with electrons comes when the theorists produce their wave equations; the situation is reversed with photons. The best one can do as a first attempt is to think of a kind of guided missile; and it is this picture that has led me into trouble.

As with so many other modern ideas, the concept of the light-particle really dates back to Newton. The following suggestions occur in the "Opticks":

that "Rays of Light are very small Bodies emitted from shining Substances";

that "they be small Bodies which, by their attractive Powers, or some other Forces, stir up Vibrations in what they act upon, which Vibrations being swifter than the Rays, overtake them successively and agitate them so as by turns to increase and decrease their Velocities";

that in the eye "several sorts of Rays make Vibrations of several Bignesses, which according to their Bignesses excite Sensations of several Colours";

and that "the changing of Bodies into Light, and Light into Bodies, is very conformable to the Course of Nature".

Assembling all these statements, something approaching the generally held view of a photon seems to emerge, although there are at least two missing features; these are the concepts of energy, and of uncertainty.

The modern idea of the photon started with the energy quanta of Planck; vibrations, or radiations, of frequency ν *transfer* energy in packets or quanta of magnitude $e = h\nu$. Here, if e is in ergs and ν in sec^{-1}, the value of Planck's constant h is $6{\cdot}5 \times 10^{-27}$. From this, it might at once be inferred that radiation *consists* of discrete quanta $h\nu$, travelling with velocity c, possessing momentum $h\nu/c$ and effective mass $h\nu/c^2$. But this is jumping to conclusions, for Maxwell's equations and classical radiation theory already describe quite satisfactorily how the energy travels. This is the first difficult step, and Bohr's Correspondence Principle dealt with it by showing that the only kind of energy changes which

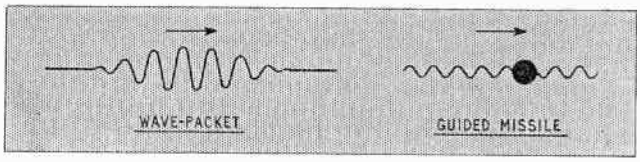


Fig. 2. *Wave-packet and guided missile. Counterfeit presentments of the photon?*

could result in the emission of a photon were those with which classical electromagnetic theory could deal once it was let loose. Quantum mechanics has confirmed this. The first conclusion then was a little rash; because even if photons are still present in the radiation as it travels, they do not need to be.

Photons in Action

But the mechanism of photoelectric emission, and also the Compton effect (1923) reveal photons in action. In the Compton effect, the scattering of a fine beam of monochromatic X-rays by electrons shows that the law of conservation of momentum applies for the interaction between photon and electron just as for two material particles. In Fig. 1, the incident photon of momentum $h\nu/c$ rebounds with reduced frequency ν' and momentum $h\nu'/c$ deflected through angle ϕ while the electron recoils with momentum p_e in a direction at an angle θ with the incident beam. Energy is also conserved, the difference $h\nu - h\nu'$ being imparted to the recoiling electron. In the earlier experiments, only ϕ was measured, and alternative explanations of the effect were possible; but the matter was established beyond all argument by experiments with gaseous scatterers by Compton and Simon, in which *both* the angles ϕ and θ were measured.

The Compton effect also helps one to understand the usual illustration of Heisenberg's Uncertainty Principle. Imagine that we try to 'see' an electron by directing a photon towards it and tracing it after the collision. The impact of the photon itself on the electron changes the momentum p and the position x of the electron, by amounts Δp and Δx, and so alters what we are trying to observe by it. The uncertainties Δp and Δx can never be less than those given by the equation $\Delta p \, . \, \Delta x = h$. If we try to evade this by choosing photons of lower ν which will disturb p less and make Δp smaller, then the reduced resolving power of our imaginary microscope increases the uncertainty Δx. No ingenuity can escape this limitation to what can be observed. Again, any attempt to ascertain the energy E of a particle at a determined time t is subject to uncertainties ΔE and Δt which can never be less than those given by $\Delta E \, . \, \Delta t = h$.

Strangely enough, the Uncertainty Principle leads to a more *precise* idea as to what we can legitimately call a particle. And with its help we may perhaps make the idea of the photon a little clearer. Let us take the line that photons are only manifested while radiation is *engaged in acting* on electrons (or other particles), not while it is travelling on the way to do so. M. Born, in his "Atomic Physics", says that light consists of a hail of light quanta, which can knock out an electron the moment they strike a metal; suppose that the quanta are generated on the spot, though?

The justification for regarding an electron itself as a particle is that it can be specified as having a given linear momentum p and position x, subject to the uncertainties $\Delta p \, . \, \Delta x = h$. A continuous wave, of course, carries momentum and, indeed, in the mathematics of Hamilton, waves can be described in terms of p and the equivalent of x, but by *continuous* functions. Uncertainty introduces the discontinuity which is characteristic of particles. When wave and particle interact, the place of interaction is uncertain to the extent Δx, and the linear momentum exchanged is uncertain to the extent Δp, from the point of view of the giver as well as the receiver. Therefore, during the interaction, the electron has inflicted its own uncertainties, and also its particle behaviour, upon the radiation. Although this may sound a rather artificial argument, it is almost the Correspondence Principle restated, and seems to have been put forward in the 1920s; to a non-mathematician it still seems attractive.

Another point of view is suggested from the photon's quantum energy $e = h\nu$. How monochromatic can a photon be? If the uncertainties in e at a given t are given by $\Delta e \, . \, \Delta t = h$, then as $e = h\nu$, $\Delta \nu \, . \, \Delta t = 1$. Now, this relation is exactly that found for the uncertainties of a radar pulse. By breaking down the pulse into Fourier components and doing the necessary transforming, it can be shown that the bandwidth $\Delta\nu$ of the pulse and the time-accuracy Δt with which it can be located are given by $\Delta\nu \, . \, \Delta t = 1$. While then, from the momentum point of view the photon appears as a particle, from the energy point of view it qualifies as a wave-packet with a finite spread of frequencies, Fig. 2. One is accustomed to the description of particles, or rather of the probability of locating them, expressed in terms of the mysterious Ψ of wave-mechanics; but the photon wave-packet is different, for it is something involving the electromagnetic waves themselves, which is perhaps easier to appreciate.

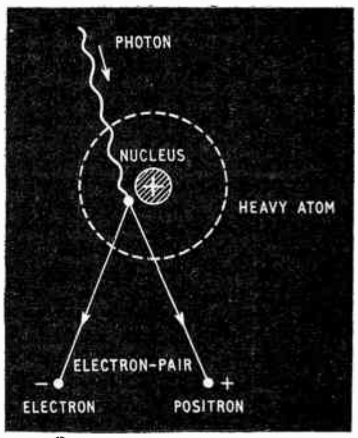


Fig. 3. *Conversion of an energetic photon into an electron-pair in the neighbourhood of the nucleus of a heavy atom. The energy requirement is that $h\nu$ for the photon shall exceed the mass-energy (mc^2) for the two particles together*

Wave-Particle Interaction

But it does not follow that this analogy from radio is complete. What happens at the end of the journey may play a decisive part, for the photon cannot reveal its

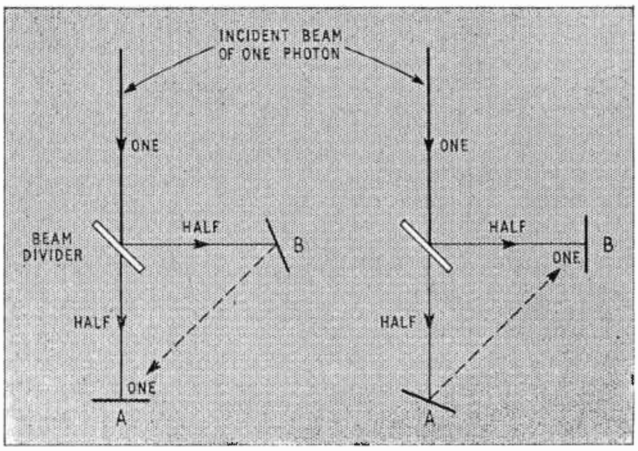


Fig. 4. *Following Dirac's warning, no attempt has here been made to draw a photon. The legends ONE and HALF represent the probability of the photon being considered in either beam or found at the end of it. The capital ONE indicates the photon which is actually found either at A or at B but not at both. To B, or to A? That is the question*

uncertainty property until the interaction occurs, and it does not necessarily follow that what is received as a wave-packet at some point has travelled all the way there as a wave-packet. Monochromatic sea waves turn into wave-packets and discontinuous breakers only when they undergo dispersion caused by a shelving beach. Photons only appear in the neighbourhood of particles. We can imagine that the wave-packets are generated when the field of a particle itself introduces dispersion. Experiment lends some support for this view; the conversion of high-energy photons into electron pairs happens only in the field of an atomic nucleus (Fig. 3); never, so far as is known, does it occur spontaneously.

I must say that the electron-cascade process observed in cosmic-ray events, when a very energetic particle generates photons which proceed to generate electron-pairs which generate more photons, and so on, is best described simply in the kind of diagram one draws for the avalanche process of ionization by collision. But, even in this, the emission and arrival of photons, rather than their transit, are concerned.

Wave-packet or guided missile? "Look here upon this picture, and on this; the counterfeit presentment of two brothers." But there is a third alternative or, to the stickler for English, a third possibility. The brother who really stimulated all the action in *Hamlet* was by that time unpresentable and uncounterfeitable, for he was an exceedingly schizophrenic kind of ghost. And this is how the photon appears when we examine its properties closely in terms of modern theory.

The mysterious workings of quantum-mechanical field theory show that photons do not interact with one another to any significant extent—the probability can be written down, but is quite unintelligibly small. In statistical terms, this mutual inoffensiveness leads to a rather interesting result, for it means that when the probability of finding an energy state *e* which *might* contain a photon has been calculated, it is impossible then to say *how many* photons will be there.

In practical terms, it means that if a hail of photons were indeed present all the time in a beam of light, it would never been possible to establish this; for they could only be revealed by some sort of interaction between them, and there is none. Well, but what about optical interference? Here I can only quote Dirac. If we suppose a single photon striking a beam-splitting arrangement in any interference apparatus, we do not ask which beam it goes into, for ***it goes into both.*** So long as the photon is partly in one beam and partly in another, interference can occur when the two beams are superposed. But the act of observation means extracting it by some kind of action, and this can only happen in one of the beams (Fig. 4). Dirac goes on to emphasize the futility of trying to construct a picture of all this, which is just what I have been trying to do.

Photon Correlation

I think that what the theory calls a photon in transit is simply the probability of finding one, which is clearly the same for both beams; and what most people call a photon is the energy quantum observed in one of them at the end. But one point is quite clear; the probability-photons never interfere with one another, and each interferes only with itself. Coming back for a moment to the wave-packet and electromagnetic waves, it looks also as if what we ordinarily speak of as electromagnetic waves are what this theory takes as the probability-photons, with the Poynting vector representing the probability. I am not sufficient of an expert to follow all the arguments in this kind of work, and indeed with Dirac's "Principles of Quantum Mechanics"; the whole is on an abstract plane that is really difficult to understand. But I think the essential point for appreciating the experiments which led to all this fruitless search for a picture has been made. If a beam-splitting experiment is done, since each of the quite unpicturable photons is in *both* beams, there is nothing whatever except the act of observation to distinguish between the beams. A photon-counter placed in either should record the same *average* reading. Two photon-counters placed, one in each, should give the same *average* reading. And, if these are sensitive enough to respond to single photons, while their statistical fluctuations will not, from the very nature of the uncertainty process, be identical, there will be a correlation between these fluctuations. This is what was indeed observed by R. Hanbury Brown and R. Q. Twiss, in an experiment described in *Nature*, 7th January 1956.

A light beam was split into two coherent portions by a half-silvered mirror, and a narrow beam fell on each of two photomultipliers; their outputs were amplified, and the correlation between their fluctuations determined. The result agreed with the correlation to be expected when the photomultipliers were in optically corresponding positions, and also when they were 'out of register'. The authors conclude that the experiment shows beyond question that the photons in two coherent beams of light are correlated, and that this correlation is preserved in the process of photoelectric emission. It is in this conclusion that I found my difficulty; for is not the appearance of a photon merely the first stage in the act of photo-emission, and the coherence persisting until that stage a purely classical wave property?

A different type of experiment by E. Brannen and H. I. S. Ferguson (*Nature*, 1st September 1956) attempted to detect *coincidence* between photons from the two halves in the split beam. This was not observed;

and indeed individual coincidence is quite a different thing from correlation of fluctuations! But the interesting point about their conclusion is that they held that any correlation would be contrary to the rules of quantum mechanics! This point was taken up by Hanbury Brown and Twiss, and also by E. M. Purcell (*Nature*, 29th December 1956), who showed that it was erroneous and that indeed the two sets of experiments were consistent with one another, and with accepted theory.

I still feel these photons are being treated as guided missiles. All the authors speak of the correlation of photons 'in' coherent light rays. It may be that this is as far as ordinary language can go towards expressing quantum-mechanical ideas, and that I have been asking too much, or even splitting hairs, in trying to delve deeper. I cannot reconcile myself to the guided missile, though, and almost feel that Dirac's probability-photons are simply Maxwell's equations dressed up a bit.

The 1954 edition of W. Heitler's "Quantum Theory of Radiation" was more helpful than Dirac, in confirming the idea that participation in an uncertainty-principle event is what really demands particle behaviour from an electromagnetic wave. Morale began to fall, however, as Heitler produced longitudinal photons, scalar photons, and even *virtual* photons—the ghost of a ghost; but it returned to normal as I began (I think) to understand at last. For, however tangible the name makes it sound, the photon is not a "thing"; it is a mode of behaviour! Which is just about where we came in.

Here for the moment I must leave the topic. I was led to it by the account of Hanbury, Brown and Twiss of their measurement of the angular diameter of Sirius, in which they adapted their intensity radio interferometer principle for use with photocells in the visible region. The work, described in *Nature*, 10th November 1956, is obviously far too important to discuss briefly in an article of the present kind. You should read it for yourselves, as it is a most exciting piece of work, in which all that the radio-astronomers have borrowed from physical optics is repaid tenfold and with interest. Incidentally, they say there, that the experiments described in January established that the *time of arrival* of photons in coherent beams of light is correlated. I think that this does after all partly meet one of my difficulties; if I succeed in clarifying the remainder any further, you shall be the first to hear about it.

Printed-Circuit Directional Coupler

A useful type of symmetrical directional coupler[1] employs coupled transmission lines. One physical form of the device employs lead-covered cable arranged as in Fig. 1. The manufacture of such a coupler entails accurate milling of flats on the cable, and great care in soldering lest the polythene insulant should melt.

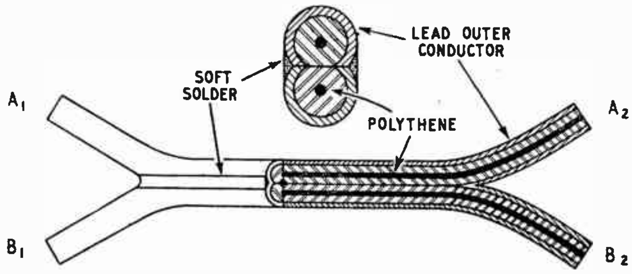
By employing strip-line instead of cable, a printed-circuit equivalent is possible and an actual coupler, comprising a through line and two auxiliary lines, has been manufactured by Printed Circuits Ltd. The instrument serves as a match indicator, reflectometer, and true output power monitor over the frequency range 150–500 Mc/s. Standing-wave ratios down to 1·2 to 1 can be measured at 500 Mc/s with an accuracy of 20%. It is simple, compact and robust.

The printed circuit is made from a laminated paper board, copper clad on both sides. One side of the board consists of three short sections of transmission line, each having a characteristic impedance of 75 ohms. On the other side of the board the copper is retained. The transmission lines are therefore of the single strip above an earth-plane type, with a laminated-paper dielectric. Fig. 2 shows the actual printed circuit used.

The middle strip-line carries the radio-frequency energy and the two auxiliary strip-lines, one on each side of the main line, are coupled to it by virtue of their mutual capacitances and inductances. The direction of the current so induced in each auxiliary line due to the couplings is such that the two components will tend to cancel in one direction and add in the opposite direction. The resulting voltages obtained across the auxiliary line terminations are, therefore, dependent on the direction of power flow in the main line; i.e., the unit will exhibit directional properties.

From the circuit, Fig. 3, it can be seen that detectors are connected across the diagonally-opposite terminations. For any given direction of power flow in the main line, the indication from one detector will be a measure of the forward power and, that from the

Fig. 1. *Directional coupler made from coaxial cable*



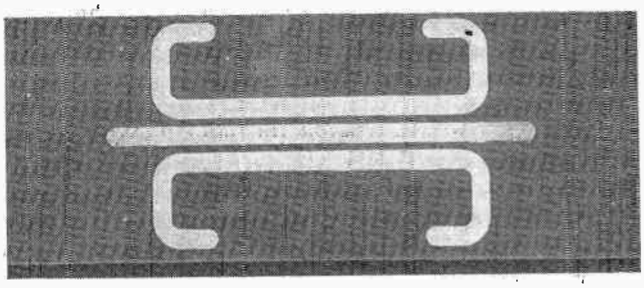


Fig. 2. *View of one side of printed circuit panel, showing the three strip-line conductor*

other, a measure of the reflected power. A 50-μA meter connected to either termination monitors these powers.

The unit may also be connected in a transmission line to monitor the actual transmitted power. The external meter is then connected so that the detected current due to the reflected power is in opposition to that due to the forward power.

Before use, the detector and meter circuits must be balanced for the frequency and power level at which the instrument is to be used. The sensitivity of the meter circuit is adjusted in each case by the variable resistor. This is performed by connecting the instrument between a source of r.f. power and a suitable load or output meter. With the r.f. tuned to maximum output, and the negative side of the 50-μA meter connected to the terminal nearer the r.f. input (the positive side of the meter to earth), the potentiometer adjacent to that terminal is adjusted so that the meter reads approximately full scale. The match meter is then reversed so that the r.f. is fed in from the other end of the line, and the potentiometer adjustment repeated, using the terminal and potentiometer which are now nearer the r.f. input. The match meter is now set for this frequency and output, and should be re-balanced before using on another frequency or power level. The unit has been designed so that the meter connected to the terminal nearer the r.f. source will read transmitted power and, when connected to the terminal nearer the load, will read reflected power. If two meters are used, one connected to each terminal, then both forward and reflected powers can be read at the same time. The meter readings are very nearly proportional to voltage; i.e., proportional to the square root of the power.

For measurement of reflection coefficient, if V_1 is the reading for the forward power, and V_2 is that for the reflected power, then the reflection coefficient is given by

$$RC = \frac{V_2}{V_1}$$

and is usually expressed as a percentage.

The standing-wave ratio can be evaluated from the formula

$$SWR = \frac{V_1 + V_2}{V_1 - V_2}$$

When used for the alignment of the grid circuit of power amplifiers (the function for which the instrument was originally designed), it is connected between the driver stage and the power amplifier, and the grid circuits of the amplifier are adjusted so that the reflected power reading is as near zero as possible.

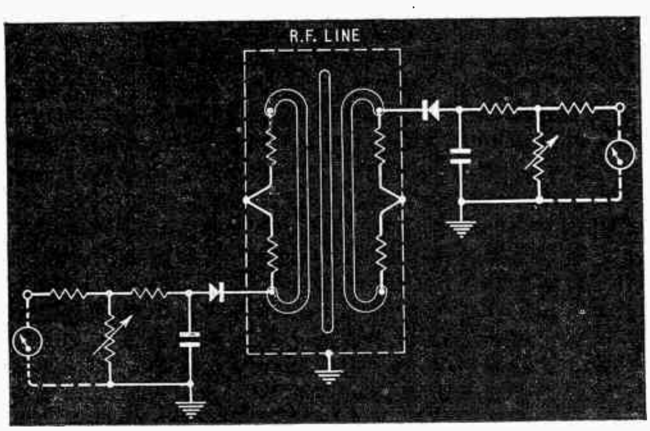
As an output monitor, the match meter, having been balanced as described, is connected in the transmission line between the output amplifier and the aerial, with a 50-μA meter across the two terminals. The reading obtained will depend upon the power being transmitted and will read zero if either the power fails or a break occurs between the amplifier and the aerial.

The printed circuit of Fig. 2 measures about $4\frac{1}{2}$ in. by $1\frac{1}{2}$ in., and the phenolic paper base board is $\frac{1}{8}$ in. thick. The complete unit is of similar length and breadth but is $3\frac{3}{4}$ in. deep. This compares favourably with the original experimental units made from lead-covered coaxial cable, in which pieces of $\frac{1}{2}$-in. diameter cable, 16–20 in. long, were used. Apart from the reduction in size, constructional difficulties are eliminated by the printed circuit, which is inexpensive and can be held to quite close tolerances. Constructing the directional coupler on the printed circuit involves nothing more than simple soldering of components to the copper foil.

One attempt to make a coupler from coaxial cable involved milling flats along each of two lengths, placing together the flat sides of the two D sections thus formed, and soldering, as indicated in Fig. 1. The resulting coupler was satisfactory electrically, but was far from being a production proposition by reason of the skill and labour involved in its manufacture.

Thus, although it is often said of the printed circuit that it is only suitable for use in long production runs, in this type of application ease of manufacture and reproducibility make it an attractive proposition even though smaller numbers may be required. In the type of application considered above, the printed circuit is more than a device for fabricating wiring ; it is rather a means of producing specially-shaped conductors to specified tolerances. This work would normally have to be done in the machine shop, where costs are high, instead of on the wiring bench. In such circumstances, the minimum economic quantity of printed circuits may be very small. In cases where a printed-circuit board can replace an intricately-shaped part stamped out of sheet metal, the new technique is of great value. Once a prototype design has been completed, it is then only a matter of making a suitable black-and-white large-scale drawing of the component to enable the printed circuit to be produced.

Fig. 3. *Circuit diagram of printed-circuit match indicator*



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[1] G. D. Monteath. "Coupled Transmission Lines as Symmetrical Directional Couplers", *Proc. Instn elect. Engrs*, Part B, No. 3, May 1955.

Triode Amplification Factor

CURRENT THEORY RE-EXAMINED

By P. Hammond, M.A., A.M.I.E.E.

Electrical engineering and electrical science have always been the closest of partners. A little reflection will show that this statement is by no means self-evident because in other branches of engineering and of science the partnership has not been so close. The cathedrals of the middle ages were built largely without structural analysis and successful heat engines were and are built in which the ingenuity and experience of the engineer counts for more than the scientific precision of thermodynamic theory. In making such statements we are not passing judgment or saying that things ought to be different, we are merely clearing our minds of a popular misconception. Science has 'hit the headlines' in the popular press and much is attributed to science that has only the remotest connection with scientific thought.

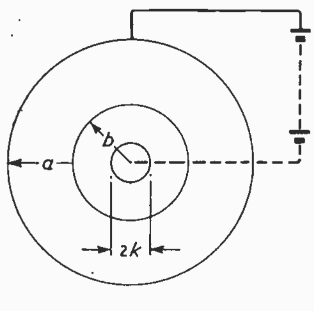

Fig. 1. *Cross-section of cylindrical diode*

(Reproduced by courtesy of I.E.E.)

Often the 'scientist' gets the credit for the ingenuity and artfulness of the engineer.

In electrical matters, however, engineering and science have perforce been on far more than speaking terms. Without a Faraday there could have been no Ferranti, without a Maxwell no Marconi. The engineer could not even get hold of the mysterious substance 'electricity' until the scientist had postulated that there was such a substance and that certain measurable phenomena could be attributed to it. This throws light on the relatively late development of electrical engineering in comparison to the age-old skills of the civil and mechanical engineer.

But, even in electrical matters, art and science are not different names for the same thing. Not infrequently the scientist concerns himself with problems that have no relevance to intended manufacture, while the engineer builds devices that work beautifully, although their scientific basis can only be dimly discerned.

A classic example of this latter case is illustrated by a recent I.E.E. monograph entitled "On the Amplification Factor of the Triode".[1] When millions of triodes have been built and when the triode itself is regarded as the aged grandparent of a large family of multi-grid valves, one will surely ask whether anything remains to be said on such a simple and well-understood subject. But when the author of this paper is Professor E. B. Moullin and one knows something of his skill in the clear exposition of intricate electromagnetic problems, a doubt arises whether the triode operation is really such a well-understood subject. It is no argument to say that triodes have been and are being successfully made—excellent meals are prepared by those whose chemical knowledge is not their strongest point.

Early Theory

Professor Moullin himself appears to have had misgivings about the novelty of his approach. His paper starts with a review of earlier work on the subject. It is interesting to find that van der Bijl as early as 1913, only seven years after the discovery of the three-electrode valve, was able to lay down an experimentally-determined relation for the action of a triode and that this equation $I_a = f(V_a + \mu V_g)$ has stood the test of time.

There is, however, a considerable difference between postulating an equation from an experimental curve and deriving such an equation from first principles. The reasoning of van der Bijl was based on the view that the positive charge on the anode, screened to some extent by the negative charge on the grid, pulled the electrons away from the cathode. This view is clearly expressed by Möller, who is quoted as follows: "The anode sends through the grid-turns lines of force into the cathode space, which get hold of space-charge electrons and pull them towards the anode". The German term for this is 'Durchgriff' and Möller defines $1/\mu$ as the 'Durchgriff', where μ is the amplification factor. This view of the action of the triode appears to be eminently reasonable and it is widely held. Those who, like the present writer, do not find it comfortable to have such views shattered will read Professor Moullin's paper all the more carefully, hoping that perhaps his attack on their beliefs cannot be sustained.

In his attack on the concept of 'Durchgriff', Professor Moullin first considers the problem of the diode. Fig. 1 shows a cylindrical diode, with an anode of radius a and a cathode of radius k. Consider now the passage of electrons from cathode to anode. Electrons leave the cathode with finite velocity, but they do not all reach the anode. It follows that the electric force close to the cathode must be directed towards the cathode. In other words, the cathode must have a certain positive charge, although it is connected to the negative end of the battery. At some distance from the cathode, however, the electric force must be towards the anode. Hence it follows that between cathode and anode there must be a surface where the electric force reverses its direction; i.e., a surface of zero electric force. This 'barrier' surface is shown at radius b. If the anode were to act in the manner described by van der Bijl and Möller, its field would have to penetrate the barrier surface. But it is an immediate consequence of the inverse square law that a cylindrical conducting surface cannot produce any electric field in the space that it surrounds.

Readers may remember that the first introduction of the inverse square law into electricity came in a very similar context to the one discussed here. Joseph Priestley about 1760 observed that there was hardly any electric force inside a charged cup. He remembered that Newton had proved a hundred years earlier that inside a charged sphere there would be no force if the charge obeyed an inverse square law of force. Newton had not been thinking of electricity but of gravitating matter, when he proved his theorem, but Priestley at once suggested that electricity might also obey this well-known law.

Further experimental investigations confirmed Priestley's idea. Cavendish found no electric force inside a charged sphere and Faraday had sufficient faith in the theory to sit inside a highly charged box. His instruments showed that there was no electric force inside, although sparks were darting from the outside! Accordingly it is one of the best-known electrical principles that the electric force inside a long charged cylinder is zero.

Well known though all this is, it has eluded engineers that the charge on the anode of a valve can consequently have no effect within the valve. The electrical force inside a diode necessarily arises entirely from the charge on the cathode or from the electrons in flight. Moreover, the existence of a surface of zero force close to the cathode, the barrier surface mentioned above, implies that at a radius greater than b the force in a diode can arise only from the electrons in transit. Surely it is a bad simplification to say: "Well, after all, it amounts to the same thing as if the force arose from the charge on the anode."

This same argument holds for a grid. This grid would be placed at a radius larger than b and hence it in turn cannot produce a force at any radius smaller than b. (Professor Moullin shows mathematically that the field of a grid of wires does not differ much from that of a closed conducting surface, except at places very close to the grid.) Thus are all our notions shattered, and one cannot help detecting a smile behind the professorial statement that "there must be some small element of confusion in the time-honoured concept of Durchgriff." Indeed, it is shown that any electron in its passage from barrier surface to anode can only be acted on by the charges behind it. This is certainly a novel concept.

Planar Electrode Structures

However, at first sight it appears that this way of looking at the subject is only essential in dealing with a cylindrical valve structure. Perhaps a planar anode can pull the electrons to itself, even if a cylindrical anode cannot. Professor Moullin is rightly wary of extending the treatment by using the asymptotic solution for a cylindrical anode of very large radius. A large cylinder is still a cylinder. Instead he treats the case of the planar diode from first principles. Once again it is shown that the net force on an electron in transit between barrier plane and anode arises from the electrons behind it. Moreover the mathematical analysis shows that the planar solution is the same as the asymptotic solution of the cylindrical case. Thus, Professor Moullin is able to generalize his treatment and he gives good reasons, by invoking Green's theorem, that his view must be substantially correct for electrode systems of any shape.

The argument so far has been applicable to diodes as well as triodes and it has been shown that the anode does not attract the electrons to itself, as a 'common sense view' might suggest. Professor Moullin, however, is not content to be destructive. He has shown that there cannot be any 'Durchgriff', how then can he explain the action of the grid in a triode? Once again he gives a close analysis of the views of previous writers. Van der Bijl is again cited, as are Eccles, Appleton and Chaffee. It is of very great interest to find that all these writers tackled the problem by first neglecting the effect of the space-charge electrons. Professor Moullin, however, points out very clearly that the only thing that causes the electrons to move towards the anode is the existence of the space charge. A treatment that neglects the very factor that causes a valve to operate can scarcely be applicable to the problem in hand. It is difficult to avoid the conclusion that the early investigators solved a problem in electrostatics which, by sheer good fortune, had a solution not unlike the electro-dynamic problem they hoped to solve.

By way of contrast the present treatment starts at once with a consideration of the current flow. The novelty and the secret of Professor Moullin's successful analysis rest largely on the fact that he solves the problem of triode action for an assigned constant anode current. This enables him to superpose the forces arising from the negative charge on the grid on the forces that would be present in a diode passing the same current. His method gives a hint as to how it came about that the older methods were so nearly successful.

The physical principles underlying the treatment are extremely satisfying and simple. As in so much of his work, Professor Moullin starts with the concept of charge. The fields that exist are described in terms of forces on charges and much of the analysis is an exercise in particle dynamics. Potential functions are introduced in terms of work done in moving a charge from one place to another. Thus, the conceptual system is simplified and this will commend this approach to the enquiring student. The present writer has never been entirely happy with the largely qualitative approach to inter-electrode capacitances. It is a pleasure to see that nothing is assumed in this paper about the existence of these capacitances. Professor Moullin even proves that the potential difference between the grid wires and the barrier plane, due to the charge on the grid, is proportional to that charge. Perhaps this was obvious, but it is stimulating to find that nothing is taken for granted.

Amplification Factor

There is a careful treatment of both the planar and the cylindrical triode and the amplification factor μ is calculated in each case. This factor turns out to be independent of the value of the current and Professor Moullin arrives at the well-known expression given by van der Bijl. As given by van der Bijl, this expression was only a tentative approximate solution to the problem of a triode, because space charge had been ignored. Now, however, it is shown that this 'workshop' approximation was in fact correct for all values of current. Van der Bijl's solution turns out to be far more successful than he may well have thought at the time. What remains unexplained, however, is how it came about that his treatment was accepted as rigorous and that no serious thought nor constructive criticism was applied to it for so long. In Professor Moullin's paper, tables are inserted giving helpful guidance about the numerical importance of various terms in the formulæ. An interesting paragraph examines the conditions that must be fulfilled if there is to be no grid current.

Professor Moullin is not oblivious of the mental upset that his treatment may cause. In an appendix he tries to meet the objection of the experienced user of the triode, who knows that the anode current will decrease when the grid is made more negative, the anode voltage remaining unaltered. If we are no longer able to say that the grid retards the electrons coming away from the cathode, how is the operation to be explained? In the view of the paper the increase of negative charge on the grid accelerates the electrons in the space between grid and anode. Thus they would arrive at the anode with additional energy and this would imply a higher anode potential than in fact exists, the definition of potential as work done per unit charge being kept in mind. If then the anode voltage is maintained constant, there must be some mechanism by which the negative charge on the grid causes the electrons to arrive at the grid with a lower velocity. Now it has been shown that the charge on the grid cannot act directly on the electrons coming towards it. A decrease in current must, therefore, be due to an increased positive charge on the cathode. Hence it becomes necessary to examine how an increase in negative charge on the grid leads to an increased positive charge on the cathode. Professor Moullin concludes that such an examination would involve the stability of the barrier surface and that this question does not appear to have been tackled. It is to be hoped that he himself will undertake this work and thus remove the mystery from this part of the theory. This is a rather baffling gap in the present treatment, but it is refreshing to have the unsolved part of the problem clearly stated instead of having it covered up with a nebulous form of scientific words.

There is no doubt that this is the sort of paper that either wins warm approval or draws upon itself scathing stricture as being academic pedantry. Those who criticize should reflect on the fact that this paper does not claim to be a patent specification relating to improvements in the design of triodes. In essence, it is an exercise in careful academic thought, which seeks to build up a logical theory from the minimum number of concepts. Undoubtedly this theory is relevant to the engineering design of triodes, but it is by no means essential to it. After all, half a century of successful triode manufacture has gone by before the theory has been presented in this paper. Engineering art and science have gone their separate ways in this matter. In this fact alone there is food for thought.

But few engineers, and especially few electrical engineers, desire such a separation of practice and theory. The profession of the electrical engineer is often far more satisfying when theory and practice, scientific rigour and engineering skill are closely allied. Those who hold such a view will propose a hearty vote of thanks to the author of the paper discussed in this article.

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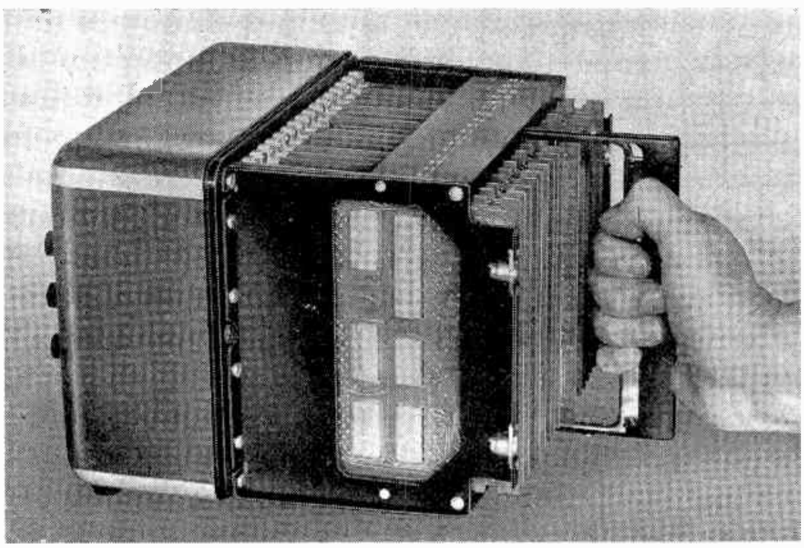
"On the Amplification Factor of the Triode", Professor E. B. Moullin, I.E.E. Monograph No. 211 R, November 1956.

Miniature Computer

The photograph shows 'Transac', a transistor digital computer developed by the Philco Corporation in the U.S.

The computer, which operates from a 3-V supply, is capable of performing all normal arithmetic processes, including addition and subtraction, multiplication and division, and taking square roots. It employs about 1,000 transistors and is housed in a case 10 in. long. Computers with larger digital capacities can be made building-block fashion by adding more printed circuit cards, one of which is being withdrawn in the photograph.



By Computer

Deriving Smooth Curves from Experimental Data

We frequently have to try to draw conclusions from results subject to experimental error, in the form of several pairs of corresponding values of an independent variable (which we shall here call x) and a dependent variable (which we shall here call y). It often happens that we have some idea of the general nature of the relation between x and y (e.g., that they are linearly related) but we require to find a specific formula for it.

Consider first the rather trivial case in which we know two pairs (x_1, y_1) and (x_2, y_2) of corresponding values of the variables, and that x and y are linearly related. Since x and y are linearly related, we must have

$$y = ax + b \quad \ldots \quad (1)$$

where a and b are constants which we have to determine. Since (x_1, y_1) and (x_2, y_2) are corresponding pairs, we must have

$$\left.\begin{aligned} y_1 &= ax_1 + b \\ y_2 &= ax_2 + b \end{aligned}\right\} \quad \ldots \quad (2)$$

and these are ordinary linear simultaneous equations for a and b, which have a unique solution. We can safely and easily find a and b by solving (2) in the ordinary way but, in fact, the solution in this case can be written down by a trick which we shall find useful when we come to consider more general relations. The required line (1) is in fact

$$y = y_1\frac{x - x_2}{x_1 - x_2} + y_2\frac{x - x_1}{x_2 - x_1} \quad \ldots \quad (3)$$

because if in (3) we put x_1 for x, the first term of the right-hand side reduces to y_1 and the second to zero, while if we put x_2 for x, the first term reduces to zero and the second to y_2; (3) is obviously linear in x and y, so it necessarily represents *a* line, and therefore *the* line, joining the points (x_1, y_1) and (x_2, y_2). By comparing (3) and (1), or by solving (2), we find

$a = (y_2 - y_1)/(x_2 - x_1)$ and
$b = (x_2y_1 - x_1y_2)/(x_2 - x_1)$.

We next have to consider what to do if there are more than two pairs, say n pairs, of corresponding values of x and y available. It must be remembered that our data is experimental so that a line is unlikely to pass through all the points. We can still write down n equations like (2) expressing that the line (1) goes through the various points representing corresponding values of the variables but, as we now have more than two of these equations, we can no longer solve them as they stand. Each pair of points may be joined by a somewhat different line from each other pair and what we want to do is to find the best approximation to a line through them all. What we have to do is to derive, from the n equations like (2), a single pair which involve the various pairs of observations symmetrically, and which can be solved to give a and b. The trick for doing this is to multiply each of the n equations by the coefficient of a and add, so that we obtain

$$\sum_{r=1}^{n} y_r x_r = a \sum_{r=1}^{n} x_r^2 + b \sum_{r=1}^{n} x_r \quad \ldots \quad (4)$$

and then we multiply each of the n equations by the coefficient of b and add; that is, we just add them all up. This gives

$$\sum_{r=1}^{n} y_r = a \sum_{r=1}^{n} x_r + n \,.\, b \quad \ldots \quad (5)$$

Solving (4) and (5) gives the required values of a and b.

Example

Suppose, for example, we are given the following pairs of values of corresponding points:

x	− 10	− 5	0	10	20
y	1·4	1·1	0·5	− 0·5	− 1·3

equations (4) and (5) become

$$-50{\cdot}5 = 625a + 15b$$
$$1{\cdot}2 = 15a + 5b$$

whence $a = -\dfrac{54{\cdot}1}{580} = -0{\cdot}0933$, $b = 0{\cdot}520$, so the line is

$$y = 0{\cdot}520 - 0{\cdot}0933x.$$

This is plotted in Fig. 1.

Now suppose that we are given the same set of points displaced as a whole. The straight line that best fits must be similarly displaced, but the equations to be solved for it may be simplified or made more complicated by the displacement. Suppose first that each x is reduced by 3 and each y by 0·24, so that the mean x and the mean y are both reduced to zero. The tabulated values now become

x	− 13	− 8	− 3	7	17
y	1·16	0·86	0·26	− 0·74	− 1·54

(4) now reduces to

$$-54{\cdot}1 = 580a$$

and (5) becomes

$$b = 0$$

so that the line is

$$y = -0{\cdot}0933x$$

and goes through the new origin, which means that with the original data, the line goes through the point where $x = 3$, $y = 0{\cdot}24$, marked A in Fig. 1. This point is the 'centre of mass' of the observed points. Hence,

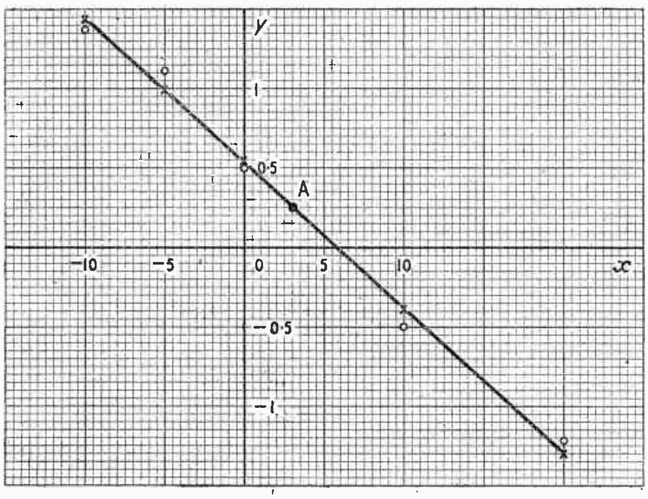


Fig. 1. *Plot of 'least-squares' line among experimental points*

making the mean value of x and y zero has greatly simplified the determination of the line.

If, on the other hand, all the x are severely displaced in the positive direction, large numbers occur in the equations for a, b:

x	40	45	50	60	70
y	1·4	1·1	0·5	− 0·5	− 1·3

$$9{\cdot}5 = 14{,}625a + 265b$$
$$1{\cdot}2 = 265a + 5b$$

We still find $a = -0{\cdot}0933$; b is now 5·1849, but much larger numbers enter into the equations.

If, as in Fig. 1, we plot the line l, derived from (1) with the values of a and b derived from (4) and (5), it will be found to lie evenly among the points representing the observed values. If all the n points lay exactly on a line, l would be that line and, in general, the line l has the property that the sum of the squares of the distances of the various points (measured in the y-direction) from l is a minimum for varying a and b. For this reason, the equations (4) and (5) are usually known as 'least-squares equations'.

It greatly simplifies (4) and (5) if a round number approximately equal to the mean x_r is subtracted from each x_r and a round number approximately equal to the mean y_r is subtracted from each y_r before (4) and (5) are written down; otherwise the coefficients of (4) and (5) tend to be inconveniently large and loss of accuracy due to the subtraction of nearly equal quantities may result. Geometrically, this means we should take the origin of co-ordinates in the (x, y) plane to be near the centre of gravity of the points (x_r, y_r); this centre of gravity, from (5), always lies on the line l.

Non-Linear Relations

The question now arises as to whether we can deal in a similar manner with a known relation which does not happen to be linear. It may be possible to replace y by some other variable Y which is a function of x and y, and x by some other variable X which is a function of x and y, in such a way that Y and X are linearly related even if y and x are not. For example, if we expect y to be exponentially related to x, log y will be linearly related to x. Again, if x and y are related by a power law, log x and log y are linearly related. By using logarithmic, probability, and other types of paper, we can, in suitable cases, find corresponding pairs of values of the variables X and Y which are linearly related merely by measuring distances along this special paper instead of by calculation. Such a change of variable, however, is not always available. We may be obliged to express the relation sought by means of a curve of higher degree. We shall therefore consider the case in which the relation is expected to be of the form

$$y = A + Bx + Cx^2 \quad \ldots \quad (6)$$

but, in fact, a similar procedure can be applied to curves of any degree. The complication, however, increases severely as the degree increases. It may happen, too, that a curve of high degree appears to fit the observed points more closely, but it may contain oscillations which are unlikely to correspond to any practically significant variation, as they are associated rather with unavoidable experimental uncertainties.

If we have three points (x_1, y_1), (x_2, y_2) and (x_3, y_3) representing corresponding pairs of values, there is just one curve of the form (6) which goes through them exactly. We can obtain it by solving for A, B, C the simultaneous equations

$$\left.\begin{aligned} y_1 &= A + Bx_1 + Cx_1^2 \\ y_2 &= A + Bx_2 + Cx_2^2 \\ y_3 &= A + Bx_3 + Cx_3^2 \end{aligned}\right\} \quad \ldots \quad (7)$$

or we can write it down; the required equation is analogous to (3) and is

$$y = y_1\frac{(x - x_2)(x - x_3)}{(x_1 - x_2)(x_1 - x_3)} + y_2\frac{(x - x_3)(x - x_1)}{(x_2 - x_3)(x_2 - x_1)} + y_3\frac{(x - x_1)(x - x_2)}{(x_3 - x_1)(x_3 - x_2)} \quad \ldots \quad (8)$$

but, when there are more than three pairs of corresponding points, say n pairs, we have to find simultaneous equations analogous to (4) and (5) for A, B, C; these are obtained by

(a) adding up (7):

$$\sum_{r=1}^{n} y_r = nA + B\sum_{r=1}^{n} x_r + C\sum_{r=1}^{n} x_r^2 \quad \ldots \quad (9)$$

(b) multiplying each of (7) by the coefficient of B and adding:

$$\sum_{r=1}^{n} x_r y_r = A\sum_{r=1}^{n} x_r + B\sum_{r=1}^{n} x_r^2 + C\sum_{r=1}^{n} x_r^3 \quad (10)$$

(c) multiplying each of (7) by the coefficient of C and adding:

$$\sum_{r=1}^{n} x_r^2 y_r = A\sum_{r=1}^{n} x_r^2 + B\sum_{r=1}^{n} x_r^3 + C\sum_{r=1}^{n} x_r^4 \quad (11)$$

and these simultaneous equations are then solved for A, B, C. They are greatly simplified, as in the case of (4) and (5), if the origin of co-ordinates is shifted to the centre of gravity of the points (x_1, y_1), (x_2, y_2), etc.

The values of A, B, C obtained from (9) determine the curve of the form (6) which has the best 'least-squares fit' to the experimental results, but the solution of equations (9), (10) and (11) is somewhat tedious. A possible way of obtaining a rough-and-ready result is to draw by eye a smooth curve among the points, choose three key well-spaced (but not necessarily equally-spaced) points on it, and apply (8), taking (x_1, y_1), (x_2, y_2) and (x_3, y_3) to be the co-ordinates of the chosen points. By plotting the curve (8) thus obtained, we can soon see if our key points were chosen unsuitably. If we are in doubt we must, of course, solve (9), (10) and (11) which are the only theoretically-defensible equations, but they require excessive labour of calculation when only a rough result is required.

In general, it is not worth while to try to fit a curve of the form (6) to points representing observed results. (6) will always fit better than (1), but it does not usually fit very much better. In a small minority of cases, however, a curve of type (6), or even a curve of higher degree, may be the most satisfactory way available for representing the experimental data.

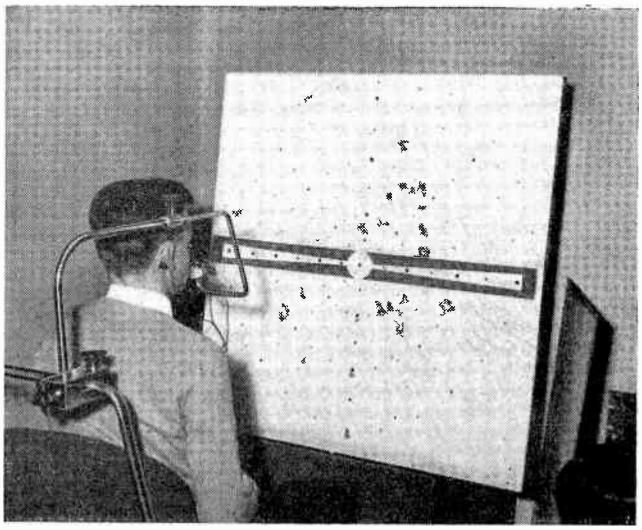
Equipment for Electro-Oculography

APPARATUS designed to show on a cathode-ray tube, and to record on a double-pen recorder, the movements of the human eyeball has been developed by E.M.I. Electronics for the Naval Motion Study Unit of the Admiralty Research Laboratory. The eye behaves as if it were a battery with a positive voltage at the front and a negative at the back. If contact is made to the skin on each side of the eye socket, the p.d. between the contacts is zero when the eye is at rest in the mid-position. When the eyeball is turned in one direction, a p.d. appears which increases with the angle through which it moves and which is positive for movement on one side of the rest position and negative for movement on the other.

The equipment comprises basically a pair of high-gain d.c. amplifiers with chopper stabilization and a servo-controlled zero adjustment. The outputs are fed to pen-recorders and to a c.r. display.

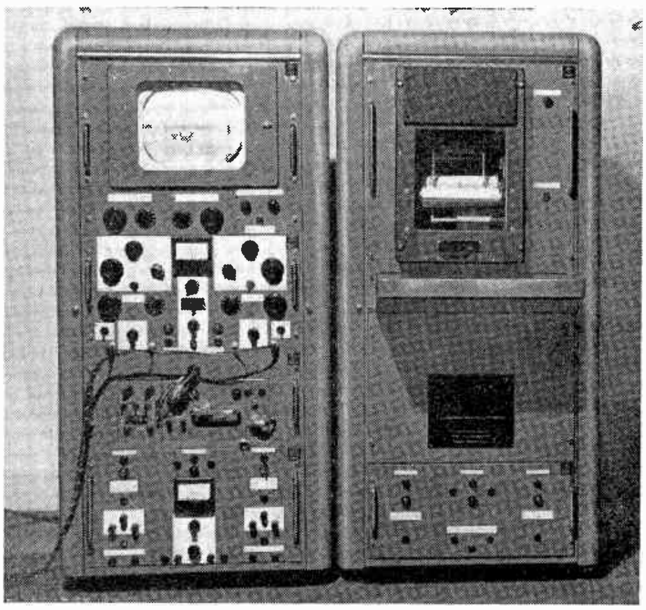
Four contacts are normally made to the subject, one on each temple, one on the forehead above one eye and one on the cheek below the same eye. The pair on the temples picks up the p.d. due to the horizontal component of eye movement and this is actually the combined effect of both eyes. The other pair picks up the p.d. produced by the vertical component. The two pen traces thus record the horizontal and vertical components of eye movement, but the c.r. trace indicates their combination and thus gives a display in polar co-ordinates. The use of a c.r. tube in this way is due to Dr. Mackworth of the M.R.C. Applied Psychology Research Unit, Cambridge.

The potentials developed are of the order of 20 μV per degree of eye movement. Great care is therefore necessary to see that they are not masked by skin potentials, etc. It is stressed that the contact elements must be of high-purity silver and must be kept free from contamination. The contact is made not to the outer skin but to the inner. The outer skin is removed at the desired point of contact with a dentist's drill, care being taken not to go deep enough to draw blood. The operation is painless. The contacts are then placed on the prepared places and held by suction cups filled with a saline solution of high purity. Accurate positioning of the cups is unnecessary because the points of connection are determined by the 'holes' drilled in the subject. It is these 'holes' which must be properly placed.



The subject is sitting in front of a test board on which each white spot represents a 5° movement of the eyes. A similar transparent pattern is placed over the screen of the c.r. tube

The left-hand rack contains the amplifiers, power supplies and c.r. tube. The right-hand is the double-pen recording unit



Phase-Lock A.F.C. Loop

TRACKING SIGNALS OF VARYING FREQUENCY

By R. Leek, A.C.G.I., B.Sc.(Eng.), Graduate I.E.E.

SUMMARY. *A simple automatic frequency-control system is analysed and the response to steps of phase, frequency and rate-of-change of frequency of the input signal calculated. A new effect, 'frequency pushing', is described: when pushing occurs, the loop oscillator is controlled to a frequency in error by about half the bandwidth of the high-frequency circuits of the loop. A 'dragging' effect has also been observed.*

A requirement which arose in a certain type of control system was the ability to track a signal of varying frequency, and a phase-lock type of a.f.c. circuit was used successfully for this purpose.

The results of work on the phase-lock circuit which have been published in the literature are mainly confined to loops suited to the synchronization of the sampling frequency in colour-television receivers[1–3]. The problem is usually one of correcting the frequency of an oscillator by a fixed amount arising from station switching or drift.

The present application is concerned with tracking a higher-order property of the input signal, namely, its rate of change of frequency. The rate of change was in practice of the order of 10 kc/per second.

1. Simple Phase-Lock Loop

Fig. 1 is a block schematic diagram of a simple phase-lock loop. The input signal is received at a frequency f_s and, for simplicity, the loop is first considered to be locked to this frequency. An oscillator O whose frequency is to be controlled to the locked condition then operates at a frequency $(f_i + f_s)$. The input signal is mixed with the controlled-oscillator signal in a balanced mixer M, to produce an output at frequency f_i. The mixer output is passed to a band-pass amplifier A whose centre frequency is f_i, and forms the input signal (v_1, ϕ_1) to a phase-sensitive detector D. The detector is switched by a signal $\left[v_2, \left(\phi_2 - \frac{\pi}{2}\right)\right]$ at a frequency f_i from a crystal-controlled local oscillator L. The two inputs to the phase-sensitive detector will, in general, differ by a constant phase angle $(\phi_2 - \phi_1 - \pi/2)$. If $|v_2|$ is several times $|v_1|$ the output of the detector is given by

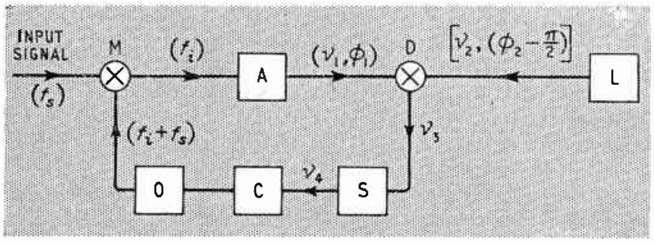
$$v_3 = |v_1| \cos (\phi_2 - \phi_1 - \pi/2),$$

neglecting terms in $|v_1|/|v_2|$ and higher orders ; or

$$v_3 = |v_1| \sin \phi_3, \text{ say,}$$

where $\phi_3 = \phi_2 - \phi_1$.

Fig. 1. *The phase-lock loop ; locked condition*



The variation of phase with time may then be represented graphically as in Fig. 2. The phase-sensitive detector is the error-sensing device in the loop and v_3 is the error voltage which actuates the feedback process. The error voltage is passed to a shaping or equalizing network S which, in the simple case, is a single-stage integrator, whose function is described below. The shaper output v_4 is just sufficient to control the frequency of the oscillator O to $(f_i + f_s)$ by means of a control C. The loop is thus in a stable locked condition.

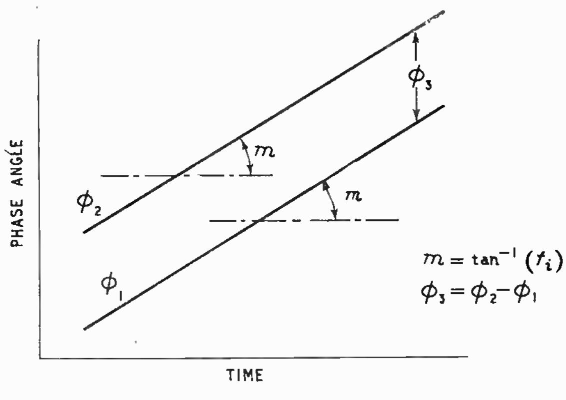


Fig. 2. *Variation of phase with time ; locked condition*

The simple phase-lock loop is effectively a position control servo-mechanism operated by a d.c. error voltage from the phase-sensitive detector. Many equalizing networks may be used in such loops and an elementary type was chosen for this investigation ; see Fig. 3. The transfer function of this network is derived in Appendix 1 where it is also shown that the high-frequency performance of this network can be represented approximately as in Fig. 4 (a).

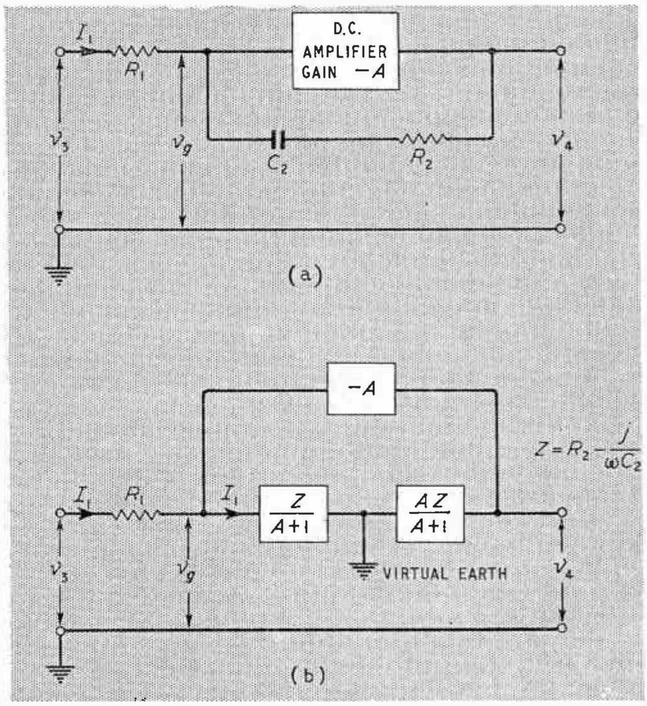


Fig. 3. *Elementary shaping network*; (*a*) *showing connection of essential components*: $R_1 = 1{\cdot}2\ M\Omega$, $R_2 = 20k\Omega$, $C_2 = 0{\cdot}125\ \mu F$, $-A = -120$; (*b*) *equivalent in block schematic form*. (R_1 *includes the series output resistance of the phase-sensitive detector*)

The performance of the loop for various types of input will be determined theoretically, but first it may be helpful to consider its operation qualitatively from first principles.

2. Qualitative Treatment

ELEMENTARY CONSIDERATIONS LEADING TO THE STATIC LOOP EQUATION

In the absence of an input signal f_s the oscillator O will operate at a frequency determined by the standing voltage, V_4 say, at the input to the oscillator control C. Let the controlled-oscillator frequency be in general $(f_i + f_g)$ and the frequency corresponding to the standing voltage V_4 be $(f_i + f_{g0})$. Then v_3 is zero but, if a d.c. potential were added to the input to S by means external to the loop, this would cause the oscillator frequency to change at a rate determined by the integrating action of S. The frequency would change approximately linearly with time with a sense and magnitude according to the polarity and size of the applied potential. It will be shown that the d.c. input or bias to the shaper consists of two parts, one of which controls the frequency of O through direct amplification in S, while the second controls the rate of change of O through the integrating action of S. In the present application of the loop, the latter will be the more important and is distinguished by applying to it the term 'lean' potential. Application of a positive 'lean' to the loop constrains the oscillator frequency to increase at a rate proportional to the magnitude of the 'lean'.

Referring to Fig. 2, when no signal is present ϕ_3 is zero and the line for ϕ_1 may be considered superimposed on the line for ϕ_2. The controlled oscillator frequency will then be $(f_i + f_{g0})$, say, corresponding to the standing voltage V_4, and $(f_i + f_{g0})$ will be termed the zero-lean frequency. After lock to a signal f_s, the controlled-oscillator frequency is constrained away from its zero-lean frequency by an amount $(f_{g0} - f_s)$. The magnitude and sense assumed by ϕ_3 is therefore such that it develops a voltage v_4 sufficient to produce a change in controlled-oscillator frequency of $(f_{g0} - f_s)$. This fact, together with a consideration of the loop gain parameters will enable the static loop equation to be written down, from the following argument.

The feedback process between the output of the controlled oscillator and the input to the phase-sensitive detector involves a frequency comparison at the balanced mixer. The controlled oscillator signal provides the switching voltage for M so that the mixer output has a level dependent only on the level of the input signal and contains the feedback information in its phase properties. Thus any voltage gain between the mixer and the detector will not enter the loop gain equation, and $|v_1|$ can be taken as the input signal level. Any shaping or time delay occurring between M and D must be accounted for, since these affect the properties of v_1, when the input signal has constant magnitude and frequency. The gain of the amplifier A can be considered normalized to its value at f_i and its gain transferred to the left of M, Fig. 1. Also, for large values of $(f_g - f_s)$, where $(f_i + f_g)$ is the frequency of the controlled oscillator, the transfer function of the balanced mixer may be involved. In all uses of the loop in the present application this action of the mixer may be ignored, since amplifiers having comparatively narrow bandwidths are used between M and D. Ideally, since the mixer output signal has a frequency $(f_i + f_g - f_s)$, the loop gain is zero when $(f_g - f_s)$ exceeds half the amplifier bandwidth.

Consider again the locked condition as in Section 1. If $|v_1|$ is the peak value of the input signal to D,

$$v_3 = C|v_1| \sin \phi_3,$$

where $C \to 1$ when v_2/v_1 is large, or

$$v_3 = k_1 \cdot \sin \phi_3 \qquad (1)$$

$$\approx k_1 \cdot \phi_3 \qquad (2)$$

when ϕ_3 is small.

The shaper has a gain $-A$, so that

$$v_4 = -A\,k_1 \sin \phi_3 \qquad (3)$$

If $-k_2$ is the combined characteristic of C and O, representing the change in output frequency of O per unit change in input voltage v_4,

$$f_{g0} - f_s = A\,k_1\,k_2 \sin \phi_3$$
$$= A\,k_3 \sin \phi_3, \text{ where } k_3 = k_1\,k_2\,;$$

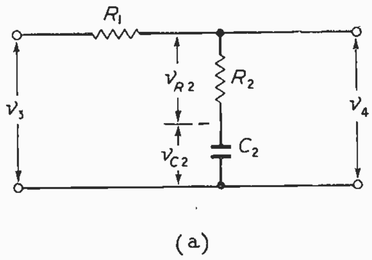
i.e., $$\phi_3 = \sin^{-1}\left(\frac{f_{g0} - f_s}{Ak_3}\right) \qquad (4)$$

or $$\phi_3 \approx \frac{f_{g0} - f_s}{Ak_3}, \text{ for } \phi_3 \text{ small} \qquad (5)$$

This is the value of ϕ_3 shown in Fig. 2 which corresponds to a case $f_{g0} > f_s$, since ϕ_3 is positive. Equation (4) is the static loop equation corresponding to an input signal of fixed magnitude and frequency. Note that k_3 has the dimension 1/time.

CONDITIONS DURING LOCK-ON

First, consider the oscillator O to be running at its zero-lean frequency $(f_i + f_{g0})$, corresponding to the standing



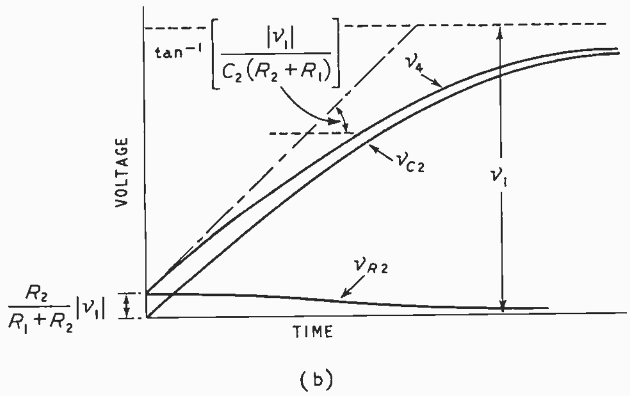


Fig. 4. *An approximate equivalent network for the shaping network at high frequencies; (a) approximate equivalent network, (b) response of circuit of (a) to a voltage step $|v_1|$ at the input*

voltage V_4. The phase-sensitive detector D is then presented with a signal at $(f_i + f_{g0} - f_s)$ and a switching signal at f_i. The output v_3 is then $|v_3| \sin [2\pi (f_{g0} - f_s)t]$ at a frequency $(f_{g0} - f_s)$. In general, this frequency will be $(f_g - f_s)$ which is called the beat frequency. Now the shaper S is of the low-pass type whose amplitude characteristic falls to -3 dB of its d.c. value at about 200 c/s, typically. The voltage v_4 will therefore be at a frequency $(f_{g0} - f_s)$ and of magnitude proportional to the product of v_3 and the shaper gain at that frequency. Frequency modulation of the controlled oscillator results, with a deviation $k_2|v_4|$, and it is an experimental fact that if $(f_{g0} - f_s)$ is sufficiently small the loop functions in such a way that $(f_{g0} - f_s)$ falls to zero; i.e. the controlled oscillator frequency pulls into lock. This pulling effect has been treated analytically elsewhere[4], a treatment which involved a study of the phase plane with integral curves. Such curves may be used to derive the conditions for which synchronization is possible, although the manner in which the system evolves a pulling force remains obscure. The pull-in process generally requires several cycles of the beat frequency (which changes throughout the process) to accomplish lock, and the pulling effect depends for its existence on the non-linearity inherent in the system. Two clocks standing on the same mantelpiece may evolve a pulling force which synchronizes the tick frequency. Two sine-wave triode oscillators exhibit a pulling effect only as a result of the non-linearity in the current–voltage characteristic of a triode. This non-linearity causes interaction between the two oscillators in such a way that the oscillators can pull into synchronism over a certain frequency range, the synchronized frequency being nearer to the free-running frequency of the stronger oscillator[5]. The interaction must attain a certain level before pulling may occur and this defines a frequency range over which pull-in is possible, known as the synchronization range. When the two oscillators are separated by a frequency difference greater than half this range, the beat frequency persists and no pulling effect exists. Similarly, with the loop, non-linearity introduced by the phase-sensitive detector causes a pulling force in the form of a d.c. component in the output v_3 at low beat frequencies, and there is a finite synchronization range within which pull-in is possible. Some non-linearity is also inevitable in the controlled-oscillator frequency characteristic and on the edge of the amplifier pass-band used in the present application. If the shaper had a gain $-A$ at all frequencies, the synchronization range would be $2Ak_3$, from equation (4), which defines the condition for synchronism and $\sin \phi \ngtr 1$; i.e. the controlled oscillator may be detuned by a maximum frequency Ak_3 on either side of $(f_i + f_{g0})$ by the pulling effect of an input signal. In practice, the gain of the shaper S varies from $-A$ at d.c. to $-R_2/R_1$ at high beat frequencies (see Appendix 1). However, in the present application, the synchronization range was determined by the bandwidth of amplifier A rather than the shaper, for the following reasons. The synchronization range as determined by the shaper alone was considerably larger than the bandwidth of the widest band-pass amplifiers used. If the amplifier A had a perfectly rectangular amplitude characteristic, no beat frequency greater than half this bandwidth could result when the frequency of the switching signal input v_2 to the phase-sensitive detector was accurately tuned to the centre of the amplifier pass-band. The synchronization range is then given by the bandwidth of the amplifier A. In practice the characteristic was not perfectly rectangular but the synchronization range was of the order expected. Also, in practice, a new phenomenon was observed during the lock-on phase due to the narrow-band amplifier A (see Section 5, "The Pushing Effect").

The synchronization range is approximately the bandwidth of the amplifier A, but the range over which pull-in is possible is given by half this bandwidth only when the switching frequency to the phase-sensitive detector is accurately tuned to the centre of the amplifier pass-band. The pull-in range is asymmetric for $f_s > f_{g0}$ and $f_s < f_{g0}$, if the switching frequency is off-tuned, up to a maximum of half the amplifier bandwidth where the pull-in range on one side is zero and on the other side is equal to the synchronization range.

Having attained the locked condition, it is now of interest to consider the loop performance for certain types of input signal change, as follows.

A STEP OF PHASE IN THE INPUT SIGNAL

For a constant frequency f_s, ϕ_3 is constant and the phase ϕ_1 increases linearly with time as in Fig. 2. A step of phase would correspond to an instantaneous change from one fixed value of ϕ_3 to another. This case will not generally be of practical interest. Since a step of phase at the input is produced at the detector output with very little delay, the steady-state phase error, $\phi_{ss(1)}$ say, would, of course, be zero.

A STEP OF FREQUENCY IN THE INPUT SIGNAL

The response of the loop to a step of frequency in the input signal is of practical interest with, for example, colour television receivers which may use phase-lock circuits to synchronize the sampling frequency. An input change approximating to a step of frequency occurs on station switching.

When the input-signal frequency to the detector D is defined as $(f_i + f_g - f_s)$, a positive step in f_s will initially cause a decrease in the variation of ϕ_1 with time. Fig. 5 shows the phase condition before and after the application of the frequency step at time T. Before T, the output voltage v_3 corresponding to $|v_1| \sin \phi_3$ is just sufficient to control the oscillator frequency to the locked condition, as in Fig. 2. On the application of a positive frequency step Δf_s, the frequency of the mixer output falls by Δf_s so that phase ϕ_1 initially changes at a rate $(f_i - \Delta f_s)$ (see Fig. 5). Conversely, a negative-frequency step causes ϕ_1 to change initially at a rate $(f_i + \Delta f_s)$. The controlled oscillator then pulls into its new locked condition, and the resulting steady-state phase error will be, from equation (4),

$$\phi_{ss(2)} = \sin^{-1}\left(\frac{f_{g0} - f_s - \Delta f_s}{Ak_3}\right), \quad \ldots \quad \ldots \quad (6)$$

i.e., when $f_{g0} = f_s$ before T, or considering the frequency step only,

$$\phi_{ss(2)} = \sin^{-1}\left(\frac{\Delta f_s}{Ak_3}\right) \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (7)$$

or

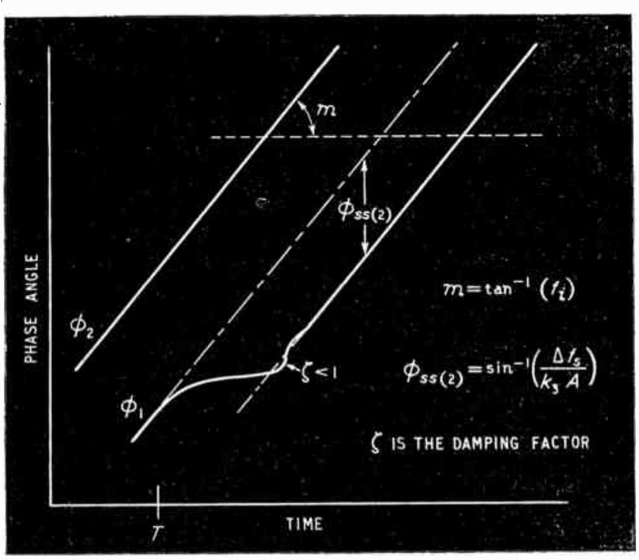
$$\phi_{ss(2)} \approx \left(\frac{\Delta f_s}{Ak_3}\right), \text{ when } \phi_3 \text{ is small} \quad \ldots \quad \ldots \quad (8)$$

As a corollary, it may be added that the maximum frequency step for which the loop will pull into lock is given by the pull-in range.

A STEP OF RATE OF CHANGE OF FREQUENCY IN THE INPUT SIGNAL

The response of the loop to a change of frequency in the input signal during a finite time was the case particularly of interest in the present application.

Fig. 5. *Response of ϕ_1 to step in f_s*



Consider the loop initially in the locked condition as for Fig. 2. Let the input-signal frequency change linearly with time. In order to follow the input frequency ramp, $df_s/dt = F_s$ say, the frequency of the controlled oscillator must change at the same rate,

$df_g/dt = F_g$, say, i.e., $F_g = F_s$ $\quad \ldots \quad \ldots \quad \ldots \quad (9)$

The output voltage from the shaper, v_4, therefore changes linearly with time, thus

$$v_4 = \frac{F_g}{-k_2} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (10)$$

Owing to the finite d.c. gain in the shaper, the input voltage, v_3, will consist of two parts, one of which is amplified directly with gain $-A$ to define the controlled-oscillator frequency, while the other part is integrated to provide the rate of change of frequency. The directly amplified part will be given by equation (6) where $\Delta f_s = (F_{s0} + \Delta F_s)\, t$, viz.

$$\phi_{ss(3a)} = \sin^{-1}\left[\frac{f_{g0} - f_{s0} - (F_{s0} + \Delta F_s)t}{Ak_3}\right] \quad (11)$$

where f_{s_0} is the input signal frequency when $t = 0$ and F_{s_0} the rate of change of frequency at $t = 0$.

The integrated part of v_3 may be derived from an elementary consideration of the shaping network, as follows. If $|v_1|$ is the peak value of the input signal to the detector, the largest step input to the shaper is very nearly $|v_1|$. For a step at the shaper input, only the high-frequency transfer function is of interest initially. In the present application $A \gg 1$ for reasons mentioned later, and the network may be replaced at high frequencies by the passive network shown in Fig. 4 (a) (see Appendix 1). A step $v_3 = C\,|v_1| = k_1$ would cause C_2 to be charged at an initial rate $k_1/C_2(R_1 + R_2)$ volts/sec. In practice $R_1 \gg R_2$ so that this initial rate may be written as k_1/C_2R_1 volts/sec. (Note: Actually the expression k_1/C_2R_1 is the *accurate* form for the shaping network. See Appendix 1.)

The initial rate of change of f_g, ΔF_g say, will therefore be

$$\Delta F_g = \frac{k_1 k_2}{C_2 R_1} = \frac{k_3}{C_2 R_1} \text{ kc/s per second.}$$

This represents the maximum rate of change of f_g, and if f_g were to change at a rate less than this maximum, v_3 would become $k_1 \sin \phi_3$, so the phase error would be,

$$\phi = \sin^{-1}\left[\frac{\Delta F_g\, C_2 R_1}{k_3}\right] \quad \ldots \quad \ldots \quad (12)$$

Thus the integrated part of this steady-state phase error may be written,

$$\phi_{ss(3b)} = \sin^{-1}\left[\frac{(F_{s0} + \Delta F_s)\, C_2 R_1}{k_3}\right] \quad \ldots \quad (13)$$

The total steady-state error is therefore given by,

$$\sin \phi_{ss(3)} = \sin \phi_{ss(3a)} + \sin \phi_{ss(3b)} \quad \ldots \quad \ldots \quad (14)$$

$$\text{i.e., } \phi_{ss(3)} = \sin^{-1}\left\{\left[\frac{f_{g0} - f_{s0} - (F_{s0} + \Delta F_s)\, t}{Ak_3}\right] + \left[\frac{(F_{s0} + \Delta F_s)\, C_2 R_1}{k_3}\right]\right\} \quad \ldots \quad (15)$$

This equation applies to the case where the controlled-oscillator frequency had zero rate of change at the time $t = 0$ when the step ΔF_s was applied. Such is generally true, although a means of providing a changing con-

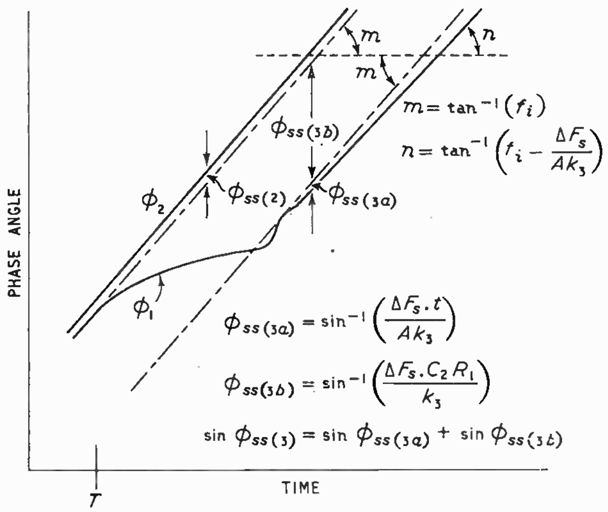


Fig. 6. *Response of ϕ_1 to step in F_s*

trolled-oscillator frequency in the absence of signal was used by the author in some practical measurements. (See Section 5). The results suggest that it is valid to replace F_{s0} by $(F_{g0} - F_{s0})$ in equation (15) when $F_g = F_{g0}$ at $t = 0$.

Thus, the steady-state error which results due to the step ΔF_s alone is given by,

$$\phi_{ss(3)} = \sin^{-1}\left\{\left(\frac{\Delta F_s \cdot t}{Ak_3}\right) + \left(\frac{\Delta F_s \cdot C_2 R_1}{k_3}\right)\right\} \quad .. \quad (16)$$

$$\text{or } \phi_{ss(3)} \approx \left(\frac{1}{A} \cdot t + C_2 R_1\right)\frac{\Delta F_s}{k_3} \quad .. \quad .. \quad (17)$$

when $\phi_{ss(3)}$ is small.

The corresponding variation of phase with time is shown in Fig. 6.

3. Theoretical Results

DERIVATION OF THE LOOP PHASE EQUATION

The loop phase equation involves the determination of ϕ_1 or ϕ_2 in terms of ϕ_3 for the purpose of examining the effect of certain types of input phase change on loop performance.

A change in the frequency of the controlled-oscillator is compared with ϕ_2 as a change in ϕ_1/p (where p is a Laplace operator), since the frequency comparison in M is converted to a phase comparison at D, and this process is equivalent to an integration between O and D. If the change of frequency is Δf_g and f_s is fixed,

$$\phi_1 = \frac{\Delta f_g}{p} \quad .. \quad .. \quad .. \quad .. \quad .. \quad (18)$$

Shaping and delay due to amplifier A are ignored in this first consideration but are discussed below in Section 4.

Now,

$$\Delta f_g = k_2 v_4$$
$$= k_2 \cdot Y_s(p) \cdot v_3,$$

where $Y_s(p)$ is the transfer function of the shaper,

i.e., $\Delta f_g = k_2 \cdot Y_s(p) \cdot k_1 \sin \phi_3$, from (1),

$$= k_3 \cdot Y_s(p) \cdot \sin \phi_3 \quad .. \quad .. \quad .. \quad (19)$$

From equations (18) and (19),

$$\phi_1 = \frac{1}{p} \cdot k_3 \cdot Y_s(p) \cdot \sin \phi_3 \quad .. \quad .. \quad (20)$$

$$\approx \frac{k_3 \cdot Y_s(p) \cdot \phi_3}{p}, \text{ when } \phi_3 \text{ is small}, \quad .. \quad (21)$$

Now, $Y_s(p) = A\left(\frac{1 + pT_2}{1 + pAaT_2}\right)$, to a good approximation, from Appendix 1.

Substituting in (21) for $Y_s(p)$ yields,

$$\phi_3 = \sin^{-1}\left[\frac{p\left(\frac{1}{k_3 A} + p\tau T_2\right)}{1 + pT_2}\right]\phi_1 \quad .. \quad .. \quad (22)$$

where $\tau = R_1/R_2k_3$ and $1/\tau$ is the 'a.c.' loop gain having the dimension (1/time), while k_3A is the 'd.c.' loop gain.

Equation (22) represents a phase vibration of natural undamped pulsatance ω_n and damping factor ζ, where,

$$\omega^2_n = \frac{1}{T_2 \tau} \quad .. \quad .. \quad .. \quad .. \quad .. \quad (23)$$

$$\text{and } 2\zeta\omega_n = \frac{\frac{1}{k_3 A T_2} + 1}{\tau} \quad .. \quad .. \quad .. \quad .. \quad (24)$$

This is more easily identified by rewriting ϕ_3 in terms of ϕ_2, using

$\phi_3 = \phi_2 - \phi_1$, (by definition),

$$\text{viz., } \phi_3 = \sin^{-1}\left[\frac{p\left(\frac{1}{k_3 A} + p\tau T_2\right)}{\frac{1}{\omega^2_n} \cdot p^2 + \frac{2\zeta}{\omega_n} \cdot p + 1}\right]\phi_2 \quad (25)$$

Equation (22) or (25) may be used to plot the transient response of the loop to changes in the input phase ϕ_1 in the usual manner. Stability criteria may be determined from the denominator of (25) by usual methods, but of immediate interest are the steady-state phase errors ϕ_{ss} which result for various types of change in the input signal.

Now,

$$\mathop{\mathcal{L}}_{t \to \infty} \phi_3 = \phi_{ss} = \mathop{\mathcal{L}t}_{p \to 0}\left[p \cdot \left(\frac{\phi_3(p)}{\phi_2(p)}\right) \cdot \phi_2(p)\right] \quad (26)$$

where $\phi_2(p)$ is the type of input phase change. It is observed that since $\phi_3 = \phi_2 - \phi_1$, ϕ_{ss} will be the same for similar changes in $\phi_1(p)$.

Thus,

$$\phi_{ss} = \mathop{\mathcal{L}}_{p \to 0} \sin^{-1}\left[p \cdot \frac{p\left(\frac{1}{k_3 A} + p\tau T_2\right)}{\frac{p^2}{\omega^2_n} + \frac{2\zeta}{\omega_n}p + 1}\right] \cdot \phi_1(p) \quad (27)$$

A STEP OF PHASE IN THE INPUT SIGNAL

For a step 1 ϕ_1, using equation (27),

$$\phi_{ss(1)} = \mathop{\mathcal{L}}_{p \to 0} \sin^{-1}\left[p \cdot \frac{p\left(\frac{1}{k_3 A} + p\tau T_2\right)}{\frac{1}{\omega^2_n}p^2 + \frac{2\zeta}{\omega_n}p + 1} \cdot \frac{\phi_1}{p}\right]$$

$$\text{i.e., } \phi_{ss(1)} = 0 \quad .. \quad .. \quad .. \quad .. \quad .. \quad (28)$$

This result was deduced in Section 2.

A STEP OF FREQUENCY IN THE INPUT SIGNAL

For a step 1 Δf_s in input signal frequency, $\phi_1(p) = \frac{\Delta f_s}{p^2}$, and from equation (27),

$$\phi_{ss(2)} = \mathop{\mathcal{L}}_{p \to 0} \sin^{-1} \left[\frac{\frac{1}{k_3 A} + p\,\tau T_2}{\frac{1}{\omega_n^2}p^2 + \frac{2\zeta}{\omega_n} p + 1} \cdot \Delta f_s \right]$$

i.e., $\phi_{ss(2)} = \sin^{-1}\left(\frac{\Delta f_s}{k_3 A}\right)$ .. .. .. (29)

This result was deduced in Section 2 as equation (7).

A STEP IN RATE OF CHANGE OF FREQUENCY IN THE INPUT SIGNAL

For a step in rate of change of input-signal frequency, $1\,\Delta f_s$, the steady-rate phase error is given by equation (27) on using

$\phi_1(p) = \frac{\Delta F_s}{p^3}$, thus,

$$\phi_{ss(3)} = \sin^{-1}\left[\left(\frac{t}{k_3 A} + \tau T_2\right)\Delta F_s\right] \quad .. \quad .. \quad (30)$$

This result was derived from fundamental reasoning in Section 2 as equation (17), where

$\tau = \frac{R_1}{R_2 k_3}$, and $T_2 = C_2 R_2$.

(To be concluded)

APPENDIX 1

Transfer Function of the Shaping Network

Fig. 3 shows the circuit of the shaping network in schematic form indicating the position of the virtual earth.

Then,

$$I_1 R_1 = v_3 - v_g, \quad .. \quad .. \quad (A1)$$

$$I_1\left(R_2 + \frac{1}{pC_2}\right) = v_g - v_4, \quad .. \quad .. \quad (A2)$$

and $v_4 = -Av_g$. .. .. (A3)

Eliminating I_1 and v_g,

$$\left(v_3 + \frac{v_4}{A}\right)\left(R_2 + \frac{1}{pC_2}\right) = -R_1\left(\frac{v_4}{A} + v_4\right)$$

or,

$$Av_3(1 + pC_2R_2) = -v_4\left\{1 + pC_2\left[(A+1)R_1 + R_2\right]\right\}$$

$$\frac{v_4}{v_3} = Y_s(p) = -A\left\{\frac{1 + pC_2R_2}{1 + pC_2\left[(A+1)R_1 + R_2\right]}\right\} \quad .. \quad (A4)$$

In practice, A is made as large as possible and $AR_1 \gg R_2$, in general, so that equation (A_4) reduces to,

$$\frac{v_4}{v_3} = Y_s(p) = -A\left(\frac{1 + pC_2R_2}{1 + pAC_2R_1}\right) \quad .. \quad (A5)$$

$$= -A\left(\frac{1 + pT_2}{1 + pAaT_2}\right) \quad .. \quad (A6)$$

where $T_2 = C_2R_2$, ... (A7)

and $a = \frac{R_1}{R_2}$ .. .. (A8)

For the purposes of high frequency performance, equation (A6) becomes, when $A \gg 1$,

$$\frac{v_4}{v_3} = -\left(\frac{1 + pT_2}{\frac{1}{A} + paT_2}\right)$$

$$= -\frac{1}{a}\left(1 + \frac{1}{pT_2}\right) \quad .. \quad .. \quad (A9)$$

or $$\frac{v_4}{v_3} = -\left(\frac{R_2}{R_1} + \frac{1}{pC_2R_1}\right) \quad .. \quad .. \quad (A10)$$

In practice, $R_1 \gg R_2$, $R_1 = 100R_2$ typically, so that the circuit of Fig. 4 (a) is a good approximation to the shaping network at high frequencies, for which the transfer function is actually,

$$\frac{v_4}{v_3} = \frac{R_2 + \frac{1}{j\omega C_2}}{R_1 + R_2 + \frac{1}{j\omega C_2}}$$

The response of the circuit of Fig. 4 (a) to a step of voltage at the input, which involves the high-frequency response, is shown in Fig. 4 (b). The initial rate of change of v_4 is given by Fig. 4 (b) as $\frac{|v_1|}{C_2(R_1 + R_2)}$, which is a good approximation to the actual rate of change for the shaping network, viz. $\frac{|v_1|}{C_2 R_1}$.

SYMBOLS

a	$\frac{R_1}{R_2}$
A	D.C. amplifier gain.
B_N	Noise bandwidth.
C_2	Shaping network capacitor, see Fig. 3.
$f_i + f_g$	Frequency of controlled oscillator signal.
$f_i + f_{g0}$	Free-running frequency of controlled oscillator, corresponding to V_4.
F_g	Rate of change of controlled oscillator frequency.
F_{g0}	Initial rate of change of controlled oscillator frequency at $t = 0$.
f_i	Intermediate frequency.
f_{pu}	Pick-up rate (kc/s/s).
f_s	Signal frequency.
f_{s0}	Signal frequency at $t = 0$.
F_s	Rate of change of signal frequency.
F_{s0}	Initial rate of change of signal frequency at $t = 0$.
k_1	Sensitivity of phase-sensitive detector in volts/radian at $\phi_3 = 0$.
k_2	Sensitivity of controlled oscillator and oscillator control in rad/sec/volt.
k_3	k_1k_2.
p	Laplace operator.
ϕ_2	Phase input from local signal generator $+ \frac{\pi}{2}$.
ϕ_1	Signal phase input to phase-sensitive detector.
ϕ_3	$\phi_2 - \phi_1$
ϕ_{3I}	r.m.s. phase error due to input signal.
ϕ_{3N}	r.m.s. phase error due to noise.
R_1, R_2	Shaping network components, see Fig. 3.
T_1	Delay in narrow-band filter.
T_2	C_2R_2.
v_1	r.m.s. input signal voltage to phase-sensitive detector.
v_2	r.m.s. input signal voltage from local oscillator.
v_3	Input voltage to shaping network.
v_4	Output voltage of shaping network.
V_4	Standing voltage at shaping network output.
τ	$\frac{R_1}{R_2 k_3}$
$Y_s(p)$	Shaping network transfer function.

"ELECTRONICS IN AUTOMATION"

A Convention under the above titles will be held by the British Institution of Radio Engineers from June 26th to July 1st at Cambridge. There will be six sessions, each dealing with a particular aspect of automation; all lectures will be held at the Cavendish Laboratory. Visits to establishments in the Cambridge area have also been arranged. Limited accommodation is available in King's College for delegates staying for the whole period of the Convention.

Those wishing to attend should apply to the British Institution of Radio Engineers, 9 Bedford Square, London, W.C.1.

ABSTRACTS AND REFERENCES INDEX

The Index to Abstracts and References published in *Wireless Engineer* during 1956 is now available, price 2s. 6d. It comprises author and subject indexes, together with a list of journals abstracted and their publishers' addresses.

Television Society's Exhibition

OPEN from 5th to 8th March, this year's exhibition was held at the Royal Hotel, Woburn Place, London, and its emphasis was unquestionably on colour television. Bush and Cintel, in co-operation, demonstrated a colour scanner with all its associated equipment and provided, from slides, a colour-television signal which was piped to other stands for receiver demonstrations. The monitor employed in this equipment has three 12-in. tubes with red, green and blue phosphors and their images are combined optically with the aid of semi-transparent mirrors.

Experimental colour receivers of Ekco, Ferguson and Murphy were demonstrated and all these embody the R.C.A. tricolour tube. Belling & Lee staged a particularly interesting demonstration to show the effect of multi-path transmissions on a colour picture. A ghost was produced by feeding the signal directly to the receiver and also through a delay line. The delay did not merely produce a displaced ghost image, as in black-and-white reception; it altered the colour of the main image and produced a differently-coloured ghost.

A monochrome receiver was operating alongside the colour one for comparison purposes and it was very evident that the effect of multi-path transmission is very much worse on colour pictures than on black-and-white.

Test apparatus for colour television was shown. Cossor had a vector oscilloscope to show the phase relation between the colour 'burst' (nine cycles of colour sub-carrier) and the chrominance signals. They also showed a colour 'burst' generator which is intended for setting up receiver circuits correctly in the absence of a colour transmission.

The transistor is now invading the instrument field. Philco showed a wobbulator covering 31–41 Mc/s using eight transistors and drawing 40 mA from a 4·5-V battery. The output is 0·1 V into 80 Ω. A Hartley oscillator is used with a 2N128 surface-barrier transistor. The coil has a ferrite-rod core polarized by a permanent magnet and placed in the field of an electromagnet carrying a current of triangular waveform. Frequency-modulation is thus achieved by varying the permeability of the core of the r.f. coil.

The sweep generator comprises a multivibrator driving a four-transistor wave-shaping circuit in which the output stage, driving the electromagnet, has a pair of transistors in push-pull.

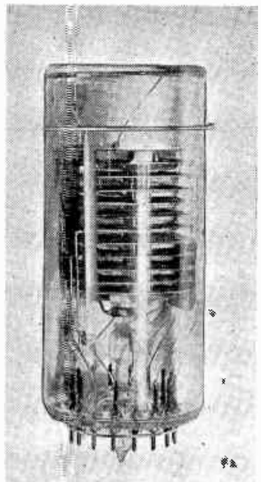
The Ferguson pattern generator is a much more elaborate instrument with 41 transistors. It is an experimental unit weighing only 4½ lb. and measuring 7½ in. × 6¾ in. × 4¼ in. There are five printed-circuit panels; master oscillator and mains lock, divider chain, sync and blanking waveform generators, video signal generator, modulated r.f. signal generator.

The output is a graticule picture plus the British sync waveform as a video signal of 7 V p-p or a modulated carrier of 56·75 Mc/s at 50 mV. The power supply is 30 mA at 13·5 V and 27 mA at 9 V.

G.E.C. demonstrated a simple method of measuring the noise factor of a television receiver. The noise generator is connected to the input and the output is measured by a thermo-couple and galvanometer connected to the c.r. tube cathode. In order that the detector may operate on a linear part of its characteristic, an unmodulated i.f. signal is fed in through a 1-pF capacitor to the input of the i.f. amplifier. The noise output with the noise-generator off is read and then the noise input is increased until the output is doubled, the noise factor being read off the calibrated scale on the generator.

This firm also showed a video wobbulator covering 50 kc/s–5 Mc/s. The oscillator is of the phase-shift type employing a chain of four cathode-followers.

A range of British and foreign test apparatus was grouped on the stand of Livingstone Laboratories. Among these, the Baird Associates Test Set enables measurements to be made at any frequency from 100 c/s to 1 Mc/s. Of American origin, it is marketed by Leland Instruments. Marconi's Wireless Telegraph Company showed waveform-generating equipment for routine checking and testing, among which the B.D.817 provides a flexible arrangement for checking linearity, transient response, frequency response and black-level stability.

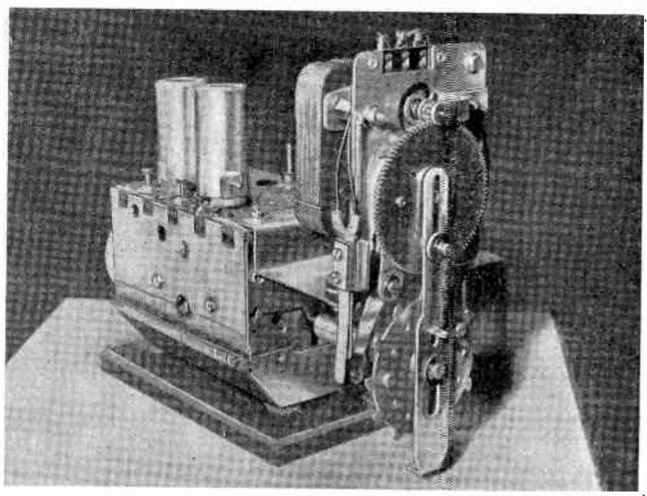


20th Century Electronics photo-multiplier tube

Mullard showed a simple way of measuring the anode voltage of a line-scan output valve. A high-voltage biased diode is used to eliminate the flyback pulse. The bias is adjusted until the diode just conducts and then the bias voltage equals the scan anode voltage. Oscilloscopes and valve voltmeters were also shown.

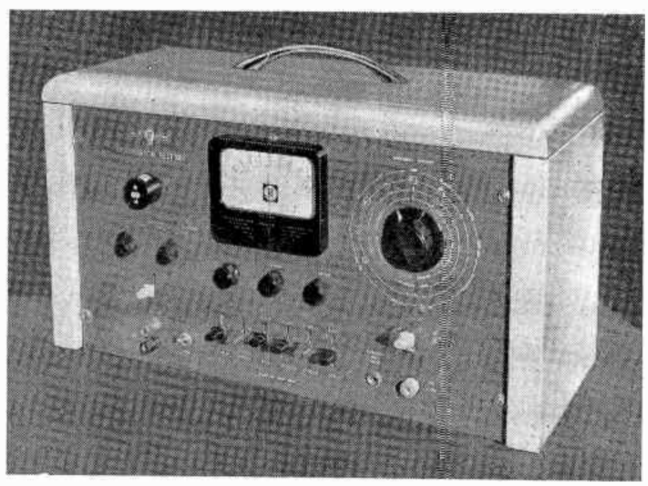
E.M.I. exhibited a range of picture monitors and oscilloscopes. The Line Selector enables any desired line to be selected and presented on a cathode-ray tube for detailed examination. It can operate on the 405-, 525- or 625-line television standards.

Oscillator radiation from television receivers is now a matter of great importance and the British Radio Equipment Manufacturers' Association demonstrated a method of measuring it in the range 30–250 Mc/s. It comprises, briefly, measuring the radiation with a field-strength meter under certain controlled conditions.

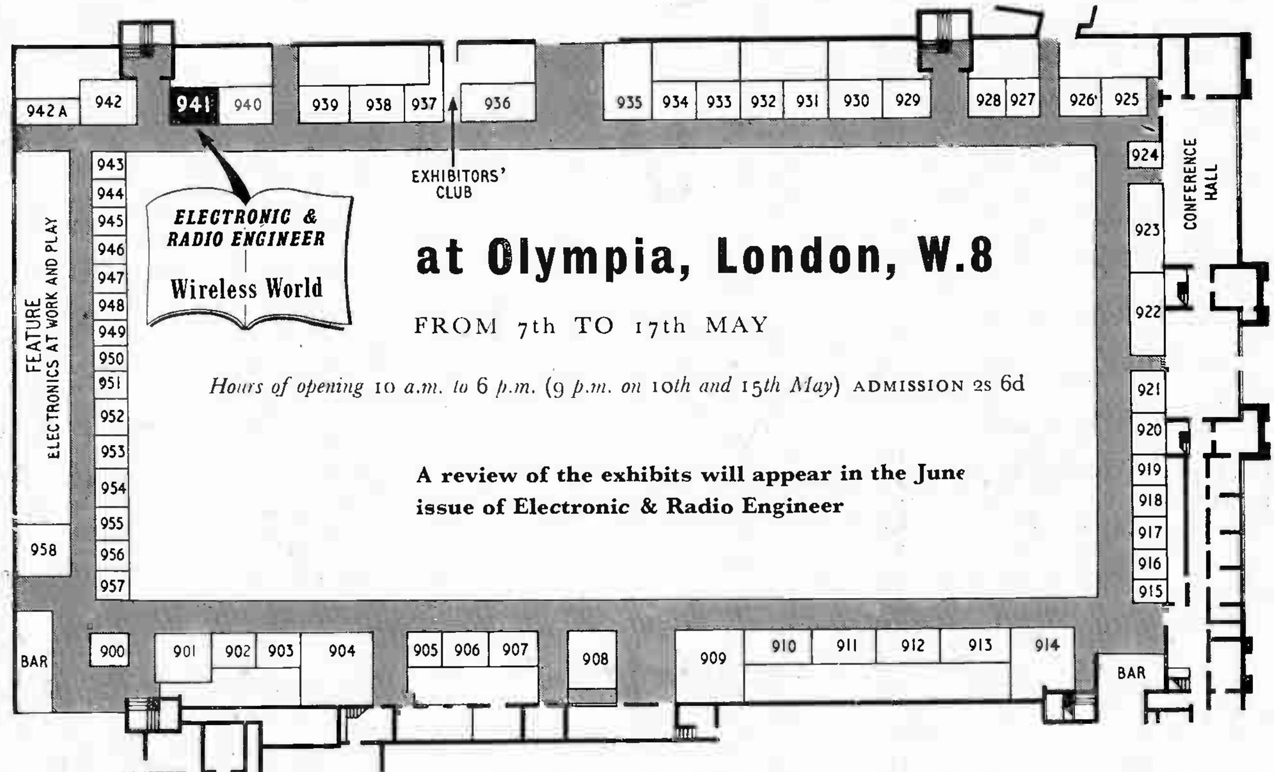


Philcomatic remote-control mechanism for operating the selector switch of a television tuner

Transistor test set marketed by Leland



Instruments, Electronics and Automation Exhibition



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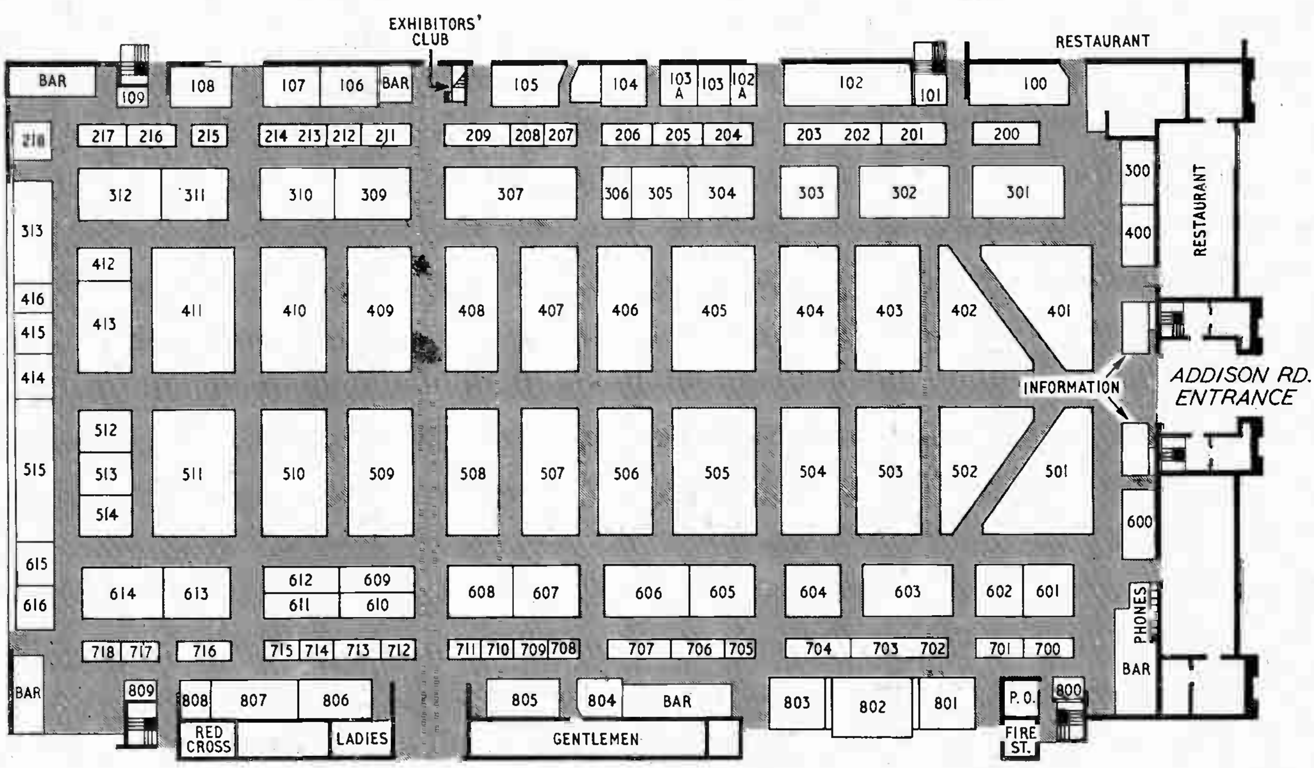
Hours of opening 10 *a.m. to* 6 *p.m.* (9 *p.m. on* 10*th and* 15*th May*) ADMISSION 2s 6d

A review of the exhibits will appear in the June issue of Electronic & Radio Engineer

GRAND HALL FIRST FLOOR



GRAND HALL GROUND FLOOR

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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.

Constant-Frequency Oscillators

SIR,—Dr. Gladwin's analysis of valve-oscillator networks (*Wireless Engineer*, January 1956, p. 13) is vindicated by the experimental confirmation which he obtained in the face of various difficulties but, of course, this is only a part of the field of study of oscillators of stable frequency. The stability of the reactances which constitute the resonant circuit is an extensive subject which has been developed by H. A. Thomas[1]. Inter-electrode capacitances are the dominant cause of trouble at any frequency in the megacycle range, but the effect of harmonic content on the oscillator frequency is a close second; the latter can in principle be analysed in terms of a non-linear differential equation, but is more profitably treated in terms of energy as by Groszkowski (the author's reference 2).

It has therefore always been surprising to me that from the time of Mallett onwards so much attention should be paid to this question of network phase-angle, which enters the frequency equation via μ, the most stable of all the valve parameters. It is true that it also enters via the resistance of the grid circuit but, if this resistance is changed by varying the grid-leak, instead of by varying an external resistor shunted across the coupling network, a noticeable part at least of its practical effect is due to change in harmonic content[2]. Dr. Gladwin is forced by the experimental difficulties to depart from the schematic circuit of his Fig. 3 and include a cathode-follower buffer valve. If more than one valve is to be used, however, a practical solution is to use two valves to raise the loop gain; i.e., to move towards $\mu \to \infty$. If $\mu \to \infty$, no stabilizing reactances are required in Llewellyn's theory but they are in Dr. Gladwin's because the latter very correctly divides his total circuit loss into series and parallel components. I think this must be mathematically equivalent (except for second-order effects during variation of the oscillator frequency) to the scheme which Professor E. B. Moullin suggested to the writer many years ago, of representing the total circuit loss by two series resistances, r_L in series with the coil and r_C in series with the capacitor (my notes of the time refer to Bruzau[3], Moullin[4] and Groszkowski[5] on this point). Using a dynatron oscillator and a constant-inductance resistor designed by Professor Moullin (interchange of copper and Eureka wires thin enough for skin effect to be negligible, so that inductance was independent of resistivity) I was able to deduce the division of total circuit resistance between r_L and r_C by observing the frequency change due to shunt damping of the whole circuit when various additions had been made to r_L and r_C in turn. In my experiment the coil was air-cored and had an inductance of 217 μH, and it was tuned with 2,845 pF to a frequency of 202·5 kc/s. The experimentally deduced values of r_L and r_C were 1·2 and 1·1 ohms respectively. At higher frequencies, however, with an air-cored coil and an air-spaced capacitor it is possible to make r_C appreciably less than r_L. It is almost essential to use an air-spaced capacitor for this purpose because, although mica is a good dielectric, clamped or moulded mica capacitors suffer from loss in the containing arrangements and silvered-mica capacitors suffer loss in the wax coating with which they are usually protected. Moreover, if its bulk can be tolerated, a well-designed air capacitor is more stable in capacitance than most other types.

To sum up, I have the greatest respect for Dr. Gladwin's investigation, but I hope its title will not lead anyone to seek the general principles of high-stability oscillators in this paper.

D. A. BELL

Electrical Engineering Dept.,
The University of Birmingham.
21st January 1957.

REFERENCES

1 H. A. Thomas, "Theory and Design of Valve Oscillators", 2nd Edition, 1951. (Chapman & Hall, London.)
2 D. A. Bell, *Wireless Engineer*, 1936, Vol. 13, p. 539.
3 Bruzau, *Onde Electrique*, 1932, Vol. 11, p. 296.
4 E. B. Moullin, *J. Inst. Elect. Engrs.*, 1933, Vol. 73, p. 186.
5 Groszkowski, *Proc. Inst. Radio Engrs., N.Y.*, 1933, Vol. 21, p. 958.

Dilemmas in Transmission-Line Theory

SIR,—In his article in the February issue, R. A. Chipman produces in equations (40) and (41)—ignoring the obvious error in (40)—simple expressions, valid at all frequencies, for the attenuation and phase coefficients, α and β.

There are four more such expressions which, I believe, have not been published and which may be of interest.

If $$\alpha + j\beta = \sqrt{(R + j\omega L)\ (G + j\omega C)} \qquad (1)$$

and $$R_0 + jX_0 = \sqrt{\frac{R + j\omega L}{G + j\omega C}} = \frac{1}{G_0 + jB_0} \qquad (2)$$

then $$\alpha R_0 - \beta X_0 = R \quad (3) \qquad \beta R_0 + \alpha X_0 = \omega L \quad (4)$$
$$\alpha G_0 - \beta B_0 = G \quad (5) \qquad \beta G_0 + \alpha B_0 = \omega C' \quad (6)$$
$$X_0\, G_0 = -\, R_0\, B_0 \quad (7)$$

Now solving for α from (3) and (5), adding and using (7) gives
$$\alpha = \tfrac{1}{2}\left(\frac{R}{R_0} + \frac{G}{G_0}\right) \qquad (8)$$

Similarly, (4), (6) and (7) give
$$\alpha = \tfrac{1}{2}\left(\frac{\omega L}{X_0} + \frac{\omega C}{B_0}\right) \qquad (9)$$

Solving for β from (3) and (5), adding and using (7) gives
$$\beta = -\tfrac{1}{2}\left(\frac{R}{X_0} + \frac{G}{B_0}\right) \qquad (10)$$

Similarly, (4), (6) and (7) give
$$\beta = \tfrac{1}{2}\left(\frac{\omega L}{R_0} + \frac{\omega C}{G_0}\right) \qquad (11)$$

E. G. GODFREY

*Borough Polytechnic, London, S.E.*1
9th February 1957.

SIR,—In a recent paper[1] Professor Chipman develops expressions for the attenuation and phase of a uniform transmission line which he claims are not generally known. We would like to point out that the formulae in question were first presented in this journal[2] in 1946.

The formulae as then given were more symmetrical in that the quantity $R_0/|Z_0|^2$ appearing in Prof. Chipman's expressions was replaced by the equivalent quantity G_0, the real part of the characteristic admittance.

Prof. Chipman's formula for the attenuation (Equ. 40) contains an erroneous factor of 2: it should read
$$\alpha = \frac{1}{2R_0}\left(R + G|Z_0|^2\right)$$

I. F. MACDIARMID
H. J. ORCHARD

Post Office Research Station,
Dollis Hill, London, N.W.2.
18th February 1957.

1 R. A. Chipman, "Dilemmas in Transmission-line Theory", *Electronic & Radio Engineer*, 1957, Vol. 34, No. 2, p. 64.
2 I. F. Macdiarmid and H. J. Orchard, "Propagation Characteristics of a Uniform Line", *Wireless Engineer*, 1946, Vol. 23, p. 168.

SIR,—Had I been aware of the paper by Messrs. Macdiarmid and Orchard I would certainly have made reference to it. Perhaps the great difference in the methods of derivation justifies putting both approaches on record. For the unfortunate factor 2 in equation (40) I can only express regret at a very careless error.

R. A. CHIPMAN

McGill University, Montreal.
25th February 1957.

Mathematical Tools

SIR,—With reference to the article "Solution of Algebraic Equations: Real Roots" by Computer in the February issue, I would draw attention to Newton's approximation. Stated briefly, if x is a near solution to a root of an equation then $x - f(x)/f'(x)$ is nearer still. In the example given

$$f(x) = x^3 + 18x^2 + 78{\cdot}75x + 81$$
$$f'(x) = 3x^2 + 36x + 78{\cdot}75$$

Using the same $x = -1{\cdot}7$, three applications given $-1{\cdot}541$, $-1{\cdot}5095$, $-1{\cdot}50091$. Compared with six of the method described by the author to obtain $-1{\cdot}49948$.

It must be remembered with Newton's method that if the polarity of the result changes the result may be less accurate than the previous.

Torquay. R. D. KNAPPE

13th February 1957.

SIR,—Mr. Knappe is quite right in thinking that Newton's method is a possible alternative to that given by me in the February issue. There are also many other methods well known to professional computers; I chose to describe Lin's method because it is very little more difficult in the case of equations of higher degree, and it can easily be applied (as explained in the March issue) to the determination of complex roots. The essential principles are easily understood and no difficult computation is involved. Newton's method can be applied to the determination of complex roots, but it involves more difficult computation.

Mr. Knappe somewhat overvalues the advantages of Newton's method in the case of

$$f(x) = x^3 + 18x^2 + 78{\cdot}75x + 81 = 0$$

because it requires only four divisions (not six, as he suggests) to obtain the root correct to five places of decimals; the quantity $-1{\cdot}49948$ which he mentions was not the end-product of that stage of the process, but was substituted into my equation (3) to give the final value $-1{\cdot}5$ of the root. He would have to apply Newton's method at least once more to obtain comparable accuracy, so that four applications of each process are needed to secure the required result. The evaluation of $f(x)$ when x is an awkward number like $-1{\cdot}50091$ is not easy when $f(x)$ has high degree; in fact, the easiest way of doing it is to divide $f(x)$ by $x + 1{\cdot}50091$; the remainder is the required value of $f(-1{\cdot}50091)$. To apply Newton's method, a similar division must be performed on $f'(x)$ as well.

22nd February 1957. "COMPUTER"

Network Matching Problems

SIR,—I wish to amplify John Deignan's article by pointing out that the geometric construction he uses may be examined from the viewpoint of vector loci theory.

Thus, for example, in his Fig. 2 the semicircle OCA is the locus of the impedance of a parallel circuit with variable susceptance and constant conductance ($G = 1/228$ mho) and similarly the semicircle OCB is the locus of impedance with constant susceptance ($B = -1/110$ mho). It follows that the intersection of these loci is the impedance of the given circuit.

In Fig. 4(c) the circle OA′CA is the locus of impedance of a resistance of 200 ohms shunted by a variable resistance. The circle OCB is used to determine the value of reactance required to make the impedance equal to that at A′ (i.e., the conjugate of A).

There are, of course, four solutions to this problem and the other two of these may be solved by drawing the "constant-conductance" impedance locus through the point P.

However, in example 4, Fig. 5, only two solutions are possible corresponding to two points on the "constant-conductance" impedance locus passing through the point P.

In the examples 3 and 4 quoted, it will be seen that the solutions may be determined by inspection of the locus diagram and I think that this synthesis method gives a better understanding of the problem than other methods.

*The Borough Polytechnic, London, S.E.*1. E. L. TOPPLE

21st February 1957.

New Books

Mathematics for Electronics

By HENRY M. NODELMAN and FREDERICK W. SMITH. Pp. 391+viii. McGraw-Hill Publishing Co. Ltd., 95 Farringdon Street, London, E.C.4. Price 52s. 6d.

This book is neither a textbook of mathematics, in the conventional sense, nor one on circuit analysis, but is something between the two. It is, in fact, quite difficult to describe its main character.

The reader is expected to start the book in the possession of a knowledge of mathematics up to the elementary calculus standard and to have a good background of physics and elementary network theory. The first part of the book does not deal with mathematics as such but with the application of mathematical methods, which the reader is expected to know already, to electrical problems.

On p. 67, matrix notation is introduced without explanation but with a forward reference to Chapter 7 in which it is treated in considerable detail. Chapter 5 deals with determinants and Chapter 6 with their use for the solution of network problems. Then come matrices and their applications, followed by series and their application in the solution of non-linear problems. Chapters on differential equations and methods of solving them follow and the Laplace transform is treated here. The main part of the book concludes with a chapter on Boolean algebra.

On the whole, the book is clearly written and there are so many examples worked out that any obscurities can be lightened by reference to them. In the reviewer's opinion, the parts on determinants and matrices are the best, for they form one of the clearest expositions of these rather difficult subjects that he has yet seen.

The book may not appeal to the mathematician so much as to the engineer, but it is not intended for him. The engineer must have, as already pointed out, quite a fair mathematical background before he starts. W.T.C.

Quartz Crystals as Oscillators and Resonators

By D. FAIRWEATHER, M.B.E., A.M.I.E.E., A.M.I.I.A., and R. C. RICHARDS, Assoc. I.E.E. *Marconi Review* Monograph Series. Pp. 54. Marconi's Wireless Telegraph Co. Ltd., Marconi House, Chelmsford, Essex. Price 7s. 6d.

Improve Your TV Reception

By JOHN CURA and LEONARD STANLEY. Pp. 112, with 134 illustrations. Published for *Wireless World* by Iliffe & Sons Ltd., Dorset House, Stamford Street, London, S.E.1. Price 5s.

A comprehensive book for the layman on how to operate the controls of a television receiver.

Information Theory. Second Edition.

By D. A. BELL. Pp. 174. Sir Isaac Pitman & Sons Ltd., Pitman House, Parker Street, Kingsway, London, W.C.2. Price 25s.

Tables of Weber Parabolic Cylinder Functions

Edited by J. C. P. MILLER. Pp. 233. Published for D.S.I.R. by H.M.S.O., York House, Kingsway, London, W.C.2. Price 63s. (By post 64s. 3d.)

Television Receiving Equipment. Fourth Edition.

By W. T. COCKING, M.I.E.E. Pp. 454, with 279 diagrams and photographs. Published for *Wireless World* by Iliffe & Sons Ltd., Dorset House, Stamford Street, London, S.E.1. Price 30s.

This new edition has been largely re-written, with the addition of much new material; in particular, on the subjects of electromagnetic deflection, synchronizing and interlacing, and multi-channel tuners.

Foundations of Wireless. Sixth Edition.

By M. G. Scroggie, B.Sc., M.I.E.E. Pp. 349, with 249 illustrations. Price 12s. 6d.

This book has been brought up to date with a new chapter on semi-conductors. In other respects it is similar to the previous edition, which was completely re-written.

Abstracts of the Literature on Semiconducting and Luminescent Materials and their Applications

Compiled by the Battelle Memorial Institute. Pp. 200. Chapman & Hall Ltd., 37 Essex Street, London, W.C.2. Price 40s.

The volume contains 765 abstracts and subject and author indexes.

A Simple and Versatile R.F. Measuring Circuit

By J. Miedzinski and S. F. Pearce. Pp. 11 + 6 figures. The Electrical Research Association, Thorncroft Manor, Dorking Road, Leatherhead, Surrey. Price 10s. 6d. (By post 10s. 10d.).

Describes impedance measurements using simple apparatus over the impedance range 10^{-2} to 10^6 ohms and the frequency range 150 kc/s to 150 Mc/s.

The Properties and Design of Iron-Cored Suppression Chokes

By J. Miedzinski. Pp. 31 + 11 figures. The Electrical Research Association, Thorncroft Manor, Dorking Road, Leatherhead, Surrey. Price 24s. (By post 24s. 7d.).

Wall Charts

A series of three wall charts illustrating "The Principles of Radio" is available from Educational Productions Ltd., East Ardsley, Wakefield, Yorks. The charts, which are produced for E.M.I. Institutes, are priced at 10s. each.

Observational Errors

By E. W. Anderson and J. B. Parker. Pp. 28. John Murray Publishers, Ltd., 50 Albemarle Street, London, W.1. Price 5s.

BRITISH STANDARDS

Graphical Symbols for Telecommunications B.S. 530 : 1948, Supplement No. 4 : 1956. Miscellaneous Recommendations and Symbols.

Pp. 22. Price 3s. 6d.

Supplement No. 5 : 1957. Functional Symbols for Switching Diagrams.

Pp. 14. Price 2s. 6d.

British Standards Institution, 2 Park Street, London, W.1.

MEETINGS

I.E.E.

10th April. "The Remote and Automatic Control of Semi-Attended Broadcasting Transmitters", R. T. B. Wynn, C.B.E., M.A., and F. A. Peachey.

29th April. "Radio in Air-Sea Rescue", informal talks by G. W. Hosie, D. Kerr and W. Kiryluk.

These meetings will be held at the Institution of Electrical Engineers, Savoy Place, Victoria Embankment, London, W.C.2, commencing at 5.30.

Brit.I.R.E.

10th April. "The Uses of Electroplated Coatings in the Electronics Industry", R. W. Stobbs, F.I.M., F.R.I.C.

24th April. "Properties of Semi-conductor Devices", A. A. Shepherd, Ph.D.

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

The Society of Instrument Technology

24th April. "Measurement and Control Circuits in the Human Operator", W. K. Taylor, M.Sc.

30th April. "The Preparation and Industrial Applications of Diffraction Gratings", L. A. Sayce, M.Sc., Ph.D., F.R.I.C., F.Inst.P.

*These meetings will be held at 7 o'clock at Manson House, Portland Place, London, W.*1.

B.S.R.A.

12th April. "Properties and Performance of Magnetic Tape", G. F. Dutton, Ph.D., D.I.C., to be held at the Royal Society of Arts, John Adam Street, Adelphi, London, W.C.2, at 7.15.

Radar Association

10th April. "Radar Techniques and Research on Wave Propagation", R. L. Smith-Rose, C.B.E., D.Sc., at 7.30 at the Anatomy Theatre, University College, Gower Street, London, W.C.1.

The British Kinematograph Society

17th April. "A New Approach to Telerecording", A. E. Sarson, B.Sc., A.Inst.P., and P. B. Stock, with an introductory survey by L. C. Jesty, B.Sc., at 7.15 at the Royal Society of Arts, John Adam Street, Adelphi, London, W.C.2.

The Institute of Navigation

26th April. "Methods of Obtaining a Ship's Aspect and Speed by Radar", Captain R. G. Swallow, R.N., and A. L. P. Milwright, at 5.15 at the Royal Geographical Society, 1 Kensington Gore, London, S.W.7.

SCATTERING OF MICROWAVES BY LONG DIELECTRIC CYLINDERS

In this paper in the November 1956 issue of *Wireless Engineer*, the plastics referred to in Fig. 5 (c) and (d) have the following dielectric properties :

	Fig. 5 (c)	Fig. 5 (d)
Relative permittivity	3·40	3·18
Loss tangent	0·0581	0·0118

STANDARD-FREQUENCY TRANSMISSIONS

(Communication from the National Physical Laboratory)

Values for February 1957

Date 1957 February	MSF 60 kc/s Frequency deviation from nominal :* parts in 10^9
1	0
2	+ 1
3	+ 1
4	+ 1
5	+ 1
6	N.M.
7	+ 1
8	+ 1
9	+ 1
10	+ 1
11	+ 1
12	+ 1
13	+ 1
14	+ 2
15	+ 2
16	N.M.
17	+ 1
18	N.M.
19	+ 1
20	+ 2
21	+ 2
22	+ 2
23	+ 2
24	+ 2
25	+ 2
26	+ 2
27	+ 2
28	+ 2

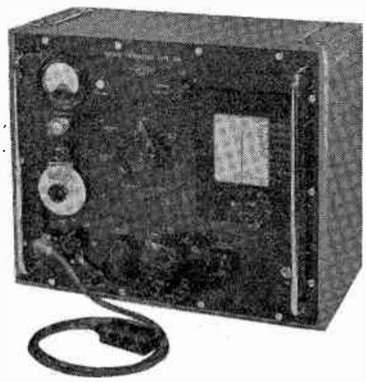
* *Nominal frequency is defined to be that frequency corresponding to a value of* 9 192 631 830 *c/s for the N.P.L. caesium resonator. N.M. = Not Measured.*

New Products

H.F. Signal Generator

The Type 201 is an entirely new standard signal generator providing a stabilized output from 30 kc/s to 30 Mc/s in seven ranges. It incorporates a film scale giving an actual scale length on each range of 48 in., together with an additional vernier scale giving an effective scale length of 260 in. on each range. A crystal calibrator is included to enable any desired frequency to be set to a very high degree of accuracy.

The output signal is amplitude-stabilized and remains constant within ±1 dB over the complete frequency range, and the harmonic distortion at all frequencies is less than 1%.



A special attenuator circuit gives continuously variable attenuation over a range of 120 dB with an output impedance of 75 ohms ± 5% under all conditions. The normal maximum output is 1 volt from the 75-ohm source, but this can be doubled when the modulation is switched off. A high-impedance output socket is provided, giving a 5-volt signal.

Internal modulation at 1,000 c/s is provided and spurious frequency modulation occurring with amplitude modulation is, in general, less than 200 c/s.

Airmec Ltd., High Wycombe, Bucks.

Flexible Terminal Strip

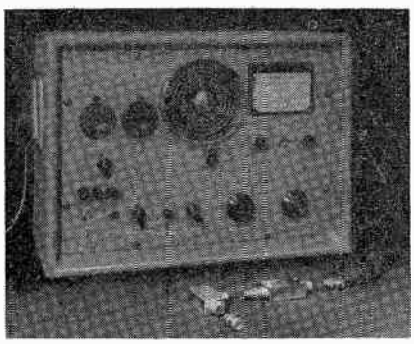
The Kabi 12-way 5–10-amp flexible terminal strip is moulded in black p.v.c. material, which is tough and resilient. The insulation resistance is in excess of 10^{12} ohms, and the breakdown voltages between terminals and between earth and terminals are 9 kV and 5 kV respectively.

Precision Components (Barnet) Ltd.,
13 Byng Road, Barnet, Herts.

Pressurised Assembly Cabinets

Cabinets as illustrated are available from B.M.B. (Sales) Ltd. They are provided with filtered air so that the assembly of precision instruments and other devices liable to damage by dust contamination can be effected under clean conditions. Automatic control of air temperature and pressure is provided on some models.

B.M.B. (Sales) Ltd.,
Boscobel, Crawley, Sussex.



F.M./A.M. Signal Generator

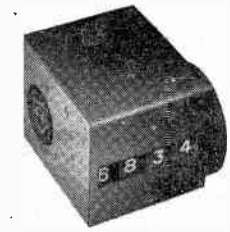
The Marconi Instruments F.M./A.M. Signal Generator TF 995A/2 is the latest of the TF 995 series. This is a compact a.c. mains-operated, transportable instrument with a frequency range of 1·5 to 220 Mc/s in five bands. There is a built-in crystal calibrator for use above 13·5 Mc/s. A precision slow-motion mechanism is employed for the main tuning drive, and a directly calibrated incremental tuning control for making bandwidth measurements has been incorporated.

The open-circuit output level is variable, in 1-dB steps, from a minimum of 0.1 μV at 52 ohms to a maximum of 100 mV at 52 ohms and 200 mV at 75 ohms. The output may be c.w., frequency-modulated, amplitude modulated, or simultaneously both frequency- and amplitude-modulated. The modulation, obtained either from an internal 1,000-c/s oscillator or from an external source, is variable to maximum frequency deviations ranging from 25 to 600 kc/s for f.m., and to depths up to 50% for a.m.

Marconi Instruments Ltd.,
St. Albans, Herts.

Lightweight Electro-Mechanical Counters

Two new high-speed electro-mechanical counters are available from Counting Instruments Ltd. Type 54/4 counts from 0 to 9999. Its mechanism is driven from a balanced escapement system of very light weight, set in jewel bearings and energized by one or more electromagnets spaced round a common armature. The



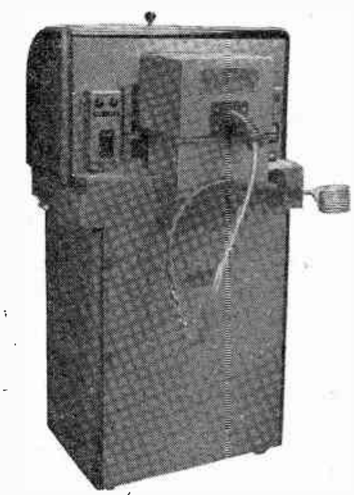
operating voltage is 22–29 V d.c., and the device is claimed to respond to 10-msec pulses at up to 37 per second, and to maintain accurate counts during accelerations of 7 g. the weight is 1·1 ounces.

The other counter, Type 52/4 (illustrated) is similar, but is provided with a mechanical reset. Its maximum speed is 16 counts per second.

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

Induction Heater for Silicon Zone Refining

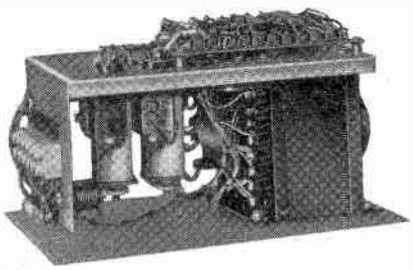
Radio Heaters Ltd. have introduced a 6-kW r.f. heating equipment C50/SR specially designed for silicon refining. A voltage in excess of 4·5 kV can be developed across a work coil of 0·5 μH, at a frequency of 5 Mc/s. The use of higher frequencies than normal is said to result in more efficient operation; the actual frequency depends on



working conditions, since the tank coil of the oscillator is the work coil, but is in the range 3·5 to 6·5 Mc/s.

A separate voltage regulator is used as a power output control. An additional facility, of great value in silicon refining, is an arrangement whereby the output of the generator can be reduced almost instantaneously from 6 kW to 1 kW. This enables a silicon rod to be rapidly heated from cold and then, as its resistance falls, supplied with reduced power so as to prevent excessive temperature rise.

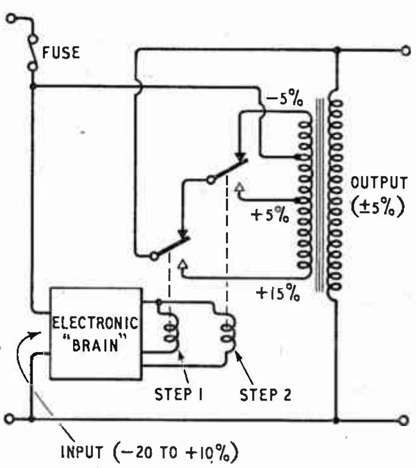
Radio Heaters Ltd.,
Eastheath Avenue, Wokingham, Berks.



Automatic Tap Changers

Claude Lyons Ltd. are now manufacturing a range of a.c. automatic tap changers. These provide a simple means of bringing widely-varying mains voltages within limits acceptable for most electronic equipment. The output waveform is undistorted, and operation is not frequency-dependent.

The diagram shows the basic circuit and the photograph an actual tap changer with

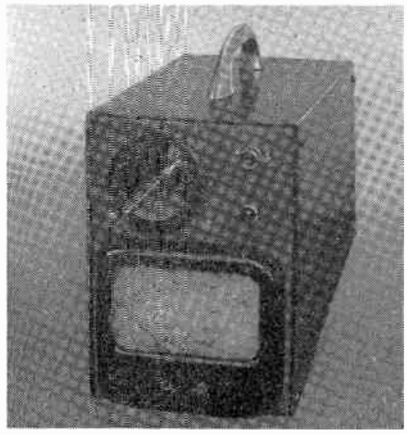


cover removed. It will be seen that the output voltage remains within 5% of the rated value for input changes of − 20% to + 10%. The tap changers are rated at 200–250 V, 2·5 or 5 A, and 100–125 V, 5 or 10 A.

Claude Lyons Ltd.,
Valley Works, Ware Road, Hoddesdon, Herts.

Television Signal-Strength Meter

A standard turret-type tuner unit forms the 'front end' of the Lab-Craft television signal-strength meter and tuner tester. The rest of the circuit consists of a sensitive amplifier and detector. The detector provides an a.g.c. voltage which is applied to



the amplifier. Indication of signal strength is provided by metering the cathode current of one of the controlled stages, and is claimed to be accurate to within ±3 dB.

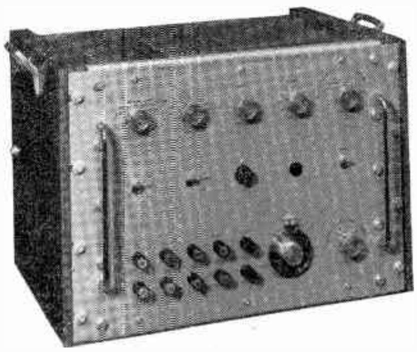
An additional facility, useful for testing receivers, is the provision of an i.f. output at 34–38 Mc/s via a cathode-follower. This output can be connected to the i.f. amplifier of a receiver to test whether the receiver's own front end is functioning properly.

Lab-Craft Ltd.,
71 Netley Road, Newbury Park, Essex.

Low-Frequency Waveform Generator

This low-frequency waveform generator (Servomex Type L.F.51) generates sine-waves in the frequency range 0·005 c/s–500 c/s, square waves and pulses with durations of 100 μsec–1,000 sec, and ramp fuctions, triangular, sawtooth and cosine-shaped pulses.

The L.F.51 embodies an integrating amplifier which converts steps of input voltage into ramp functions. The input voltage-steps are obtained from a trigger



circuit which can be switched manually or by an external drive, or by the integrator itself to form a free-running oscillator. Special facilities are the provision for outputs of one half-cycle, one cycle, and asymmetrical waves. A trigger pulse for starting an external oscilloscope before the generator output pulse is available.

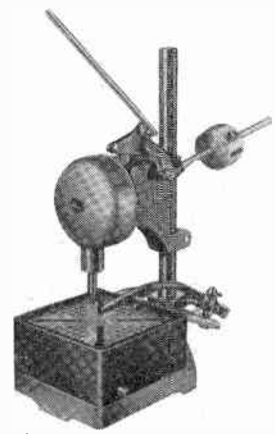
Sine waves are generated from the triangular waves by a biased-diode network; the total distortion is less than 1%.

Servomex Controls Ltd.,
Crowborough Hill, Jarvis Brook, Sussex.

New Ultrasonic Equipment

A new ultrasonic generator, type E. 7589, provides outputs suitable for driving the Mullard 50-watt ultrasonic drill, soldering iron, or tinning bath.

Also available are accessories for the 50-watt drill. These include a slurry pump and work-table designed to be used together



to maintain a continuous flow of abrasive slurry, and new matching stubs. The latter are of stepped cylindrical construction instead of the usual exponential taper, and are said to give greatly increased cutting speeds, and to permit the use of larger tools. A drill with work table, slurry feed, and stepped matching stub is illustrated.

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

Noiseless Air-Operated Screwdriver

The air exhaust system of the new Consolidated Pneumatic screwdriver is such that exhaust waves are raised to a frequency above the range of audibility. The usual irritating high-pitched whine is thus eliminated.

The tool, which weighs 30 ounces, is suitable for 0, 2 and 4 B.A. and $\frac{3}{16}$ in. to $\frac{1}{4}$ in. B.S.F. and Whitworth sizes.

Consolidated Pneumatic Tool Co. Ltd.,
232 Dawes Road, London, S.W.6.

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

534.121.2 975
A Difference Equation for the Approximate Calculation of the Natural Frequencies of a Membrane (Recurrence Method).—J. Hersch. (*C. R. Acad. Sci., Paris*, 12th Nov. 1956, Vol. 243, No. 20, pp. 1475–1478.)

534.75 976
Auditory Reaction Time as a Function of Frequency of the Signal Tone.—M. S. P. Rao & N. A. Nayak. (*Curr. Sci.*, Aug. 1956, Vol. 25, No. 8, p. 255.) Reaction times of the human ear to tones of frequencies between 600 c/s and 15 kc/s have been studied. For a constant intensity of 30 dB there is a minimum reaction time for frequencies in the range 1·5–4 kc/s; this is also the frequency range over which the sensitivity of the human ear is greatest.

534.75 : 534.862.3/.4 977
An Audio Flutter Weighting Network.—F. A. Comerci & E. Oliveros. (*J. Soc. Mot. Pict. Telev. Engrs*, Aug. 1956, Vol. 65, No. 8, pp. 419–425.) The results of listener tests are compared with flutter-index measurements. The meter used incorporates two automatically switched weighting networks, and is thus able to provide a correct objective assessment of flutter effect under different flutter conditions. See also 2507 of 1955 (Comerci).

621.317.7.029.4 : 537.54 978
Narrow-Band A.F. Noise Generator.—Steffen. (See 1197.)

621.395.623.7 979
Efficiency and Power Rating of Loudspeakers.—R. W. Benson. (*Trans. Inst. Radio Engrs*, Jan./Feb. 1956, Vol. AU-4, No. 1, pp. 19–23.) For abstract, see *Proc. Inst. Radio Engrs*, May 1956, Vol. 44, No. 5, p. 716.

621.395.623.7 980
High-Fidelity Loudspeakers: the Performance of Moving-Coil and Electrostatic Transducers.—H. J. Leak. (*J. Brit. Instn Radio Engrs*, Dec. 1956, Vol. 16, No. 12, pp. 681–693.) The advantages and disadvantages of moving-coil, ribbon and electrostatic-type loudspeakers with power-handling capacities of about 10 W are discussed. The advantages of the balanced push-pull e.s. loudspeaker are particularly mentioned.

621.395.623.7 + 621.395.61] : 534.61 981
An Automatic Integrator for Determining the Mean Spherical Response of Loudspeakers and Microphones.—A. Gee & D. E. L. Shorter. (*B.B.C. Engng Div. Monographs*, Aug. 1956, No. 8, pp. 1–16.) Detailed description of apparatus designed for use in conjunction with polar plotting equipment; the necessary integrations are effected simultaneously with the measurement of the polar characteristics. When a loudspeaker is tested it is rotated in front of a stationary microphone; the a.f. output from the microphone is amplified, rectified and converted by a vibrating interrupter to a fixed frequency of 50 c/s, and the resulting signal is applied through separate amplifiers to the voltage and current coils of a specially designed kWh meter, which thus registers a quantity proportional to the rate of energy flow per unit area of wave front.

621.395.625.3 982
Magnetic Recording, 1888–1952.—C. F. Wilson. (*Trans. Inst. Radio Engrs*, May/June 1956, Vol. AU-4, No. 3, pp. 53–81.) An extensive bibliography including 38 important patents.

AERIALS AND TRANSMISSION LINES

621.315.213 : 621.397.24 983
Video-Pair Cable System.—S. Aoki, O. Kameda, Y. Yokose & T. Uchino. (*Rep. elect. Commun. Lab., Japan*, June 1956, Vol. 4, No. 6, pp. 20–25.) A cable for a television studio/transmitter link is formed by twisting 1·4-mm foamed-polyethylene-insulated wires and screening the pair with Cu tape. Transfer-constant/frequency and characteristic-impedance/frequency curves are shown. The repeater amplifiers and synchronizing-pulse clamping circuits are discussed briefly.

621.372.2 984
Dilemmas in Transmission-Line Theory.—R. A. Chipman. (*Electronic Radio Engr*, Feb. 1957, Vol. 34, No. 2, pp. 64–67.) Errors due to approximations used in calculations of transmission characteristics of electrically-short lines are calculated and the 'optimum' and 'proper' line terminations are discussed. Some useful relations between line constants are also given.

621.372.2 **985**

The Wave Impedance Occurring in One Kind of Symmetrical Feed System.—K. Bochenek. (*Archiwum Elektrotech*, 1956, Vol. 5, No. 1, pp. 135–147. English summary, p. 147.) The characteristic impedance of a particular symmetrical transmission line is determined by a method involving conformal mapping.

621.372.8+621.372.413 **986**

Ferrite Post in a Rectangular Waveguide.—P. S. Epstein & A. D. Berk. (*J. appl. Phys.*, Nov. 1956, Vol. 27, No. 11, pp. 1328–1335.) "A thin circular ferrite post magnetized lengthwise is placed in a rectangular waveguide with its axis normal to the direction of propagation of the incident waves. The polarization is such that the electric vector is parallel to the post. The reflected and transmitted waves are calculated both with respect to their intensities and phases. The results are also applied to find the influence of a thin ferrite post upon the resonant frequency of a rectangular cavity."

621.372.8 **987**

On Transient Radiation of a Dipole inside a Waveguide.—R. Gajewski. (*Acta phys. polon.*, 1956, Vol. 15, No. 1, pp. 25–41. In English.) Exact formulae are given for the e.m. field radiated by a dipole of moment **M** inside a waveguide of arbitrary cross-section; the time-dependent factor of **M** was taken as $1(t)$ $[1-\exp(-pt)]$ sin $\omega_0 t$, where $1(t)$ is the Heaviside step function.

621.372.8 **988**

Observed 5·6-mm Attenuation for the Circular Electric Wave in Small and Medium-Sized Pipes.—A. P. King. (*Bell Syst. tech. J.*, Sept. 1956, Vol. 35, No. 5, pp. 1115–1128.) Measurements are reported on two circular-section waveguides, of internal diameter $\frac{7}{16}$ in. and $\frac{7}{8}$ in. respectively. The attenuation of the TE_{01} mode is considerably less than that of the dominant mode in both cases; transmission losses as low as 0·5 dB/100 ft have been attained. For a given line, the frequency variation of attenuation can be reduced by inserting mode filters. Losses due to oxygen absorption are taken into account.

621.372.8 : 621.384.622.2 **989**

Determination of the Series Impedance and of the Attenuation Length-Constant of a Helical Waveguide for a Linear Proton Accelerator.—A. Septier. (*C. R. Acad. Sci., Paris*, 26th Nov. 1956, Vol. 243, No. 22, pp. 1748–1750.) Continuation of work reported previously (927 and 928 of 1955). Calculated and experimental results are compared. Application of the results to travelling-wave valves is indicated.

621.396.67 **990**

Circular-Arc Antennas.—S. B. Rao. (*Indian J. Phys.*, Aug. 1956, Vol. 30, No. 8, pp. 390–406.) General analysis is presented for the radiation from a circular-arc element with current distributed sinusoidally along it. Two symmetrical composite arrangements are studied particularly. Measurements of the radiation patterns of these arrangements are compared with calculated values.

621.396.674.3 : 550.837 **991**

The Radiation Resistance of a Dipole Aerial above a Conducting Plane, from the Viewpoint of Geophysical Prospecting.—F. Minaw. (*C. R. Acad. Sci., Paris*, 19th Nov. 1956, Vol. 243, No. 21, pp. 1603–1605.) Conditions approximating to those for a layer of sand covering a conducting layer, e.g. of water, are considered. The periodic variation of the radiation resistance with frequency and with dipole height, due to interference between the direct and reflected fields, is studied. In practical conditions, the atmospheric humidity must be taken into account.

621.396.677.81 **992**

Effect of Spacing of Vibrators on Resonance and Directional Properties of a System of Vibrators of the 'Wave Channel' [Yagi] Type.—D. M. Vysokovski. (*Radiotekhnika, Moscow*, May 1956, Vol. 11, No. 5, pp. 21–25.) Theoretical characteristic curves are given for element spacings of 0·1, 0·2, 0·3 and 0·4 λ for Yagi aerials using 1, 2, or 3 director elements.

621.396.677.83 **993**

The Construction of a Sheet-Reflector Aerial with Conical Radiation Pattern.—W. Güth. (*Z. angew. Phys.*, Aug. 1956, Vol. 8, No. 8, pp. 368–372.) The aerial consists of a flat box with the front partially transparent to e.m. waves and the reflecting back plate carrying a ring of absorption wedges surrounding a small klystron-fed dipole. Useful directivity is obtained; the efficiency is low, but may be improved by making the enclosure a resonator.

621.396.677.833.2 **994**

A 60-ft-Diameter Parabolic Antenna for Propagation Studies.—A. B. Crawford, H. T. Friis & W. C. Jakes, Jr. (*Bell Syst. tech. J.*, Sept. 1956, Vol. 35, No. 5, pp. 1199–1208.) Details are given of a steerable aerial with high gain and narrow beam width, designed for studies of beyond-horizon propagation. The structure comprises 48 aluminium sectors and a central hub 8 ft long, and weighs 5½ tons. Measurements of gain and radiation pattern at 460 Mc/s, 3·89 kMc/s and 9·4 kMc/s are reported.

621.396.677.85 **995**

Experimental Investigation of Wavelength Lenses.—G. von Trentini. (*Z. angew. Phys.*, Aug. 1956, Vol. 8, No. 8, pp. 364–368.) Results are given of tests on the beaming of microwaves by means of disks of insulating material arranged transversely along the main path of propagation. Lenses consisting of trolitul or glass disks were tested with three different primary aerials at a wavelength of 3·25 cm. Arrays of loaded wire grids (see also 3483 of 1953) gave similar results, which compare favourably with those obtained from dielectric rod lenses, though side lobes require further reduction.

621.396.677.85 **996**

A Homogenous Dielectric Sphere as a Microwave Lens.—G. Bekefi & G. W. Farnell. (*Canad. J. Phys.*, Aug. 1956, Vol. 34, No. 8, pp. 790–803.) Analysis based on geometrical optics and on the diffraction theory of optical aberrations indicates that a sphere of not too high refractive index and of diameter not greater than about 30 λ has imaging properties suitable for the rapid scanning of a microwave beam through an angle of 360°. Spheres of larger size can be used if the radiation source is designed to eliminate spherical aberration.

AUTOMATIC COMPUTERS

681.142 **997**

Electronic Computers.—(*Onde élect.*, Aug./Sept. 1956, Vol. 36, Nos. 353/354.) The main part of this issue is devoted to a group of papers on computers, including the following:

The Principles of Universal Numerical Computers.—F. H. Raymond (pp. 709–718).

The Electronic Computer GAMMA, with Magnetic Drum (pp. 719–726).

The I.B.M. Type-650 Electronic Machine for Scientific Management.—J. G. Maisonrouge & J. Montigny (pp. 727–731).

An Automatic Method of Solving Mathematical Problems with an Arithmetic Electronic Computer.—L. Gaudfernau (pp. 732–741).

The Problem of Locating the Characteristic Values of Matrices in the Complex Plane and the Criteria of Stability in the Operation of Analogue Computers.—M. Parodi (pp. 753–761).

Possibilities and Developments of the Method of Rheoelectric Analogues.—L. Malavard (pp. 762–769).

A New Computing Method using High-Frequency Currents.—H. J. Uffler (pp. 770–779).

The DJINN Analogue Computer.—J. Girerd & A. Riotte (pp. 780–786).

The 'Micro-network': Possible Types of Investigation and Recent Improvements.—R. Robert (pp. 787–790).

681.142 **998**

Industrial Data-Reduction and Analogue-Digital Conversion Equipment.—P. Partos. (*J. Brit. Instn Radio Engrs*, Dec. 1956, Vol. 16, No. 12, pp. 651–678.) A review of typical system specifications is presented and several existing and proposed installations are described.

681.142 **999**

Document Processor Reads Coded Dots.—R. L. Fortune. (*Electronics*, Dec. 1956, Vol. 29, No. 12, pp. 164–168.) The equipment described converts information in the form of printed dots into pulse signals for the operation of data-handling equipment.

681.142 : 512 **1000**

Solution of Algebraic Equations on an Analogue Computer.—C. R. Cahn. (*Rev. sci. Instrum.*, Oct. 1956, Vol. 27, No. 10, pp. 856–858.) The roots of the equation are found, with an electronic differential analyser, using a method in which the operator adjusts a gauged potentiometer while observing a transient on a voltmeter or oscilloscope. Factors affecting the accuracy are discussed.

681.142 : 512.831 **1001**

Analogue Computer Synthesis and Error Matrices.—P. M. Honnell & R. E. Horn. (*Commun. & Electronics*, March 1956, No. 23, pp. 26–32.) The performance of analogue networks is studied by means of matrix analysis ; errors and stability are evaluated.

681.142 : 538.221 **1002**

High-Speed Coincident-Flux Magnetic Storage Principles.—L. P. Hunter & E. W. Bauer. (*J. appl. Phys.*, Nov. 1956, Vol. 27, No. 11, pp. 1257–1261.) Random-access magnetic-core storage systems are discussed in which the summation of coincident magnetic fluxes effects switching, the magnitude of the currents inducing the flux not being critical. Flux densities much greater than that corresponding to the coercive field may be used, giving very short switching times.

681.142 : 621.375.4.018.7 :621.314.7 **1003**

Transistor Pulse Regenerative Amplifiers.—Tendick. (See 1034.)

681.142 : 621.385.832 **1004**

A Function Multiplier.—J. D. N. van Wyk. (*Nature, Lond.*, 1st Dec. 1956, Vol. 178, No. 4544, pp. 1247–1248.) A function multiplier for incorporation in an electronic differential analyser is based on displacing a rectangular area relative to a system of rectangular axes which divide the area, when undeflected, into four equal component rectangles. A c.r. tube is used, with the operational area formed on the screen by using the deflection plates as a rectangular aperture. Light emitted by the component rectangles passes along perspex light-guides to four separate photomultipliers.

CIRCUITS AND CIRCUIT ELEMENTS

621.316.825 **1005**

Thermistor Equivalent Circuits and their Application.—E. De Castro. (*Piccole Note Ist. super. Poste e Telecomunicazioni*, July/Aug. 1956, Vol. 5, No. 4, pp. 481–508.) Four basic types of linear network are considered as equivalents to nonlinear temperature-sensitive elements for small changes around a given static condition. The behaviour of thermistors used in v.l.f. oscillators and voltage-stabilizing circuits is examined. A systematic study of transients in control circuits containing thermistors is planned.

621.318.3 : 629.13 **1006**

Solenoids for Airborne Applications.—A. S. Gutman. (*Electronic Radio Engr*, Feb. 1957, Vol. 34, No. 2, pp. 42–45.) A formula is derived for the optimum dimensions of a single-turn solenoid, which takes account of weight limitations for the solenoid and associated equipment. The space efficiency of foil-wound coils exceeds that of wire-wound types. Although edge winding results in greater power saving, wafer-type layer windings are preferable because of ease of manufacture.

621.318.4.011.1 **1007**

Multiple Resonance Frequencies.—W. W. Fain. (*Electronic Radio Engr*, Feb. 1957, Vol. 34, No. 2, pp. 68–69.) A formula for single-layer coils is derived empirically.

621.318.42 : 621.385.029.6 **1008**

The Magnetic Field in Wafer-Type Solenoids.—A. S. Gutman. (*Proc. Inst. Radio Engrs*, Jan. 1957, Vol. 45, No. 1, pp. 88–89.) Foil-wound solenoids used for beam focusing in travelling-wave valves are considered, and an analysis is made of the non-uniformity of the field in the gaps between wafer-type sections.

621.318.57 : 621.314.7 **1009**

D.C. Graphical Analysis of Junction-Transistor Flip-Flops.—T. R. Bashkow. (*Commun. & Electronics*, March 1956, No. 23, pp. 1–7.)

621.319.45.002.2 **1010**

Measurement of the True Surface of a Metal.—S. S. Gutin, L. L. Prochakov & M. G. Serbulenko. (*Zh. tekh. Fiz.*, April 1956, Vol. 26, No. 4, pp. 865-869.) A method is proposed for rapid measurement of the surface area of aluminium foil for use in electrolytic capacitors during the electrochemical etching process.

621.37.049.7.002.72 : 679.5 **1011**

The Production and Testing of Potted Circuits.—T. C. B. Talbot. (*Electronic Engng*, Dec. 1956, Vol. 28, No. 346, pp. 512-516.) Method and equipment suitable for small-batch production are described and future developments are outlined. Details of special test gear are given.

621.372.012 : 621.396.822 **1012**

Influence of Normal Fluctuations on Typical Nonlinear Elements.—I. N. Amiantov & V. I. Tikhonov. (*Bull. Acad. Sci. U.R.S.S., tech. Sci.*, April 1956, No. 4, pp. 33–41. In Russian.) A method of calculating moments of various orders in the case of normal fluctuations acting on non-inertial nonlinear elements is presented Piecewise linear characteristics are assumed.

621.372.413 + 621.372.8 **1013**

Ferrite Post in a Rectangular Waveguide.—Epstein & Berk. (See 986.)

621.372.413 **1014**

Application of the Method of Curvilinear Coordinates to the Design of a Π-Type Resonator.—V. L. Patrushev. (*Zh. tekh. Fiz.*, April 1956, Vol. 26, No. 4, pp. 821–831.) Extension of analysis presented previously (2385 of 1951) to the general case of a Π-type resonator with a tuning rod of an arbitrary thickness. A numerical example of the design is included.

621.372.413 : 621.385.029.6 **1015**

The Excitation of a Cavity Resonator by a Density-Modulated Electron Beam Passing Through the Entire Resonator Cross-Section.—P. Szulkin. (*Archiwum Elektrotech.*, 1956, Vol. 5, No. 1, pp. 149–208. English summary, pp. 207–208.) The effect of the modulated beam on the frequency and amplitude of oscillation is analysed by determining the scalar and vector potentials as functions of the exciting space charges and currents.

621.372.45.011.1 **1016**

Nonlinear Circuit Equation.—J. Irving & N. Mullineux. (*Electronic Radio Engr*, Feb. 1957, Vol. 34, No. 2, pp. 53–55.) A perturbation method of solving nonlinear equations is described and checked by numerical integration ; it is more generally applicable than the analysis given by Liebetegger (687 of 1956).

621.372.5 **1017**

Delay Unit with Computing Amplifiers and Capacitors.—Ya. I. Grinya & P. N. Kopai-Gora. (*Avtomatika i Telemekhanika*, June 1956, Vol. 17, No. 6, pp. 524–531.) A delay unit using a capacitor storage system is described. The delay of signals in the frequency range 0·05–0·5 c/s is variable between 0·1 and 20 sec.

621.372.5 : 621.3.018.75 **1018**

The Design of Pulse Systems based on the Method of Moments.—R. Kulikowski. (*Archiwum Elektrotech.*, 1956, Vol. 5, No. 1, pp. 69–80. English summary, pp. 79–80.) A method of analysis is presented based on the relation between the transient and the steady-state response of a network. An expression is derived for the steady-state amplitude characteristic corresponding to minimum rise time for the transient. An amplifier and a differentiating circuit are treated as examples.

621.372.51 **1019**

Network Matching Problems.—J. Deignan. (*Electronic Radio Engr*, Feb. 1957, Vol. 34, No. 2, pp. 70–73.) A graphical method for solving problems involving impedances in parallel is described with numerical examples.

621.372.542.2 **1020**

The Properties and the Problem of Realization of the Fundamental Transfer Functions of a Low-Pass Network.—J. Dörr. (*Nachrichtentech. Z.*, Aug. 1956, Vol. 9, No. 8, pp. 356–364.) Special and general transfer functions for the calculation of transient response are derived mathematically. The conversion into practical circuit elements is achieved by approximation with the aid of fractional rational functions in the lower half of the complex plane. A reasonably close approximation produces a response virtually identical with the transfer function.

621.372.543.2 : 621.396.6 **1021**

Survey of Mechanical Filters and their Applications.—J. C. Hathaway & D. F. Babcock. (*Proc. Inst. Radio Engrs*, Jan. 1957, Vol. 45, No. 1, pp. 5–16.)

621.372.63 : 621.317.74 **1022**

Coupled High-Frequency Transmission Lines as Directional Couplers.—H. Wolf. (*Nachrichtentech. Z.*, Aug. 1956, Vol. 9, No. 8, pp. 375–382.) The 8-terminal network formed by two coupled lines is analysed using scattering matrices, which leads to a clear expression of the directional properties of the system. Formulae are derived for the application of the network as a reflectometer and performance estimates are compared with experimental results.

621.373+621.375.9] : 538.561.029.6 **1023**

Proposal for a New-Type Solid-State Maser.—Bloembergen. (See 1062.)

621.373 : 538.567 : 621.396.822 **1024**

Shape of the Spectral Line of an Oscillator with Fluctuating Frequency.—A. N. Malakhov. (*Zh. eksp. teor. Fiz.*, May 1956, Vol. 30, No. 5, pp. 884–888.) Both 'natural' and 'technical' fluctuations are considered; the former include thermal and shot noise, the latter microphony in a valve oscillator.

621.373.42 : 621.396.822 **1025**

Effect of Slope Fluctuations on the Sensitivity of Oscillators.—M. Buyle-Bodin. (*C. R. Acad. Sci., Paris*, 19th Nov. 1956, Vol. 243, No. 21, pp. 1618–1621.) Discussion of noise in oscillators operating at frequencies near lower cut-off, due to variations of valve slope associated with flicker variations of current.

621.373.43 : 513.83 **1026**

Topological Analysis Methods for the Solution of Nonlinear Differential Equations. Application to Oscillators used in Radio Equipment.—Hontoy & Janssens. (See 1179.)

1027

621.373.5+621.375.4] : 621.314.7 : 621.311

Application of Germanium Triodes in Equipment for the Protection, Telemechanics and Communication Channels of Power Systems.—G. K. Martynov & V. V. Pavlov. (*Avtomatika i Telemekhanika*, June 1956, Vol. 17, No. 6, pp. 570–580.) Characteristics and circuit diagrams are given of a multistage a.f. amplifier, oscillator and multivibrator. The characteristics of 12 Russian junction-type and nine point-contact transistors are tabulated.

621.374.4 : 621.373 **1028**

Even-Order Subharmonic Oscillations.—W. J. Cunningham. (*J. appl. Phys.*, Nov. 1956, Vol. 27, No. 11, pp. 1374–1375.) "The generation of an even-order subharmonic, or harmonic, oscillation in a driven nonlinear resonant system described by just a cubic nonlinear term requires the simultaneous appearance of a zero-frequency component. This component effectively introduces a squared nonlinear term. A simple experiment with an electrical circuit is described, showing the presence of the zero-frequency component."

621.375.132 **1029**

Resistance-Capacitance Tuned Amplifiers using Negative Feedback.—D. J. O'Connor. (*Electronic Engng*, Dec. 1956, Vol. 28, No. 346, pp. 536–539.) A design procedure is outlined for circuits with predicted performance.

621.375.2.029.3 **1030**

Output Transformerless Amplifiers.—(*Wireless World*, Feb. 1957, Vol. 63, No. 2, pp. 58–62.) A review with 13 references.

621.375.3 **1031**

Characteristics of Magnetic Amplifiers with Feedback.—N. M. Tishchenko. (*Avtomatika i Telemekhanika*, June 1956, Vol. 17, No. 6, pp. 532–539.) Approximate formulae are derived.

621.375.3 **1032**

The Operation of the Self-Balancing Magnetic Amplifier.—A. D. Krall & E. T. Hooper. (*Commun. & Electronics*, March 1956, No. 23, pp. 79–84.) Analysis explaining the operation of the circuit is presented.

621.375.4.018.7 : 621.314.7 **1033**
: 621.394 : 621.376.56

Transistorized Binary Pulse Regenerator.—Wrathall. (See 1228.)

621.375.4.018.7 : 621.314.7 : 681.142 **1034**

Transistor Pulse Regenerative Amplifiers.—F. H. Tendick, Jr. (*Bell Syst. tech. J.*, Sept. 1956, Vol. 35, No. 5, pp. 1085–1114.) Design techniques are presented for synchronized regenerative amplifiers operating at a pulse repetition rate of the order of 1 Mc/s and suitable for use in digital computers.

621.375.422 : 621.314.7 **1035**

Temperature Stability of Transistor Amplifiers.—G. Stuart-Monteith. (*Electronic Engng*, Dec. 1956, Vol. 28, No. 346, pp. 544–547.) An analysis of the general form of d.c. amplifier leads to the definition of a 'figure of merit' for expressing the stability and gain characteristics of the circuit. Multistage d.c. coupled amplifiers are also considered.

621.375.9 : 538.569.4.029.6 **1036**

Quantum-Mechanical Amplifiers.—M. W. P. Strandberg. (*Proc. Inst. Radio Engrs*, Jan. 1957, Vol. 45, No. 1, pp. 92–93.) Possible alternatives to the molecular-beam amplifier [see e.g. 403 of 1956 (Gordon et al.)] are discussed; systems involving interaction between protons or electron spins and magnetic fields are given as examples. Noise-free amplifiers for any frequencies should be attainable.

GENERAL PHYSICS

53.05 : 519.24 **1037**

The Analysis of Experimental Results by the Method of Least Inaccuracy or by the Method of Least Squares.—P. Vernotte. (*C. R. Acad. Sci., Paris.*, 26th Nov. 1956, Vol. 243, No. 22, pp. 1733–1734.)

53.087/.088 **1038**

Optimum Smoothing of Two-Dimensional Fields.—P. D. Thompson. (*Tellus*, Aug. 1956, Vol. 8, No. 3, pp. 384–393.) "The problem of smoothing out nonsystematic errors in a two-dimensional field of measurements has been studied from the standpoint of finding the type of weighted area average for which the r.m.s. difference between the true field and the weighted average of the field of observations is the least. For fields whose space-autocorrelation functions are invariant with rotation and have a simple and rather typical form, the optimum weighting function is a linear combination of Bessel functions, whose rate of decrease away from the origin depends partially on the so-called 'signal/noise' ratio, but primarily on the ratio of the scales of the true field and error field. A comparison of optimum averaging with the analyst's subjective process of smoothing indicates that the former is significantly superior in its ability to distinguish between random small-scale fluctuations and minor synoptic features of only slightly greater scale." The discussion is conducted with particular reference to weather prediction.

534.2 : 537.3 **1039**

Acoustodynamic Effects in Semiconductors.—G. Weinreich. (*Phys. Rev.*, 15th Oct. 1956, Vol. 104, No. 2, pp. 321–324.) Effects resulting from the interaction between charge carriers and acoustic waves, first discussed by Parmenter (2281 of 1953), are further analysed.

535.215 : 537.311.33 **1040**

Exciton Structure of Spectral Curves of the Internal Photoelectric Effect in Crystals.—E. F. Gross, A. A. Kaplyanski & B. V. Novikov. (*C. R. Acad. Sci. U.R.S.S.*, 11th Oct. 1956, Vol. 110, No. 5, pp. 761–764. In Russian.) HgI_2 and CdS crystals are considered.

537.22 **1041**

General Problem of the Charge Acquired by a Spherical Particle in an Electric Field associated with Positive and Negative Ions.—M. Pauthenier, R. Cochet & J. Dupuy. (*C. R. Acad. Sci., Paris*, 19th Nov. 1956, Vol. 243, No. 21, pp. 1606–1608.) Analysis shows that there is a limiting value to the charge acquired by the particle.

537.221 **1042**

Electrostatic Charge Separation at Metal/Insulator Contacts.—P. E. Wagner. (*J. appl. Phys.*, Nov. 1956, Vol. 27, No. 11, pp. 1300–1310.) Experiments continuing those of Peterson (3516 of 1954) were made with the object of clarifying the effective contact potential mechanism. Insulators used were quartz, Al_2O_3, MgO, NaCl, KCl, KBr and KI; metals used were Ni, Cu and Pt.

537.311.1 : 061.3 **1043**

Electron Transport in Metals and Solids.—J. M. Ziman. (*Nature, Lond.*, 1st Dec. 1956, Vol. 178, No. 4544, pp. 1216–1217.) Brief report of an international conference held in Ottawa in September 1956. A full account is to be published as a special number of *Canad. J. Phys.*

537.311.62 **1044**

Matrix Theory of Skin Effect in Laminations.—L. A. Pipes. (*J. Franklin Inst.*, Aug. 1956, Vol. 262, No. 2, pp. 127–138.) A simplified method for calculating the field and current distribution in composite slabs is presented; matrix multiplication is used.

537.312.62 : 538.569.4 **1045**

Transmission of Superconducting Films at Millimetre-Microwave and Far-Infrared Frequencies.—R. E. Glover, III, & M. Tinkham. (*Phys. Rev.*, 1st Nov. 1956, Vol. 104, No. 3, pp. 844–845.) A note of measurements made on evaporated films of Pb of thickness ≈ 20 Å and Sn ≈ 100 Å.

537.523 **1046**

Temporal Growth of Ionization in Gases.—C. G. Morgan. (*Phys. Rev.*, 1st Nov. 1956, Vol. 104, No. 3, pp. 566–571.) Rate of current growth in a uniform electric field E in hydrogen at pressure p was measured over a wide range of E/p between 50 and 400 V/cm per mm Hg. Comparison of experimental with analytical data shows a change in the relative importance of secondary processes as E/p changed. For low values of E/p (≈ 50) the predominant secondary process was photoelectric emission from the cathode ; at high values (≈ 300) 50% of the emission was due to the incidence of positive ions.

537.523 **1047**

Microwave Studies of the Electron Loss Processes in Gaseous Discharges.—R. F. Whitmer. (*Phys. Rev.*, 1st Nov. 1956, Vol. 104, No. 3, pp. 572–575.) Electron loss processes in pure hydrogen have been studied by measuring the phase change and attenuation of microwave signals transmitted through a discharge. For electron densities of 5×10^{13} cm^{-3} the electron-ion recombination coefficient was $\approx 5 \cdot 9 \times 10^{-11}$ cm^{-3} sec^{-1}. The dominant loss process was attachment.

537.533/.534 **1048**

The Desorption of Positive and Negative Ions due to Strong Electric Fields.—F. Kirchner & H. A. Ritter. (*Z. Naturf.*, Jan. 1956, Vol. 11a, No. 1, pp. 35–37.) Continuation of work reported previously [1360 of 1956 (Kirchner & Kirchner)]. Observations of field-type electron emission from evaporated films of KCl on W points indicate that positive K ions can be pulled off by positive fields and negative Cl ions by negative fields when the thickness of the film is greater than that corresponding to minimum work function ; the effective work function for electrons is increased in the first case and decreased in the second. With the thinnest possible films, only positive ions could be pulled off at the field strengths used.

537.533 **1049**

The Emission of Electrons during Crystallization.—G. Bathow & H. Gobrecht. (*Z. Phys.*, 16th Aug. 1956, Vol. 146, No. 1, pp. 1–8.) Investigations of some metals failed to reveal an increase in emission associated with the crystallization process. Increases noted under certain conditions may be due to the liberation of gases when the sample solidifies.

537.533 **1050**

Higher-Order Corrections to the Field-Emission Current Formula.—P. H. Cutler & R. H. Good, Jr. (*Phys. Rev.*, 15th Oct. 1956, Vol. 104, No. 2, p. 308.) Approximations involved in analysis presented by Murphy & Good (3694 of 1956) are discussed quantitatively.

537.533 **1051**

Origin of the Characteristic Energy Losses of Electrons in Solids.—E. J. Sternglass. (*Nature, Lond.*, 22nd Dec. 1956, Vol. 178, No. 4547, pp. 1387–1389.) An explanation is outlined in terms of individual atomic ionization and excitation processes according to the Bohr-Bethe theory.

537.533 : 537/534.8 **1052**

Auger Ejection of Electrons from Tungsten by Noble Gas Ions.—H. D. Hagstrum. (*Phys. Rev.*, 15th Oct. 1956, Vol. 104, No. 2, pp. 317–318.) Results of a previous study (681 and 682 of 1955) were subsequently found to include an effect due to a small proportion of the ions being in metastable states. Data are here presented on the yield and kinetic-energy distribution of electrons ejected by normal singly charged ions only. In a separate paper (*ibid.*, pp. 309–316) it is shown that ions in metastable states can be detected by their greater ability to eject electrons from a metal surface.

537.533 : 537.534.8 **1053**

Auger Ejection of Electrons from Molybdenum by Noble Gas Ions.—H. D. Hagstrum. (*Phys. Rev.*, 1st Nov. 1956, Vol. 104, No. 3, pp. 672–683.) Basic measurements of electron yield and energy distribution of ejected electrons have been made for ions in the range 10–1 000 keV.

537.533.8 **1054**

The Distortion of Secondary-Emission Voltage/Current Characteristics in the Region of Positive Potential on the Collector.—N. B. Gornyi. (*Zh. tekh. Fiz.*, April 1956, Vol. 26, No. 4, pp. 723–725.) A discussion of the previously observed effect that secondary-emission current increases as the collector potential is increased from zero to small positive values. The usual explanations (effect of space charges, of electrons with 'insufficient' energy) are regarded as unsatisfactory, and it is suggested that this phenomenon is due to emission of tertiary electrons from the collector.

537.56 : 523.165 **1055**

Energy Loss of a Charged Particle Traversing Ionized Gas and Injection Energies of Cosmic Rays.—S. Hayakawa & K. Kitao. (*Progr. theor. Phys.*, Aug. 1956, Vol. 16, No. 2, pp. 139–148.) The energy loss is calculated taking into account direct collisions with free electrons and plasma excitation. The loss increases with the degree of ionization.

537.56 : 538.56 **1056**

Theory of Wave Motion of an Electron Plasma.—A. I. Akhiezer & R. V. Polovin. (*Zh. eksp. teor. Fiz.*, May 1956, Vol. 30, No. 5, pp. 915–928.) A theoretical investigation of nonlinear wave motion of an electron plasma with arbitrary electron velocities is reported. The plasma temperature is assumed to be zero and the state of the plasma is described by the particle density given as a function of position and time. The frequency characteristics of longitudinal and nonlinear transverse plasma oscillations are calculated and relations are obtained for complex coupled transverse-longitudinal oscillations.

537.56 : 538.6 **1057**

Experimental Study of Ionized Matter Projected Across a Magnetic Field.—W. H. Bostick. (*Phys. Rev.*, 15th Oct. 1956, Vol. 104, No. 2, pp. 292–299.) A gun has been developed which is capable of emitting pulses of plasma comprising electrons and metallic and deuterium ions at speeds up to 2×10^7 cm/s. Experimental evidence indicates that the plasma comes away in the form of expanding toroidal entities (termed 'plasmoids') which are shaped by their own magnetic field. Characteristic configurations and interactions of such plasmoids in an external magnetic field are discussed; photographs are reproduced showing structures rather like smoke rings at various stages.

538.3 **1058**

The Concept of the Infinitely Thin Infinitely Conducting Screen.—P. Poincelot. (*C. R. Acad. Sci., Paris*, 19th Nov. 1956, Vol. 243, No. 21, pp. 1616–1618.) The importance in e.m. theory of the particular method chosen for proceeding to the limit of the infinitely thin infinitely conducting screen is indicated. A simple formula for Babinet's principle is given which is not based on the concept of magnetic currents; this is developed more fully in a separate paper (*ibid.*, 26th Nov. 1956, Vol. 243, No. 22, pp. 1743–1745).

538.3 **1059**

Electromagnetic Field Solutions for Rotational Coordinate Systems.—R. C. Hansen. (*Canad. J. Phys.*, Aug. 1956, Vol. 34, No. 8, pp. 893–895.) The vector-potential approach is used.

538.3 : 531.19 **1060**

Statistical Mechanics of Matter in an Electromagnetic Field: Part 2—On Pressure and Ponderomotive Force in a Dielectric.—P. Mazur & S. R. de Groot. (*Physica*, Aug. 1956, Vol. 22, No. 8, pp. 657–669.) Ambiguity in the definitions of ponderomotive force and pressure is elucidated on the basis of a derivation of these quantities from the known microscopic interactions between the constituent particles of the system. Part 1 : 1390 of 1954 (Mazur & Nijboer).

538.521 **1061**

Shielding of a Transient Electromagnetic Dipole Field by a Conducting Sheet.—J. R. Wait. (*Canad. J. Phys.*, Aug. 1956, Vol. 34, No. 8, pp. 890–893.) Analysis presented previously for the shielding provided in the steady state (119 of 1954) is extended to apply to the case of a transient field.

538.561.029.6 : [621.373+621.375.9 **1062**

Proposal for a New-Type Solid-State Maser.—N. Bloembergen. (*Phys. Rev.*, 15th Oct. 1956, Vol. 104, No. 2, pp. 324–327.) "The Overhauser effect [*Phys. Rev.*, 15th Oct. 1953, Vol. 92, No. 2, pp. 411–415] may be used in the spin multiplet of certain paramagnetic ions to obtain a negative absorption or stimulated emission at microwave frequencies. The use of nickel fluosilicate or gadolinium ethyl sulphate at liquid helium temperature is suggested to obtain a low-noise microwave amplifier or frequency converter. The operation of a solid-state maser based on this principle is discussed."

538.566 **1063**

The Estimation of Kottler's Correction Factors.—S. Pogorzelski. (*Archiwum Elektrotech.*, 1956, Vol. 5, No. 1, pp. 81–106. English summary, pp. 104–106.) Methods of calculating the e.m. field in a homogeneous dielectric from the field distribution on a surface enclosing the sources is discussed; an evaluation is made of the correction factors representing the difference between values given by Kottler's method and those given by the Kirchhoff and Larmor-Tedone methods. The relevance of the discussion to aerial calculations is indicated.

538.566 **1064**

Wide-Band Resonance Absorber for Centimetre Electromagnetic Waves.—H. J. Schmitt. (*Z. angew. Phys.*, Aug. 1956, Vol. 8, No. 8, pp. 372–382.) The absorber described consists of a regular grid of lossy dipoles at a distance of $\lambda/4$ in front of a metal surface. By selecting suitable materials and spacings, an effective bandwidth of half an octave is obtained for the waveband around 3 cm. The addition of a second grid rotated by 90° with respect to the first makes the absorption independent of the polarization angle of the incident wave.

538.566 : 535.43 **1065**

The Scattering of Electromagnetic Waves by Conducting Spheres and Disks.—J. S. Hey, G. S. Stewart, J. T. Pinson & P. E. V. Prince. (*Proc. phys. Soc.*, 1st Oct. 1956, Vol. 69, No. 442B, pp. 1038–1049.) "A laboratory method is described for measuring the returned signal scattered from an object in an electromagnetic field. Measurements on conducting spheres and disks are compared with theoretical formulae. A new computation of the scattering function for conducting spheres is tabulated."

538.566 : 537.56 : 621.385.029.6 **1066**

Growing Electric Space-Charge Waves.—J. R. Pierce & L. R. Walker. (*Phys. Rev.*, 15th Oct. 1956, Vol. 104, No. 2 pp. 306–307.) Discussion of theory developed by Piddington (2258 of 1956), with particular reference to travelling-wave and related types of valves.

538.569.4 **1067**

Radiation Damping and Resonance Shapes in High-Resolution Nuclear Magnetic Resonance.—C. R. Bruce, R. E. Norberg & G. E. Pake. (*Phys. Rev.*, 15th Oct. 1956, Vol. 104, No. 2, pp. 419–420.) "An analysis of a nuclear spin-resonant circuit system shows that the electric circuit parameters rather than the nuclear spin relaxation times may determine resonance widths, maximum signal, and integrated intensities in high-resolution continuous-wave nuclear magnetic resonance."

538.569.4 : 537.312.62 **1068**

Nuclear Magnetic Resonance in a Superconductor.—W. D. Knight, G. M. Androes & R. H. Hammond. (*Phys. Rev.*, 1st Nov. 1956, Vol. 104, No. 3, pp. 852–853.) Discussion of the nuclear magnetic resonance observed in colloidal Hg above and below the transition temperature, 4·15°K.

539.15.098 **1069**

Spectral Diffusion in Magnetic Resonance.—A. M. Portis. (*Phys. Rev.*, 1st Nov. 1956, Vol. 104, No. 3, pp. 584–588.) "Electron spin-spin interaction is discussed for the case of strong hyperfine broadening."

539.15.098 : 538.569.4 **1070**

Sample Spinning and Field Modulation Effects in Nuclear Magnetic Resonance.—G. A. Williams & H. S. Gutowsky. (*Phys. Rev.*, 15th Oct. 1956, Vol. 104, No. 2, pp. 278–283.)

539.153 : 548 : 538.63 **1071**

Energy Spectrum of an Electron in a Crystal in a Magnetic Field.—G. E. Zil'berman. (*Zh. eksp. teor. Fiz.*, June 1956, Vol. 30, No. 6, pp. 1092–1097.)

530.1 **1072**

Modern Physics. A Textbook for Engineers. [Book Review]—R. L. Sproull. Publishers: John Wiley, New York, and Chapman & Hall, London, 1956, 491 pp., 62s. (*Nature, Lond.*, 29th Dec. 1956, Vol. 178, No. 4548, pp. 1420–1421.) Aims at supplying the theoretical background for engineers grounded in wave propagation and communication theory. Analogies between macroscopic properties of e.m. waves and the behaviour of wave functions are indicated. Numerical exercises are included.

537.533 **1073**

Elektronik des Einzelelektrons. [Book Review]—F. Ollendorff. Publishers: Springer, Vienna, 1955, 643 pp., DM 97. (*Acta phys. austriaca*, Aug. 1956, Vol. 10, No. 3, pp. 303–304.) An authoritative work on fundamental electronic theory.

GEOPHYSICAL AND EXTRATERRESTRIAL PHENOMENA

523.16 **1074**

Radio Emission from the Extragalactic Nebula M87.—J. E. Baldwin & F. G. Smith. (*Observatory*, Aug. 1956, Vol. 76, No. 893, pp. 141–144.) Results of interferometer measurements made at a frequency of 100 Mc/s using aerial spacings between 3λ and 157λ indicate that the source previously observed by Mills (1754 of 1954) is surrounded by a halo.

523.7 : 538.12 **1075**

The Sun's General Magnetic Field.—H. Alfvén & B. Lehnert. (*Nature, Lond.*, 15th Dec. 1956, Vol. 178, No. 4546, p. 1339.) Continuation of discussion noted previously [110 of January (Babcock)].

523.7 : 538.12.082 **1076**

A Solar Magnetograph.—D. W. Beggs & H. von Klüber. (*Nature, Lond.*, 22nd Dec. 1956, Vol. 178, No. 4547, p. 1412.) A note on the technique of use and some observations made with the photoelectric magnetometer newly installed at Cambridge, England.

523.75 : 550.385 **1077**

The Time Interval between Chromospheric Eruptions and Geomagnetic Perturbations.—O. Sipahioglu. (*C. R. Acad. Sci., Paris*, 5th Nov. 1956, Vol. 243, No. 19, pp. 1427–1430.) An analysis of records for the period 1939–1954 indicates that the characteristic distribution of time lag is very different for geomagnetic storms from that for isolated impulses; for the latter class of perturbation the most frequently occurring value of time lag is 25–30 h.

55 : 621.396.934 **1078**

Electronics in the I.G.Y. Program.—D. A. Findlay. (*Electronics*, Dec. 1956, Vol. 29, No. 12, pp. 138–142.) Details of the satellite tracking transmitter and the measuring and telemetering systems are summarized. See also 2718 of 1956.

550.385 **1079**

The Diurnal Behaviour of Sudden Commencements of Magnetic Storms at Agincourt [Canada].—J. A. Jacobs & T. Obayashi. (*Canad. J. Phys.*, Aug. 1956, Vol. 34, No. 8, pp. 876–883.) Analysis of data obtained during the period 1946–1953. The results suggest that the diurnal control of the magnetic variation must be due to some additional field produced in the earth's upper atmosphere at the time of sudden commencement, tending to modify the primary cause.

551.510.535 **1080**

Horizontal Wind Systems in the Ionospheric E Region Deduced from the Dynamo Theory of the Geomagnetic *Sq* Variation.—(*J. Geomag. Geoelect.*, Dec. 1955, Vol. 7, No. 4, pp. 121–132 & March 1956, Vol. 8, No. 1, pp. 24–37.)

Part 1—Nonrotating Earth.—H. Maeda.

Part 2—Rotating Earth.—S. Kato.

It is shown that the diurnal variation of the wind velocity in the ionosphere dominates the semidiurnal variation in its influence on quiet-day magnetic variations. The semidiurnal component is nearly in phase with that of winds on the ground, and its tidal amplification is estimated as about 50 for the nonrotating earth and 25–30 for the rotating earth. Estimates of the vertical drift velocities in the F region are derived.

551.510.535 : 621.396.11 **1081**

Influence of Radio Waves on the Properties of a Plasma (Ionosphere).—A. V. Gurevich. (*Zh. eksp. teor. Fiz.*, June 1956, Vol. 30, No. 6, pp. 1112–1124.) A method is developed of determining the electron velocity distribution function for a plasma in the presence of both an alternating electric and a constant magnetic field, assuming elastic collisions between the electrons and the molecules and ions. Expressions are derived for the mean electron energy, the conductivity and the permittivity of the plasma and the effective number of electron collisions.

551.594.6 **1082**
Noise Radiation from Tropical Thunderstorms in the Standard Broadcast Band.—S. V. C. Aiya. (*Nature, Lond.*, 1st Dec. 1956, Vol. 178, No. 4544, p. 1249.) Results of measurements made at Poona of the power radiated by atmospherics at frequencies of 620 and 930 kc/s indicate values lower than those derived from the formula presented previously (3263 of 1955). Further examination of the data indicates that radiation at frequencies < 1 Mc/s is contributed only by the stepped leaders of discharges to the ground; a modified formula is derived consistent with these findings.

551.594.6 : 621.396.821 **1083**
Measured Statistical Characteristics of V.L.F. Atmospheric Radio Noise.—A. D. Watt & E. L. Maxwell. (*Proc. Inst. Radio Engrs*, Jan. 1957, Vol. 45, No. 1, pp. 55–62.) Equipment for measuring the amplitudes and timing of atmospheric noise pulses is described. The greatest variation in average power level observed in a region of America between latitudes 9° and 71° N during the autumn of 1955 was about 46 dB, using a receiver bandwidth of about 1 kc/s around 22 kc/s. The dynamic range of the instantaneous noise envelope, defined as the ratio of the field strength exceeded during 0·000 1% of the time to that exceeded during 90% of the time, varied from 59 to 102 dB for 66 measurement periods of 20–30 min; the average dynamic range in the arctic region was 68 dB, and in the tropics 81 dB. The change in the dynamic range with reduction in the receiver bandwidth is discussed.

LOCATION AND AIDS TO NAVIGATION

621.396.93 **1084**
The Effect of Ground Inhomogeneities on the Calibration of Direction Finders.—J. Grosskopf & K. Vogt. (*Nachrichtentech. Z.*, Aug. 1956, Vol. 9, No. 8, pp. 349–355.) Investigations show that the maximum bearing error on medium and short waves due to local ground conductivity variations of up to 1 : 10 is unlikely to exceed 2°; this figure may be increased by re-radiation. To forecast the azimuthal error in the d.f. signal from conductivity measurements is only possible where the distribution of ground conductivity values follows a simple pattern.

621.396.96 **1085**
Marine Radar Equipment.—(*Engineer, Lond.*, 17th Aug. 1956, Vol. 202, No. 5247, p. 239.) Description of commercially available equipment intended for craft where size and weight must be kept low. The minimum range is 35 yd or less and the maximum range 48 miles. The aerial system is a 60-ft end-fed slotted waveguide in which the slots are set at different angles in order to reduce side lobes. The transmitter operates at a frequency of 9·32–9·5 kMc/s and uses a 60-kW magnetron with a pulse repetition rate of 1 100 per sec. A 9-in. c.r. tube is used for the p.p.i. display.

621.396.96 **1086**
Radar Performance Nomograph.—E. A. Wolff. (*Electronics*, Dec. 1956, Vol. 29, No. 12, p. 182.) A nomogram is presented for determining the performance of a pulsed radar system in terms of the percentage of rated range available for a given target area from the pulse parameters and the minimum detectable signal.

621.396.96 : 621.32 **1087**
The Illumination of Rooms used for Radar Screen Monitoring.—K. Ohlsen. (*Elektronische Rundschau*, July 1956, Vol. 10, No. 7, p. 200.) The lamp described produces white illumination from a combination of red, green and blue light, to avoid the excitation of afterglow screens by yellow light.

621.396.963.325 : 621.385.832 **1088**
Storage Tube projects Radar P.P.I. Display.—Gates. (See 1288.)

621.396.969 : 551.57 **1089**
Radar-Scope Interpretations of Wind, Hail and Heavy Rain Storms between May 27 and June 8, 1954.—G. E. Stout & H. W. Hiser. (*Bull. Amer. met. Soc.*, Dec. 1955, Vol. 36, No. 10, pp. 519-527.) From a detailed study of field data and radar observations, it appears that in many cases radar can give additional information useful in short-range weather forecasting.

621.396.969.3 **1090**
On the Mechanisms of Radar Sea Clutter.—M. Katzin. (*Proc. Inst. Radio Engrs*, Jan. 1957, Vol. 45, No. 1, pp. 44–54.) Discussion of observations indicates that the scattering elements of the sea surface are illuminated indirectly by reflection from neighbouring elements, as well as directly. At small depression angles, destructive interference occurs, giving rise to the so-called critical angle, polarization dependence, 'spikiness' in the A-scope display, and steeper frequency dependence. Theory is developed relating the frequency dependence of the scattering to the size and slope distribution of the elementary surface facets.

MATERIALS AND SUBSIDIARY TECHNIQUES

533.5 **1091**
High-Vacuum Seals Suitable for Baking Out.—M. J. Higatsberger. (*Acta phys. austriaca*, Aug. 1956, Vol. 10, No. 3, pp. 181–185.)

533.5 **1092**
A Simple Vacuum Leak Detector using a Radio-Frequency Mass Spectrometer.—P. F. Váradi & L. G. Sebestyén. (*J. sci. Instrum.*, Oct. 1956, Vol. 33, No. 10, pp. 392–394.)

535.215 : 537.29 **1093**
Photoelectric Work Function from Analysis of Emission in an Accelerating Field.—P. E. Carroll. (*Phys. Rev.*, 1st Nov. 1956, Vol. 104, No. 3, pp. 660–661.) "A plot of I *vs* $E^{\frac{1}{4}}$ gives a straight line for incident light a few tenths of an eV from the threshold. The ratio of the zero-field intercept to the slope of this line is directly proportional to $h(\nu-\nu_0)$ and is independent of the intensity of the incident light. The work function can be determined from this ratio for both metallic and semiconducting emitters." The work function of Te determined by this method from data of Apker et al. (1098 of 1949) is 4·78 eV.

535.215 : 546.472.21 **1094**
Potential Distribution and Localized Photoeffects in Zinc Sulphide Single Crystals.—A. Lempicki. (*J. opt. Soc. Amer.*, Aug. 1956, Vol. 46, No. 8, pp. 611–614.) Potential distributions have been measured and correlated with photoconductive regions found by light-scanning experiments. Crystals having uniform potential distributions have peak photosensitivity in the middle. An interpretation of the results based on nonuniform absorption of light is proposed.

535.215 : 546.482.21 **1095**
The Structure of the Spectral Curve of the Internal Photoeffect in Cadmium Sulphide Crystals.—E. F. Gross, A. A. Kaplyanski & B. V. Novikov. (*Zh. tekh. Fiz.*, April 1956, Vol. 26, No. 4, pp. 913–916.) Experimental results indicate that the photoeffect in CdS crystals is due to the optical excitation of excitons.

535.215 : 546.482.21 : 621.396.822 **1096**
Measurement of Noise and Response to Modulated Light of Cadmium Sulphide Single Crystals.—K. M. van Vliet, J. Blok, C. Ris & J. Steketee. (*Physica*, Aug. 1956, Vol. 22, No. 8, pp. 723-740.) The noise of photoconducting single crystals of Ag-activated and undoped CdS has been investigated in the frequency range 1 c/s–2 Mc/s. The observed noise spectra are not of inverse-frequency type; they differ according as the irradiation is in the fundamental absorption band or beyond the absorption limit. The observed response to light modulated at frequencies in the range 7 c/s–10 kc/s indicates that a large part of the noise is photo-induced. The remainder of the noise is ascribed to fluctuations in the rates of recombination and trapping. See also 3796 of 1956 (van Vliet & Blok).

535.37 **1097**
Some Optical and Electrical Measurements on Blue-Fluorescent ZnS-Cl Single Crystals.—F. A. Kröger. (*Physica*, Aug. 1956, Vol. 22, No. 8, pp. 637–643.)

535.37 **1098**
The Luminescent Response of Silver-Activated Zinc Sulphide to Lithium Ions of Different Energies.—C. F. Eve & H. E. Duckworth. (*Canad. J. Phys.*, Aug. 1956, Vol. 34, No. 8, pp. 896–897.) The work of Hanle & Rau (734 of 1953) is extended to include Li^{+} ions of energy 15–40 keV.

535.37 : 535.215 **1099**
The Photoconductivity of Phosphors with Different Luminescence Mechanisms: Part 2.—H. Gobrecht, D. Hahn &

551.594.6 **1082**

Noise Radiation from Tropical Thunderstorms in the Standard Broadcast Band.—S. V. C. Aiya. (*Nature, Lond.*, 1st Dec. 1956, Vol. 178, No. 4544, p. 1249.) Results of measurements made at Poona of the power radiated by atmospherics at frequencies of 620 and 930 kc/s indicate values lower than those derived from the formula presented previously (3263 of 1955). Further examination of the data indicates that radiation at frequencies < 1 Mc/s is contributed only by the stepped leaders of discharges to the ground; a modified formula is derived consistent with these findings.

551.594.6 : 621.396.821 **1083**

Measured Statistical Characteristics of V.L.F. Atmospheric Radio Noise.—A. D. Watt & E. L. Maxwell. (*Proc. Inst. Radio Engrs*, Jan. 1957, Vol. 45, No. 1, pp. 55–62.) Equipment for measuring the amplitudes and timing of atmospheric noise pulses is described. The greatest variation in average power level observed in a region of America between latitudes 9° and 71° N during the autumn of 1955 was about 46 dB, using a receiver bandwidth of about 1 kc/s around 22 kc/s. The dynamic range of the instantaneous noise envelope, defined as the ratio of the field strength exceeded during 0·000 1% of the time to that exceeded during 90% of the time, varied from 59 to 102 dB for 66 measurement periods of 20–30 min; the average dynamic range in the arctic region was 68 dB, and in the tropics 81 dB. The change in the dynamic range with reduction in the receiver bandwidth is discussed.

LOCATION AND AIDS TO NAVIGATION

621.396.93 **1084**

The Effect of Ground Inhomogeneities on the Calibration of Direction Finders.—J. Grosskopf & K. Vogt. (*Nachrichtentech. Z.*, Aug. 1956, Vol. 9, No. 8, pp. 349–355.) Investigations show that the maximum bearing error on medium and short waves due to local ground conductivity variations of up to 1 : 10 is unlikely to exceed 2°; this figure may be increased by re-radiation. To forecast the azimuthal error in the d.f. signal from conductivity measurements is only possible where the distribution of ground conductivity values follows a simple pattern.

621.396.96 **1085**

Marine Radar Equipment.—(*Engineer, Lond.*, 17th Aug. 1956, Vol. 202, No. 5247, p. 239.) Description of commercially available equipment intended for craft where size and weight must be kept low. The minimum range is 35 yd or less and the maximum range 48 miles. The aerial system is a 60-ft end-fed slotted waveguide in which the slots are set at different angles in order to reduce side lobes. The transmitter operates at a frequency of 9·32–9·5 kMc/s and uses a 60-kW magnetron with a pulse repetition rate of 1 100 per sec. A 9-in. c.r. tube is used for the p.p.i. display.

621.396.96 **1086**

Radar Performance Nomograph.—E. A. Wolff. (*Electronics*, Dec. 1956, Vol. 29, No. 12, p. 182.) A nomogram is presented for determining the performance of a pulsed radar system in terms of the percentage of rated range available for a given target area from the pulse parameters and the minimum detectable signal.

621.396.96 : 621.32 **1087**

The Illumination of Rooms used for Radar Screen Monitoring.—K. Ohlsen. (*Elektronische Rundschau*, July 1956, Vol. 10, No. 7, p. 200.) The lamp described produces white illumination from a combination of red, green and blue light, to avoid the excitation of afterglow screens by yellow light.

621.396.963.325 : 621.385.832 **1088**

Storage Tube projects Radar P.P.I. Display.—Gates. (See 1288.)

621.396.969 : 551.57 **1089**

Radar-Scope Interpretations of Wind, Hail and Heavy Rain Storms between May 27 and June 8, 1954.—G. E. Stout & H. W. Hiser. (*Bull. Amer. met. Soc.*, Dec. 1955, Vol. 36, No. 10, pp. 519-527.) From a detailed study of field data and radar observations, it appears that in many cases radar can give additional information useful in short-range weather forecasting.

621.396.969.3 **1090**

On the Mechanisms of Radar Sea Clutter.—M. Katzin. (*Proc. Inst. Radio Engrs*, Jan. 1957, Vol. 45, No. 1, pp. 44–54.) Discussion of observations indicates that the scattering elements of the sea surface are illuminated indirectly by reflection from neighbouring elements, as well as directly. At small depression angles, destructive interference occurs, giving rise to the so-called critical angle, polarization dependence, 'spikiness' in the A-scope display, and steeper frequency dependence. Theory is developed relating the frequency dependence of the scattering to the size and slope distribution of the elementary surface facets.

MATERIALS AND SUBSIDIARY TECHNIQUES

533.5 **1091**

High-Vacuum Seals Suitable for Baking Out.—M. J. Higatsberger. (*Acta phys. austriaca*, Aug. 1956, Vol. 10, No. 3, pp. 181–185.)

533.5 **1092**

A Simple Vacuum Leak Detector using a Radio-Frequency Mass Spectrometer.—P. F. Váradi & L. G. Sebestyén. (*J. sci. Instrum.*, Oct. 1956, Vol. 33, No. 10, pp. 392–394.)

535.215 : 537.29 **1093**

Photoelectric Work Function from Analysis of Emission in an Accelerating Field.—P. E. Carroll. (*Phys. Rev.*, 1st Nov. 1956, Vol. 104, No. 3, pp. 660–661.) "A plot of I *vs* $E^{\frac{1}{4}}$ gives a straight line for incident light a few tenths of an eV from the threshold. The ratio of the zero-field intercept to the slope of this line is directly proportional to $h(\nu-\nu_0)$ and is independent of the intensity of the incident light. The work function can be determined from this ratio for both metallic and semiconducting emitters." The work function of Te determined by this method from data of Apker et al. (1098 of 1949) is 4·78 eV.

535.215 : 546.472.21 **1094**

Potential Distribution and Localized Photoeffects in Zinc Sulphide Single Crystals.—A. Lempicki. (*J. opt. Soc. Amer.*, Aug. 1956, Vol. 46, No. 8, pp. 611–614.) Potential distributions have been measured and correlated with photoconductive regions found by light-scanning experiments. Crystals having uniform potential distributions have peak photosensitivity in the middle. An interpretation of the results based on nonuniform absorption of light is proposed.

535.215 : 546.482.21 **1095**

The Structure of the Spectral Curve of the Internal Photoeffect in Cadmium Sulphide Crystals.—E. F. Gross, A. A. Kaplyanski & B. V. Novikov. (*Zh. tekh. Fiz.*, April 1956, Vol. 26, No. 4, pp. 913–916.) Experimental results indicate that the photoeffect in CdS crystals is due to the optical excitation of excitons.

535.215 : 546.482.21 : 621.396.822 **1096**

Measurement of Noise and Response to Modulated Light of Cadmium Sulphide Single Crystals.—K. M. van Vliet, J. Blok, C. Ris & J. Steketee. (*Physica*, Aug. 1956, Vol. 22, No. 8, pp. 723-740.) The noise of photoconducting single crystals of Ag-activated and undoped CdS has been investigated in the frequency range 1 c/s–2 Mc/s. The observed noise spectra are not of inverse-frequency type; they differ according as the irradiation is in the fundamental absorption band or beyond the absorption limit. The observed response to light modulated at frequencies in the range 7 c/s–10 kc/s indicates that a large part of the noise is photo-induced. The remainder of the noise is ascribed to fluctuations in the rates of recombination and trapping. See also 3796 of 1956 (van Vliet & Blok).

535.37 **1097**

Some Optical and Electrical Measurements on Blue-Fluorescent ZnS-Cl Single Crystals.—F. A. Kröger. (*Physica*, Aug. 1956, Vol. 22, No. 8, pp. 637–643.)

535.37 **1098**

The Luminescent Response of Silver-Activated Zinc Sulphide to Lithium Ions of Different Energies.—C. F. Eve & H. E. Duckworth. (*Canad. J. Phys.*, Aug. 1956, Vol. 34, No. 8, pp. 896–897.) The work of Hanle & Rau (734 of 1953) is extended to include Li^+ ions of energy 15–40 keV.

535.37 : 535.215 **1099**

The Photoconductivity of Phosphors with Different Luminescence Mechanisms: Part 2.—H. Gobrecht, D. Hahn &

H. J. Kösel. (*Z. Phys.*, 16th Aug. 1956, Vol. 146, No. 1, pp. 87–94.) Previous investigations (1437 of 1954) were continued for a further 30 powder phosphors, using improved apparatus. Photocurrents and dark currents are tabulated. The importance of conductivity investigations in relation to electroluminescence is emphasized.

535.37 : 535.215 **1100**

The Temperature Dependence of the Dark Current and Photocurrent of Phosphors.—H. Gobrecht, D. Hahn & H. J. Kösel. (*Z. Phys.*, 16th Aug. 1956, Vol. 146, No. 1, pp. 95–106.) In continuation of previous work (1776 of 1954) further powders were investigated at temperatures up to about 270 °C. Photocurrent characteristics differed according to the mechanism of luminescence and no saturation was noted in recombination phosphors. Plotted 'conductivity-glow' curves show the trap distribution, and the spectral distribution of photocurrent excitation is examined in terms of temperature and field strength.

537.226/.288.1 **1101**

Ferroelectric Materials.—P. Popper. (*J. Instn elect. Engrs*, Aug. 1956, Vol. 2, No. 20, pp. 450–457.) A short review describing the basic physical properties and indicating possible applications of ferroelectric materials, particularly $BaTiO_3$.

537.226/.228.1 **1102**

A Calculation of Physical Constants of Ceramic Barium Titanate.—M. Marutake. (*J. phys. Soc. Japan*, Aug. 1956, Vol. 11, No. 8, pp. 807–814.) The dielectric, piezoelectric and elastic constants of polycrystalline material are calculated on the assumption that it is composed of spherical crystallites. The calculated values are in good agreement with experimentally determined values. The 'de-stressing factor', expressing the relations between the internal stress of the sphere and the stress in the surrounding medium, is defined and calculated.

537.226 **1103**

New Non-ferroelectric Dielectrics with High Dielectric Constant and Low Conductivity.—G. I. Skanavi & E. N. Matveeva. (*Zh. eksp. teor. Fiz.*, June 1956, Vol. 30, No. 6, pp. 1047–1051.) The combination of an internal field favouring polarization with relaxation ionic polarization results in a high dielectric constant without spontaneous polarization or other ferroelectric properties. This is the case in strontium titanate containing a small amount of bismuth trioxide; experimentally determined ϵ/temperature and $\tan\delta$/temperature characteristics at frequencies between 5 kc/s and 10 Mc/s and $\log \rho/(1/T)$ curves are presented, as well as curves showing the relation between the temperatures of two electrodes in a specimen, the current between them and time. At room temperature $\epsilon \approx 800$ and varies only slightly with frequency. Other materials of this class are (Ca,Bi) titanate and (Ba,Bi) titanate.

537.226.2/.31 **1104**

Permittivity and Loss Angle of some Solid Dielectrics at a Wavelength of 3 cm and their Dependence on Temperature and Frequency.—G. I. Skanavi & G. A. Lipaeva. (*Zh. eksp. teor. Fiz.*, May 1956, Vol. 30, No. 5, pp. 824–832.) Experimental results are reported. The frequency and temperature dependence of ϵ and $\tan\delta$ are presented graphically and the values of ϵ and $\tan\delta$ at $3{\cdot}1$ cm λ are tabulated for materials including steatite, barium tetratitanate, the titanates of Mg, Zn, Ca, Bi and Sr, and porcelain. The graphs cover a frequency range from l.f. to 10^{10} c/s and a temperature range from about 20° to 160° C.

537.227 **1105**

Ferroelectricity of Glycine Sulphate.—B. T. Matthias, C. E. Miller & J. P. Remeika. (*Phys. Rev.*, 1st Nov. 1956, Vol. 104, No. 3, pp. 849–850.) Glycine sulphate and its isomorphous selenate are ferroelectric, with Curie points 47°C and 22°C respectively. For glycine sulphate at room temperature the spontaneous polarization is $2{\cdot}2 \times 10^{-6}$ coul/cm² and the coercive field is 220 V/cm. A formal similarity among ferroelectric sulphates regardless of crystal structure is suggested.

537.311.31 + 537.311.33 **1106**

Pictorial Kinetic Methods in the Theory of Metals and Semiconductors.—R. B. Dingle. (*Physica*, Aug. 1956, Vol. 22, No. 8, pp. 671–680.) The 'pictorial kinetic method' of treating electron transport problems is based on calculations of the average drift velocity in the direction of the applied field. The importance of the particular method used for superposing the drift velocity on the distribution function corresponding to the absence of applied field is demonstrated. Relations valid for semiconductors are derived by averaging over the transport distribution function the corresponding relations for metals.

537.311.31 : 539.234 : 538.63 **1107**

Influence of a Magnetic Field on the Electrical Resistance of Thin Films of Nickel.—T. Rappeneau. (*C. R. Acad. Sci., Paris*, 5th Nov. 1956, Vol. 243, No. 19, pp. 1403–1406.) Measurements have been made on evaporated films at normal temperature. With medium-strength fields (up to 500 oersted) the resistance decreases when the magnetization is perpendicular to the current and increases when the magnetization is parallel to the current; hysteresis effects are exhibited. With high-strength fields (1 000–6 000 oersted) the resistance decreases slightly with magnetization in either direction.

537.311.31 : 546.56 : 537.533 **1108**

Electron Irradiation of Copper below 10° K.—J. W. Corbett, J. M. Denney, M. D. Fiske & R. M. Walker. (*Phys. Rev.*, 1st Nov. 1956, Vol. 104, No. 3, pp. 851–852.) Measurements on high-purity Cu foil bombarded by $1{\cdot}35$-MeV electrons give a value of $(8{\cdot}25 \pm 1{\cdot}2) \times 10^{-27}$ Ω.cm for the resistivity change per electron per cm².

537.311.33 **1109**

Semiconducting Intermetallic Compounds.—L. Pincherle & J. M. Radcliffe. (*Advances Phys.*, July 1956, Vol. 5, No. 19, pp. 271–322.) A comprehensive survey of published data on the preparation, properties, theory and applications of these materials, with an extensive bibliography.

537.311.33 **1110**

Recombination of Electrons and Holes at Dislocations.—S. R. Morrison. (*Phys. Rev.*, 1st Nov. 1956, Vol. 104, No. 3, pp. 619–623.) "The phenomenon of hole-electron recombination at dislocations is examined, and it is demonstrated that the space-charge barrier surrounding the dislocation may have a dominant effect in determining the characteristics of recombination. In particular, the inclusion of the space-charge effect leads directly to the slow decay phenomena observed in silicon and *n*-type germanium. The characteristics of electrical fluctuations due to trapping at these levels are discussed on the basis of the model."

537.311.33 **1111**

The Statistics of Charge-Carrier Fluctuations in Semiconductors.—R. E. Burgess. (*Proc. phys. Soc.*, 1st Oct. 1956, Vol. 69, No. 442B, pp. 1020–1027.) "The statistical fluctuations in the number of charge carriers (conduction electrons or valence-band holes) in a given volume of semiconductor in the steady state is calculated from the transition probabilities of electrons between the conduction and valence bands or between either band and impurity levels. The case in which one independent fluctuating variable (either n or p) specifies the electronic state of the system is considered. Simple general formulae are developed for the mean value n_0 of n and its variance and it is shown that for large numbers n tends to be normally distributed about n_0. The relaxation time for small deviations from equilibrium is evaluated. These results are applied to three cases: (*a*) the intrinsic semiconductor, (*b*) the strongly intrinsic semiconductor and (*c*) the slightly extrinsic semiconductor with all impurity atoms ionized. The relation between the statistical approach and the thermodynamical treatment [793 of 1956] is indicated."

537.311.33 **1112**

Defects with Several Trapping Levels in Semiconductors.—P. T. Landsberg. (*Proc. phys. Soc.*, 1st Oct. 1956, Vol. 69, No. 442B, pp. 1056–1059.) Analytical discussion is presented.

537.311.33 : 535.215 **1113**

Structural Characterization of Caesium Antimonide: Temperature Factors in Cubic Crystals.—K. H. Jack & M. M. Wachtel. (*Nature, Lond.*, 22nd Dec. 1956, Vol. 178, No. 4547, pp. 1408–1409.)

537.311.33 : 535.215 : 546.482.21 **1114**

Changes in Conductivity Resulting from Breakdown in Cadmium Sulphide Single Crystals.—J. Woods. (*Proc. phys. Soc.*, 1st Oct. 1956, Vol. 69, No. 442B, pp. 975–980.) Experiments are described, the results of which are in general agreement with those of Diemer (2960 of 1954); CdS crystals can be activated to become good photoconductors simply by passing large currents through them.

537.311.33 : 535.3 **1115**

The Influence of Electrons on the Optical Properties of Semiconductors.—E. Groschwitz & R. Wiesner. (*Z. angew. Phys.*, Aug. 1956, Vol. 8, No. 8, pp. 391–398.) The contribution of the conduction electrons to the optical properties is investigated in detail for *n*-type Ge. The principal optical parameters are plotted as functions of light frequency, temperature and impurity content. Convenient measurements are not yet possible in the mm-λ and tenth-mm-λ ranges where the electron contribution is greatest, but parameters can be predicted from results of experiments in adjoining frequency ranges.

537.311.33 : 535.34 **1116**

The Anomalous Skin Effect and the Optical Absorptivity of Semiconductors: Part 1.—R. B. Dingle. (*Physica*, Aug. 1956, Vol. 22, No. 8, pp. 683–697.) The 'pictorial kinetic method' (1106 above) is used to derive tentative expressions for optical absorption by semiconductors. The variations of carrier concentration and collision time with temperature and impurity concentration are discussed and the relative importance of the 'Drude-Kronig' and 'anomalous' terms in the optical absorption are assessed. The anomalous term may be important at wavelengths from 1 to 300 μ for semiconductors with a fairly high impurity concentration, but is comparatively unimportant for nondegenerate systems unless the effective carrier mass is unusually small.

537.311.33 : 537.32 **1117**

Thermoelectric Properties of Cd-Sb Alloys.—V. A. Yurkov & N. E. Alekseeva. (*Zh. tekh. Fiz.*, April 1956, Vol. 26, No. 4, pp. 911–912.) A brief report is presented on an experimental investigation which suggests that the energy structure of CdSb is of the type normal for semiconductors.

537.311.33 : 539.23 **1118**

The Use of an Interference Microscope for Measurement of Extremely Thin Surface Layers.—W. L. Bond & F. M. Smits. (*Bell Syst. tech. J.*, Sept. 1956, Vol. 35, No. 5, pp. 1209–1221.) "A method is given for the thickness measurement of *p*-type or *n*-type surface layers on semiconductors. This method requires the use of samples with optically flat and reflecting surfaces. The surface is lapped at a small angle in order to expose the *p-n* junction. After detecting and marking the *p-n* junction, the thickness is measured by an interference microscope. Another application of the equipment is the measurement of steps in a surface. The thickness range measurable is from 5×10^{-6} cm to 10^{-3} cm."

537.311.33 : 546.23 **1119**

Influence of the Physical State and of Infrared Irradiation on the R.F. Dipolar Absorption of Very Pure Specimens of Hexagonal Selenium.—J. Meinnel, M. Eveno & F. Trigolet. (*C. R. Acad. Sci., Paris*, 26th Nov. 1956, Vol. 243, No. 22, pp. 1761–1764.) The energy level of acceptors due to crystal imperfections is determined from measurements of the r.f. absorption. Irradiation at wavelengths > 1·4 μ is ineffective in displacing the absorption bands; peaks in this effect occur at 0·7 and 1·1 μ, probably as a result of trapping levels.

537.311.33 : [546.28+546.289 **1120**

Absorption and Emission Spectra of Silicon and Germanium in the Soft-X-ray Region.—D. H. Tomboulian & D. E. Bedo. (*Phys. Rev.*, 1st Nov. 1956, Vol. 104, No. 3, pp. 590–597.)

1121

537.311.33 : [546.28+546.289] : 538.569.4

Cyclotron-Resonance Experiments in Silicon and Germanium.—R. N. Dexter, H. J. Zeiger & B. Lax. (*Phys. Rev.*, 1st Nov. 1956, Vol. 104, No. 3, pp. 637–644.) "Experimental techniques are described for cyclotron resonance in silicon and germanium at 9 000 Mc/s, 24 000 Mc/s, and higher frequencies. Results are presented for electrons and holes in both germanium and silicon. The parameters for the heavy holes are evaluated, with corrections from an approximate theory of line shape for warped surfaces. Observations of the harmonics of cyclotron resonance of the heavy holes in germanium and silicon are described."

537.311.33 : 546.281.26 **1122**

The Mechanism of the Voltage-Dependent Contact Resistance of Silicon Carbide.—W. Heywang. (*Z. angew. Phys.*, Aug. 1956, Vol. 8, No. 8, pp. 398–405.) Examination of experimental results indicates that the boundary-layer model proposed by Jones et al. (3168 of 1949) correctly represents the capacitance of SiC contacts and its pressure dependence for voltages below 10 V per single contact.

537.311.33 : 546.289 **1123**

Interferometric Wavelength Measurements of Germanium Lines of a Hollow-Cathode Discharge.—R. D. VanVeld & K. W. Meissner. (*J. opt. Soc. Amer.*, Aug. 1956, Vol. 46, No. 8, pp. 598–604.) Spectral lines of wavelengths from 4 685 to 2 019 Å have been investigated experimentally. From the results precise calculations can be made of the wavelengths of 29 lines in the range 1 998–1 691 Å.

537.311.33 : 546.289 **1124**

Effects of Growth Rate on Crystal Perfection and Lifetime in Germanium.—A. D. Kurtz, S. A. Kulin & B. L. Averbach. (*J. appl. Phys.*, Nov. 1956, Vol. 27, No. 11, pp. 1287–1290.) "Effects of crystal growth rate and growth direction on the density of random dislocations and on the minority-carrier lifetime have been observed. The dislocation density increases rapidly with growth rate above a rate of about 0·15 in. per minute and varies somewhat with growth direction. The capture efficiency per unit length of dislocation decreases at high growth rates and it is suggested that this effect is caused by the failure of impurity atoms to segregate at dislocations or by the clustering of dislocations." See also 2435 of 1956.

537.311.33 : 546.289 **1125**

Investigation of Single-Crystal Ge Films Prepared by Evaporation in Vacuum.—G. A. Kurov, S. A. Semiletov & Z. G. Pinsker. (*C. R. Acad. Sci. U.R.S.S.*, 21st Oct. 1956, Vol. 110, No. 6, pp. 970–971. In Russian.) Results are reported of various electrical measurements and a structural investigation of films produced by evaporation of 2–30-Ω.cm *n*- or *p*-type Ge on single crystals of Ge. In one case, deposition (at 550° C) of a film 18·5 μ thick on a Ge crystal of thickness 0·7 mm and resistivity 10·5 Ω.cm reduced the combined resistivity to 0·83 Ω.cm. Measurements also showed that the Hall constant for the film was ≈ 3 cm³/C and the hole mobility ≈ 150 cm²/V.sec, these values being considerably lower than those in the single crystal. The films obtained were all *p*-type, irrespective of the type of the evaporated Ge. Electron-microscope photographs of the surfaces are shown and discussed.

537.311.33 : 546.289 **1126**

Galvanomagnetic Effects in a Heavily Doped Germanium Crystal.—W. Sasaki. (*J. phys. Soc. Japan*, Aug. 1956, Vol. 11, No. 8, pp. 894–895.) Measurements over the temperature range 1·3°–280° K of the variations of resistivity and Hall constant with the strength of an applied magnetic field are reported.

537.311.33 : 546.289 **1127**

Some Experiments on a Germanium Surface Layer.—M. Kikuchi. (*J. phys. Soc. Japan*, Aug. 1956, Vol. 11, No. 8, p. 898.) Resistivity measurements were made, using the four-probe method, on a thin *p*-type layer formed by heat treatment on an *n*-type single crystal. The effects of variations in the ambient conditions are shown.

537.311.33 : 546.289 **1128**

Dislocations in Plastically Bent Germanium Crystals.—F. L. Vogel, Jr. (*J. Metals, N.Y.*, Aug. 1956, Vol. 8, No. 8, Section 2, pp. 946–949.) The densities and distributions of dislocations were studied before and after annealing of the bars. Three significant changes were produced by the annealing process; (*a*) the average density of dislocations is reduced; (*b*) dislocations migrate from the high-density outer regions towards the low-density neutral axis; (*c*) a polygonized structure is formed by movement of the dislocations into walls normal to the slip plane.

537.311.33 : 546.289 **1129**

Combined Measurements of Field Effect, Surface Photovoltage and Photoconductivity.—W. H. Brattain & C. G. B. Garrett. (*Bell Syst. tech. J.*, Sept. 1956, Vol. 35, No. 5, pp. 1019–1040.) An experimental study of the properties of fast surface states on etched Ge surfaces is reported. Both *n*- and *p*-type specimens were investigated, and the surfaces were exposed to a series of gaseous ambients as described previously [1698 of 1953 (Brattain & Bardeen)]. The results indicate that the height of the surface barrier, measured with respect to the Fermi level, varies from $-0\cdot13$ to $+0\cdot13$ V, and that the surface recombination velocity varies over about a factor of ten in this range. The dependence of the charge trapped in fast surface states on barrier height and on the steady-state concentration within the semiconductor is determined.

537.311.33 : 546.289 **1130**

Distribution and Cross-Sections of Fast States on Germanium Surfaces.—C. G. B. Garrett & W. H. Brattain. (*Bell Syst. tech. J.*, Sept. 1956, Vol. 35, No. 5, pp. 1041–1058.) A theoretical interpretation is provided for the experimental results reported in 1129 above. It is deduced that the density of fast states is lowest near the centre of the energy gap, increasing sharply as the accessible limits of surface potential are approached; the fast states are largely of acceptor type. Estimates are made of the cross-sections for transitions between the fast states and the conduction and valence bands.

537.311.33 : 546.289 **1131**

Scattering of Holes by Phonons in Germanium.—H. Ehrenreich & A. W. Overhauser. (*Phys. Rev.*, 15th Oct. 1956, Vol. 104, No. 2, pp. 331–342.) Expressions are derived for the differential cross-sections for scattering of holes in the valence band of Ge by acoustical and optical phonons. The wave functions are calculated for holes in the valence band near $\boldsymbol{k} = 0$. The electron-phonon interaction Hamiltonian is developed, and the matrix elements and transition probabilities for lattice scattering are derived.

537.311.33 : 546.289 **1132**

Lattice-Scattering Mobility of Holes in Germanium.—H. Ehrenreich & A. W. Overhauser. (*Phys. Rev.*, 1st Nov. 1956, Vol. 104, No. 3, pp. 649–659.) Results of preceding analysis (1131 above) are used to calculate the mobility for a temperature range approximately 100°–300° K where lattice scattering is the predominant scattering mechanism.

537.311.33 : 546.289 **1133**

Mechanism of Diffusion of Copper in Germanium.—F. C. Frank & D. Turnbull. (*Phys. Rev.*, 1st Nov. 1956, Vol. 104, No. 3, pp. 617–618.) "To explain the rapid diffusivity of copper in germanium and its dependence on structure, it is proposed that the copper be dissolved in two states, interstitial and substitutional. It is deduced that in the interstitial state the solubility of copper is about 10^{-2} times less and the diffusivity many orders of magnitude greater than in the substitutional state. Conversion from the interstitial to the substitutional state is effected by lattice vacancies which are generated at free surfaces and dislocations; this accounts for the structure dependence of the diffusivity observed by Tweet and Gallagher [169 of January]."

537.311.33 : 546.289 **1134**

Mass Ratio and Magnetoresistance in *N*-Type Germanium.—G. C. Della Pergola. (*Phys. Rev.*, 1st Nov. 1956, Vol. 104, No. 3, pp. 598–599.) "An upper limit of $15\cdot7$ for the ratio of longitudinal to transverse mass of conduction electrons at room temperature was determined by magnetoresistance measurements on *n*-type germanium single crystals. Experimental values of this ratio range between $7\cdot0$ and $11\cdot4$."

537.311.33 : 546.289 **1135**

Electrical Properties of Germanium at Very Low Temperatures.—E. I. Abaulina-Zavaritskaya. (*Zh. eksp. teor. Phys.* June 1956, Vol. 30, No. 6, pp. 1158–1160.) Results are reported of an experimental determination of (*a*) resistance/temperature characteristics of 1-Ω.cm Ge specimens at field strengths of 50–100 mV/cm, and (*b*) resistance/field-strength characteristics at temperatures between $0\cdot15$ and $4\cdot2$°K. The critical field strength at which the resistance drops sharply is 11 V/cm. Curves (*a*) indicate that the activation energy between $0\cdot15$ and 1 °K is less by one order of magnitude than between $1\cdot6$ and $4\cdot2$ °K.

537.311.33 : 546.289 : 538.214 **1136**

Further Measurements on the Magnetic Susceptibility of Germanium down to Liquid-Helium Temperatures.—A. van Itterbeek & W. Duchateau. (*Physica*, Aug. 1956, Vol. 22, No. 8, pp. 649–656.) Continuation of work reported previously [2022 of 1955 (van Itterbeek et al.)]. For pure Ge crystals the diamagnetic susceptibility increases by about 5% between room and liquid-hydrogen temperatures and is nearly constant in the liquid-helium region. For specimens containing Sb over a certain low concentration a minimum is observed in the susceptibility/temperature curve between liquid-H and liquid-He points; a paramagnetic term appears at the lowest temperatures.

537.311.33 : 546.289 : 538.63 **1137**

High-Field Longitudinal Magnetoresistance of Germanium.—H. P. Furth & R. W. Waniek. (*Phys. Rev.*, 15th Oct. 1956, Vol. 104, No. 2, pp. 343–345.) "The longitudinal magnetoresistance of germanium N_{100}, N_{111}, P_{100}, P_{111}, and P_{211} single crystals of 2-Ω. cm resistivity has been measured to the point of saturation, by means of transient magnetic fields up to 600 000 gauss. An *N*-type effective mass ratio of $17\cdot2\pm0\cdot4$ has been determined at 300° K. The magnitude and variation with field of the *P*-type magnetoresistances was found to be anomalous."

537.311.33 : 546.289 : 548 **1138**

Defects in Germanium Crystals Grown from the Melt.—E. Billig. (*Brit. J. appl. Phys.*, Oct. 1956, Vol. 7, No. 10, pp. 375–376.) "Thermal stresses arising from differential shrinkage as the crystal cools down from the freezing point to room temperature are considered as a major source of structural defects. The distribution of etch pits over various parts of a crystal has been studied and correlation has been obtained with the lifetime of minority carriers and with transistor action."

537.311.33 : 546.289 : 621.396.822 **1139**

Excess Noise in Deformed Germanium.—J. J. Brophy. (*J. appl. Phys.*, Nov. 1956, Vol. 27, No. 11, pp. 1383–1384.) Brief report of experiments indicating that plastic deformation greatly increases the current noise in Ge single crystals.

537.311.33 : 546.561-31 **1140**

Study of Cuprous Oxide Formed at 410° C at Pressures of Air between 0·5 and 75 mm of Hg.—K. R. Dixit & V. V. Agashe. (*Z. Naturf.*, Jan. 1956, Vol. 11a, No. 1, pp. 41–45. In English.) "At these low pressures we get only one oxide namely Cu_2O. The increase of pressure and the time of oxidation appear mainly to produce a change in the orientation of the Cu_2O crystallites. The films when sufficiently thick peel off, but even at this stage of thickness (1 μ to 3 μ) they do not show any electrical resistance or rectification."

537.311.33 : 546.682.86 **1141**

Carrier Lifetime in Indium Antimonide.—G. K. Wertheim. (*Phys. Rev.*, 1st Nov. 1956, Vol. 104, No. 3, pp. 662–664.) "The lifetime in well-compensated, single-crystal indium antimonide samples has been obtained as a function of temperature between 130° and 250° K. The results suggest that the lifetime is limited by radiative recombination at high temperatures and by a recombination-centre mechanism at low temperatures."

537.311.33 : 546.682.86 : 621.396.822 **1142**

Excess Noise in InSb.—G. H. Suits, W. D. Schmitz & R. W. Terhune. (*J. appl. Phys.*, Nov. 1956, Vol. 27, No. 11, p. 1385.) Measurements on several specimens are briefly reported; the frequency used was 20 c/s. Very low values of excess noise were observed.

537.311.33 : 546.817.221 **1143**

Magnetoresistance Effect of Lead Sulphide Group of Semiconductors: Part 1—Measurements on Natural Specimens of Lead Sulphide.—T. Irie. (*J. phys. Soc. Japan*, Aug. 1956, Vol. 11, No. 8, pp. 840–846.) Measurements were made with various angles between the electric and magnetic field directions. Results are discussed in relation to theory based on spheroidal energy surfaces.

537.311.33 : 546.817.221 : 621.383.4 **1144**

Field-Induced Doping of PbS Layers.—D. E. Martz, L. G. LaMarca & R. S. Witte. (*J. appl. Phys.*, Nov. 1956, Vol. 27, No. 11, pp. 1382–1383.) Brief report of measurements of the resistance of a PbS photoconductive cell subjected to an electric field, as a function of time and temperature; the results indicate that the effect of the substrate may be important when interaction occurs between the PbS film and the substrate.

537.311.33 : 621.317.3 **1145**

Direct Method of Measuring the Contact Injection Ratio [of a rectifying barrier].—O. L. Curtis, Jr, & B. R. Gossick. (*Rev. sci. Instrum.*, Oct. 1956, Vol. 27, No. 10, pp. 828–829.) A method requiring no auxiliary contacts is discussed. The injection ratio is determined by comparing the area on an oscilloscope screen corresponding to a current injection pulse with the area of the resulting hole storage pulse.

537.312.9 : 546.87 **1146**

Piezoresistance in Bismuth.—R. W. Keyes. (*Phys. Rev.*, 1st Nov. 1956, Vol. 104, No. 3, pp. 665–666.) Piezoresistance phenomena in Bi are consistent with multivalley models proposed.

538.22 **1147**

Magnetic Compounds with Perovskite Structure: Part 4—Conducting and Nonconducting Compounds.—G. H. Jonker. (*Physica*, Aug. 1956, Vol. 22, No. 8, pp. 707–722.) It is shown that the antiferromagnetic compound $LaMnO_3$ would be ferromagnetic if the cubic perovskite structure present at high temperatures could be preserved at low temperature. Part 3: 2701 of 1953 (Jonker & van Santen).

538.22 **1148**

Contribution to the Experimental Study of Interactions of Molecular-Field Type. Case of Solid Solutions of a Ferromagnetic or Antiferromagnetic Metal in Palladium.—J. Cohen. (*C. R. Acad. Sci., Paris*, 19th Nov. 1956, Vol. 243, No. 21, pp. 1613–1616.)

538.22 **1149**

Calculation of the Primary Excitations in Magnetic Substances.—P. G. de Gennes. (*C. R. Acad. Sci., Paris*, 26th Nov. 1956, Vol. 243, No. 22, pp. 1730–1732.) The spectrum of the spin waves can be calculated from measurements of elastic diffusion of neutrons.

538.221 **1150**

On the Minimum of Magnetization Reversal Time.—R. Kikuchi. (*J. appl. Phys.*, Nov. 1956, Vol. 27, No. 11, pp. 1352–1357.) "A modified Landau-Lifshitz equation is solved for a single-domain sphere and an infinitely-wide thin single-domain sheet of ferromagnetic material neglecting anisotropy. The external magnetic field is switched from one direction to its opposite instantaneously at the initial time and the behaviour of the magnetization vector is investigated thereafter. It is shown that there is a critical value of the damping constant corresponding to the minimum value of the (repetitive) magnetization reversal time."

538.221 **1151**

Spatial Correlations in a Ferromagnetic Material Near the Curie Point.—P. G. de Gennes & A. Herpin. (*C. R. Acad. Sci., Paris*, 19th Nov. 1956, Vol. 243, No. 21, pp. 1611–1613.) The form of the spin correlations is deduced from the theory of the molecular field.

538.221 **1152**

Fluctuation Magnetic After-Effect Near the Curie Point.—D. Pescetti & J. C. Barbier. (*C. R. Acad. Sci., Paris*, 26th Nov. 1956, Vol. 243, No. 22, pp. 1740–1743.) The variation of the effect with temperature is studied; a maximum is observed near the Curie point.

538.221 **1153**

The Anisotropy Correction in Ferromagnetic Resonance.—K. J. Standley & K. W. H. Stevens. (*Proc. phys. Soc.*, 1st Oct. 1956, Vol. 69, No. 442B, pp. 993–996.) A method is described for finding the net absorption, for a given magnetic field, resulting from the superposition of absorption lines from the randomly distributed crystallites of a polycrystalline material. Owing to magnetocrystalline anisotropy, the maximum in a ferromagnetic resonance curve does not coincide with the centre of gravity of the absorption line. The magnitude of the correction required is estimated; it can be important in iron and in some ferrites.

538.221 **1154**

The Saturation Magnetization of Nickel under High Hydrostatic Pressure.—K. H. von Klitzing & J. Gielessen. (*Z. Phys.*, 16th Aug. 1956, Vol. 146, No. 1, pp. 59–64.) Three different methods are described which were used to determine the effect of pure hydrostatic pressure. Results obtained agree more closely with those of Ebert & Kussmann (*Phys. Z.*, 1937, Vol. 38, pp. 437–445) than with those of Stacey (3115 of 1956), whose considerably higher values of the pressure coefficient may be due to the combination of unidirectional and hydrostatic pressure.

538.221 **1155**

The Magnetomechanical Hysteresis Loop of Nickel.—M. Kornetzki. (*Z. Phys.*, 16th Aug. 1956, Vol. 146, No. 1, pp. 107–112.) The results of torsion tests on hard and annealed Ni tubes are plotted as elastic-hysteresis loops and are analysed. The value of 'coercive force' is assessed and compared with that obtained for soft iron.

538.221 **1156**

Saturation Magnetization in Copper-Nickel Alloys.—S. A. Ahern & W. Sucksmith. (*Proc. phys. Soc.*, 1st Oct. 1956, Vol. 69, No. 442B, pp. 1050–1052.) Measurements are reported on six alloys with compositions ranging from 4·7% to 34·3% Cu.

538.221 **1157**

Spectroscopic Splitting Factors for Iron and Silicon Iron.—G. S. Barlow & K. J. Standley. (*Proc. phys. Soc.*, 1st Oct. 1956, Vol. 69, No. 442B, pp. 1052–1055.)

538.221 **1158**

Neutron Diffraction Study of the Structures and Magnetic Properties of Manganese Bismuthide.—B. W. Roberts. (*Phys. Rev.*, 1st Nov. 1956, Vol. 104, No. 3, pp. 607–616.)

538.221 **1159**

The Temperature Characteristics of the Initial Permeability of Mn_2Sb, Cobalt, Iron and Nickel.—M. Kersten. (*Z. angew. Phys.*, Aug. 1956, Vol. 8, No. 8, pp. 382–386.) An analysis of experimental results of other workers confirms the correctness of the temperature characteristics derived from the theory outlined previously (501 of February).

538.221 : 534.232 : 538.652 **1160**

The Dynamic Magnetostriction of Nickel-Cobalt Alloys.—C. A. Clark. (*Brit. J. appl. Phys.*, Oct. 1956, Vol. 7, No. 10, pp. 355–360.) Ni-Co alloys for transducers are discussed. Measurements of the electromechanical coupling coefficient, the reversible permeability and Young's modulus are described. Two alloys containing respectively about 4·4% and 18·4% Co give good performance.

538.221 : 537.311.31 **1161**

The Effect of Spontaneous, True and Ferromagnetic Magnetization on Electrical Resistance.—E. Böhringer. (*Z. Phys.*, 16th Aug. 1956, Vol. 146, No. 1, pp. 65–74.) Resistance changes were measured in ferromagnetic wires under transverse magnetization up to and above saturation, for temperatures from −185° to +232°C. The magnitude of the changes decreases with decreasing temperature; above saturation the fall in resistance is proportional to the magnetizing field.

538.221 : 538.6 : 539.23 **1162**

Magnetic Domains in Thin Films by the Faraday Effect.—C. A. Fowler, Jr, & E. M. Fryer. (*Phys. Rev.*, 15th Oct. 1956, Vol. 104, No. 2, pp. 552–553.) Technique developed previously for investigating magnetic domains by examining the rotation of reflected light (2441 of 1954) is adapted to observations of the transmitted light.

538.221 : 539.234 **1163**

The Domain Structure of Thin Films of Iron.—B. Elschner & D. Unangst. (*Z. Naturf.*, Jan. 1956, Vol. 11a, No. 1, pp. 98, 48d.) Observations have been made on oriented films deposited on NaCl bases; photomicrographs are reproduced.

538.221 : 539.234 : 538.67 **1164**

Magnetic Domains in Evaporated Thin Films of Nickel-Iron.—C. A. Fowler, Jr, E. M. Fryer & J. R. Stevens. (*Phys. Rev.*, 1st Nov. 1956, Vol. 104, No. 3, pp. 645–649.) Domain patterns have been observed in Ni-Fe films of thickness 500–5 000 Å by the longitudinal Kerr magneto-optical effect [2441 of 1954 (Fowler & Fryer)]. Certain unusual features of domain behaviour appear characteristic of the thinnest specimens. Films of thickness 10 000 Å and 20 000 Å showed no domain structure by this technique.

538.221 : 621.318.12 **1165**

Preferred Orientations and Magnetic Properties of Rolled and Annealed Permanent - Magnet Alloys. — W. R. Hibbard, Jr. (*J. Metals, N.Y.*, Aug. 1956, Vol. 8, No. 8, Section 2, pp. 962–967.) Pole figures, torque curves and coercive force have been determined for cunife, cunico, silmanal, vicalloy I, vicalloy II and Heusler's alloy.

538.221 : 621.318.134 **1166**

Properties and Uses of Ferrites.—K. J. Standley. (*Nature, Lond.*, 22nd Dec. 1956, Vol. 178, No. 4547, pp. 1371–1373.) Report of the conference organized by the Institution of Electrical Engineers in the autumn of 1956. Nearly 60 papers were read; these are to be published, with the discussion, in *Proc. Instn elect. Engrs* during 1957.

538.221 : 621.318.134 **1167**

Method for Forming Large Ferrite Parts for Microwave Applications.—L. G. Van Uitert, F. W. Swanekamp & F. R. Monforte. (*J. appl. Phys.*, Nov. 1956, Vol. 27, No. 11, pp. 1385–1386.) Sludge pressing technique is briefly discussed.

538.221 : 621.318.134 **1168**

Neutron Diffraction Study of Manganese Ferrite.—J. M. Hastings & L. M. Corliss. (*Phys. Rev.*, 15th Oct 1956, Vol. 104, No. 2, pp. 328–331.)

538.221 : 621.318.134 **1169**

Anisotropy Constants and *g* Value of Nickel Ferrite.—D. W. Healy, Jr, & R. A. Johnson. (*Phys. Rev.*, 1st Nov. 1956, Vol. 104, No. 3, pp. 634–636.) Experimental data are presented for the temperature range 4°–300°K and frequency range 7·9–11·5 kMc/s. Measured *g* values show a significant variation with frequency not observed in previous measurements on single crystals.

538.221 : 621.318.134 **1170**

Magnetic Properties of Rare-Earth Ferrites $3M_2O_3.5Fe_2O_3$, with M = Tb, Dy, Ho, Er, Tm, Yb, Lu. Experimental Results.—R. Pauthenet. (*C. R. Acad. Sci., Paris*, 12th Nov. 1956, Vol. 243, No. 20, pp. 1499–1502.)

538.221 : 621.318.134 **1171**

Interpretation of the Magnetic Properties of the Ferrites $3M_2O_3$. $5Fe_2O_3$ where M = Y, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu.—R. Pauthenet. (*C. R. Acad. Sci., Paris*, 26th Nov. 1956, Vol. 243, No. 22, pp. 1737–1740.)

539.15.098 : 538.569.4 **1172**

Antiferromagnetism and Antiferromagnetic Resonance in $CuBr_2.2H_2O$ at 9 800 Mc/s.—M. Date. (*Phys. Rev.*, 1st Nov. 1956, Vol. 104, No. 3, pp. 623–624.)

539.23 : 537.533.8 **1173**

Preparation and Properties of Thin-Film MgO Secondary Emitters.—P. Wargo, B. V. Haxby & W. G. Shepherd. (*J. appl. Phys.*, Nov. 1956, Vol. 27, No. 11, pp. 1311–1316.) "Some simple methods of preparing MgO thin films on Mg-Ag alloy with high secondary-emission ratios are discussed. The oxidation procedure and a discussion of the underlying phenomena are presented. Films with a secondary yield of 12 at 600 V may be produced by oxidation in either oxygen or carbon dioxide. Results of a study of some of the factors influencing the life of a secondary emitter are given. These include the effects on the secondary emitting characteristics of evaporation products from an oxide-coated cathode and the deterioration of the thin film under electron bombardment."

539.234 : 548.5 **1174**

The Orientation of Thin Evaporated Metal Films.—H. Göttsche. (*Z. Naturf.*, Jan. 1956, Vol. 11a, No. 1, pp. 55–68.) Report of an electron-diffraction investigation of the growth of layers of metals with face-centred cubic crystal structure (Ag, Au, Al, Pd and Cu) on alkali halide crystals with the same structure.

546.56 : [621.385 : + 666.1.037.5 **1175**

Copper as a Material in High-Vacuum Technology.—W. Espe. (*Nachr-Tech.*, Aug. & Sept. 1956, Vol. 6, Nos. 8 & 9, pp. 355–364 & 401–408.) Comprehensive data are presented on the physical and chemical properties of pure Cu; its advantages and disadvantages in the manufacture of vacuum apparatus are tabulated. Particular uses are discussed; Cu/glass seals receive special attention.

549.514.51 **1176**

Paramagnetic Resonance of Lattice Defects in Irradiated Quartz.—R. A. Weeks. (*J. appl. Phys.*, Nov. 1956, Vol. 27, No. 11, pp. 1376–1381.)

549.514.51 : 621.372.412 **1177**

The Effect of Various Types of Radiation on Piezoelectric Quartz and Crystal Resonators.—F. Seidl. (*Acta phys. austriaca*, Aug. 1956, Vol. 10, No. 3, pp. 169–174.) Experimental results obtained by various workers indicate that the piezoelectric properties of quartz are affected by exposure to X rays and particle rays. The increase in the piezoelectric constant induced by X rays decays more rapidly in a loaded than in an unloaded resonator. The relation between discoloration and frequency deviation in resonators is discussed [see also 3309 of 1946 (Frondel)].

621.315.613.1 **1178**

Surface Adhesion and Elastic Properties of Mica.—G. L. Gaines, Jr, & D. Tabor. (*Nature, Lond.*, 8th Dec. 1956, Vol. 178, No. 4545, pp. 1304–1305.) The important role of e.s. forces in the adhesion of mica is indicated.

MATHEMATICS

513.83 : 621.373.43 **1179**

Topological Analysis Methods for the Solution of Nonlinear Differential Equations. Application to Oscillators used in Radio Equipment.—P. Hontoy & P. Janssens. (*Rev. HF, Brussels*, 1956, Vol. 3, No. 6, pp. 221–244.) General theory is presented and the case of the multivibrator with common cathode resistance is analysed in detail.

517 **1180**

A Direct Approach to the Problem of Stability in the Numerical Solution of Partial Differential Equations.—J. Todd. (*Commun. pure appl. Math.*, Aug. 1956, Vol. 9, No. 3, pp. 597–612.) An arithmetic treatment is presented applicable to the wave equation and some other partial differential equations.

517 :[535.3/.4 + 534.24/.26 **1181**

On Radiation Conditions.—J. J. Stoker. (*Commun. pure appl. Math.*, Aug. 1956, Vol. 9, No. 3, pp. 577–595.) Steady-state solutions of the differential wave-propagation equation are discussed for waves refracted, reflected or diffracted at a boundary. An examination is made of the conditions to be imposed at infinity to ensure the uniqueness of a desired solution.

517 : [535.42 + 534.26 **1182**

The Scope and Limitations of the Method of Wiener and Hopf.—A. E. Heins. (*Commun. pure appl. Math.*, Aug. 1956, Vol. 9, No. 3, pp. 447–466.) Boundary-value problems arising in the solution of certain elliptic partial differential equations are discussed; the method is applicable to diffraction problems.

517 : 621.384.612 **1183**

Hill's Nonlinear Equation and the Stroboscopic Method of Minorsky.—Blaquière. (See 1210.)

517.942.9 **1184**

The Solutions of Laplace's Equation for the Case of Cylindrical Symmetry.—S. Colombo. (*C. R. Acad. Sci., Paris*, 12th Nov. 1956, Vol. 243, No. 20, pp. 1471–1473.)

519.2 : 621.396.822 **1185**

The Statistical Distribution of the Maxima of a Random Function.—D. E. Cartwright & M. S. Longuet-Higgins. (*Proc. roy. Soc. A*, 9th Oct. 1956, Vol. 237, No. 1209, pp. 212–232.) A study is made of a random function which is the sum of an infinite number of sine waves in random phase. The work is related to that of Rice (440 and 2168 of 1945) on electrical noise, but the particular application in this case is to sea waves.

517 **1186**

Functional Analysis. [Book Review]—F. Riesz & B. Sz.-Nagy. Publishers: Blackie, London and Glasgow, 1956, 468 pp., 65s. (*Nature Lond.*, 22nd Dec. 1956, Vol. 178, No. 4547, p. 1369.) English translation of second French edition. Fundamental ideas are introduced step by step; numerous illustrative examples are included.

MEASUREMENTS AND TEST GEAR

531.76 : 621.374.32 **1187**

The Vernier Time-Measuring Technique.—R. G. Baron. (*Proc. Inst. Radio Engrs*, Jan. 1957, Vol. 45, No. 1, pp. 21–30.) A detailed description is given of a system for accurate measurement of the time interval between nonperiodic pulses. The coarse measure is obtained by means of a clock pulse of usual type, while the intervals between the start and end pulses on the one hand and the nearest clock pulse on the other hand are determined by causing the start and end pulses to generate a train of auxiliary pulses with a repetition rate greater than that of the clock pulses. Readings are taken at coincidence between the auxiliary and clock pulses, the operation being thus analogous to that of a mechanical vernier.

538.569.4.029.6 : 535.33 **1188**

Further Extension of Microwave Spectroscopy in the Submillimetre-Wave Region.—M. Cowan & W. Gordy.

(*Phys. Rev.*, 15th Oct 1956, Vol. 104, No. 2, pp. 551–552.) The wavelength range of the investigations described previously [e.g. 2156 of 1956 (Burrus & Gordy)] has been extended down to 0·587 mm.

621.317.3 : 537.311.33 : 537.323 **1189**

Methods of Measuring the Coefficient of Thermo-e.m.f. of Semiconductors.—G. I. Skanavi & A. M. Kashtanova. (*Zh. tekh. Fiz.*, April 1956, Vol. 26, No. 4, pp. 895–899.) Two known methods are discussed and their deficiencies pointed out. A modified method is described which gives satisfactory results.

621.317.3 : 621.315.61 **1190**

A New Electrode System for Determining the Transverse Resistivity of Insulators.—R. Lacoste. (*C. R. Acad. Sci., Paris*, 19th Nov. 1956, Vol. 243, No. 21, pp. 1609–1611.) The use of evaporated-film electrodes is outlined.

621.317.3.029.6(43) : 621.396.65 **1191**

Microwave Measuring Devices.—H. H. Klinger. (*Electronic Engng*, Dec. 1956, Vol. 28, No. 346, pp. 524–527.) Brief review of German equipment for measurements in radio-link systems.

621.317.33 : 621.315.612.6 **1192**

Determination of Resistivity of Lossy Materials from Dielectric Measurements, making Use of Interfacial Polarization.—R. T. Lewis & L. R. Bickford, Jr. (*J. Amer. ceram. Soc.*, 1st June 1956, Vol. 39, No. 6, pp. 222–226.) A method is described in which the resistivity of glass is determined from measurements of the variation with temperature and frequency of the capacitance and dielectric loss of a sandwich comprising a relatively thick piece of glass and a relatively thin piece of mica.

621.317.361 : 621.396.822 **1193**

Some Results on the Analysis of Random Signals by means of a Cut-Counting Process.—I. Miller & J. E. Freund. (*J. appl. Phys.*, Nov. 1956, Vol. 27, No. 11, pp. 1290–1293.) Extension of work reported by Steinberg et al. (2060 of 1955).

621.317.361.029.6 **1194**

Measurement of Instantaneous Frequency with a Microwave Interferometer.—H. P. Raabe. (*Proc. Inst. Radio Engrs*, Jan. 1957, Vol. 45, No. 1, pp. 30–38.) A system is described in which a frequency discriminator comprising a transmission-line circuit is used to convert frequency variations of a microwave signal to amplitude variations; these are applied to a detector followed by an amplifier and oscilloscope indicator. The adjustment of the discriminator to minimize distortion is discussed. The method has been found practical for measuring the frequency stability of a radar pulse.

621.317.4 **1195**

Magnetic Measurements. — C. E. Webb. (*Metallurgia, Manchr*, Aug. 1956, Vol. 54, No. 322, pp. 57–66.) "The basic principles of the chief methods of determining the properties of ferromagnetic materials—ballistic, slowly varying flux, and alternating current methods—are described. Special consideration is given to the testing of permanent magnets by standard and comparative methods, and to the conditions necessary to ensure that test results give reliable indications of practical performance. Some representative methods of measuring field strength are reviewed."

621.317.42 **1196**

Measurement of Nonuniform Magnetic Fields in Narrow Gaps.—J. Knizak. (*Acta phys. austriaca*, Aug. 1956, Vol. 10, No. 3, pp. 186–189.) A probe suitable for use in very restricted spaces, with volumes down to 1 mm³, is described; operation is based on the deflection of current carriers in Hg by the field to be measured.

621.317.7.029.4 : 537.54 **1197**

Narrow-Band A.F. Noise Generator.—D. Steffen. (*Elektronische Rundschau*, July 1956, Vol. 10, No. 7, pp. 185–188.) The equipment described, comprising glow-discharge generator followed by a selective amplifier and frequency changer, produces a noise band of width variable from about 10 to 165 c/s anywhere in the a.f. range. It facilitates qualitative measurements, e.g. of loudspeaker frequency response and distortion, because the effects of standing acoustic waves are avoided.

621.317.7.029.6 : 621.315.212 **1198**

Short-Circuiting Plunger for Coaxial Lines.—H. K. Ruppersberg. (*Arch. elekt. Übertragung*, Aug. 1956, Vol. 10, No. 8, pp. 358–360.) A plunger is described which comprises a brass cylinder with radial slits held by a spiral spring at one end so as to exert pressure on the inner and outer conductors at the other end; the short-circuiting plane does not shift with variations of signal frequency.

621.317.7.029.6 : 621.373.423 : 621.385.029.6 **1199**

The Use of Travelling-Wave Valves for Measurements.—A. Lauer. (*Elektronische Rundschau*, July 1956, Vol. 10, No. 7, pp. 190–192.) Wobbulator, frequency-doubler and oscillator circuits using the Type-TL6 valve (4-kMc/s range) are briefly described.

621.317.726 **1200**

A Novel High-Voltage Peak Voltmeter.—W. P. Baker. (*Proc. Instn elect. Engrs*, Part A, Oct. 1956, Vol. 103, No. 11, pp. 519–522.) The performance of the instrument is made nearly independent of the characteristics of the rectifiers by including them in a feedback loop.

621.317.755 : 621.3.014.33 **1201**

A High-Speed-Oscillograph Cathode-Ray Tube for the Direct Recording of High Current Transients.—R. Feinberg. (*Electronic Engng*, Dec. 1956, Vol. 28, No. 346, pp. 540–541.) The tube described uses an external single-turn coil for direct signal deflection. An oscillogram of a 1 650-A, 15-μs pulse with a gradient of 250 A/μs is shown.

621.317.761 **1202**

Theory and Practice of a Very-High-Accuracy Arrangement for Frequency Measurement.—G. Becker. (*Arch. elekt. Übertragung*, Aug. 1956, Vol. 10, No. 8, 315–325.) Details are given of an arrangement using frequency multiplication of the unknown, followed by comparison with a reference frequency and counting of the resulting beats. Typical measurement results are discussed in relation to the theoretical results, and the errors are hence determined. Over the range 15 kc/s–15 Mc/s the maximum error is 1 part in 10^9 for a measuring time of 100 sec. By using averaging methods, the error can be reduced to a few parts in 10^{11} for a measuring time of about 1 sec.

621.317.761 **1203**

Direct-Reading High-Sensitivity Frequency Meter.—J. Lagasse, R. Lacoste & J. Prades. (*C. R. Acad. Sci., Paris*, 5th Nov. 1956, Vol. 243, No. 19, pp. 1406–1408.) Apparatus for determining frequencies between 47 and 51 c/s is based on measurement of the frequency of beats between a multiple of the frequency to be determined and a sub-multiple of the frequency of a quartz-controlled reference oscillator.

OTHER APPLICATIONS OF RADIO AND ELECTRONICS

531.768 : 534.86 **1204**

Calibration of Vibration Pickups by the Reciprocity Method.—S. Levy & R. R. Bouche. (*J. Res. nat. Bur. Stand.*, Oct. 1956, Vol. 57, No. 4, pp. 227–243.)

550.837 : 621.396.674.3 **1205**

The Radiation Resistance of a Dipole Aerial above a Conducting Plane, from the Viewpoint of Geophysical Prospecting.—Minaw. (See 991.)

621-526 : 621.387 **1206**

Grid Control of Thyratrons with Particular Reference to Servomechanism Applications.—K. R. McLachlan. (*J. Brit. Instn Radio Engrs*, Dec. 1956, Vol. 16, No. 12, pp. 695–699.)

621.319.3 : 621.385.833 **1207**

Use of Electrostatic High-Voltage Machines with the Electron Microscope.—W. Herchenbach & H. Düker. (*Optik, Stuttgart*, 1956, Vol. 13, No. 8, pp. 375–376.) A short note indicating that e.s. generators can be used satisfactorily, even without stabilizing devices, for power supply in e.s. electron microscopes and electron diffraction apparatus.

621.384.611 **1208**

Modes of Acceleration of Ions in a Three-Dee Cyclotron.—M. Jakobson, M. Heusinkveld & L. Ruby. (*Phys. Rev.*, 15th Oct. 1956, Vol. 104, No. 2, pp. 362–365.)

621.384.612 **1209**

Elimination of the Critical Energy in a Strong-Focusing Synchro-phasotron.—A. A. Kolomenski. (*Zh. tekh. Fiz.*, April 1956, Vol. 26, No. 4, pp. 740–748.)

621.384.612 : 517 **1210**

Hill's Nonlinear Equation and the Stroboscopic Method of Minorsky.—A. Blaquière. (*C. R. Acad. Sci., Paris*, 26th

Nov. 1956, Vol. 243, No. 22, pp. 1711–1714.) Discussion of stabilization conditions for an equation representing oscillations occurring in a strong-focusing cosmotron.

621.385.833 : 537.533/.534 **1211**

The Resolving Power of the Field [-emission] Ion Microscope.—E. W. Müller. (*Z. Naturf.*, Jan. 1956, Vol. 11a, No. 1, pp. 88–94.) Considerations of resolving power indicate that the field-emission microscope should be operated with ion rather than electron emission. Helium is particularly suitable for examining metal surfaces. Cooling to very low temperature enables the atomic structure of the specimen to be made visible. See also 3329 of 1956 (Müller & Bahadur).

621.398 **1212**

Radio Transmission of an Electrocardiogram.—E. Evrard & J. Rens. (*Rev. HF*, Brussels, 1956, Vol. 3, No. 6, pp. 193–208.) Description of a f.m. telemetry system for recording on the ground the cardiogram of an aircraft pilot in flight.

621.398 : 621.396.41 **1213**

Radio System controls Railroad in Venezuela.—Sheffield. (See 1232.)

PROPAGATION OF WAVES

621.396.11 **1214**

Wave Scattering and Meteoric Influences on Short and Near-Ultra-Short Waves.—H. Wisbar. (*Arch. elekt. Übertragung*, Aug. 1956, Vol. 10, No. 8, pp. 343–352.) It is shown that in a frequency band about 30 Mc/s wide above the critical frequency for grazing incidence a certain residual ionization favours scatter propagation even with low-power transmitters; the intensity of this ionization depends on the diurnal and seasonal variations in the E and F layers. At higher frequencies, scattering occurs only as a result of the 'background effect', assumed to be directly related to the incidence of sporadic meteors. Turbulence in the ionosphere enhances the reflection effect due to the weak ionization produced by meteoric dust; corpuscular radiation may also make a small contribution at the poles and the magnetic equator. Auroral and other effects on scatter propagation are considered.

621.396.11 : 551.510.535 **1215**

The Waveguide Mode Theory of V.L.F. Ionospheric Propagation.—J. R. Wait & H. H. Howe. (*Proc. Inst. Radio Engrs*, Jan. 1957, Vol. 45, No. 1, p. 95.) Calculations are made and the results are shown in graphs for the attenuation factor as a function of the reciprocal of the ionospheric conductivity, (*a*) for different propagation modes, and (*b*) for different values of ground conductivity.

621.396.11.029.6 **1216**

Propagation of Ultra-short Waves Far Beyond the Horizon.—V. N. Troitski. (*Radiotekhnika, Moscow*, May 1956, Vol. 11, No. 5, pp. 3–20.) The u.s.w. field strength is calculated taking into account both stratification and turbulence in the troposphere. Fading and distortion of the signal are also discussed and the calculated and published experimental results are compared.

621.396.11.029.6 : 551.510.535 **1217**

A Disturbing Factor in Very-High-Frequency Communications via Ionospheric Forward Scatter.—D. A. Crow, F. A. Kitchen, G. A. Isted & G. Millington. (*Nature, Lond.*, 8th Dec. 1956, Vol. 178, No. 4545, pp. 1280–1283.) Difficulties experienced with a frequency-shift telegraphy link between Gibraltar and the U.K. on 37·3 Mc/s are discussed. On effectively pulsing the transmitter it was observed that discrete delayed signal components were present. The path of the delayed components is apparently first backward from the transmitter via the E layer and ground, and then forward by normal reflection at the F layer, the critical frequency being near the solar-cycle maximum. In order to achieve a safe signal/interference ratio, the back/front ratio of the array must be greatly increased.

621.396.812.3 **1218**

The Analysis of U.S.W. Fading.—G. Eckart. (*Z. angew. Phys.*, Aug. 1956, Vol. 8, No. 8, pp. 407–416.) A detailed discussion in physical terms of dielectric-constant variations and turbulence in the troposphere and their effect on propagation at $\lambda > 3$ m, based on mathematical analysis to be published elsewhere.

RECEPTION

621.396.621 : 621.376.3 **1219**

Effect of a Discontinuity of the Instantaneous Frequency on an Ideal Frequency-Modulation Receiver.—J. Charles & H. Vigneron. (*Rev. HF, Brussels*, 1956, Vol. 3, No. 6, pp. 209–219.) The response of a f.m. receiver with ideal i.f. band-pass characteristics to a sudden variation of signal frequency, is compared with that of an a.m. receiver to a sudden variation of amplitude. Differences in the observed overshoot effects are discussed.

621.396.621 : 621.376.33 **1220**

Limiters and Discriminators for F.M. Receivers.—G. G. Johnstone. (*Wireless World*, Jan. & Feb. 1957, Vol. 63, Nos. 1 & 2, pp. 8–14 & 70–74.) The performance of the Round-Travis, Foster-Seeley, ratio-detector, locked-oscillator, phase-difference-comparator and counter discriminator circuits, and of the grid, anode, dynamic and clipper-type limiters is discussed.

621.396.621.001.11 **1221**

Interference Immunity of the Correlation Reception Method.—A. E. Basharinov. (*Radiotekhnika, Moscow*, May 1956, Vol. 11, No. 5, pp. 26–34.) The general case of correlation reception, when the signal frequency is initially not accurately known, is investigated theoretically. The calculations show that the relative interference immunity of the correlation-type receiver with incoherent detection is only $\sqrt{2}$ times that of a receiver with a square-law detector.

621.396.621.54 : 621.3.018.783 **1222**

Contribution to the Theory of Nonlinear Distortion.—E. Henze. (*Arch. elekt. Übertragung*, Aug. 1956, Vol. 10, No. 8, pp. 326–338.) General formulae are derived for the characteristics of nonlinear circuit elements, with particular reference to valves. The production of harmonics and the mixing process are discussed; i.f. amplitudes resulting from cross-modulation with an interfering signal are calculated and compared with the normal i.f. amplitudes. The dependence of these nonlinear effects on the applied bias is investigated.

621.396.621.54.029.6 **1223**

Wideband V.H.F. Converter.—G. P. Anderson. (*Wireless World*, Feb. 1957, Vol. 63, No. 2, pp. 88–91.) Details are given of the construction of a superheterodyne unit extending the tuning range of a s.w. receiver up to 60 Mc/s.

621.396.821 : 551.594.6 **1224**

Measured Statistical Characteristics of V.L.F. Atmospheric Radio Noise.—Watt & Maxwell. (See 1083.)

STATIONS AND COMMUNICATION SYSTEMS

621.39 : 621.376.5 **1225**

Pulse Technique with Particular Reference to Line and Radio Communication.—E. M. Deloraine. (*J. Instn elect. Engrs*, Aug. 1956, Vol. 2, No. 20, pp. 458–463.) A short review including a discussion of the relative merits of frequency-division a.m. and time-division p.m. multichannel systems; a table shows the estimated channel-miles of pulse-multiplex radio links in various countries as at January 1956.

621.39.001.11 **1226**

A Theory of Word-Frequency Distribution.—A. F. Parker-Rhodes & T. Joyce. (*Nature, Lond.*, 8th Dec. 1956, Vol. 178, No. 4545, p. 1308.) A simple experimental relation governing word frequencies in language is explained in terms of a process of scanning the words in the memory.

621.39.001.11 : 621.372.012 **1227**

Signal-Flow Graphs and Random Signals.—W. H. Huggins. (*Proc. Inst. Radio Engrs*, Jan. 1957, Vol. 45, No. 1, pp. 74–86.) The flow-graph technique discussed previously [e.g. 2985 of 1956 (Mason)] is used to derive formulæ for the correlation functions and power spectra of signals; particular cases studied include a random telegraph message, a series of periodic pulses with time jitter, and a series of pulses of alternate polarity with random timing.

621.394 : 621.376.56 **1228**
: 621.375.4.018 : 621.314.7

Transistorized Binary Pulse Regenerator.—L. R. Wrathall. (*Bell Syst. tech. J.*, Sept. 1956, Vol. 35, No. 5, pp. 1059–1084.) A simple repeater circuit is described which is suitable for use in a 12-channel p.c.m. system over substantial lengths of transmission line. The system is arranged so that distortion due to l.f. cut-off in the output of one repeater is compensated in the next repeater, special feedback connections being provided for this purpose. Some performance figures and oscillograms are presented. The effect of interference on the production of errors is discussed.

621.396.3 **1229**

Phase-Shift Radio Teletype.—J. P. Costas. (*Proc. Inst. Radio Engrs*, Jan. 1957, Vol. 45, No. 1, pp. 16–20.) A system using suppressed-carrier keyed a.m. with phase shift is compared with the frequency-shift system and the 'predicted-wave' system [see *Convention Record Inst. Radio Engrs*, 1954, Part 8, pp. 63–69 (Doelz & Heald), also 861 of 1955 (Doelz)]. Coherent or synchronous detection is used at the receiver.

621.396.3 **1230**

Radio Teleprinter Systems with Automatic Error Correction.—F. Hennig. (*Nachrichtentech. Z.*, Aug. 1956, Vol. 9, No. 8, pp. 341–348.) Methods for increasing the reliability of teleprinter operation via radio links are outlined. They include the adoption of synchronous systems using codes capable of error detection and correction.

621.396.41 : 621.396.65 : 621.396.82 **1231**

Interference in Radio Links and Radio-Frequency Channelling.—B. Peroni. (*Ricerca sci.*, Aug. 1956, Vol. 26, No. 8, pp. 2483–2511.) An investigation is made of interference in a multichannel system from transmitters external to the system; an expression is derived for the ratio between the unwanted and the wanted signals. The design of terminal equipment to minimize interference effects is discussed. C.C.I.R. proposals for frequency channelling are compared with the method adopted in the TD-2 system, and measurements on systems of both types are reported; the latter type is preferred.

621.396.41 : 621.398 **1232**

Radio System controls Railroad in Venezuela.—B. Sheffield. (*Electronics*, Dec. 1956, Vol. 29, No. 12, pp. 158–163.) The installation described permits centralized traffic control by means of a multiplex f.m. carrier system. Safety measures and a number of mobile radio and other communication channels are also provided.

621.396.65 : 621.317.3.029.6(43) **1233**

Microwave Measuring Devices.—Klinger. (See 1191.)

SUBSIDIARY APPARATUS

621.311.6 : 621.314.7 **1234**

Transistorized Regulated Power Supply.—M. Lillienstein. (*Electronics*, Dec. 1956, Vol. 29, No. 12, pp. 169–171.)

621.311.62 : 621.316.722.1 **1235**

Cathode-Follower-Type Power Supplies.—B. J. Perry. (*Electronic Engng*, Dec. 1956, Vol. 28, No. 346, pp. 517–520.) The use of triodes as rectifiers in variable-voltage power supplies is examined. A power pack combining series-stabilization with a cathode-follower-type rectifier circuit is described; it is suitable for electrophoresis applications and performance details are given.

621.314.6 **1236**

Current-Rectifying Devices.—J. D. Cooney. (*Elect. Mfg*, Sept. 1955, Vol. 56, No. 3, pp. 139–157.) A review of thermionic and solid-state rectifiers, providing comparative data for selecting appropriate types for particular purposes.

621.314.63 **1237**

An Investigation into the Rectifying Properties of *n-p* Junctions: Selenium–Sulphides or Selenides of Tin.—V. R. Grimm & D. N. Nasledov. (*Zh. tekh. Fiz.*, April 1956, Vol. 26, No. 4, pp. 707–715.) The *n-p* junctions at the boundaries between selenium and sulphides or selenides of tin were investigated experimentally: they possess sharply defined rectifying properties. On the basis of these results, Se rectifiers of a new type have been developed and their properties investigated. In comparison with ordinary Se rectifiers the new types have a decreased voltage drop in the forward direction (of the order of 0·2 V) and allow a higher forward current density. The disadvantages of the new rectifiers are the temperature dependence of the reverse current and the adverse effect of heating on their electric strength.

621.314.63 : [546.28 + 546.289 **1238**

Germanium and Silicon Power Rectifiers.—T. H. Kinman, G. A. Carrick, R. G. Hibberd & A. J. Blundell. (*Proc. Instn elect. Engrs*, Part A, Oct. 1956, Vol. 103, No. 11, pp. 533–536.) Discussion on 2885 of 1956.

621.316.722 : 621.314.7 **1239**

Transistor Voltage Regulator.—R. H. Spencer & T. S. Gray. (*Commun. & Electronics*, March 1956, No. 23, pp. 15–17.) A circuit which makes use of the high voltage gain and low emitter resistance of the junction transistor is described.

621.316.722.1 **1240**

A Stabilized Mains Rectifier.—H. W. Jaskula. (*Elektrotech. Z.*, *Edn B*, 21st Aug. 1956, Vol. 8, No. 8, pp. 298–300.) The voltage-supply unit described uses saturated transformer stabilization, full-wave valve rectification and gas-filled, as well as hard-valve, stabilizing circuits. It can supply 400-V, 0–100-mA d.c. with a variation of less than 0·005% for mains fluctuations of ± 10%.

TELEVISION AND PHOTOTELEGRAPHY

621.397.24 : 621.315.213 **1241**

Video-Pair Cable System.—Aoki, Kameda, Yokose & Uchino. (See 983.)

621.397.5 **1242**

A Method for Narrowing the Frequency Band of a Television Channel.—D. A. Novik. (*Zh. tekh. Fiz.*, April 1956, Vol. 26, No. 4, pp. 900–910.) The proposed method is based on the extension in time of the steeper edges of television signals at the expense of the contraction of the more gradual ones. Storage tubes could be used for such a redistribution of the time scale. The restoration of the original signal at the receiving end is considered, and the saving in bandwidth is estimated. Use of the method for transmission on long-distance lines is suggested.

621.397.5 : 356/359 **1243**

Television as a Military Intelligence and Communications Medium.—N. Gray & J. C. Jangarathis. (*J. Soc. Mot. Pict. Telev. Engrs*, Aug. 1956, Vol. 65, No. 8, pp. 415–418.) An outline of essential requirements and possible applications. Equipment used in recent manoeuvres includes a slow-scan vidicon camera tube.

621.397.5 : 535.623 **1244**

N.T.S.C. Colour Information.—E. L. C. White. (*Wireless World*, Feb. 1957, Vol. 63, No. 2, pp. 75–78.) The efficacy of the N.T.S.C. system of transmitting the colour information is criticized on the ground that the amplitude of the colour subcarrier is dependent not only on the colour saturation but also on the brightness; the particular method of gamma correction used also has disadvantages. An outline is presented of a receiver for operation with a single-gun picture tube, using a 'symmetrical-ratio' signal.

621.397.5 : 535.623 **1245**

The Choice of a Colour-Television System Conforming to the 'Gerber' Standards and the Effect of the Chrominance Subcarrier on Monochrome Picture Reception.—J. Piening. (*Nachrichtentech. Z.*, Aug. 1956, Vol. 9, No. 8, pp. 365–370.) Possible systems for German colour television and modifications required to adapt the N.T.S.C. system to the 625-line standard are outlined. Transmission in bands IV and V is considered as well as in bands I and III. Test results are given showing the interference caused in monochrome reception by the chrominance signal.

621.397.6.001.4 : 621.317.755 **1246**

A Television Line Selector Unit.—P. L. Mothersole. (*Electronic Engng*, Dec. 1956, Vol. 28, No. 346, pp. 520–523.) The unit described enables a triggered oscilloscope to be used as a line waveform monitor.

621.397.611.2 : 778.5 **1247**

Flying-Spot and Vidicon Film Scanners. A Comparison on the Basis of the Gerber [C.C.I.R.] Standard.—W. Dillenburger. (*Elektronische Rundschau*, July & Aug. 1956, Vol. 10, Nos. 7 & 8, pp. 181–184 & 216–218.) The comparison indicates that the vidicon arrangement has the advantage that picture quality is largely independent of film density.

621.397.62 **1248**

Improved Sync Separator.—M. P. Beddoes. (*Wireless World*, Feb. 1957, Vol. 63, No. 2, pp. 83–87.) A circuit is described using a pentode-triode valve, the pentode portion serving to separate the composite synchronizing signal from the picture signal while the triode portion separates the frame synchronizing signal, its output consisting of single narrow pulses. Though the accuracy of timing is good, the noise immunity is less than that of some other separator circuits.

621.397.621.2 : 535.623 : 621.385.832.002.2 **1249**

Control of Fluorescent-Screen Dot Size for Colour TV.—S. H. Kaplan. (*J. Soc. Mot. Pict. Telev. Engrs*, Aug. 1956, Vol. 65, No. 8, pp. 407–410.) Photographic methods are outlined for producing fluorescent screens for parallax-mask colour-television tubes. Dot size control is facilitated by using an annular light source.

621.397.7 : 621.3.06 **1250**

Video Switching for TV Broadcast Centres.—E. B. Pores. (*Electronics*, Dec. 1956, Vol. 29, No. 12, pp. 146–149.) Electronic and electromechanical systems are briefly described and their relative advantages and cost are discussed.

621.397.7 : 621.325 **1251**

Carbon Arcs for Television-Studio Lighting.—R. B. Dull & J. G. Kemp. (*J. Soc. Mot. Pict. Telev. Engrs*, Aug. 1956, Vol. 65, No. 8, pp. 432–434.) The performance of typical carbons, including colour-corrected types, is summarized.

621.397.8 **1252**

The Influence of Phase Errors on the Picture Quality of Television Transmissions.—H. J. Griese & P. Klopf. (*Elektronische Rundschau*, Aug. 1956, Vol. 10, No. 8, pp. 212–216.) The effect of various forms of phase delay on transient response and the importance of delay characteristics in specifying television circuits is examined. A method is outlined for measuring sideband phase and amplitude in television transmitters.

621.397.8 : 778.5 **1253**

Gradation Problems in Television Film Transmissions.—G. Uhlenbrok. (*NachrTech.*, Aug. 1956, Vol. 6, No. 8, pp. 341–346.) Gamma-control systems are discussed, based on use of (*a*) variable external resistance, e.g. a diode, (*b*) variable slope, depending on the sequential cutting-off of parallel-connected valves, and (*c*) variable modulation, also with parallel-connected valves.

TRANSMISSION

621.376.22 **1254**

Amplitude Modulation with Diodes —A. D. Artym. (*Radiotekhnika, Moscow*, May 1956, Vol. 11, No. 5, pp. 35–43.) The modulation method described is designed for low distortion at modulation depths up to nearly 100% and modulation frequencies approaching carrier frequency. The circuit is based on a pair of opposed diodes.

621.396.61 **1255**

The B.B.C. Radio Microphone.—F. A. Peachey & G. A. Hunt. (*Electronic Radio Engr*, Feb. 1957, Vol. 34, No. 2, pp. 46–48.) Description of a pocket f.m. transmitter for use by radio commentators. It operates in the range 50–70 Mc/s with an output of ¼ W.

621.396.61 : 621.385.029.6 **1256**

Scatter S.S.B. Technique uses Power Klystron.—Badger. (See 1276.)

VALVES AND THERMIONICS

621.3.018.783 : 621.396.621.54 **1257**

Contribution to the Theory of Non-linear Distortion.—Henze. (See 1222.)

621.314.63 **1258**

Surface Leakage Current in Silicon Fused-Junction Diodes.—M. Cutler & H. M. Bath. (*Proc. Inst. Radio Engrs*, Jan. 1957, Vol. 45, No. 1, pp. 39–43.) "The forward and reverse current of fused-junction silicon diodes are compared with the predicted equations arising from a simplified model for surface leakage. It is found that analysis of the forward current in the 'exponential' region leads to resolution of the contributions of the junction and the leakage path. The activation energies of the parameters describing these two contributions were determined ; the former agrees with the value of the band gap. The implications and deficiencies of the model are discussed."

621.314.7 **1259**

Accurate Measurement of Emitter and Collector Series Resistance in Transistors.—B. Kulke & S. L. Miller. (*Proc. Inst. Radio Engrs*, Jan. 1957, Vol. 45, No. 1, p. 90.)

621.314.7 **1260**

Approximating the Alpha of a Junction Transistor.—A. B. Macnee. (*Proc. Inst. Radio Engrs*, Jan. 1957, Vol. 45, No. 1, p. 91.) A simple method based on a second-order power series is presented.

621.314.7 : [621.373.5 + 621.375.4] : 621.311 **1261**

Application of Germanium Triodes in Equipment for the Protection, Telemechanics and Communication Channels of Power Systems.—Martynov & Pavlov. (See 1027.)

621.38 + 537.533] (083.74) **1262**

I.R.E. Standards on Electron Tubes : Physical Electronics Definitions, 1957.—(*Proc. Inst. Radio Engrs*, Jan. 1957, Vol. 45, No. 1, pp. 63–65.) Standard 57 I.R.E. 7.S1.

621.383 **1263**

Wavelength Dependence of Radiation-Noise Limits on Sensitivity of Infrared Photodetectors.—J. R. Platt. (*J. opt. Soc. Amer.*, Aug. 1956, Vol. 46, No. 8, pp. 609–610.) A formula is derived for the limiting sensitivity as a function of the area and long-wavelength cut-off of the photocell and of the exposure time.

621.383.2 **1264**

Electron-Microscope Investigation of the Structure of Photocathodes.—A. I. Frimer & A. M. Gerasimova. (*Zh. tekh. Fiz.*, April 1956, Vol. 26, No. 4, pp. 726–732.) The object of this investigation was to determine the relation between the structure and the sensitivity of complex (oxygen-caesium and bismuth-caesium) photocathodes. A number of photomicrographs are shown.

621.383.2 **1265**

The Resistance of Semitransparent Photocathodes.—W. J. Harper & W. J. Choyke. (*J. appl. Phys.*, Nov. 1956, Vol. 27, No. 11, pp. 1358–1360.) "The resistance of the semitransparent photoemissive films Sb-Cs, Sb-Rb, Bi-Cs, Bi-Rb, Te-Cs, Te-Rb, and Ag-O-Cs was measured as a function of temperature. A thermal activation energy associated with conductivity was determined for each of the materials."

621.383.42 **1266**

An Anomaly in the Forward and Backward Conduction of a Selenium Photocell Cooled to Low Temperature and Reactivated by Infrared Radiation.—G. Blet. (*C. R. Acad. Sci., Paris*, 26th Nov. 1956, Vol. 243, No. 22, pp. 1753–1755.) Experimental evidence indicates that at temperatures below 125°K, and for low values of applied voltage, current is passed in the reverse direction. The effect did not vary with frequency over the range 50 c/s–5 kc/s. The photoelectric current did not exhibit this reversal.

621.385.029.6 **1267**

International Congress on Microwave Valves.—(*Le Vide*, Sept./Oct. 1956, Vol. 11, No. 65, pp. 210–432). The text is given of the following papers presented at the Congress :—

The Principal Results Achieved in the Field of Microwave Valves.—R. R. Warnecke (pp. 217–225).

Transmitter Valves with Control Grid.—F. Hülster (pp. 226–235).

'Moding' in Magnetrons.—C. Azéma (pp. 236–242).

Asymmetries in Strapped Resonator Systems of Magnetrons.—B. Vallantin (pp. 243–247).

The Use of Getters in Magnetrons.—P. Zijlstra (pp. 248–250, in French & English).

An Experimental Cold-Cathode Magnetron.—J. R. M. Vaughan (pp. 251–257, in French & English). See 2580 of 1956.

Practical Millimetre-Magnetron Considerations.—L. W. Roberts & R. S. Briggs (pp. 258–263, in French & English).

Reflex Klystrons for Millimetre Waves.—B. B. van Iperen (pp. 264–269).

A Low-Noise High-Power Klystron Oscillator of Great Reliability.—G. A. Espersen (pp. 270–280, in French & English).

Operation and Application of the Retarding-Field Oscillator at Millimetre Wavelengths.—C. J. Carter, W. H. Cornetet, Jr, & M. O. Thurston (pp. 281–285, in French & English).

A Transmitter Klystron for Radio Links.—C. Azéma (pp. 286–289).

A Travelling-Wave Valve for 4-cm

Wavelength.—A. Bobenrieth (pp. 290–295).

Wide-Band Travelling-Wave Valves for Wavelengths of 2–3 cm.—D. H. O. Allen (pp. 296–302, in French & English).

A 4 000-Mc/s Low-Noise Travelling-Wave Valve.—P. F. C. Burke & W. J. Pohl (pp. 303–309, in French & English).

Characteristics of a Strophotron Oscillator of 10-cm Wavelength.—T. S. Robinson (pp. 310–320, in French & English).

Preliminary Electron Bunching in the Linear Accelerator.—M. Papoular (pp. 321–327).

Electrolytic Tank with Current Input Elements for the Study of Space-Charge Distribution in Valves.—V. S. Loukochkov [Lukoshkov] (pp. 328–337, in French & English).

Plasma Electron Oscillations.—F. Berz (pp. 338–344).

Breakdown of Air at Microwave Frequencies.—W. Roberts (pp. 345–351, in French & English).

A Wide-Band T.R. Valve Incorporating an Interdigital Line.—D. Reverdin (pp. 352–356).

The Fully-Coupled T.R. Valve.—R. Jean & D. Reverdin (pp. 357–361).

Contribution to the Study of Keep-Alive Electrodes of T.R. Valves.—R. Jean (pp. 362–372).

Measurements on Gas-Filled [t.r. and a.t.r.] Valves.—R. Belbeoch & M. Bricon (pp. 373–376).

Measurement of the Transmission Characteristic of [t.r.] Switching Valves for Millimetre Radar.—A. Regeffe (pp. 377–378).

Investigation of Noise in Travelling-Wave Valves.—A. S. Tagher (pp. 379–388, in French & English).

Overlapping the Operating Ranges of Gas-Filled Noise Tubes and Noise Diodes by means of Helical Lines.—H. Schnitger (pp. 389–399, in French & German).

Oscillograph for the Observation and Photography of Microwave Signal Patterns.—A. M. Tchernouchenko [Chernushenko] (pp. 400–409, in French & English). See 885 of March.

High-Power Microwave Test Bench.—L. Milosevic & –. Vautey (pp. 410–416).

Shock Sensitivity of Reflex Klystron.—J. Boissière (pp. 417–419).

[Use of] Ceramics in Valves.—G. Gallet (pp. 420–423).

Resistance Welding of Microwave Valves.—R. Paliès (pp. 424–428).

The Development of Microwave Valves in Electronic Aids to Navigation.—N. Schimmel (pp. 429–432, in French & English).

621.385.029.6 **1268**

Anomalies of Power Output and Modulation Sensitivity in Reflex [-klystron] **Oscillators.**—J. Labus. (*Nachrichtentech. Z.*, Aug. 1956, Vol. 9, No. 8, pp. 371–374.) The deviation from the theoretical output characteristic is shown to be due to a spread in the values of electron transit time, and the anomalies in the sensitivity are attributed to space-charge effects near the reflector.

621.385.029.6 **1269**

Performance and Design of Low-Noise Guns for Travelling-Wave Tubes.—R. C. Knechtli & W. R. Beam. (*RCA Rev.*, Sept. 1956, Vol. 17, No. 3, pp. 410–424.) Discussion indicates that sharp potential discontinuities should be avoided in a low-noise gun; an exponential type of space-charge-wave transformation is hence desirable. Suitable conditions can be established with 'multi-region' guns comprising a triode section followed by a number of appropriately spaced apertured plane parallel electrodes.

621.385.029.6 **1270**

The Backward-Travelling Power in High-Power Travelling-Wave Amplifiers.—P. K. Tien: J. E. Rowe. (*Proc. Inst. Radio Engrs*, Jan. 1957, Vol. 45, No. 1, pp. 87–88.) The discussion of methods of analysing the large-signal operation of travelling-wave valves [3577 of 1956 (Rowe & Hok)] is continued.

621.385.029.6 : 537.533 **1271**

Confined Electron Flow in Periodic Electrostatic Fields of Very Short Periods.—K. K. N. Chang. (*Proc. Inst. Radio Engrs*, Jan. 1957, Vol. 45, No. 1, pp. 66–73.) "By utilizing the centrifugal force of an electron, resulting from a magnetic field in the cathode plane as a restoring force, an electrostatically-confined beam flow can be obtained through the strong focusing of a periodic electric field. Because of the extremely steep nature of the potential valley derived from its particular force field, the focusing scheme is far more stable than any previous ones. A uniform magnetic field threading the cathode is employed when a very thin, hollow beam is to be focused. By using a radially varying magnetic field, the focusing scheme can be applied to thick, hollow beams, of low as well as of high perveance. Experimental results indicate that the focusing performance obtained is much less critical than that obtained with a periodic magnetic field which has been recently tested extensively."

621.385.029.6 : 538.566 : 537.56 **1272**

Growing Electric Space-Charge Waves.—Pierce & Walker. (See 1066.)

621.385.029.6 : 621.372.2 **1273**

Approximate Calculation of the Propagation Constants of Transmission Lines in the Presence of an Electron Beam.—L. N. Loshakov. (*Zh. tekh. Fiz.*, April 1956, Vol. 26, No. 4, pp. 809–820.) A general method of calculation, based on certain simplying assumptions, is proposed for analysing conditions in a travelling-wave valve.

621.385.029.6 : 621.372.413 **1274**

The Excitation of a Cavity Resonator by a Density-Modulated Electron Beam Passing Through the Entire Resonator Cross-Section.—Szulkin. (See 1015.)

621.385.029.6 : 621.385.2 **1275**

The Behaviour of the Space Charge in a Diode with an Axial Magnetic Field: Part 2—The Probe Method.—M. M. Filippov. (*Zh. tekh. Fiz.*, May 1956, Vol. 26, No. 5, pp. 1004–1014.) In Part 1 (*Zh. tekh. Fiz.*, 1953, Vol. 23, p. 1716) a report was given of an experimental investigation into the behaviour of the space charge in a cylindrical magnetron by the method of equivalent currents. The present report deals with measurements of the current flowing through an auxiliary probe electrode in the cathode-anode space of the magnetron. The probe characteristics so obtained are used for appraising the theoretical conclusions regarding the distribution of the electrons and the shape of electron trajectories in a non-oscillating cylindrical magnetron with a thin cathode.

621.385.029.6 : 621.396.61 **1276**

Scatter S.S.B. Technique uses Power Klystron.—G. M. W. Badger. (*Electronics*, Dec. 1956, Vol. 29, No. 12, pp. 176–179.) The performance of high-power klystrons in s.s.b. tropospheric-scatter transmitters is improved by using a segmented collector, with successively lower voltages on the segments, and special mixer and modulator circuits which are described.

621.385.029.6 : 621.396.822 **1277**

Factors Affecting the Correlation Conditions in Space-Charge Waves.—H. W. König. (*Arch. elekt. Übertragung*, Aug. 1956, Vol. 10, No. 8, pp. 339–342.) An investigation is made of the effect on the coherence conditions discussed by Haus (3123 of 1955) of passing an electron beam through a linear quadripole. Analysis is based on the transformation properties of the correlation determinant. It is shown that if the quadripole has a specified determinant the voltage and current fluctuations of the beam will be correlated at its output irrespective of the conditions at its input.

621.385.032:216 **1278**

The Electron Temperature in Oxide Cathodes.—D. G. Bulyginski & D. N. Dobretsov. (*Zh. tekh. Fiz.*, May 1956, Vol. 26, No. 5, pp. 977–984). No definite answer has yet been given to the question whether the temperature of the electron gas can exceed that of the crystal lattice in an oxide cathode. A method is proposed for measuring the electron temperature, and experiments are described in detail. These show that an 'overheating' of the electron gas does take place and that it increases with temperature. A theoretical interpretation of the results is given; it is pointed out that the emission from an oxide cathode is not of a purely thermionic nature.

621.385.032.216 **1279**

The Schottky Effect in Oxide Cathodes.—G. Déjardin, G. Mesnard & R. Uzan. (*Le Vide*, July/Aug. 1956, Vol. 11, No. 64, pp. 194–205.) Measurements on nearly saturated diodes at normal operating temperatures show that the Schottky effect tends to exceed the theoretical value. Various aspects of cathode surface condition are discussed as possible causes of the anomaly. 25 references.

621.385.032.216 **1280**

Emission of Oxide Cathodes Supported on a Ceramic.—G. E. Moore & H. W. Allison. (*J. appl. Phys.*, Nov. 1956, Vol. 27, No. 11, pp. 1316–1321.) Experiments made with a (BaSr)O layer applied to a MgO ceramic support, thus eliminating the metal support and interface, indicated that these two latter features are not of fundamental importance for the cathode emission. From the results of treatments with methane and hydrogen, it is concluded that other factors are much more important than excess Ba content for determining the emission.

621.385.032.216 **1281**

The Decrease of Thermionic Emission of Alkaline-Earth-Oxide and Thoria Cathodes in a Pulsed Regime.—G. Mesnard & R. Uzan. (*C. R. Acad. Sci., Paris*, 12th Nov. 1956, Vol. 243, No. 20, pp. 1502–1504.) A comparison is made of the effect in the two types of cathode. The extent of the emission decrease increases with rising temperature in both types, but the variation with duty factor is more pronounced in the case of the oxide cathodes. In these, at temperatures up to a certain level, the decreased emission is preceded by a significant increase which is never observed with thoria cathodes. The mechanism described by Plumlee (3583 of 1956) is thought to apply in the case of the oxide cathodes.

621.385.032.216 **1282**

Reactions Occurring during Decomposition of Alkaline-Earth Carbonates on Tungsten.—M. A. Cayless & B. N. Watts. (*Brit. J. appl. Phys.*, Oct. 1956, Vol. 7, No. 10, pp. 351–354.) Report of an investigation made to elucidate reactions occurring during the breakdown and activation of an oxide cathode on a tungsten substrate. Analysis shows that CO_2, CO and H_2 are the principal gases evolved. The CO is produced during the formation of a basic tungstate interface of the type $(Ba, Sr, Ca)_3WO_6$. The chemical reactions involved do not reach equilibrium during normal decomposition schedules. The rate of formation of free Ba in the completed cathode is determined by the amount of interface produced during breakdown.

621.385.032.216 : 537.226 **1283**

Dielectric Constant of Barium Orthosilicate.—C. P. Hadley, H. W. Kraner & M. R. Royce. (*J. appl. Phys.*, Nov. 1956, Vol. 27, No. 11, pp. 1384–1385.) Measurements are reported on specially prepared specimens, as a function of the apparent density. The results are plotted; they are probably valid for frequencies up to several hundred Mc/s, and may be used in calculations of the thickness of oxide-cathode interface layers.

621.385.032.216 : 621.396.822 **1284**

New Mechanism for the Generation of Flicker Noise in Tubes with Oxide-Coated Cathodes.—W. W. Lindemann & A. van der Ziel. (*J. appl. Phys.*, Oct. 1956, Vol. 27, No. 10, pp. 1179–1183.) "Evidence is presented which seems to indicate that a major part of the flicker noise in tubes with oxide-coated cathodes is generated in a thin surface layer of the coating. The effect is shown to be caused by the fact that a d.c. voltage drop and a noise voltage fluctuation are generated in the surface layer. In tubes with a porous cathode coating this noise voltage modulates the current coming out of the surface pores, thus leading to a true fluctuation in the current. In tubes with a nonporous cathode coating this noise voltage modulates the emission current, thus leading to a true fluctuation in the emission."

621.385.2/.3 : 621.396.822 **1285**

Correlation Conditions for Noise Fluctuations at the Potential Minimum of a Diode (Triode).—H. Kosmahl. (*Arch. elekt. Übertragung*, Aug. 1956, Vol. 10, No. 8, pp. 353–357.) A rigorous calculation is made of the correlation between the electron current and velocity fluctuations for a particular case. A value of 0·65–0·75 is found for the correlation coefficient in the ideal case; for practical valves the value is considerably lower. The use of this coefficient for calculating the induced grid noise current is outlined.

621.385.3 : 621.365 **1286**

The New Transmitting Tube FTL 3-1 for Industrial Purposes.—R. Hübner. (*Brown Boveri Rev.*, July 1956, Vol. 43, No. 7, pp. 279–280.) Data are presented for an air-cooled triode with a directly heated thoriated-tungsten cathode, for use as an oscillator at frequencies up to 30 Mc/s; outputs up to 6·4 kW are obtainable.

621.385.832 **1287**

Electrostatic Cathode-Ray Storage Tubes and their Applications.—C. Dufour. (*Ann. Radioélect.*, July 1956, Vol. 11, No. 45, pp. 200–215.) The various types are classified and the principles of operation and applications are detailed. 11 references.

621.385.832 : 621.396.963.325 **1288**

Storage Tube projects Radar P.P.I. Display.—H. W. Gates (*Electronics*, Dec. 1956, Vol. 29, No. 12, pp. 172–175.) A 50-in. remote p.p.i. display is obtained by means of an 'iatron' tube. This is a combined storage and projection device which uses a narrow writing beam of low intensity to create an e.s. image of the signal on a thin insulating target supported by a mesh screen. A high-intensity beam continuously floods the image and is thereby modulated on passing through the mesh and striking the phosphor screen. Ancillary circuitry providing erasure and clutter attenuation is also described.

621.385.832.002.2 **1289**
: 621.397.621.2 : 535.623

Control of Fluorescent-Screen Dot Size for Colour TV.—Kaplan. (See 1249.)

621.387 : 621-526 **1290**

Grid Control of Thyratrons with Particular Reference to Servomechanism Applications.—K. R. McLachlan. (*J. Brit. Instn Radio Engrs*, Dec., 1956, Vol. 16, No. 12, pp. 695–699.)

621.387.002.2 **1291**

New Method of Filling [gas-] **Discharge Valves.**—R. Hübner. (*Elektronische Rundschau*, Aug. 1956, Vol. 10, No. 8, p. 227.) A tablet containing HgO and other materials is enclosed in the valve envelope and, after the extraction of gases, an adequate amount of Hg is freed in a chemical reaction started by induced heat. Valves thus prepared can be used in any position, no preheating of the cathode is necessary and the risk of arcing is reduced.

621.385 : 533.5 **1292**

Arbeitsverfahren und Stoffkunde der Hochvakuumtechnik, Technologie der Elektronenröhren. [Book Review]—H. Steyskal. Publishers: Physik Verlag, Mosbach/Baden, 1955, 185 pp., D.M. 14.40. (*Acta phys. austriaca*, Aug. 1956, Vol. 10, No. 3, pp. 309–310.) A useful work for valve development engineers.

621.385.029.6 **1293**

Studien über Travelling-Wave Tubes. Mitteilungen aus dem Institut für Hochfrequenztechnik der E.T.H. Zürich, Nr. 23. [Book Review]—G. E. Weibel. Publishers: Leemann, Zürich, 1956, 95 pp., 9.35 Swiss Fr. (*Arch. elekt. Übertragung*, Aug. 1956, Vol. 10, No. 8, p. 360.) Detailed theory is presented, including a new method of investigating the behaviour of the beam on entering a monotonically increasing magnetic field. The construction of a demountable valve is described.

MISCELLANEOUS

621.3.002.2 **1294**

Automatic Component Assembly [for Printed Circuits].—K. M. McKee. (*Wireless World*, Feb. 1957, Vol. 63, No. 2, pp. 63–69; *J. Instn elect. Engrs*, Sept. 1956, Vol. 2, No. 21, pp. 515–519.) Description of a multistation in-line conveyor system of a general type in use in the U.S.A. and being introduced in G.B. for the mass production of electronic equipment. Printed wiring boards are transported along the conveyor and the various components are introduced by separate machines. Adjustments for production change-over can be effected rapidly, and individual machines can be mounted as bench units for short production runs.

621.3.002.2 : 68 **1295**

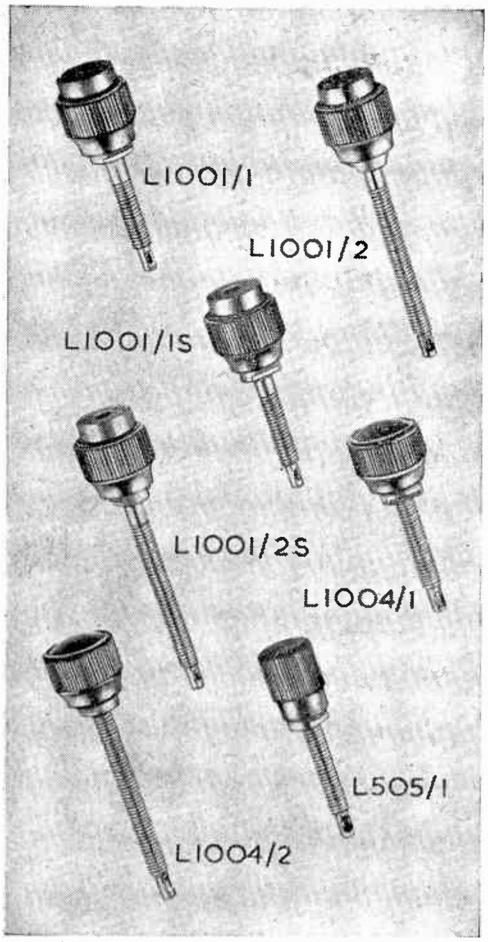
The Flowsolder Method of Soldering Printed Circuits.—R. Strauss & A. F. C. Barnes. (*Electronic Engng*, Nov. 1956, Vol. 28, No. 345, pp. 494–496.) A method is described in which a stationary wave of molten solder is created by pumping the metal upwards through a rectangular nozzle, and the pre-fluxed circuit panels are passed through the crest of the wave.

01.891 : 621.396 **1296**

Report of the Radio Research Board for 1955. [Book Review]—Publishers: H.M. Stationery Office, London, 1956, 56 pp., 3s. 6d. (*Nature, Lond.*, 29th Dec. 1956, Vol. 178, No. 4548, pp. 1446–1447.) Includes the report of the Director of Radio Research, reviewing the work of the Radio Research Station of the Department of Scientific and Industrial Research, and giving a description of the new building.

413=00 : [537 + 621.3 **1297**

International Electrotechnical Vocabulary (Electronics). [Book Review]—Publishers: British Standards Institution, London, 2nd edn 1956, 157 pp., 24s. (*Brit. J. appl. Phys.*, Sept. 1956, Vol. 7, No. 9, p. 343.) Gives definitions in French and English and the terms themselves also in German, Spanish, Italian, Dutch, Polish and Swedish.



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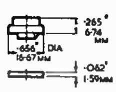
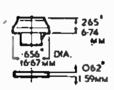
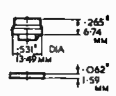
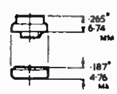
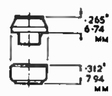
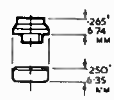
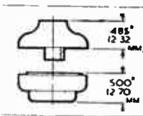
COLLAR ASSEMBLY							
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L1001/1S	L1001/1SB	L1001/1SL	L1001/1SU	L1001/21SB	L1001/21SL	L1001/31S	—
L1001/2S	L1001/2SB	L1001/2SL	L1001/2SU	L1001/22SB	L1001/22SL	L1001/32S	L1001/42S
L1004/1	L1004/1B	L1004/1L	L1004/1U	L1004/21B	L1004/21L	L1004/31	—
L1004/2	L1004/2B	L1004/2L	L1004/2U	L1004/22B	L1004/22L	L1004/32	L1004/42
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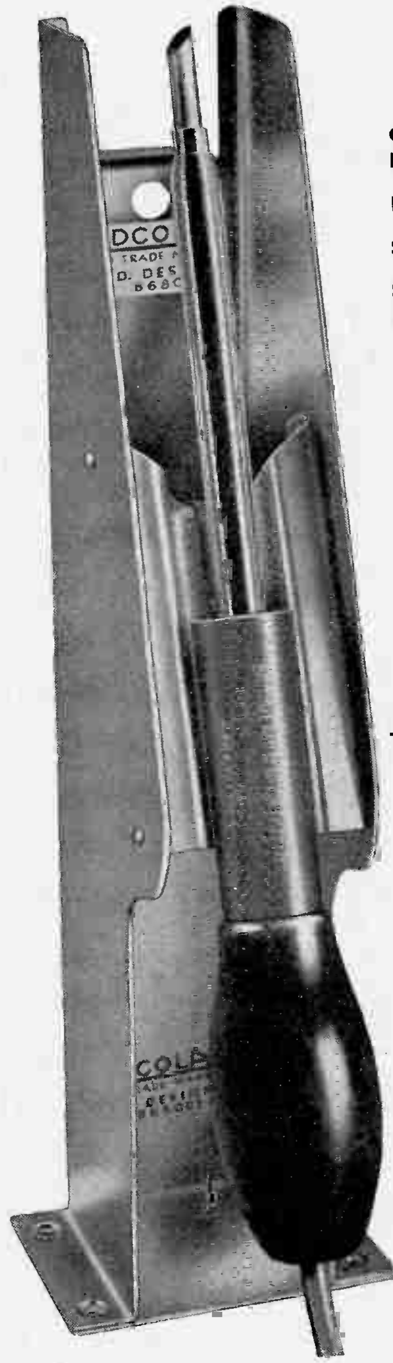

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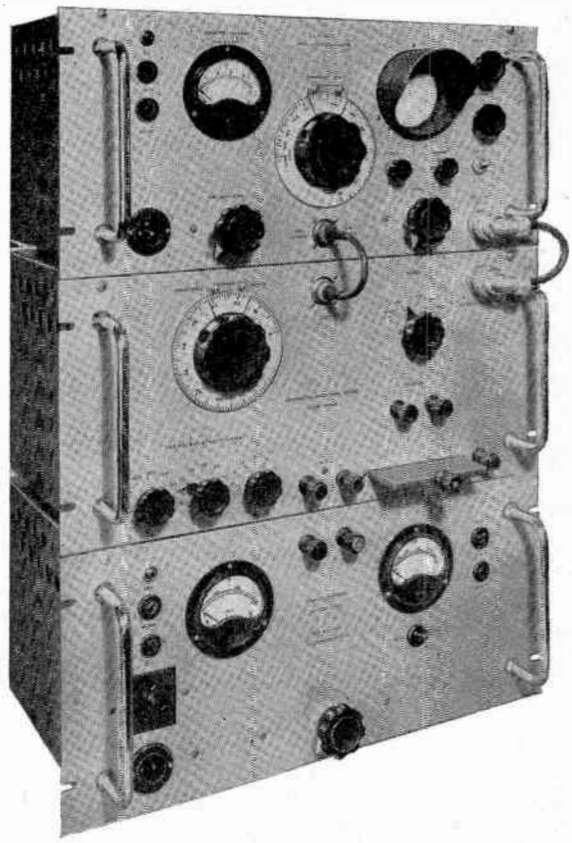

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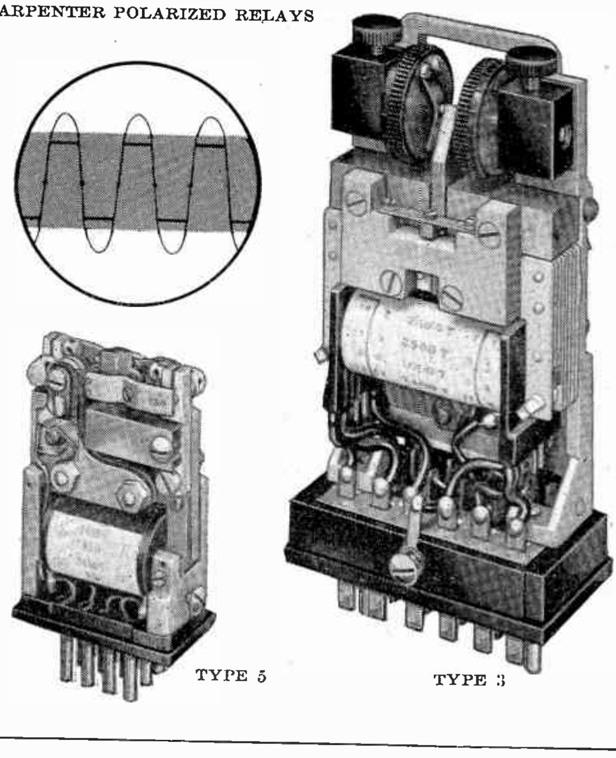

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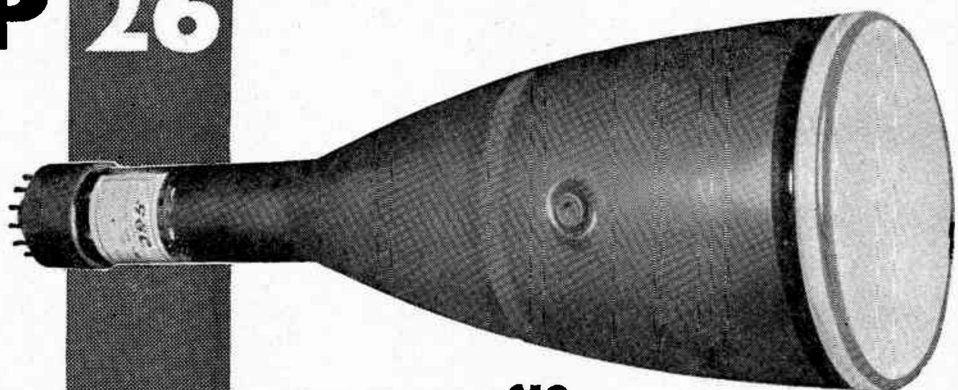

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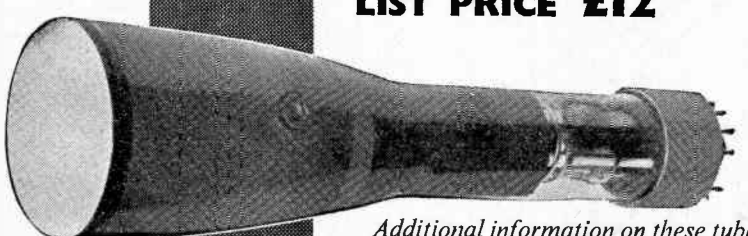

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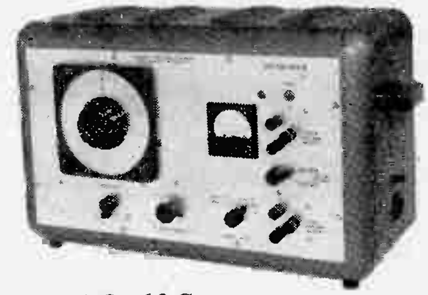

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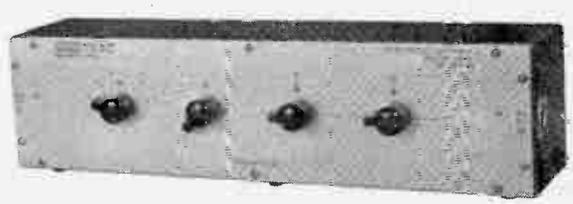

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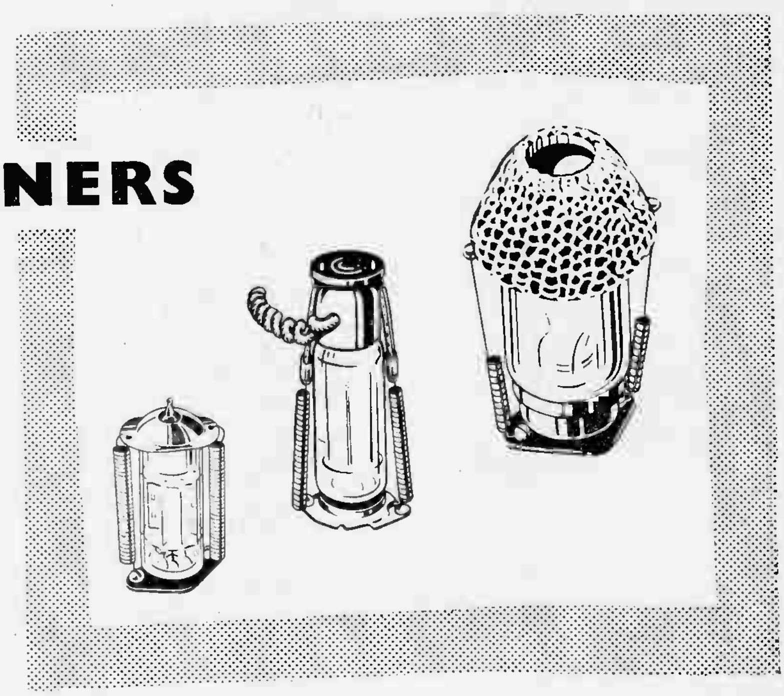

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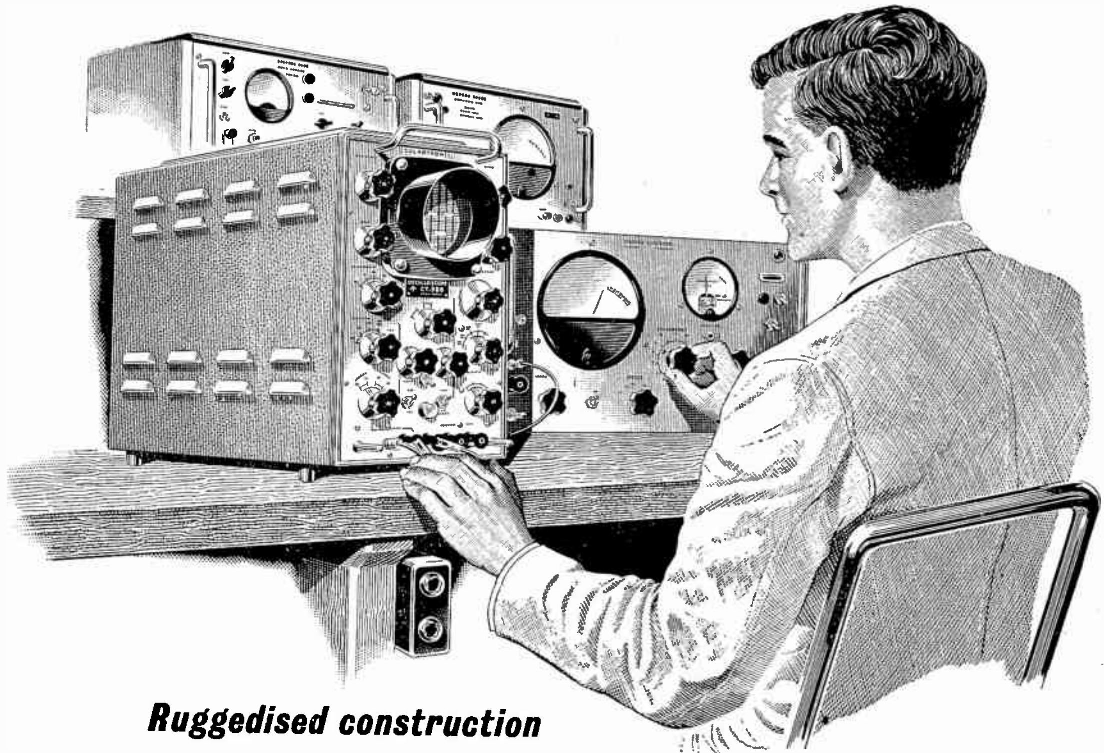

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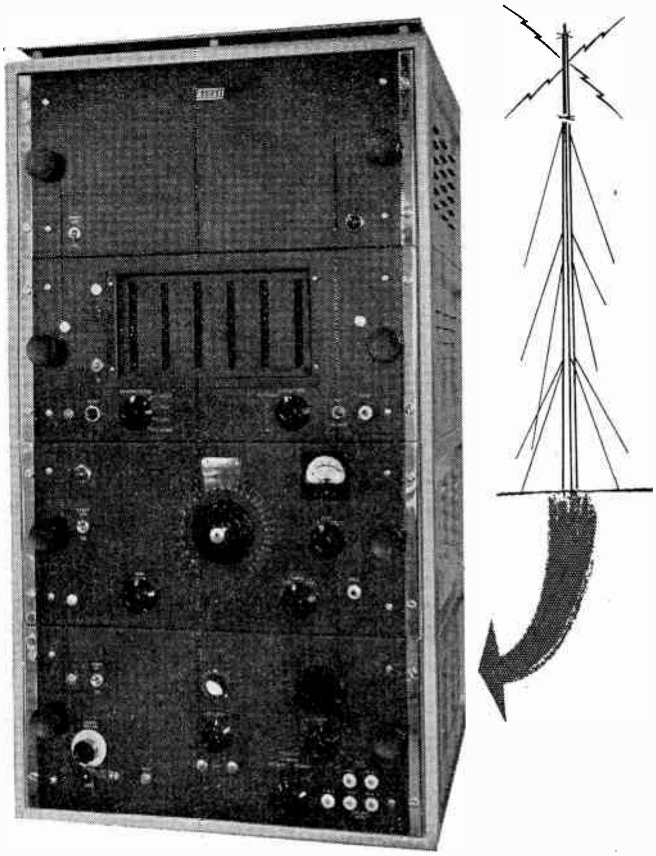

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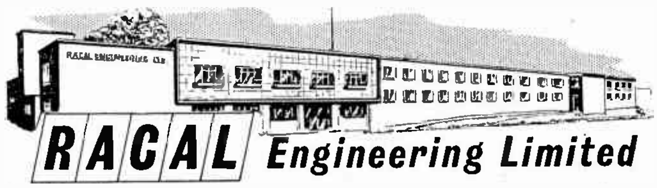

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INTERVIEW Boards will sit at intervals, as required. Early application is advised. [1045

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require a
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Department of Electrical Engineering

SENIOR Electronics Technician required, to take charge of a new electronics workshop for constructing and maintaining laboratory equipment. Salary within the scale £560 to £660 per annum. Good prospects of promotion. Form of application and conditions of appointment from Mr. H. Pickbourne, Registrar. [1056

PHYSICISTS or Electrical Engineers required by Ministry of Supply, R.A.E., Farnborough, Hants, for analysis work on problems connected with communication systems. Candidates should have 1st or 2nd class honours degree in Physics or Electrical Engineering or equivalent. Applications from Mathematical Physicists or Applied Mathematicians also considered. Appointments as Scientific Officer (minimum age 21). Salary within range £565–£995 (superannuable). Forms from M.L.N.S., Technical and Scientific Register (K), 26 King Street, London, S.W.1, quoting A77/7A. Closing date 24th April, 1957. [1048

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SUPERINTENDENT of Lights required by Hong Kong Government Marine Department for appointment on probation to pensionable establishment. Normal tour four years. Salary scale (including expatriation pay and present temporary allowance) (I) single men: £1,504 rising to £2,290 a year; (II) married men without children: £1,672 rising to £2,539 a year; (III) family men £1,840 rising to £2,785 a year. Free passages. Liberal leave on full salary. Candidates, aged 28–35, must be A.M.I.Mech.E. or A.M.I.E.E. and have had three years' practical experience with all types of marine navigational aids. They should also be conversant with R/T and W/T for port communications. Write to the Crown Agents, 4 Millbank, London, S.W.1. State age, name in block letters, full qualifications and experience and quote M2A/41861/WJ. [1047

JUNIOR Electronic Engineers required to assist in the development of electronic equipment associated with Railway Traffic Control Systems. Together with two or three years' electronic development experience applicants should possess C. and G. Telecommunication Certificates to Intermediate or Final level. This latter requirement may be waived for applicants with more than five years' experience, and who are capable of developing outline circuitry to its final state with a minimum of supervision. Some experience of transistor circuitry is desirable, but not essential. Pension Scheme and five-day week. Write giving full particulars of age, qualifications and experience, to The Personnel Superintendent, Westinghouse Brake & Signal Co., Ltd., Chippenham, Wilts, quoting reference no. EQUIP/N/W. [1053

PLESSEY NUCLEONICS, LTD., have vacancies for Electronic Engineers to work on the design of reactor instruments, pulse circuits, and other applications of electronics to nuclear problems. Both Senior and Junior posts are offered. All applicants should possess a thorough knowledge of basic electronic theory, a degree in science or electrical engineering, H.N.C., or appropriate equivalent standards of technical education for the two grades. Previous experience in nucleonics advantageous but not essential. The other important qualifications are enthusiasm and initiative to progress in this new and expanding field. These posts will carry attractive salaries commensurate with qualifications and experience. Apply in writing to Chief Engineer, Plessey Nucleonics, Ltd., Weedon Road, Northampton. [1052

ELECTRONIC Engineer required for development of Railway Traffic Control and Signalling Equipment. Age 25–30. Essential qualifications—a Communications Degree or H.N.C. Electronics or C. and G. Certificates. The post is permanent and there are good prospects of progress for a successful applicant showing the necessary interest and ability. Applicants should preferably have had two or three years' experience in some electronic field, such as the design of communication equipment, or of amplifiers and/or filters for similar purposes. Experience with transistor circuitry an advantage but not essential. Pension scheme and five-day week. Write giving full particulars of age, qualifications and experience to The Personnel Superintendent, Westinghouse Brake & Signal Co., Ltd., Chippenham, Wilts. [1034

APPLICATIONS are invited from experienced technicians for the post of Electro-Encephalography Recordist, grade 1 in a newly created department at this hospital. The department will also serve other hospitals in the district. Whitley Council salary scale and conditions apply. A house is available. Applications giving details of experience, together with the names of two referees to be addressed to the Medical Superintendent, Parkside Hospital, Macclesfield, Cheshire. [1054

PHYSICIST/Electrical Engineer, a young man with degree or equivalent is offered an exceptional opportunity to undertake research work on insulating materials and processes. Anyone with proven ability will be given ample scope to make rapid progress. Applications please to Personnel Officer, The London Electric Wire Co., and Smiths, Ltd., Church Road, E.10. [1057

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PHYSICISTS or Electrical Engineers required by Ministry of Supply at R.A.E., Farnborough, Hants, to develop and design circuits to deal with special problems. Candidates should have 1st or 2nd class hons. degree in Physics or Electrical Engineering. Physicists should have engineering bias, and Engineers leaning towards Physics. Appointments as Scientific Officer (min. age 21) with salary in range £565–£995 (superannuable). Forms from M.L.N.S., Technical and Scientific Register (K), 26 King Street, London, S.W.1, quoting A83/7A. Closing date 24th April, 1957. [1051

PHYSICIST or Electrical Engineer required by Ministry of Supply at R.A.E., Farnborough, Hants, for work on aerials generally, and possibly on related field of radio wave propagation. Candidates should have 1st or 2nd class honours degree in Physics or Electrical Engineering, and be capable of applying radiation theory. Appointment as Scientific Officer (minimum age 21). Salary within range £565–£995 p.a. (superannuable). Forms from M.L.N.S., Technical and Scientific Register (K), 26 King Street, London, S.W.1, quoting A82/7A. Closing date 24th April, 1957. [1049

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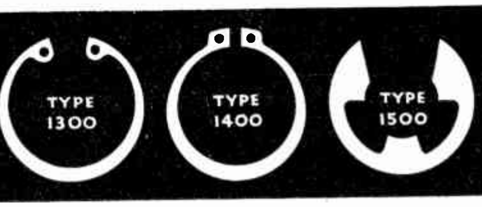

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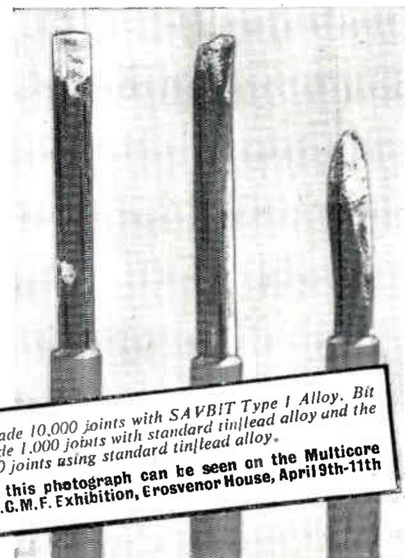
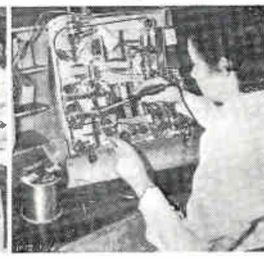


Bit on left has made 10,000 joints with SAVBIT Type 1 Alloy. Bit in centre has made 1,000 joints with standard tin/lead alloy and the bit on right 7,500 joints using standard tin/lead alloy.

The bits used in this photograph can be seen on the Multicore Stand at the R.E.C.M.F. Exhibition, Grosvenor House, April 9th-11th

An Alba Radio set being assembled and soldered at the factory of A. J. Balcombe Ltd.

An operative from Bush Radio Ltd. using SAVBIT Type 1 Alloy.



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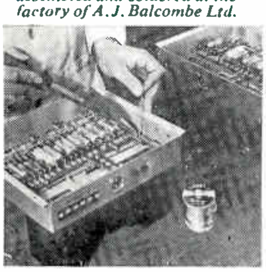
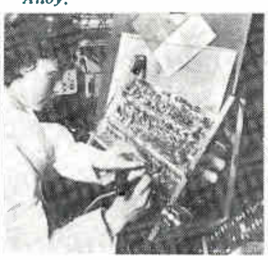
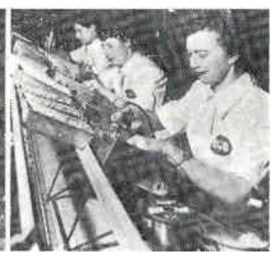


Soldering on a TL/10 "Point One" High Fidelity Amplifier at H. J. Leak & Co.'s works.



Joints on Pye Television Camera being soldered with SAVBIT.



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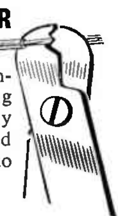

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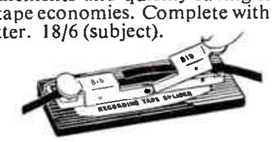

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