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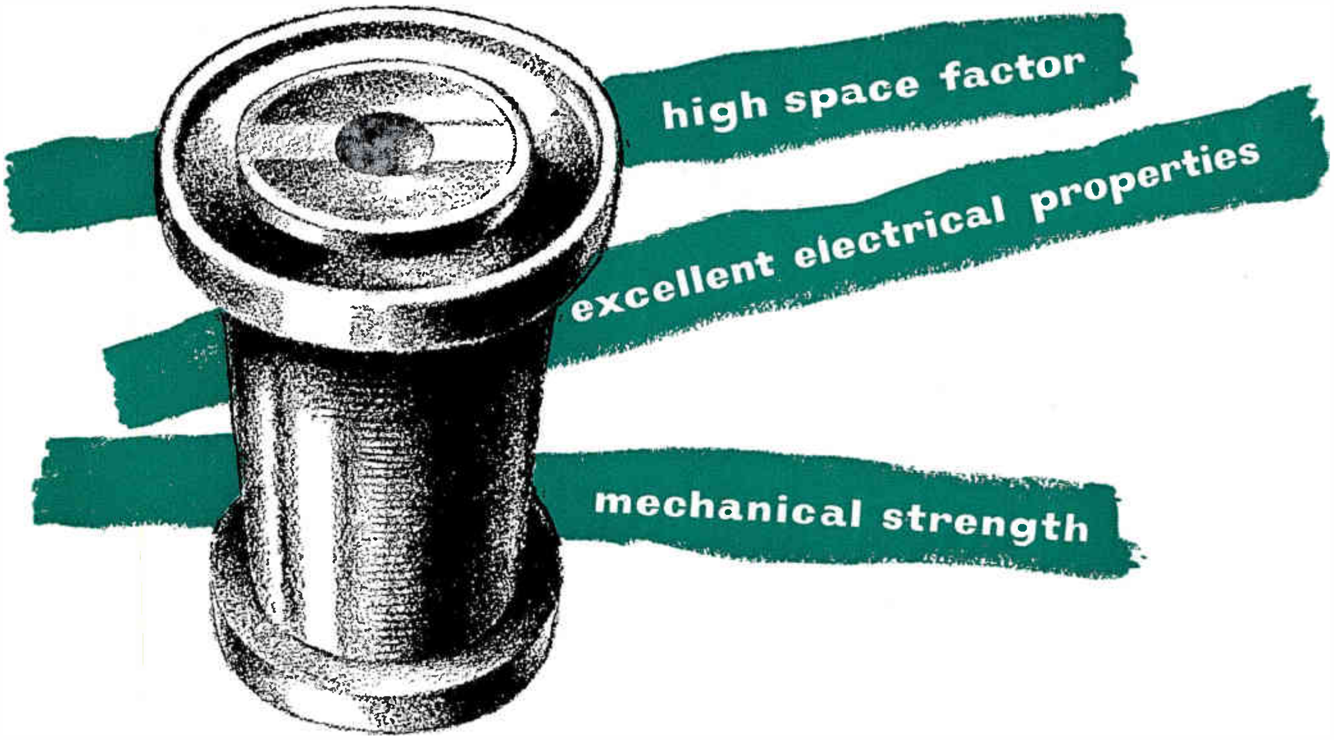


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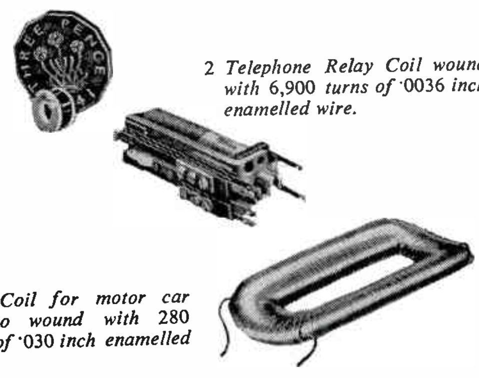

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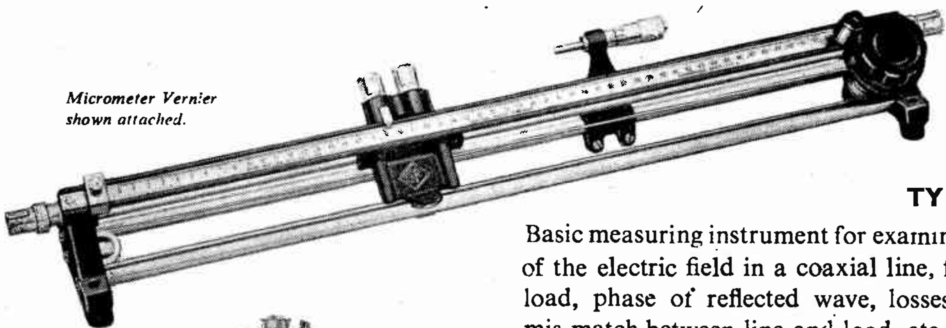

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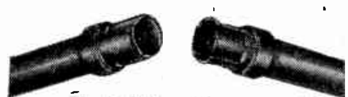

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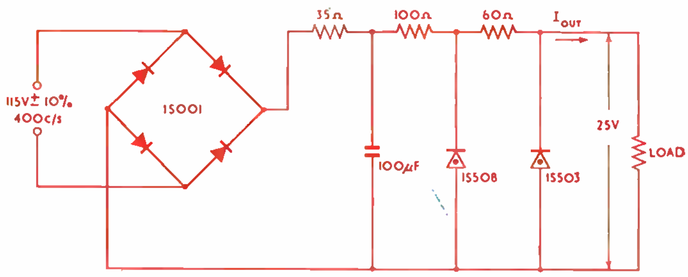


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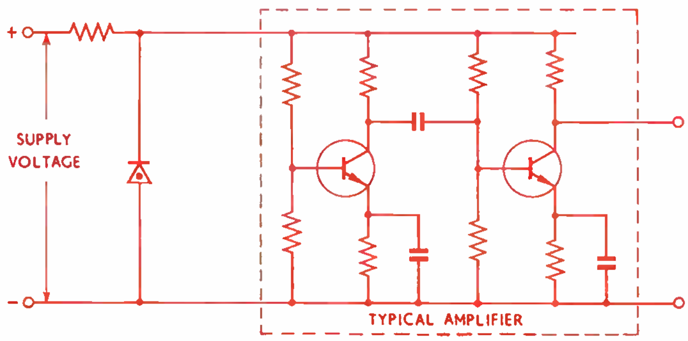


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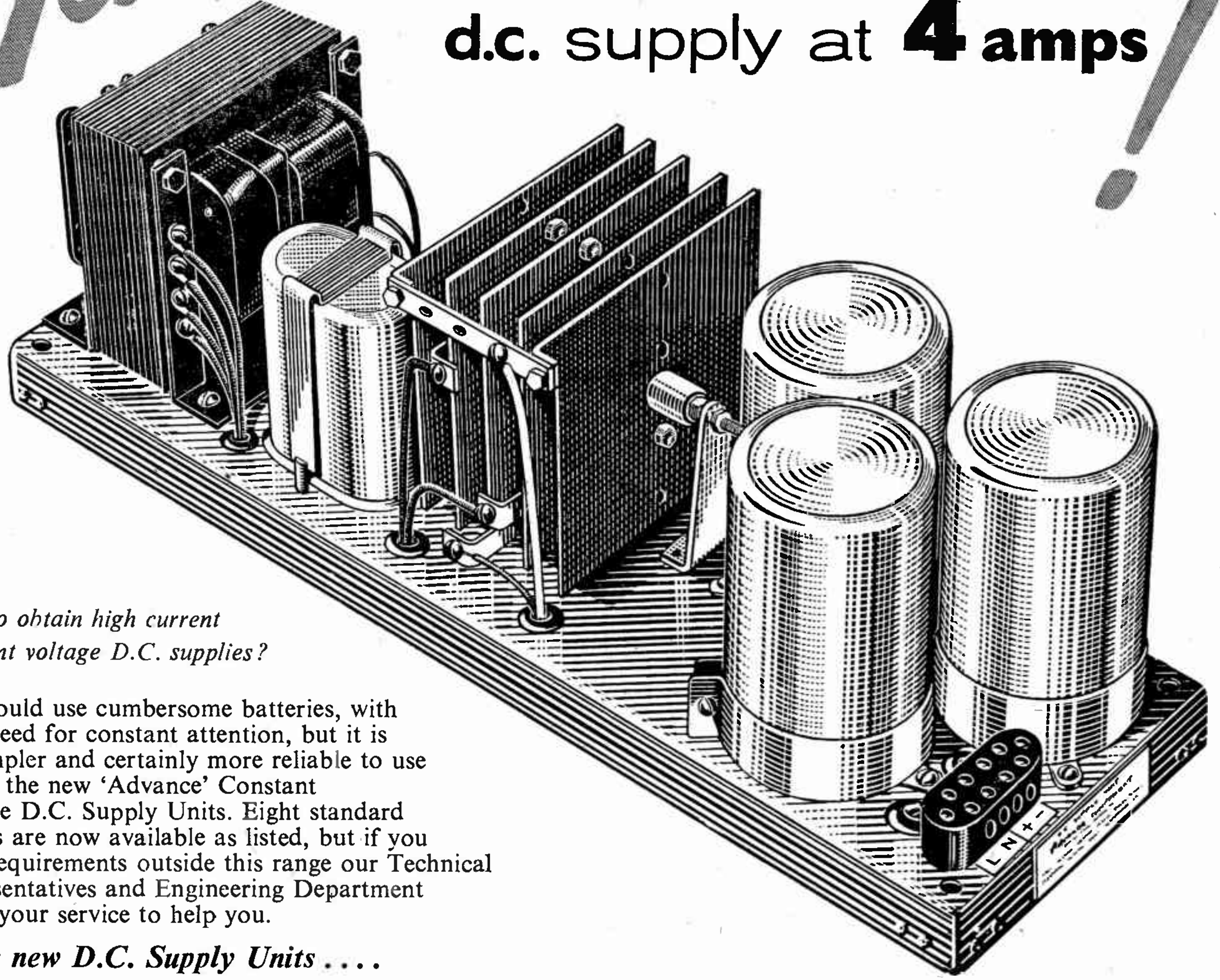


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#  ELECTRONIC & RADIO ENGINEER

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HUGH S. POCOCK M.I.E.E. *Managing Editor*
W. T. COCKING M.I.E.E. *Editor*



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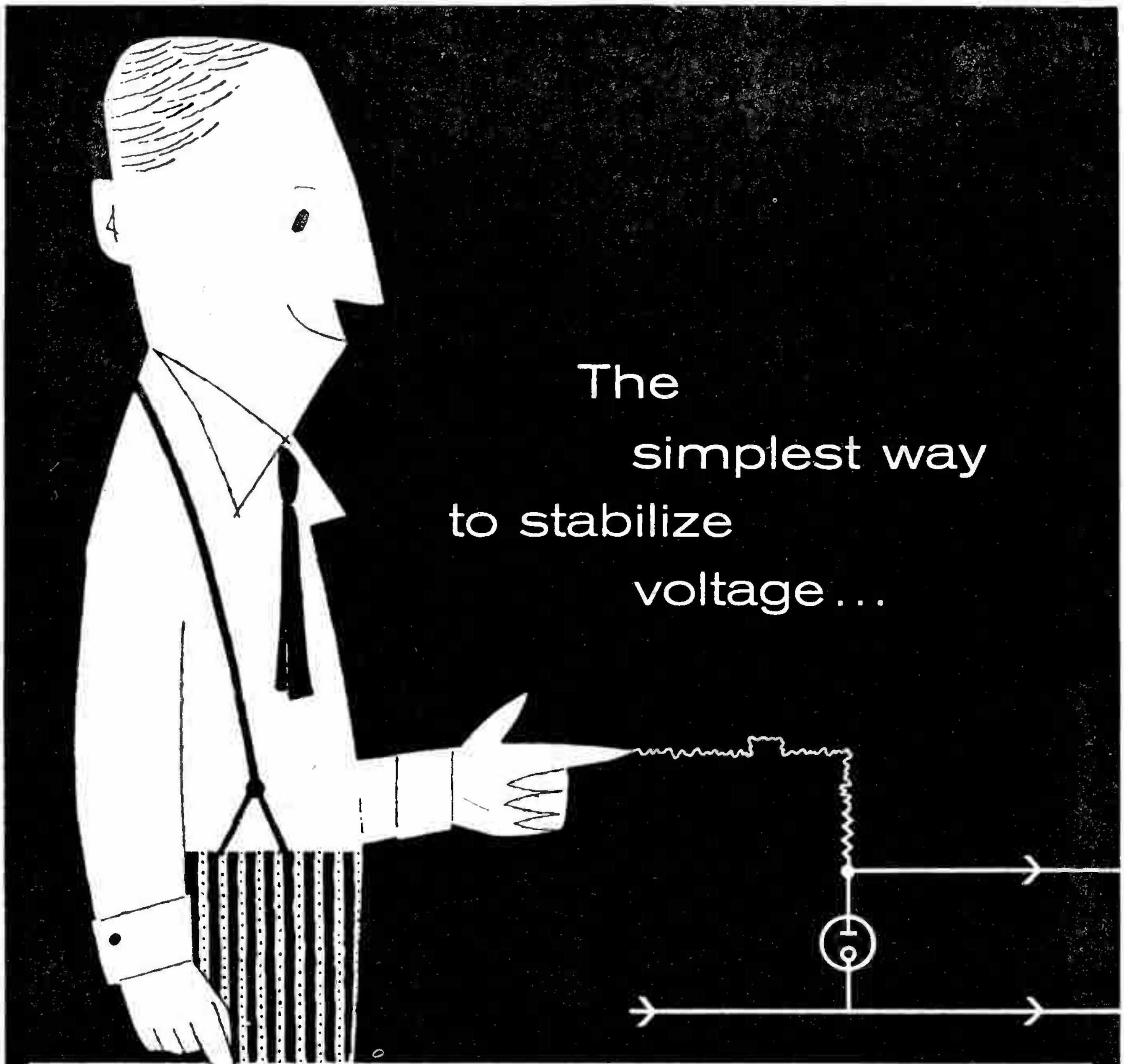


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VOLUME 36 NUMBER 5 **ELECTRONIC & RADIO ENGINEER**

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# Parametric Amplifiers

THE so-called parametric amplifier (it would be better called a non-linear reactance amplifier) has lately been arousing much interest. Unlike most recent developments, it is characterized by great simplicity and the interest in it comes about because it is a low-noise device. If it were not for unavoidable circuit losses, it would be noise-free.

The non-linear capacitance is provided by a semiconductor diode back-biased to be non-conductive. It is driven by a local oscillator, termed the 'pump', so that the capacitance varies at the frequency of this oscillator.

The capacitance couples together two tuned circuits, one at signal frequency and another at 'idling' frequency. The arrangement is thus like that of a diode frequency-changer but using a non-linear capacitance instead of a non-linear resistance. The device acts as an amplifier or an amplifying frequency-changer because energy is transferred from the pump to both the signal and idling circuits. As a simple amplifier, the pump frequency can be twice the signal frequency and then the idling circuit can be omitted.

According to the March *R.C.A. Review*, amplifier gains of 8 dB with a noise figure of under 6 dB are obtainable at 5,840 Mc/s. As an 'up-converter' an input of 460 Mc/s will produce an output of 9,375 Mc/s with a conversion gain of 9 dB and a noise figure of about 2 dB.

An understanding of the basic principle of the amplifier is most easily obtained by considering a tuned circuit fed with a sinusoidal signal. If the capacitor plates are separated when the voltage between them is at its maximum, mechanical work must be done and this appears as extra electrical energy, increasing the voltage. The plates can be replaced a quarter of a cycle later when the voltage is zero without doing work, so that the repetition of this process twice per cycle continually adds energy to the signal and so its amplitude is increased. Practically, much the same effect is secured by a non-linear capacitance varied at the pump frequency, the principle being to reduce the capacitance when the voltage across it is large and increase it when the voltage is small.

# Digital Voltmeter

By H. Sutcliffe, M.A., A.M.I.E.E.*

SUMMARY. *A description is given of a digital decade voltmeter in which Dekatron selector tubes are used to control the switching of precise values of current to a chain of precision resistors. The resulting potential difference is compared with the unknown voltage in a detecting unit which has automatic correction of datum level. The instrument is shown to have great accuracy, high operating speed and very-high input impedance.*

The digital voltmeter described in this article was the result of an attempt to produce an instrument in which the accuracy of the method of measuring potential difference by a potentiometer was combined with the high input impedance of an electrometer and the convenience of an ordinary moving-coil meter. It was felt that the operation should be in digital fashion so that the instrument would be adaptable to automatic digital recording and that the scale should be decimal rather than binary. This latter choice is imposed by considering that even scientists and engineers will count in tens for many years to come, and that a very convenient ten-state electronic device, the Dekatron, is available[1]. The method of operation chosen for this voltmeter is similar to that of a manually-operated potentiometer, except that all dial settings are changed automatically and by electronic switching instead of mechanical switching. The specification which the design attempted to meet is shown in Table 1.

TABLE 1

| | |
|---|---|
| Voltage ranges | 0 – 1 V     0 – 10 V |
| Maximum error | ± 0·02% of full scale |
| Maximum input current | $10^{-9}$ A |
| Maximum response time | 1 second |
| Display | Digital in decades |

A number of decade digital voltmeters have been announced or advertised recently in the technical press, but little information about their method of operation has so far been published. One such instrument[2] uses a time-modulation principle and so is radically different in its mode of operation to the instrument which is described here. A binary digital voltmeter, especially suitable for low voltages and using electromagnetic relays as switching elements, has been described[3].

## DESCRIPTION OF VOLTMETER

### Sequence of Events

It is convenient for the purpose of description to consider that the voltmeter consists of two interconnected units as in Fig. 1. The unknown voltage $v_u$ and a known voltage $v_p$ are each fed to the 'detector unit'. Voltage $v_p$ is produced by the 'p.d. unit', and its

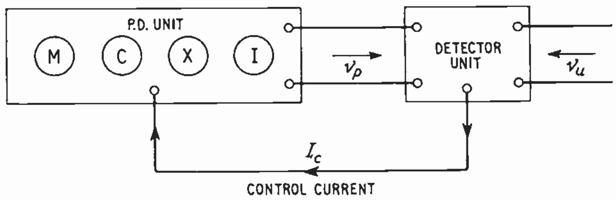



Fig. 1. *Schematic diagram of voltmeter. The voltage to be measured is* $v_u$

value appears on four dials, M, C, X and I, which are the faces of four Dekatron selector tubes[1]. A control current $I_c$ is established in the 'detector unit' and fed to the 'p.d. unit' where it controls the latter in such a manner that $v_p$ becomes equal to $v_u$. The measurement of $v_u$ is then complete, and the value may be read from the four dials as a decimal number.

The sequence of events during a measurement may be illustrated by considering the particular situation where $v_u$ lies between 4·302 and 4·303 V and the voltmeter is set to read 10 V at full scale. During the course of the measurement, the relation between $v_u$ and $v_p$ is sampled and the value of $v_p$ is modified during short periods of time at the end of successive longer intervals of time. A possible sequence for $v_p$ would be to advance in steps of 1 mV until $v_u$ was reached, but this would occupy 4,302 intervals. The sequence followed in the voltmeter described here is shown in Table 2, and occupies 18 intervals only. The largest duration of a measurement would be for $v_u$ = 9·999 V and would occupy 44 intervals. It is convenient to use the 50-c/s mains to generate the waveforms used during the sampling period, so an interval is one fiftieth of a second and the greatest duration of a measurement is 0·88 second.

It can be seen from Table 2 that during most of the intervals $v_p$ is less than $v_u$. The sampling operation at

* *Department of Electrical Engineering, University of Bristol.*

**TABLE 2**

| Interval Number | Dial Readings | | | |
|---|---|---|---|---|
| | M | C | X | I |
| 1 | 0 | 0 | 0 | 0 |
| 2 | 1 | 0 | 0 | 0 |
| 3 | 2 | 0 | 0 | 0 |
| 4 | 3 | 0 | 0 | 0 |
| 5 | 4 | 0 | 0 | 0 |
| 6 | 5 | 0 | 0 | 0* |
| 7 | 4 | 0 | 0 | 0 |
| 8 | 4 | 1 | 0 | 0 |
| 9 | 4 | 2 | 0 | 0 |
| 10 | 4 | 3 | 0 | 0 |
| 11 | 4 | 4 | 0 | 0* |
| 12 | 4 | 3 | 0 | 0 |
| 13 | 4 | 3 | 1 | 0* |
| 14 | 4 | 3 | 0 | 0 |
| 15 | 4 | 3 | 0 | 1 |
| 16 | 4 | 3 | 0 | 2 |
| 17 | 4 | 3 | 0 | 3* |
| 18 | 4 | 3 | 0 | 2 |

Sequence of readings on dials of 'p.d. unit' when the unknown voltage $v_u$ is 4·302 (+). The value of $v_p$ is less than $v_u$ except during intervals marked with an asterisk.

the end of each interval confirms this, and the change required from the 'p.d. unit' is:

"Advance one digit of the decade which is currently in operation."

This instruction will be called instruction (i), and is conveyed by control current $I_c$.

Four of the intervals in the table are marked with an asterisk and it may be seen that for these intervals $v_p$ is greater than $v_u$, the 'p.d. unit' having overshot by one digit. The sampling operation confirms this and the change required from the 'p.d. unit' is:

"If operating on decade M(C, X) move back one digit on M(C, X) and prepare to operate for subsequent sampling periods on decades C(X, I)."

"If operating on decade I move back one digit on I, then adjust the circuits to prevent any further alteration in the dial readings."

This instruction will be called instruction (ii) and is conveyed by reversal of the control current $I_c$.

The description of the 'p.d. unit' will show that (i) is followed if $I_c$ is approximately 10 mA, while (ii) is followed when $I_c$ is reversed in sense.

The 'detector unit' is required to provide the control current according to the following conditions.

If $v_p < v_u$ during an interval, $I_c$ is to be + 10 mA during the next sampling period.

If $v_p > v_u$ during an interval, $I_c$ is to be − 10 mA during the next sampling period.

It will be noticed that, while the final reading on any dial will be one of the ten numbers 0 to 9, the sequence of events requires the equivalent of a further digit on each dial; i.e., there is a requirement for eleven positions per dial. Ten-cathode Dekatrons cannot be used but, fortunately, selector tubes with twelve cathodes are available commercially.

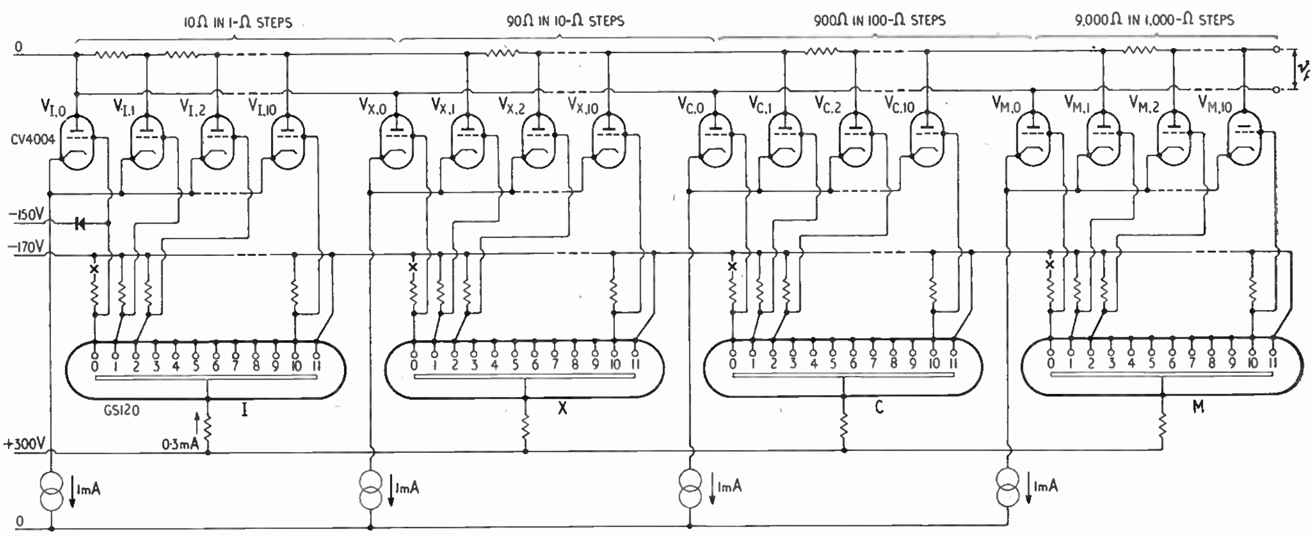
## Potential Difference Unit

*Correlation of $v_p$ with Dial Readings*

This section describes the method of relating the dial readings on the faces of the four Dekatrons to the value of $v_p$. Fig. 2 is a diagram of the relevant circuits in the unit, while Fig. 3 is a circuit equivalent to Fig. 2. The switches in Fig. 3 correspond to glow transference in the Dekatrons of Fig. 2.

Suppose, for example, that the glow in tube X invests cathode No. 2. The glow current flows through the 100-kΩ cathode resistor to the −170-V supply line, and would have raised the potential of this second cathode to −140 V if the cathode potential were not held by a catching diode (not shown in the figure) at the level of the −150 V supply line. Cathode No. 2 is connected to the grid of triode $V_{x2}$, which is one of a bank of eleven triodes with common cathode connections all associated with Dekatron X. The eleven cathodes have followed the grid of $V_{x2}$ on its positive excursion from −170 V, while the grids of the remaining ten 'X' valves

Fig. 2. *Circuit diagram of part of 'p.d. unit'. When cathode number m of M, c of C, etc. is invested, the value of $v_p$ is m decimal cxi volts*



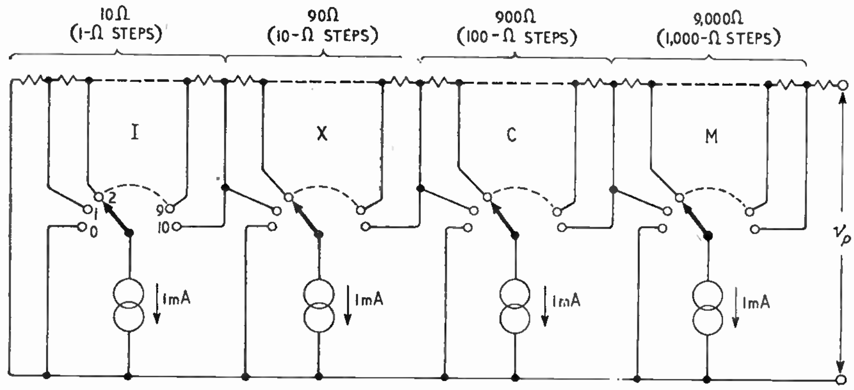



Fig. 3. *Circuit equivalent to Fig. 2*

have stayed at a potential of −170 V. Thus of the group only $V_{x2}$ is conducting and the 1 mA constant current is routed through a resistance of 20 Ω to the point 0. The contribution of the X circuits to $v_p$ is 20 mV.

In general, if cathodes numbered m, c, x, i of tubes M, C, X, I are invested, the value of $v_p$ in millivolts is m thousands plus c hundreds plus x tens plus i units. The accuracy with which $v_p$ can be produced depends almost entirely on the precision of the chain of resistors and on the accuracy of the circuits which are represented by the four constant-current generators in Fig. 2. The scale of the instrument is changed from 10 V to 1 V full scale by inserting a resistance, $\frac{1}{9}$ of 10 kΩ across the $v_p$ terminals.

*Constant-Current Sources*

Each current source has a circuit as shown in Fig. 4, the four sources sharing a reference voltage $V_{ref}$. The reference voltage is obtained from a potential divider across a highly stable reference tube, and the particular value of 84 V is maintained with great accuracy over long periods of time. Fig. 4(a) shows the circuit connections in the waiting period before the voltmeter is required to make a measurement. A switch is closed at the instant when a measurement is required, and the closing of an electromagnetic relay causes the circuit to change to that shown in Fig. 4(b). The relay, not shown in the figure, is of the type PO 3000, and each current source requires two change-over contacts and one break contact.

The grid connection in Fig. 4(a) is made to a point labelled $V_{bias}$, on the same potential-divider chain which supplies $V_{ref}$. The value of $V_{bias}$ is chosen so that with an average valve and nominal heater voltage the cathode potential is 84 V positive with respect to the negative line. Variations in valve characteristics and in heater voltage will occur and the cathode potential will be in error by a small but not negligible amount. This error voltage appears across capacitor *C*.

When the voltmeter is put into operation, the circuit configuration is transformed into that of Fig. 4(b), capacitor *C* being inserted in series with the grid connection in such a sense that the grid potential changes in the direction which corrects the original error. The final error in cathode potential is negligibly small, as is demonstrated in Appendix 1. There is no direct connection to the grid in Fig. 4(b), and the value of grid potential will in time drift away from its correct value; this effect is negligible within the operating time of the voltmeter.

*Control Circuits*

These circuits follow the instructions (i) or (ii) which were described previously. Fig. 5 is a diagram of the relevant parts of the 'p.d. unit'. Three tiny cores of square-loop ferrite material are driven well into saturation at 50 c/s. Output pulses $v_1$, $v_2$ and $v_3$ are as shown

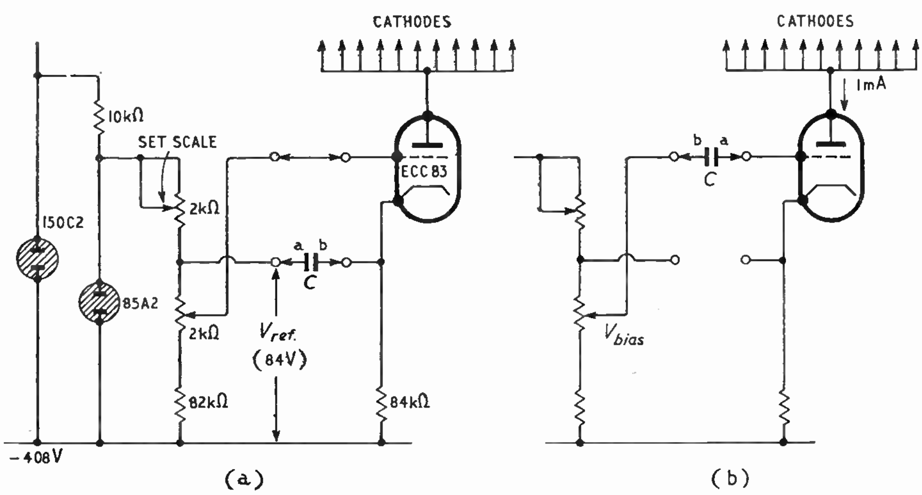



Fig. 4. *Circuit diagram of constant-current source; (a) during the re-set period before operation; (b) during operation. Voltages $V_{ref}$ and $V_{bias}$ are common to all four current sources*

in Fig. 6. The dotted line shows the position of $v_1$ when $I_c$ is reversed in sense.

Single-stage transistor amplifiers (not shown in the figure) pass the three pulses to the first grids of pentode amplifying valves which drive the guide electrodes of the four main Dekatrons M, C, X and I, and of an auxiliary Dekatron A. Pulse $v_1$ is applied continuously to the first guides of all five Dekatrons; pulse $v_2$ is applied to the second guide of either M, C, X or I, depending on the bias of the pentode amplifiers $V_2$, $V_3$, $V_4$ and $V_5$. This bias depends in turn on the particular cathode of tube A which is invested by the glow. If, for instance, cathode 2 of A is invested, then the potential of cathode 2 is raised by approximately 14 V from that of the $-170$ V line, transferred from cathode 2 to cathode 3. The potential at the grid of $V_4$ will be lowered, and that of $V_5$ raised, with time-constant *CR*. When the next group of pulses arrives, after an interval of 1/50th second, Dekatron I will be in operation. The value of *CR* is not critical but should be intermediate between the pulse duration, 0·1 msec, and the interval between pulses, 20 msec.

The end of the measurement will take place when Dekatron I is in operation and a pulse group arrives when $I_c$ is reversed. Dekatron I counts back one digit, and in Dekatron A the glow transfers to cathode 4. It is desirable to clamp the readings at this stage, and a convenient method of achieving this is to use the p.d. developed across a resistor in series with cathode 4 of

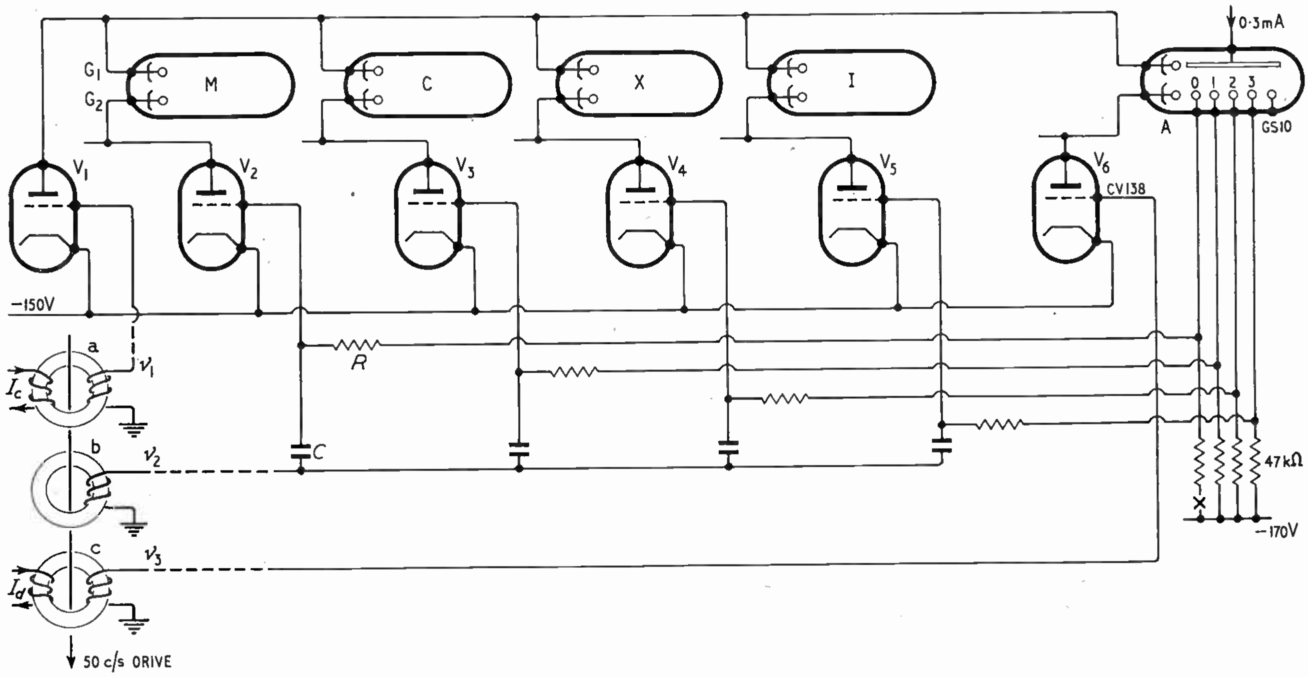



Fig. 5. *Controlling circuits in the 'p.d. unit'. Many circuit details such as anode load resistors are omitted from the diagram*

and the bias on pentode $V_4$ is $-6$ V. The bias on pentodes $V_2$, $V_3$ and $V_5$ is $-20$ V. The amplitude of pulse $v_2$ at the common connection to the coupling capacitors is 10 V, so valve $V_4$ passes the pulse to the second guide of Dekatron X, while the second guides of M, C and I are not disturbed.

If then control current $I_c$ is positive, and instruction (i) is to be followed, Dekatron X will receive a pair of guide pulses, with $v_2$ lagging behind $v_1$, and will advance one digit. Dekatron A will receive two guide pulses, $v_1$ and $v_3$, but they will be separated in time, and will not change the cathode investment.

If $I_c$ is reversed, and instruction (ii) is to be followed, Dekatron X receives a pair of guide pulses with $v_2$ now leading $v_1$ and will therefore step back one digit. Dekatron A receives two guide pulses, $v_1$ and $v_3$, which now slightly overlap each other, and the glow will be Dekatron A. This p.d. applies positive bias to $V_6$, which cannot then pass pulses to the guide of Dekatron A. The glow then cannot transfer to any of cathodes 0, 1, 2 or 3 and so pulses cannot be passed by $V_2$, $V_3$, $V_4$ or $V_5$, and the position of the glow on M, C, X and I cannot be changed. The circuit details for this clamping operation are not shown in the figures, nor are details associated with the commencement of a measurement. The suppressors of pentodes $V_1$ to $V_6$ have a common connection and the potential of this common point is switched from a large negative value to cathode potential by a relay contact which closes when a measurement is initiated. Before a measurement is required, re-setting of all five Dekatrons may be achieved by applying a negative impulse from a switch and capacitor circuit to the common connection of cathodes numbered 0 in all five Dekatrons. This re-setting circuit is not illustrated in the figures, but the point of common connection to the cathode circuit is indicated by points labelled x.

*Detector Unit*

The functions required of the 'detector unit' have already been described and the requirements can be met by a d.c. amplifier with automatic datum setting, as illustrated in Fig. 7. Switches $S_1$, $S_2$ and $S_3$ are contacts on a relay which is energized at the instant at which a measurement of $v_u$ is desired. The positions of the contacts shown in the figure relate to the period before the relay is energized. The unknown voltage $v_u$ is applied between the line 0 and the grid of $V_1$ in such a sense that the grid potential is the more negative. Valves $V_1$ and $V_2$ are connected as a differential amplifier and together with $V_4$ and $V_5$ constitute a direct-coupled voltage amplifier of very high gain.

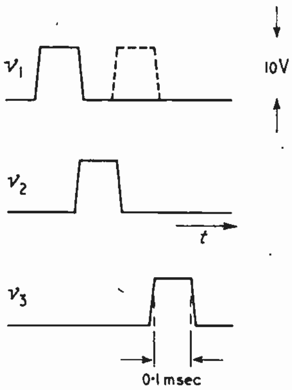



Fig. 6. *Output waveforms $v_1$, $v_2$ and $v_3$ from cores a, b and c after one stage of transistor amplification (not shown in Fig. 5). The dotted outline shows the changed position of $v_1$ when $I_c$ is in the reversed sense*

Negative feedback is applied through $S_2$ and the cathode follower $V_3$, and the amplifier maintains itself in a condition in which the anode potential of $V_5$ is in the region of 100 V. The function of valves $V_6$ and $V_7$ is to supply $I_c$ to the 'p.d. unit'. During the course of a measurement one only will be conducting at any time, but in the period before a measurement the grids of both are at the potential of the anode of $V_5$. When a measurement is initiated, switches $S_1$, $S_2$ and $S_3$ change in sequence, an operation which takes place in a small fraction of a second. When $S_1$ is open, the grid potential of $V_7$ is maintained by $C_3$ at its former value, while the grid potential of $V_6$ can follow the potential of the anode of $V_5$ after a time delay which is dependent on $C_2$ and on the associated resistance. The opening of $S_2$ has no effect on the grid potentials of $V_3$ and $V_2$, but leaves the amplifier in a condition of high gain. The departure of the grid potential of $V_1$ from its former value $v_u$ by more than a fraction of a millivolt in either direction now suffices to switch the anode potential of $V_5$ through 50 volts or so to its positive or negative limits, which in turn causes $I_c$ to flow in a forward or a reversed direction. The voltage across $C_1$ remains constant for the duration of the measurement and holds the grid of $V_3$ at a constant potential. Valve $V_3$ is a cathode follower, employed to maintain a constant potential at the grid of $V_2$, and is operated at low anode voltage and low cathode current in order to reduce grid current to a small value. Grid current in $V_2$ would cause excessive drift of datum level if $V_3$ were omitted and $C_1$ were connected directly to the grid of $V_2$.

The operation of the 'detector unit' may be illustrated by events taken from Table 1. The voltage $v_p$ is 4 V during interval 5, and since $v_u$ is 4·302 V the grid potential of $V_1$ is positive with respect to the datum level which was established prior to the measurement. At the output end of the amplifier, current in $V_5$ is cut off and the grid potential of $V_6$ is a few volts more positive than that of $V_7$. Component values are such that grid current flows in $R_5$ and $R_6$, which prevents excessive rise of potential at the grid and cathode of $V_6$. No current flows in $V_7$, so $I_c$ is in the direction shown in the figure.

The group of pulses from the control circuit at the close of interval 5 initiates interval 6, during which $v_p$ is 5 V. The 'p.d. unit' has overshot by one digit and the anode potential of $V_5$ falls immediately to a value of some 50 volts below the grid potential of $V_7$. Reversal of $I_c$ does not take place at once because the time of discharge of $C_2$ is finite. The delay is introduced in order to avoid the confusion which would occur in the control circuit if $I_c$ were to be allowed to reverse during the period of production of a group of pulses. The reversal of $I_c$ takes place during interval 6.

Interval 7 is initiated by a group of pulses whose sequence is dictated by the reverse sense of $I_c$ and which causes the 'p.d. unit' to follow instruction (ii). Voltage $v_p$ is reduced to 4 V, while circuits in the 'p.d. unit' adjust themselves so that Dekatron M is isolated with the glow on cathode 4, while the pentode amplifier associated with Dekatron C prepares to operate in readiness for the next pulse group. Control current $I_c$ is restored to its former positive sense, the change taking place with a delay in time as $C_2$ is charged through $R_5$.

**Performance and Sources of Error**

One model of the digital voltmeter has been built and tested. It was found that the specification listed in Table 1 could be met provided that care was exercised in the details of certain aspects of the design.

One obvious possible source of error is the reference tube together with its associated circuits. The tube is not a standard element and it is necessary to calibrate the voltmeter against a standard cell, a process during which $V_{ref}$ is set to 84 V. Any subsequent change im $V_{ref}$ leads to a proportionate error in the instrument; thus, if the full-scale error on the 10-V scale is to be less than 1 mV, then $V_{ref}$ must not drift by more than 8·4 mV. This degree of stabilization is just within the capabilities of the reference tube, provided the ambient temperature has no great variation[4].

It is shown in the appendix that an error of 5 parts in $10^5$ can arise in the constant-current source circuits, caused by incorrect setting of the voltage $V_{bias}$ in Fig. 4 (b). The accuracy of the current sources is also effected to some extent by variation of the p.d. between the $-150$ V supply line of Fig. 2 and the $-408$ V line of Fig. 4. The current supplied from these lines is a few milliamperes only, and cold-cathode tubes provide adequate stabilization.

It can be seen in Fig. 2 that 44 triode anodes are connected to the resistance chain, so the effect of leakage in these valves must be considered. The type used, the double triode CV4004, exhibits leakage current whose magnitude is in the region of $10^{-8}$ A. This can lead to an error in $v_p$ whose magnitude is $5 \times 10^{-5}$ times the full-scale value of $v_p$.

The input stage of the 'detector unit' (Fig. 7) is a sensitive part of the instrument. Accuracy depends on the maintenance of p.d. across $C_1$ during the period of a second or so occupied by a measurement. A good quality paper capacitor of value in the region 1 $\mu$F and working voltage 500 V will normally have a time-constant of many hours and will prove to be a suitable component. Another point which is relevant to this part of the instrument is that the operating periodicity and supply frequencies are identical, so it is desirable to avoid excessive 'hum' pick-up in the detecting amplifier. This is not difficult to achieve when the significant signal amplitude is 100 $\mu$V. The supply lines marked (S) employ cold-cathode stabilizer tubes, but long term stability is not required in the 'detector unit'. Resistors may be of the common composition type and the line stabilizers should be chosen for low impedance rather than for constancy over periods of time or with changes of temperature.

The input impedance of the instrument as shown in Fig. 7 is such that currents in the region $10^{-9}$ A are taken from the source whose p.d. is to be measured. This is adequately low for most purposes, but a very much greater input impedance may be obtained by inserting an electrometer triode in the common-anode configuration between the moving contact of $S_3$ and the grid of $V_1$ in Fig. 7.

## Conclusions

It appears that an accurate and rapid digital decade voltmeter has been devised, with reasonably economical use of circuit elements. The principle of operation is most suitable when the requirement is for full-scale ranges of between one and ten volts with accuracy up to, but not beyond, one part in $10^4$ times full-scale, with exceptionally high input impedance.

Two further lines of development are considered to be worth following. The first of these concerns the controlling circuits (shown in Fig. 5) which have been conceived on a somewhat extravagant scale. A simpler arrangement is envisaged in which the six pentodes are not required and the power consumption of the instrument is reduced from its present 140 watts to 100 watts. The second line of development concerns the 'detector unit', where hum pick-up and drift impose a limit in the region of 100 $\mu$V for the smallest significant signal. An improvement by a factor of ten, and possibly by a factor of 100, should be possible here, the ultimate limit being imposed by valve flicker noise.

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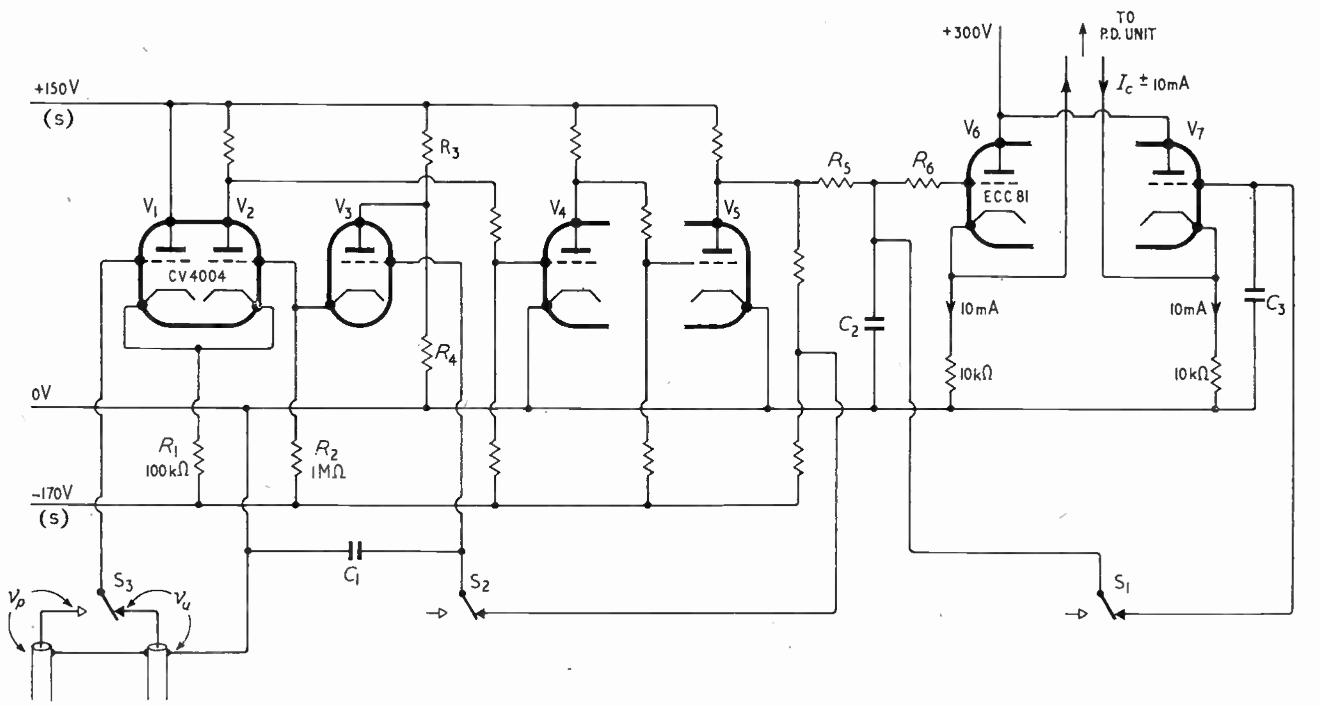
## APPENDIX 1

### Error in Constant-Current Source

Suppose the initial error in cathode potential is $e_1$ volts; i.e., in Fig. 4(a), the p.d. across the 84-k$\Omega$ cathode load is $(84 + e_1)$ V. Then when the transformation to Fig. 4(b) takes place, the

Fig. 7. *Circuit diagram of 'detector unit'. The switch contacts are shown in their positions during the re-set period before operation. Stabilized supply lines denoted by (S)*



change in grid potential is $-e_1$ volts, and the change in cathode potential $e_c$ is given by:

$$e_c = \frac{-e_1\mu}{R_a/R_L + (1+\mu)}$$

where $\mu$ is the triode amplification factor,
$R_a$ is the triode anode slope resistance,
$R_L$ is the resistance in the cathode circuit.

When a triode such as the ECC83 (CV4004) is used, $\mu$ is say 100, and $R_a$ is approximately equal to $R_L$; i.e., 84 kΩ. Then:

$$e_c \simeq -e_1 (1 - 0{\cdot}02)$$

The final value of cathode potential is $(84 + e_1 + e_c)$ V; i.e. $(84 + 0{\cdot}02\, e_1)$ V.

The initial error $e_1$ may be within $\pm$ 0·2 V, in which case the value of the current through the load resistor, and consequently through the valve is given by:

$$I \simeq 1 \pm (0{\cdot}2 \times 0{\cdot}02/84) \text{ mA} \simeq 1 \pm 5.10^{-5} \text{ mA.}$$

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***The Fringe of the Field*** ***By Quantum***

# ČERENKOV RADIATION

Incentives seem to be among the many debatable topics that crop up for passing mention in "Lycidas". "Fame is the spur that the clear spirit doth raise (that last infirmity of noble mind) to scorn delights and live laborious days." Does this, in fact, act as the driving urge of the scientific investigator? Does he strive always with his eye on the ultimate goal, the Small Back Room at the Top? I do not think so really. But if the emphasis is shifted slightly from personal renown to a public-spirited attempt to ease the work of the historian, there may be something in it. For many distinguished scientists seem almost deliberately to have selected just those fields of work that would render them memorable, at least to the tidy-minded. What could have been more fitting than that A. H. Compton should have sought the Compton Effect, and that the Lamb Shift should have capitulated to W. E. Lamb? And Sir Edward Appleton, with lots of layers to choose from, might have discovered a different one from the Appleton Layer, but somehow didn't. Things were not always so well organized; there was, you will remember, some confusion spread about by Robert Hooke as to whether he had discovered Hooke's Law at all or merely got hold of Boyle's by mistake; which must have got pneumatics and mechanics nicely muddled up until it was sorted out. And what is now almost accepted as a universal principle, the Law of Eponymous Quest, is not really of very long standing. The more conservative or sentimental among you may dispute this view, and say that the facts are equally consistent with a much older principle that the historians have always applied to things like Forks and Purges and Wars about Ears—the Tradition of Honorific Ascription. If so, I shall certainly not argue further at this stage. For, in the case in point now, I suspect that all that you can tell me about Čerenkov radiation is that it is a radiation discovered by Čerenkov. And that is quite enough to start off with anyhow. Never mind the why and wherefore.

When, in 1958, the Nobel Prize in Physics was awarded jointly to the Russian scientists P. A. Čerenkov, I. M. Frank, and Ig. Tamm, few people knew much more about the radiation than they had been able to observe in a respectful glance at a water-moderated 'swimming-pool' reactor that had been exhibited in public. A bluish light, originating from the passage of high-energy radiation through water, was certainly not a fluorescence or scintillation effect of the ordinary kind. In the readily available journals that most of us are able to see regularly, there seemed to be very little information; one realized that it was being used to detect very high energy radiation, and had some general idea that it was analogous to the Mach wave of a supersonic projectile, but that was about all. The recent and very timely publication of Dr. J. V. Jelley's "Čerenkov Radiation and its Applications" (Pergamon Press, for the United Kingdom Atomic Energy Authority, 1958) gives a complete and up-to-date review of what has already developed into a vast subject; and one's first reaction on reading it is wonder and amazement at the possibilities it opens. Most of these, it is true, appear to be in the realm of high-energy physics; but at least one application to the generation of microwaves suggests that there may be an alternative to the maser just round the corner (that is, if I have understood it all correctly).

### Early Observations and Theory

Mme Curie in 1910 had observed a pale blue glow in solutions of radioactive compounds, and L. Mallet during 1926–29 found that it occurred when transparent materials were placed near to a powerful radioactive source and also that it had a continuous spectrum. Čerenkov, during the years 1934–38, investigated the effect thoroughly and discovered the directional effect which distinguishes it from all other kinds of energy-to-light conversions. He used powerful $\gamma$-ray sources irradiating water or benzene, and very long photographic exposures and established that it was not a fluorescence effect. He also showed, from the effect of a magnetic field on the emission, that the real agents for the energy-to-light conversion were the secondary electrons produced in the material by the $\gamma$-rays, and not the $\gamma$-rays themselves; and obtained the radiation with $\beta$-particles.

In 1937, Frank and Tamm gave a theoretical explanation in terms of charged particles moving through a dielectric medium with speeds exceeding that of light *in the medium*; this predicted that the radiation should be confined to a very narrow angular range about the direction of motion of the particles. An asymmetry in the distribution consistent with this was found by Čerenkov at about that time; and, since the development of the photomultiplier, the exact direction of the radiation caused by a single particle can be found, and agrees with the theory. Fluorescence is ruled out both by the continuous spectrum and the directional effect; the possibility of bremsstrahlung was considered, but this would lie within the X-ray region instead of the visible and would be differently directed.

The first approach to the theory can be worked out in terms of Huygens' construction. The only suppositions made are that the refractive index, $n$, of the medium is greater than 1, so that the speed of light in it is $c/n$; and that the velocity $v$ of the charged particle, which must traverse a straight-line path several wavelengths long, is greater than $c/n$. This means, of course, that only high-energy particles can be involved; the ratio $\beta = v/c$ must be of the order 0·7 or so at least, depending on the actual material.

It might be asked how it is that Huygens' construction can be relevant. This is usually used to trace the new position of a coherent wave-front when you already know its old position; you have a perfectly good wave-front to begin with anyhow. But a little closer investigation shows that you are in fact stepping off from the wave-front in order to consider its effect on the medium; for the wave-front excites each portion of the medium lying on it at each instant to act as a secondary source of radiation. This radiation spreads out in all directions from each secondary source; but the only place where a new wave-front is to be observed is that in which the secondary wavelets are all in phase with one another—that is, along the surface which at the appropriate instant envelops the secondary wavelets. Looked at from this point of view, the original wave-front is in a sense redundant; only the radiating secondary sources in the medium are needed in order to be able to specify what happens at any *later* time. The original wave-front was simply there to ensure coherence—that is, to give them all a fair start, like the competitors in a cross-country race. But there are other kinds of 'fair start' in races. Thus in 'Torpids' (a modern Oxford slang term for what is properly The Toggers, a fixed-seat affair for which prudent oarsmen wear special small clothes, or togs) the boats all start simultaneously, but separated in space. The analogy to this, in Huygens' construction terms, is the diffraction grating. Again, motor rallies start competitors at the same place, but equally separated in time; I can't think of an analogy to this one, but never mind. Given a 'fair start', it is easy to calculate the winner of a race, whatever the actual conditions are.

There are no winners with light waves, since all travel at the same speed in the case considered; but, *given a 'fair start', there is always a coherence pattern* which enables a new wave-front to be found at any given time. Now 'Torpids' has a certain feature which was overlooked above but could, in different circumstances, be quite relevant. The boats do *not* start simultaneously, if they set off at the sound of the starting-gun. I forget where this is sited, but we will suppose that it is at the back of the line. If the separation of the boats is $x$, and the speed of sound in air is $v$, each is delayed with respect to its predecessor by a time interval $x/v$. There is no need to rush to the O.U.B.C. with this discovery. You can reflect for yourself on the fairness of it, and whether the increased chance of being bumped is compensated for by the increased chance of making a bump. If you agree that it is fair, and that all it really does is to reduce the spacing between the boats, then the point is made—that if they are set in motion, *staggered both in space and in time* then there is still a coherence pattern, which would be preserved if they all travelled at the same rate. The reason is, that the staggering is done by means of a signal that travels very much faster than the boats; if, for example, they were intended to be set off by somebody walking slowly along the towpath and mentioning it to each in turn, then only the first one could ever be started. Where is all this talk leading us? Simply to the proposition that the Huygens' construction, which works obviously when the initial coherence pattern starts the secondary wavelets from an instantaneous position of an optical wave-front, separated in space but coincident in time, must work equally well when they are started with a coherence pattern derived without any initial wave-front, separated both in space *and also in time* according to a regular pattern.

Coming back to Čerenkov radiation, the 'secondary sources' are produced by the momentary polarization of the material, which is a dielectric, as a charged particle

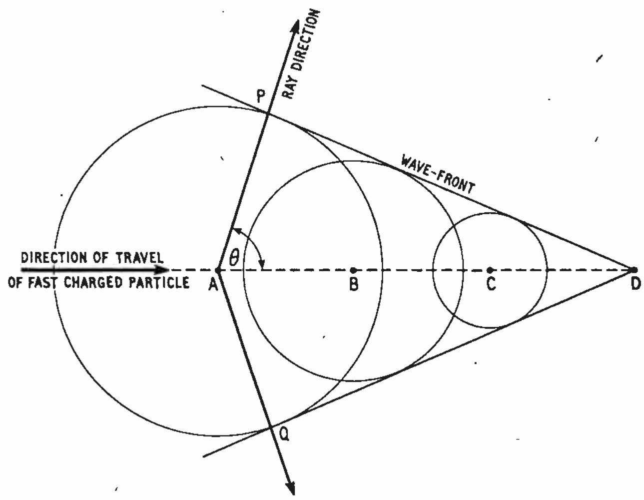



Fig. 1. *Huygens' construction interpretation of Čerenkov radiation. Here A, B, C, D are four positions of the exciting particle at equal intervals of time, and the particle has just reached D. The circles represent the traces of pulses of light emitted from secondary sources on the path of the particle as it passes; these travel outwards with velocity c/n. The wave-front is a cone enveloping all the secondary wavelets at any instant, here intersecting the plane of the diagram at DP and DQ. The rays AP, AQ, and others which could be drawn parallel to them, give the direction in which the emitted light is propagated. The angle θ in the figure is the 'Čerenkov angle'*

shoots by, instead of by the action of the $E$ and $H$ vectors of an electromagnetic wave, Fig. 1 shows the construction in two dimensions, with A, B, C, successive 'sources' which each radiated their secondary wavelet as the particle passed, and D the present position of the particle. The sides of the conical wave-front are PD and QD, and the rays along which the light travels outwards are perpendicular to the wave-front. The light travels from A to P in the direction AP, making an angle $\theta$ with the path of the particle, in the same time $t$ sec that it takes the particle to travel from A to D. Thus, AP $= ct/n$, while AD $= vt$; and $\cos\theta = \text{AP}/\text{AD} = c/vn = 1/\beta n$.

For Fig. 1 to represent what is actually happening, the particle must travel at a uniform speed over the interval considered; and for a high energy particle which is providing the energy to generate only visible photons this is nearly true. Also, the length of the path AD should be at least a few wavelengths of the radiated light in length; otherwise the coherence of the reconstructed wave-front will be that corresponding to the diffraction pattern of a narrow slit instead of a definitely directed wave-front.

The equation $\cos\theta = 1/\beta n$ shows that there must be a threshold value of $\beta$ for the particle, $\beta_{min}$, such that $\beta_{min} = 1/n$. There is also a maximum possible value of $\theta$, which is $\theta_{max} = \cos^{-1}(1/n)$—corresponding to a particle of infinite energy for which $\beta = 1$. And, although it is not so obvious from the equation, the physical properties of transparent materials like water, benzene, glass and so on are such that the *two* necessary conditions —a value of $n$ greater than 1, and the absence of any considerable absorption of the radiation—occur together in the visible spectrum, or close to it. This is not the only region in which Čerenkov radiation can be obtained with suitable media which may be able to satisfy these two conditions at other wavelengths; it is the only region for the transparent materials mentioned. It does perhaps seem a little strange to find that the wavelength of the radiation does not depend at all on the energy of the particle, once it exceeds the threshold value; that even then, it is the value of $\beta$ rather than the actual energy which is involved; and that it is only the *direction* of emission that is determined by $\beta$. The approximate threshold energies, corresponding to $\beta_{min}$, for the various high-energy charged particles in different media are listed in Table 1.

The threshold appears to depend only on the refractive index; that is, however diverse other properties may be, materials with the same value of $n$ have the same threshold for a given kind of particle.

## Spectral Distribution of the Radiation

The wavelength of the light does not appear explicitly in Fig. 1, but since in a dispersive medium, $n$ depends on the wavelength $\lambda$, there will be a different value of $\theta$ for each wavelength. The light-pulse thus has a finite angular extent, and also a finite duration in time.

The theory, derived classically by Frank and Tamm, gives the law for the distribution of the energy of the Čerenkov radiation over the spectrum; this, like the classical Rayleigh-Jeans law for black-body radiation, gives an integral extending over all possible wavelengths, and so theoretically leads to an infinite output of radiation. But, since $\beta n$ must exceed 1, the output is in fact limited to certain narrow ranges.

The expression for the number of photons, $N$, emitted between wavelengths $\lambda_1$ and $\lambda_2$ over a path-length $l$, is given by the equation

$$N = 2\pi\alpha l\left(\frac{1}{\lambda_2} - \frac{1}{\lambda_1}\right)(1 - 1/\beta^2 n^2),$$

where $\alpha$ is the fine-structure constant, $1/137 = 2\pi e^2/hc$, and $n$ the average refractive index. For a 500-keV electron ($\beta^2 = 0{\cdot}75$), taking $\lambda_1$ and $\lambda_2$ to be 6000 and 4000 Å respectively, $N$ works out to be about 10 photons per millimetre length.

## Refractive Index Greater than Unity

For dielectrics in the microwave region (say, $\lambda = 10^{-2}$ cm to a little over 1 cm) the refractive index $n$, which is the square root of the dielectric constant, is greater than unity. It should thus be possible to generate microwave Čerenkov radiation. There are two main difficulties. The first is that, as the equation for $N$ shows, the yield will be very low at such long wavelengths. The second is that, if the medium is to be thick enough to avoid diffraction effects, then the high-energy particle will shed a good deal of its energy on the way, and perhaps not last the course. Looking at it as a potential means of actually getting microwaves, there is the further disadvantage that the spectrum of the emission is continuous; but more or less monochromatic radiation could be obtained by using resonators.

**Table 1**

| | Liquid nitrogen, $n = 1{\cdot}205$ | Water, $n = 1{\cdot}33$ | Glass, Perspex, Lucite, $n = 1{\cdot}50$ |
|---|---|---|---|
| electron | 420 keV | 280 keV | 175 keV |
| $\mu$-meson | 80 MeV | 40 MeV | 36 MeV |
| $\pi$-meson | 105 MeV | 54 MeV | 48 MeV |
| K-meson | 4 GeV | 2·5 GeV | 1·8 GeV |
| proton | 750 MeV | 360 MeV | 220 MeV |

The yield problem has been attacked by bunching the particles, as in a klystron, and that of energy-loss by allowing the particles to travel through a fine hole drilled in the medium, or simply very close to the surface of the medium.

Fig. 2 shows the scheme of the apparatus used by M. Danos and his collaborators in 1953. The dielectric used, polycrystalline titanium dioxide, had a dielectric constant of 105 at the wavelength used, which was 1·25 cm. This meant that the threshold voltage for electrons was well below 10 keV. Electrons from a heated tungsten filament, accelerated under 10 keV and passing through a bunching cavity energized from an oscillator at 24 kMc/s (corresponding to 1·25-cm wavelength), closely skimmed the surface of the block of titanium dioxide which was cut so as to transfer the Čerenkov radiation through a quarter-wave matching plate to the detection system. The power output was about $10^{-7}$ watt.

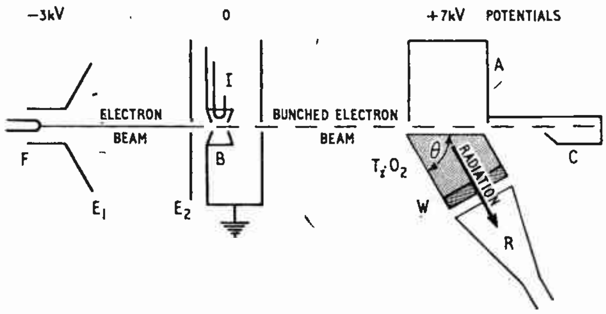



Fig. 2. *Scheme of the apparatus used by M. Danos and his collaborators for Čerenkov generation of microwaves. Here F is the heated filament; $E_1$ and $E_2$ focusing electrodes; B the bunching cavity, energized at I by a microwave source of power; A the high-potential anode, C a Faraday cage to collect used electrons, W a quarter-wave matching plate, and R the connection to the receiver*

Perhaps the sub-heading to this section has seemed a little obscure in purpose so far. Of course $n$ must exceed unity, and the medium must be transparent, at a given wavelength; and if these two conditions are satisfied, then some radiation of that wavelength, albeit feeble in the microwave range, is to be expected. How about the generation of microwaves by high-energy particles passing through air? Well, at a wavelength of 8 mm there is a transparent 'window' in the atmosphere; Dr. Jelley calculates the signal-to-noise ratio for a 10-ft diameter mirror receiving system collecting the radio pulses associated with cosmic-ray showers, and shows that for a $10^{16}$ eV shower the microwaves should not be detectable, but that for $10^{17}$ eV the signal-to-noise ratio should be 5 to 1. But the diffraction and wave-front coherence problems involved in making this system work seem to be quite formidable.

For a plasma of ions and electrons, the plasma oscillation frequency $(N_0e^2/\pi m)^{1/2}$, and the electron cyclotron resonance frequency $Be/2\pi mc$ can, for suitable values of the electron density $N_0$ and the flux density $B$, lie within the radio-frequency range; and, in the neighbourhood of such frequencies, the value of $n$ is appreciably greater than unity. It has been suggested that all the conditions for generating radio waves by Čerenkov emission are present in sunspots, and that this may be the origin of the solar radio bursts.

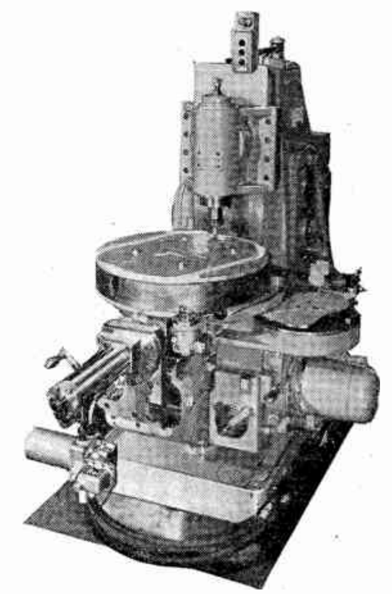
## And the Doppler Effect

Although the agent of emission is travelling at a high speed, the source of Čerenkov radiation is the medium itself, which is at rest with respect to the particle. A beam of electrons travelling at high speed in a vacuum cannot, of course, give rise to Čerenkov radiation. But it can modify the frequency of microwaves impinging on the beam. This is analogous to the Doppler-effect change of frequency in optics, when a beam of light is reflected from a moving mirror; and in fact is rather closer than mere analogy. Where Čerenkov radiation comes into things here is in forecasting what should happen if the radiation beam makes a head-on collision with an electron beam travelling faster than the radiation does. In Chapter 11 of his book, Dr. Jelley mentions some of the theoretical work that has been done with the object of using this Doppler-effect method of frequency change to generate microwaves; one set of results quoted suggests that a hundred-fold frequency increase by this means could be obtained with 2 MeV electrons. The necessary slowing up of the radio waves would presumably be done using a loaded waveguide, or something analogous to the structure of a travelling-wave linear accelerator. In fact, it seems that the whole idea here is simply operating a linear accelerator in reverse, or doing something very much like it.

## Conclusion

Some of the interesting possibilities mentioned in the last section may eventually be developed practically; but the main application of Čerenkov radiation at present is for the 'counting' of high-energy charged particles. The Čerenkov counter, of which there are two main types, does much more than merely count. With a thin layer of transparent medium, the measurement of $\theta$ for the radiation enables both $\beta$ for the particle, and also its direction, to be found. Deep or total absorption counters enable the total energy of the particle to be measured. The ancillary light-conserving and focusing devices, and the characteristics of materials and photomultipliers, are dealt with very fully by Dr. Jelley, who also gives an appendix full of graphical data. If, indeed, you have to find the answer quickly to questions such as "What is the light output from an 80-MeV $\pi$-meson in a 1-cm slab of Perspex, between wavelengths 4000 and 5000 Å?", this is the sort of crib to keep under your desk. Incidentally, still harping on the same old topic, I notice that he deals with the rontgen and the rep; but in the matter of the rem and the rad he is *two* down on Glasstone 1958.

## MACHINE TOOL CONTROL



*Sperry Gyroscope electro-hydraulic servo attachment fitted to a Kearney & Trecker milling machine. The rotating template can be seen on the right with the a.c. inductive pick-off sensing element contacting its profile. The working slide is controlled by a hydraulic actuator.*

# Subjective Impairment of Television Pictures

EFFECT OF SIGNAL-TO-RANDOM NOISE RATIO

By L. E. Weaver, B.Sc., A.M.I.E.E.*

SUMMARY. *The paper describes a series of tests which were undertaken by the B.B.C. in order to determine the statistical spread of opinion among viewers on the degree of impairment introduced into a television picture by known levels of wideband random fluctuation noise.*

*It has for some time been recognized that present methods of specifying random-noise limits for television apparatus and circuits are inadequate, and it is hoped that the results presented below will go an appreciable way towards supplying the deficiency.*

*The tests were planned to simulate, as far as possible, home viewing of a picture under optimum conditions. They were made with flat and triangular noise waveforms on both 405-line and 625-line pictures.*

*The observers were presented with an accurately standardized television picture on which a series of known levels of random noise could be superimposed, and they were asked to record their opinion of each such display on a 6-point scale of picture impairment. The results were smoothed by a method described in detail and, finally, a set of curves was obtained relating the signal-to-noise ratio in each case with the mean observer opinion of the degree of impairment caused to the picture.*

*A simple application of the Binomial Distribution Law then allows one to predict from every such value of the mean score what percentage of observers is likely to correspond to each step of the rating scale. A table of this distribution is provided.*

*An opinion limen is defined in a manner analogous to the well-known stimulus limen, and the interesting result is obtained that the opinion limen is equivalent to the value of 3 dB in signal-to-noise ratio, irrespective of whether the noise is flat or triangular, or whether the picture is to 405-line or 625-line standards.*

As is well known, a television signal is always accompanied by some level of random fluctuation noise. A certain amount is present in the signal at its point of origin in the generating equipment, and more noise is added to a lesser or greater extent at every subsequent stage in the processes of signal distribution and radiation.

Above a certain threshold of visibility this random noise degrades the picture, and unless it can be kept at a sufficiently low level, it may interfere with the viewers' enjoyment of the programme. One would, therefore, always like to be able to keep the noise at such a low level that under no circumstances could it produce any visible impairment of the picture. However, as a general rule improved noise performance has to be paid for, often at a high rate, so that it is evidently a matter of concern to administrations and authorities engaged in the generation and distribution of television signals that they should know what limits to set on the overall tolerable signal-to-noise ratio under normal conditions.

It seems that the great majority of the attempts which have been made in the past to determine a limit for the overall maximum tolerable signal-to-noise ratio in television transmission, have been based upon an estimate, either theoretically or through practical tests, of the mean threshold of visibility of random fluctuation noise on some idealized picture or test pattern[1,2,3,4]. In some instances comparatively narrow bands of noise have been used instead of wide-band noise, with the object of determining a limit for the noise after frequency-weighting[(5,6)].

Quite serious objections, however, can be raised against limits which have been derived from measurements of threshold visibility.

First of all, the implication is present that the normal viewer is alert for the first appearance of noise on his screen. In fact, of course, he concentrates upon the subject matter and action of the picture unless some degradation in picture quality becomes severe enough to obtrude upon his consciousness. Experience with outside broadcasts and very long distance relays when conditions are really adverse has shown that considerable amounts of some forms of picture impairment will be accepted without comment, provided the subject matter is of outstanding interest.

The second and more serious objection is that a threshold value or, for that matter, any limit based upon a single criterion, can give no information about the state of affairs if that limit should be exceeded. For example, if the noise limit on a given circuit is 45 dB and at some moment it is found to be 43 dB, is that deterioration to be considered negligible, tolerable, or intolerable? The single figure gives no guide whatsoever.

Finally, these previous determinations have taken no account of the wide variation of opinion of a given impairment which can be found over a large number of observers. The threshold of visibility criterion entirely avoids any consideration of the degree of annoyance to the observer and, where this has been taken into account

* *B.B.C. Engineering Department.*

previously, only averaged values seem to have been used. It will be shown in a later section that this can be misleading.

This need for revised criteria for the signal-to-noise performance of television apparatus has recently become very much more urgent, in step with the very great extension of television distribution networks both here and abroad.

The difficulties experienced have been aggravated particularly by the great increase in the number of microwave links in service in the television distribution networks. They are, of course, extremely good for that purpose, but to offset their many advantages they have the shortcoming that the propagation over each repeater section is vulnerable to degradation caused by atmospheric and other effects.

As a result, the random-noise power introduced into a repeater section is not constant but varies with time in a manner which depends upon geographical and other factors; experience shows that the statistical distribution often approximates to a Rayleigh or log-normal type[7]. This means that for perhaps 90% of a given period the signal-to-noise ratio is not likely to change very significantly; for the remaining 10% the deterioration is significant and for, say, 0·1% of the period it is likely to be very large. On a long circuit, especially where large changes in the nature of the terrain occur at points along the circuit, the probability of deteriorations in the signal-to-noise ratio is considerably higher.

It is very evident that it is not possible to design such a link on an economical basis by using a single tolerance for the signal-to-noise ratio such that the likelihood of a noticeably degraded picture is extremely remote, and now that the distribution network is so extensive it has become all the more essential that links should be designed economically. The cost to the B.B.C. of its complete distribution network during the course of each year is a by no means negligible percentage of its engineering budget, and other administrations are or will be eventually in a similar position. For these reasons it was decided that the Measurements Laboratory of the B.B.C. Designs Department should undertake a series of tests with the object of providing the information required.

## Planning the Tests

If a number of observers are shown under identical conditions a television picture which has a certain visible level of random noise, their opinions will vary very widely; indeed, the total range of opinion which is normal in such cases is usually found to be rather surprising at first encounter. If the observers' opinions of the degree of picture impairment can be expressed on a quantitative scale, then it should be possible by suitable statistical methods to find what percentage of the viewing population is likely to hold each of the several steps of opinion for a given signal-to-noise ratio. This, in fact, is the kind of information which is desirable for the purpose in hand.

It was decided that the principle underlying the tests should be to try to simulate as far as possible the relaxed and comfortable home viewing of a very high-quality monochrome television picture, which would then be deliberately impaired by adding known levels of random noise.

It was originally proposed to carry out these tests using 405-line pictures only, but it soon became evident that even at the cost of doubling the labour involved, it would be well worthwhile to repeat the tests with a picture of some other standard. It happened that some 625-line apparatus which had been prepared for another purpose was still available, so this was the obvious choice, and two series of tests were carried out under as far as possible identical conditions using both 405-line and 625-line pictures.

It also had to be decided what type of random fluctuation noise should be used. Now the spectrum of the noise depends upon its source but, in practical cases, it almost always lies between the limits of a flat spectrum (flat or white noise) and one in which the envelope increases with increasing frequency at the rate of 6 dB per octave (triangular noise).

For this reason it seemed to be indispensable to repeat each series of tests with both flat and triangular random-noise waveforms. Once again the work was doubled, but it was considered that essential information would have been lost if this step had not been taken.

## The Display

The use of two television picture standards and two types of random noise made it imperative to keep the number of observations to a minimum, so it was decided that only a single still picture could be used for the display. However, it was selected with great care from a set of transparencies which had previously been collected for similar purposes.

A Swiss village scene was finally chosen for the following reasons: (a) the subject was of general pictorial interest without, however, being such as to cause any particular emotional reaction in the observers; (b) there was no area of especially marked interest, so observers would not be led to concentrate on one particular part of the picture; (c) the various centres of interest contained sufficiently large areas of roughly uniform tone as well as detail throughout the tonal range from near-black to near-white, so that various backgrounds against which to see the noise were available in the areas where an observer's eyes would be most likely to dwell.

The picture signal was obtained in each instance from a high-grade slide scanner which was checked at frequent intervals to ensure that the quality of the output signal remained constant. The bandwidth was in each case appreciably greater than the nominal value for the standards in use, and the inherent noise level of the signal was quite invisible on the display monitor at the chosen viewing distance.

The picture was displayed on a 21-inch high-quality picture monitor; not the same instrument for both 405-line and 625-line pictures, but both monitors used the same type of cathode-ray tube and were in all other respects as alike as possible. The displays were also standardized at frequent intervals by measuring the peak highlight brightness and the contrast range by means of an S.E.I.† photometer.

The peak highlight brightness was maintained at 15

† Salford Electrical Instruments.

foot-lamberts. Although this is by no means the greatest brightness which can be obtained from modern display tubes, it was found by experiment that it seemed to strike a very good mean between a somewhat dim picture and one whose brightness seemed to fatigue some of the observers. This judgment was confirmed by the B.S.I. recommended screen brightness for monochrome motion pictures, which is 12 to 24 foot-lamberts with a decided preference for values near the lower limit[8].

Another important reason for not choosing too high a brightness was to avoid defocusing on peak whites, which would modify the appearance of the noise by increasing the area of the 'spots' corresponding to the higher-noise amplitudes. This effect is frequently noticeable on receivers showing a picture containing automobile ignition interference.

The main contrast range of the picture was standardized by measuring the brightness of two selected points on the screen of the picture monitor by means of an S.E.I. photometer. The overall contrast range was greater than 100 : 1.

The picture monitors were not fed with separate synchronizing signals, but the very effective flywheel-synchronizing systems fitted prevented any visible movement of the line structure due to interference from the random noise, until the maximum noise level was reached. At this point the picture was very severely degraded by the noise alone but, in any case, it was thought not unfair to include this secondary effect since it will always form a part of the total impairment due to random noise.

## Viewing Ratio

Most previous subjective tests with television pictures seem to have used a viewing ratio of 4 : 1; that is, the viewer's eyes are at a distance of four times the picture height from the screen of the display tube. The most likely reason for this choice seems to be that it was regarded formerly as the optimum viewing ratio in the cinema.

Although it is likely that many people use a somewhat greater viewing ratio when watching television in their homes, it was thought best to adhere to the 4 : 1 ratio in order to conform with previous work. It is perhaps not altogether a disadvantage either, that it gives a somewhat pessimistic view of the impairment caused by the presence of the noise.

The practical drawback of such a small ratio is that the actual distance from the eyes to the screen is only about 4½ feet, so that quite small changes in the observers' posture can alter the viewing ratio by a serious amount.

After several attempts to fix the distance without tiring or distracting the observers, the following very successful solution was found.

Each observer was allowed a few minutes before the tests started to become used to the surroundings and for his eyes to become adapted, and during this period he was given his instructions. He was asked while listening to find his most comfortable and relaxed posture for viewing the picture, remembering that he would have to remain in that position for the duration of the test.

When he gave an assurance that he was quite comfortable the viewing distance was quickly adjusted, and it was found that almost without exception the posture could be held without strain for a sufficient time with negligible movement.

## Viewing Conditions

It was fortunate that a permanent viewing room was available for the duration of the tests. It could be completely blacked-out except for some subdued diffused lighting which was shielded from the observer's eyes.

Although this gave a brightness of a sheet of white paper held by the observer of only about 0·05 foot-lambert, it seemed to be quite adequate for recording the scores during the tests since the eyes had been allowed to become adapted. It was also found to reduce fatigue caused by a high contrast between the monitor screen and the background, without at the same time making the background obtrusive.

An important advantage of this viewing room was that it was quiet and shut off from the main laboratories, so that those being tested were not distracted by extraneous noises or by inquisitive spectators.

The picture monitors were fitted in console-type cabinets, so that the screen was at the correct height for an average person seated in a normal comfortable chair. Otherwise, it was only necessary to stand them in such a position that the screens were shielded from the ambient light.

## Circuit Arrangements

The method used for adding the various levels of the two types of random noise to the picture signal is shown in Fig. 1. The source of the random noise was a generator which had been designed for a special method of random-noise measurement[9]; it provides a high and stable output of random fluctuation noise into a 75-ohm termination with a spectrum flat to more than 5 Mc/s.

The output noise level was set to the desired value by means of a 75-ohm attenuator, and could be switched into either of two paths.

The upper switch position, as shown, connected the attenuator output directly to one pair of terminals of a three-way resistive combining network. The lower switch position directed the noise generator output through an attenuator, a network whose loss decreases at very close to 6 dB per octave over a video band greater than 5 Mc/s and, finally, a video amplifier feeding into the combining network.

Therefore, the spectrum of the noise signal presented to the combining network could be chosen to be either flat or triangular, according to whether the switches were placed in the upper or lower positions respectively. The attenuator and amplifier in the lower path served to set the noise powers from the two paths to the same value, and care was taken that the amplifier had sufficient overload margin to prevent clipping of the noise peaks.

Whichever type of noise happened to be in use was mixed linearly with the picture signal in the combining network, and was then connected to the input of the picture monitor through a low-pass filter, the purpose of which will be described later.

Especial pains were taken to ensure that the measurement of the signal-to-noise ratio was correct. The peak-to-peak voltage of the picture component of the waveform was measured with a precision waveform monitor, and the noise level by means of a standard thermocouple-type milliwattmeter, so that the signal-to-noise ratio in the standard form of peak-to-peak signal to r.m.s. noise voltage was immediately available. For this purpose each of the two inputs was removed from the combining network and individually measured when terminated in 75 ohms, but care was taken to include the low-pass filter in series with the noise path since it was required to know the actual signal-to-noise ratio existing at the input to the picture monitor. Since the loss of the combining network was 6 dB to each of its inputs, its removal did not affect the value of the signal-to-noise ratio.

The measurement of the random-noise level was, in practice, carried out with the attenuator following the noise source set to zero dB, from which the attenuator setting for any desired signal-to-noise ratio could be obtained immediately.

## The Rating Scale

The methods used for carrying out the tests were given considerable thought, since it is by no means simple to be sure that the precise information required is obtained from the observers without influencing them in any way.

The first difficulty lay in the choice of a suitable rating scale for the observers to use in recording their votes. This problem is common to many types of psychometric investigation, and considerable attention has already been given to the subject[10].

In the present instance, it was considered necessary to use more than two or three intervals over the scale; in the event, a 6-point scale was chosen because the number of steps seemed to be suitable and also because the B.B.C. already had some experience with rating scales of this type.

The problem is then to indicate the steps of impairment in such a manner that they can be recognized by the observer without ambiguity, and yet without influencing his choice. The English language, or for that matter any language which the writer knows of, does not possess an adequate set of adjectives to describe such a sequence of progressive impairment.

If one is to use verbal description, the following is a typical set:

(1) Imperceptible
(2) Just perceptible
(3) Definitely perceptible but not disturbing
(4) Somewhat objectionable
(5) Definitely objectionable
(6) Unusable

This has been used very successfully in a large number of tests, and yet it is not logically consistent since it contains three different criteria: perceptibility, objectionability and usability. Nevertheless, the average observer seems to have no difficulty in interpreting this as a scale of successive impairment.

A logically acceptable and emotionally neutral series would be the sequence of numbers from one to six, but they are of no value unless the bounds of the range are fixed in a consistent manner, and it seems difficult to achieve this; one has to fall back on 'Imperceptible' and 'Unusable', or some similar pair. In any case, a preliminary experiment showed that a number of the observers, particularly those who were not engineers, had difficulty in visualizing what was required unless all the steps carried descriptions.

Finally, it was decided to use the sequence of descriptions given in the list above together with numbers attached. Observers were asked just before each test to pay as little attention as possible to the wording, but rather to try to consider the scale as a purely numerical one between the two extremes and to score accordingly. Although this compromise does not avoid all the objections which can be raised, it was found in general to give the observers greater confidence, and perhaps for this reason it gave excellent results.

## Values of Signal-to-Noise Ratio

The preliminary tests mentioned above were also used to settle the total range of signal-to-noise ratios and the spacing of the steps which were to be presented to the observers.

The results showed that 4-dB steps appeared to be most suitable, and that the total range should be 20 dB to 44 dB for flat noise and 16 dB to 36 dB for triangular noise.

A special precaution had to be taken in this connection. The order in which such a sequence of impairments on a picture is presented to an observer can affect his judgment; for example, if the impression should be given that the series of pictures forms some recognizable pattern, he may be tempted to 'correct' his results in accordance with his assumption.

Errors due to this were avoided by presenting each sequence in an order previously determined from a table of random numbers. The score sheet contained a series of columns for the results of the tests which were numbered successively, but the observer was told that these numbers were for purposes of reference only, and bore no relation to the magnitudes of the impairments. In addition, to avoid any possible tension due to psychological causes, he was assured during the preliminary instructions that the tests were in no wise competitive, and that the results would only be disclosed in the form of mean or smoothed values in which his identity would be submerged.

The actual scoring was very simply carried out by the observer selecting each column of the score sheet in turn as the tests were presented, and then placing a cross or tick in the row of that column which corresponded to the rating which he selected.

Yet a further precaution was necessary in the case of some observers who were not engineers. During the experimental phase before the tests were started, it was noticed that the score sheets handed in by some of the 'lay' observers showed curious anomalies. These were traced to the fact that those persons did not understand from the description given exactly what form the impairment would take, and a few steps of signal-to-noise ratio might have to be presented before they realized what was required. Their score-sheets, therefore, were not necessarily marked on a consistent basis.

The device finally adopted to overcome this difficulty was to show 'lay' observers first of all the picture without noise, and then the picture with a quite visible amount of flat noise. They were told that the latter represented

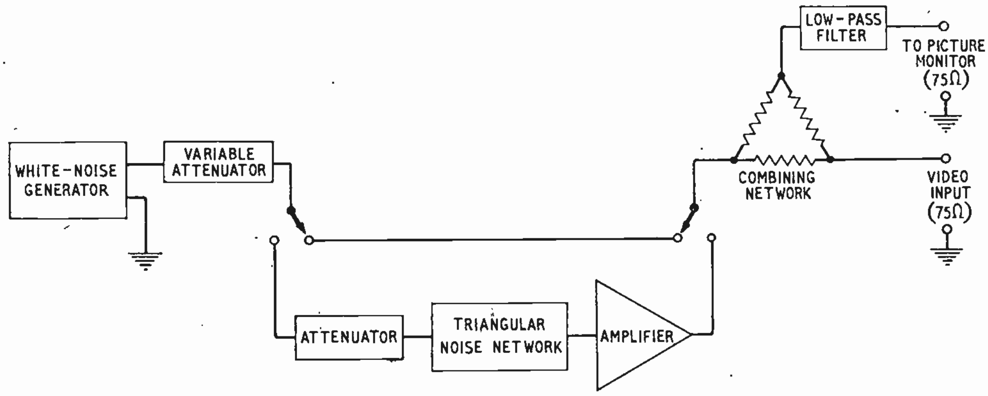



Fig. 1. *General form of the picture-signal and noise mixer*

an impairment of the kind which was to be used but was to be regarded as illustrative only, and great care was taken to avoid using any phrase which could be construed as indicating the magnitude of the impairment.

Fortunately, almost all of the observers were known personally to the engineer who carried out the practical part of the tests, so he was able to use a certain amount of tact in deciding what preliminary instructions were required in each individual case.

**Bandwidth Limitation**

The low-pass filter shown in the output lead to the picture monitor in Fig. 1 was inserted for a very important reason.

The video and the noise bandwidths of a signal as it reaches a transmitter are not necessarily equal but, under normal conditions, neither should be appreciably less than the nominal video bandwidth for the system in use. However, two situations occur subsequently where the bandwidth of the signal is restricted at the high-frequency end by networks having a quite rapid cut-off, that is in the transmitter and in the viewer's receiver. Consequently, the signal and noise bandwidths corresponding to the picture seen by the viewer are normally identical within reasonable limits.

Now the appearance on the screen of the picture and the random noise is in each case a function of the bandwidth, as is well known, so that one would imagine that the degree of impairment corresponding to a given signal-to-noise ratio is not likely to remain constant if either bandwidth is altered. In addition, there is reason to believe that the appearance of the random noise is affected by the shape of the high-frequency cut-off characteristic[11].

In view of these facts it seemed essential to include a low-pass filter in the noise-plus-signal path not only to limit the bandwidth, but also to do it in a manner comparable with optimum practical reception conditions. It also provides a definable and easily repeatable condition of measurement and, in fact, it is now certain that internationally-agreed methods of random-noise measurement will include a filter of identical form to that used.

A different filter was used for each of the two transmission standards; both had an equivalent rectangular bandwidth exactly equal to the nominal maximum video bandwidth of the standards in use; that is, 3 Mc/s for the 405-line system and 5 Mc/s for the 625-line system. The cut-off characteristic was reasonably similar to that given by a very high-quality commercial television receiver.

No attempt was made to phase compensate the filters. The only effect they introduced on the picture itself was a 'ring' at the nominal cut-off frequency, but this was not at all obtrusive to an observer seated at the viewing distance used for the tests.

**The Observers**

Experience has shown that for reliable results a minimum of 20 observers is advisable, and in fact it was possible to find 34 observers for the 405-line tests and 40 for the 625-line tests.

Roughly three-quarters were engineers and the rest drawing-office and clerical staff, because these happened to be the people readily available. The majority were young, with a few in early middle age; the median age was in the neighbourhood of 30 years. No attempt was made to select the observers or to eliminate any sets of results because of supposed inconsistencies.

**Analysis of the Results**

The results were obtained in the form of a number of impairment ratings corresponding to each step of signal-to-noise ratio, for each type of noise and for each of the two standards. The number of each impairment rating was taken to be the numerical score assigned to that rating; that is, a score of 1 for 'Imperceptible' increasing up to 6 for 'Unusable'.

Then, from a count of the number of votes cast for each rating, the mean score for that particular signal-to-noise ratio could be found. With flat noise and a signal-to-noise ratio of 28 dB, the actual votes cast in the 405-line test are given in Table 1.

Then the mean score is

$$m = \frac{2 \times 1 + 8 \times 2 + 15 \times 3 + 7 \times 4 + 2 \times 5 + 0}{34}$$

$$= 2{\cdot}97 \qquad \ldots \qquad (1)$$

Now on the basis of analogous work carried out in the field of psychometrics, a plot of $m$ against the signal-to-noise ratio in decibels would be expected to give the sigmoid type of curve characteristic of a logistic function[10, 12]. If this is so, then a suitable transformation of the dependent variable $m$ such as the 'logit' [12, 13, 14] should convert the sigmoid curve into a straight line.

This is a remarkably convenient method of smoothing the data.

The nature of this transformation is easier to appreciate by first introducing the normalized mean score $p$, where $p$ is effectively the probability that the displayed picture will be given a 'favourable' rating; that is, given a rating in the range from 1 to 3. For a 6-point rating scale, the relation is:

**TABLE 1**

| Score | Opinion | Number of Votes |
|---|---|---|
| 1 | Imperceptible | 2 |
| 2 | Just perceptible | 8 |
| 3 | Definitely perceptible but not disturbing | 15 |
| 4 | Somewhat objectionable | 7 |
| 5 | Definitely objectionable | 2 |
| 6 | Unusable | 0 |
| | Total votes cast = | 34 |

$$p = \frac{6 - m}{5} \quad \ldots \quad (2)$$

The final dependent variable is $M$, where:

$$M = \log_{10} \frac{p}{1 - p} \quad \ldots \quad (3)$$

which is easily recognized as the logarithm of the ratio of the probability of a 'favourable' rating to the probability of an 'unfavourable' rating.

For purposes of calculation, of course, there is no need to introduce $p$, and one can calculate $M$ directly from $m$ by means of:

$$M = \log_{10} \frac{6 - m}{m - 1} \quad \ldots \quad (4)$$

The plot of $M$ against $d$, the signal-to-noise ratio in decibels, would be expected to yield a straight line, and a glance at the results of the four series of tests as plotted in Fig. 2 shows that this is very well realized in practice. The distribution of the points leaves no doubt at all that the best-fit curve is indeed a straight line.

This fact in itself is important, since it implies that the subjective impairment of a television picture in terms of the signal-to-noise ratio can be defined by two parameters only. This point will be considered in more detail later. Let these be $D$, the intercept which a line of Fig. 2 makes with the axis of signal-to-noise ratios, and $G$ its slope. Then the equation of the line is:

$$M = G(d - D) \quad \ldots \quad (5)$$

so that $M$ can be eliminated between equations (4) and (5) to give the following relation between $m$, the mean opinion score, and $d$, the signal-to-noise ratio, in terms of smoothed data:

$$m = \frac{6 + \text{antilog}\, G(d - D)}{1 + \text{antilog}\, G(d - D)} \quad \ldots \quad (6)$$

The curves calculated from this expression are given in Fig. 3.

### Distribution of Observers

These curves enable the mean opinion rating of a picture corresponding to a given signal-to-noise ratio to be found for either flat or triangular noise and 405-line or 625-line standards.

However, this is not sufficient; it is really required to know not the mean rating of all observers, but the percentages of the observers likely to hold each of the six opinion ratings in a given instance. For example, in Table 1 the mean rating of all observers happened to be 3, yet only 44% of the observers actually voted for that category; 6% even held Opinion 1 and 6% Opinion 5.

Wide experience has shown that in a reasonably homogeneous population the distribution of opinion is very closely binomial, so that by application of the

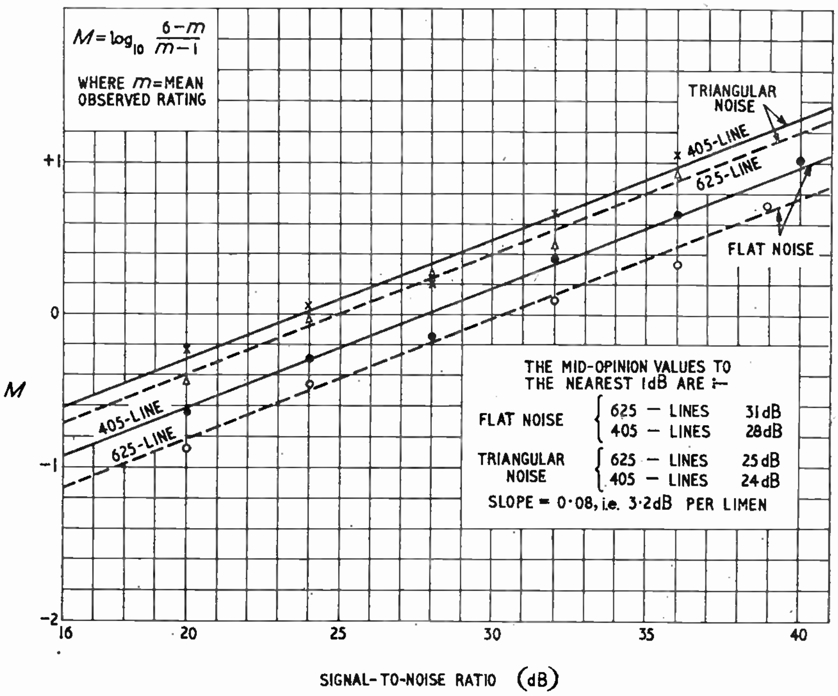



Fig. 2. *Experimental points and straight lines fitting them for the relation of M to signal-to-noise ratio*

**TABLE 2**

**The Binomial Distribution of Observers on a 6-Point Rating Scale**

The proportions are given below to the nearest ½%.

| Mean Score ($m$) | Percentage of Observers: Opinion $q = 1$ | Opinion $q = 2$ | Opinion $q = 3$ | Opinion $q = 4$ | Opinion $q = 5$ | Opinion $q = 6$ |
|---|---|---|---|---|---|---|
| 1.00 | 100 | 0 | 0 | 0 | 0 | 0 |
| 1.25 | 77.5 | 20.5 | 2 | 0 | 0 | 0 |
| 1.50 | 59 | 33 | 7 | 1 | 0 | 0 |
| 1.75 | 44.5 | 39 | 14 | 2.5 | 0 | 0 |
| 2.00 | 33 | 41 | 20.5 | 5 | 0.5 | 0 |
| 2.25 | 23.5 | 39.5 | 26.5 | 9 | 1.5 | 0 |
| 2.50 | 17 | 36 | 31 | 13 | 3 | 0 |
| 2.75 | 11.5 | 31 | 33.5 | 18 | 5 | 0.5 |
| 3.00 | 8 | 26 | 34.5 | 23 | 7.5 | 1 |
| 3.25 | 5 | 20.5 | 33.5 | 27.5 | 11.5 | 2 |
| 3.50 | 3 | 15.5 | 31.5 | 31.5 | 15.5 | 3 |
| 3.75 | 2 | 11.5 | 27.5 | 33.5 | 20.5 | 5 |
| 4.00 | 1 | 7.5 | 23 | 34.5 | 26 | 8 |
| 4.25 | 0.5 | 5 | 18 | 33.5 | 31 | 11.5 |
| 4.50 | 0 | 3 | 13 | 31 | 36 | 17 |
| 4.75 | 0 | 1.5 | 9 | 26.5 | 39.5 | 23.5 |
| 5.00 | 0 | 0.5 | 5 | 20.5 | 41 | 33 |
| 5.25 | 0 | 0 | 2.5 | 14 | 39 | 44.5 |
| 5.50 | 0 | 0 | 1 | 7 | 33 | 59 |
| 5.75 | 0 | 0 | 0 | 2 | 20.5 | 77.5 |
| 6.00 | 0 | 0 | 0 | 0 | 0 | 100 |

Binomial Probability Law the probability that a rating $q$ will be chosen when the normalized mean score is $p$ is given by[15]:

$$P(r) = {}^5C_r p^r (1-p)^{(5-r)} \quad \ldots \quad (7)$$

where $r = (6 - q)$ and ${}^5C_r = \dfrac{5 \times 4 \ldots (6-r)}{r!}$

$P(r)$ also gives the fraction of the total number of observers likely to choose a rating $q$ when the mean rating is $m$. Table 2 provides a list of the percentages of the number of observers calculated from equation (7), for values of $m$ in steps of 0·25.

For example, the analysis of votes shown in Table 1 was for only 34 observers in all, and the mean score was 3. As has already been mentioned 6% voted for Opinion 1, 44% for Opinion 3 and 6% for Opinion 5. Table 2 shows that with a very large number of observers 8% would vote for Opinion 1, 34·5% for Opinion 3 and 7·5% for Opinion 5. The agreement happens to be very good considering the relatively small number of observers in the practical case.

As a further example, suppose it is required to know the distribution of opinion for a 405-line picture with a signal-to-random noise ratio of 30 dB. The appropriate curve of Fig. 3 gives the corresponding value of $m$ as 2·25, so that by reference to Table 2 the percentages are as given in Table 3.

It is worth noticing in passing that although the mean score is very 'favourable' to the picture, 10·5% of observers would nevertheless put this picture in the 'unfavourable' category (score of 4 or more). This emphasizes how easy it is to reach a misleading conclusion if the mean score only is considered.

## The Opinion Limen

The use of the liminal unit or 'limen' of stimulus[10] is very well known. An extremely valuable analogous concept is that of the 'opinion limen', which is due to Dr. N. W. Lewis. In the present instance it can be derived as follows.

At the central value of mean opinion $m = 3·50$, Table 2 shows that 50% of observers have opinions in the 'favourable' range, ratings 1, 2 and 3, and consequently 50% have opinions in the 'unfavourable' range, ratings 4, 5 and 6. This is also the point where $M = 0$, so that the parameter $D$ of the last section corresponds to the signal-to-noise ratio for equal division of opinion in this manner. In Fig. 2 it is indicated as the 'mid-opinion value'.

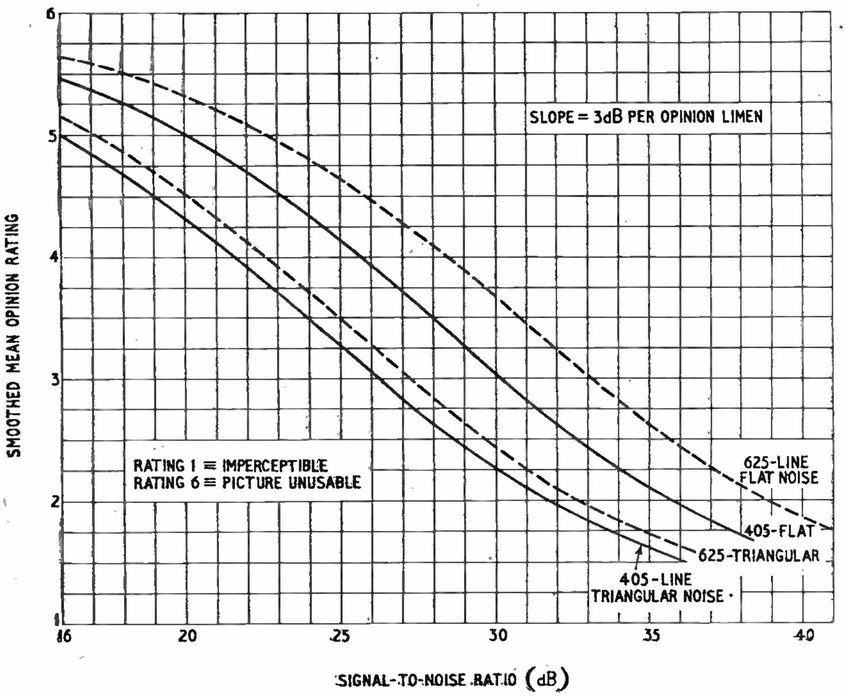



Fig. 3. *Relation between signal-to-noise ratio and mean opinion rating on a 6-point scale*

**TABLE 4**

| Number of Opinion Limens | dB | Opinions (per cent) | | | | | | 'Favourable' (per cent) | 'Unfavourable' (per cent) |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | | |
| 0 | 0 | 3 | 15.5 | 31.5 | 31.5 | 15.5 | 3 | 50 | 50 |
| 1 | 3 | 11 | 30 | 34 | 19 | 5 | 1 | 75 | 25 |
| 2 | 6 | 25.5 | 40 | 25.5 | 8 | 1 | 0 | 90.8 | 9.2 |
| 2.5 | 8 | 35 | 41 | 19 | 4.5 | 0.5 | 0 | 95.2 | 4.8 |
| 3 | 9 | 45 | 39 | 14 | 2 | 0 | 0 | 97.4 | 2.6 |

For negative limens the 'Favourable' and 'Unfavourable' opinions are reversed.

Now suppose the signal-to-noise ratio is varied from this central value $D$ in either direction until 75% of observers have opinions in the one range and 25% in the other. Then the change in signal-to-noise ratio is defined as unit value of the opinion limen.

The significance of the figure of 75% is that when exactly 50% of observers are justified in changing their opinion on the degree of picture impairment, the remaining 50% must be uncertain whether or not to change their opinion. They are, therefore, as likely to vote for a change in impairment having occurred as for no change, with the result that a total of 75% will appear to have changed opinion and 25% will appear not to have done so.

The fact that the lines of Fig. 2 are straight suggests that the above definition can be generalized.

As has already been pointed out, the normalized mean score $p$ represents the probability of an impaired picture being put into the 'favourable' category. Hence, if $L$ is the number of opinion limens taken from the central value of mean opinion, the ratio of the probability of a 'favourable' rating to an 'unfavourable' rating can be written:

**TABLE 3**

| Opinion | Percentage of Observers |
|---|---|
| 1 Imperceptible | 23.5 |
| 2 Just perceptible | 39.5 |
| 3 Definitely perceptible but not disturbing | 26.5 |
| 4 Somewhat objectionable | 9 |
| 5 Definitely objectionable | 1.5 |
| 6 Unusable | 0 |

$$\frac{p}{1-p} = \left(\frac{p_L}{1-p_L}\right)^L \qquad \text{(8)}$$

where $p_L$ is the value of $p$ when $L = 1$.

This value is obtained from equation (7) and substituted in equation (8), giving

$$\frac{p}{1-p} = 1{\cdot}786^L \qquad \text{(9)}$$

But by definition $M = \log\left(\frac{p}{1-p}\right)$, equation (3), so that the equation of each of the lines of Fig. 2, from equation (5), becomes

$$\log\left(\frac{p}{1-p}\right) = 0{\cdot}252^L = G(d-D) \qquad \text{(10)}$$

Also, since the slope $G$ is a constant, the relation between $d$ and the opinion limen may be obtained by putting $(d - D) = 1$ in equation (10), so that one opinion limen is equivalent to

$$\frac{0{\cdot}252}{G}\ \text{dB} \qquad \text{(11)}$$

Now an outstanding feature of the smoothed data plotted in Fig. 2 which has not so far been commented upon, is that all the lines are exactly parallel. Equation (11) makes the significance of this evident: it is that the opinion limen in terms of signal-to-noise ratio has the same value for both flat and triangular noise, irrespective of whether the picture is to 405-line or 625-line standards. When rounded off this value is, in fact, 3 dB.

In other words, although the signal-to-noise ratio $D$ corresponding to the central opinion rating varies with the type of noise and standards of transmission, in every instance the noise power must be either doubled or halved if 50% of observers are to change their opinion.

## Simplified Form of the Results

This relationship is remarkably convenient in practice because, for many purposes, one can dispense with the table of the Binomial Distribution by remembering or noting the percentage of 'favourable' or 'unfavourable' opinions corresponding to a very few liminal steps, which in turn are equivalent to known numbers of decibels. Table 4 gives, for the sake of completeness, the full distributions; the detailed opinion figures are given to the nearest one-half percent to agree with Table 2.

It is not difficult to remember the column of 'Unfavourable' percentages, particularly since for almost all practical purposes they can be rounded off to give the series: 50, 25, 10, 5 and 2·5.

It then follows from the fact that each of the sets of smoothed data can be represented by two parameters, that one piece of information other than the common value of the opinion limen is all that is required to define each of the curves of Fig. 3. This will obviously be the 'mid-opinion value' tabulated in Fig. 3, which is the signal-to-noise ratio at which opinion is equally divided between the 'Favourable' and 'Unfavourable' categories.

For a 405-line picture with superimposed flat noise the mid-opinion value is 28 dB, so that the signal-to-noise ratio at which only 5% of observers regard the impairment caused in an 'unfavourable' light is 28 + 8 = 36 dB; conversely, only 5% find the picture 'favourable' at a signal-to-noise ratio of 28 − 8 = 20 dB.

## Influence of the Test Picture

Since it was realized that the validity of the above results might be questioned on the grounds that only one selected picture had been used for the test object, it was thought desirable to form some idea of the influence of the type of picture on the results.

The easiest method of verification seemed to be to repeat the main tests in some simplified form using another selected picture of a different type.

The original conditions laid down for the tests ruled out the use of a constructed test pattern of any sort, so a pictorial subject was sought which had large areas of grey and near-black tone in the centres of interest of the picture, since this would be likely to make the noise appreciably more apparent. A very suitable one was found in a transparency showing work in progress on the deck of a ship at sea.

To avoid the investigation becoming too lengthy, only 405-line pictures were used under the same conditions as before, and the tests were stopped when the process of smoothing the data showed that the straight lines could be drawn with fair confidence. It is interesting to note that this required only 14 observers although, as one might expect, the spread of the points was a good deal worse than in the main tests.

It is not intended to show these results since they are inevitably less reliable and might therefore prove misleading, but they were sufficient to show that the difference between the mid-opinion values (i.e., values of $D$) was not likely to be much more than one decibel less noise for the same impairment, for the change in picture subject. This is not thought to be at all serious. Also, as nearly as could be determined, the slope of the lines was exactly the same as previously, so that the value of the opinion limen remained unchanged.

However, some of the experiments preliminary to the tests suggested that if an artificial test pattern had been chosen, actually Test Card C, 5 or 6 dB less noise might have been required for the same impairment. Nevertheless, it seems true to say in general that provided the subject remains pictorial in character, a change in picture does not invalidate the results obtained.

### Conclusions

The reactions of a group of observers have been measured to a standardized television picture which has been impaired by the addition of random fluctuation noise, and found to be expressible in terms of two parameters only. One of these, the value of the opinion limen in terms of signal-to-noise ratio, has been found to be the same for both 405-line and 625-line pictures and for both flat and triangular noise waveforms.

This is a remarkably interesting result, and it is tempting to be led to suppose that the value of 3 dB (that is, a doubling or halving of the noise power for a change of one opinion limen), has some special significance. However, some brief preliminary tests seemed to indicate that the magnitude of the opinion limen is different when no band-limiting filter is included in series with the display monitor (Fig. 1).

The remaining parameter is the mid-opinion rating, which not only enables a figure to be deduced for the overall maximum permissible signal-to-noise ratio from picture source to the viewer's receiver, but also compares 405-line and 625-line pictures in their sensitivity to impairment by random noise.

The table of mid-opinion values given in Fig. 3 shows that for flat noise a 625-line system is 3 dB more sensitive than a 405-line system; that is, as far as viewers are concerned who are favourably sited with respect to a transmitter, the signal-to-noise ratio should be maintained at a 3-dB better value for 625-line than for 405-line pictures.

However, Dr. R. D. A. Maurice of the B.B.C. Research Department has pointed out to the writer that in fringe-area reception where the receiver random-noise contribution swamps the noise level present in the radiated signal, a 625-line viewer would be 5 dB worse off than a 405-line viewer at the same point, since the increase of the receiver pass-band from 3 Mc/s to 5 Mc/s in itself adds 2 dB to the noise level. As a result, although the main service areas for the same transmitter power would be roughly identical, the 625-line service would fall off more sharply.

The differences between flat and triangular noise levels for the same degree of picture impairment are also given by the table of Fig. 2. For 405-line pictures it is 6 dB, and it is interesting to note that the C.M.T.T.‡ revised noise-weighting network for television agrees with this value precisely. For 625-line pictures it is 8 dB, and the weighting network still agrees to an amount which is well within one opinion limen.

However, in order to be able to make use of the figures to produce working signal-to-noise limits for transmission purposes, further steps have to be taken.

First, it has to be decided where the limit of tolerability should be set in terms of percentages of viewers giving the final picture an unfavourable rating. There can be no absolute criterion for this but, as an example, the selected value of signal-to-noise ratio might be 8 dB greater numerically, i.e., one which gives an impairment of 2·5 opinion limens less than the mid-opinion value. At this point only 5% of viewers would be likely to hold an 'unfavourable' opinion and, as Table 4 shows, 4·5% of these would not find the impairment very objectionable and none would be likely to find the picture unusable. It must be borne in mind, of course, that the figure so arrived at would include every source of noise in the complete picture chain.

Next, account has to be taken of fading on links by a modified figure, say for 1% of transmission time over any month, and a further figure for 0·1% of the time.

Finally, the global signal-to-noise tolerance figure has to be broken down into the maximum allowable figures which can be assigned to each component portion of the total signal chain.

However, it is not proposed to embark on a discussion of these points, which would necessarily be quite lengthy, but it is hoped that the work presented above will form a sounder basis for the important decisions of this nature which have to be taken than has heretofore been available.

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‡ Comité Mixte des Transmissions Télévisuelles.

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## MATHEMATICAL TOOLS


By Computer


# Differentiation for Engineers

Frequently we need to differentiate an expression such as a function of time, and we may need to do this several times. There are a number of useful tricks which help in practical cases, and several of these tricks are discussed below, with only sufficient background information to make this article self-contained. As in earlier articles of this series, we are primarily concerned with the use that can be made of established mathematical results, rather than with proofs of their validity.

The fundamental starting-point to which we always have to return when exploring any new differential ground is

$$f'(x) \text{ or } \frac{df(x)}{dx} = \lim_{h\to 0} \frac{f(x+h) - f(x)}{h} \quad .. \quad (1)$$

and although this equation appears somewhat formidable in symbols, its significance is quite clear in terms of the geometry of Fig. 1.

In Fig. 1, the curve is $y = f(x)$. A is a typical point on the curve, whose co-ordinates are $OL = x_A$ and $AL = y_A = f(x_A)$. B is a neighbouring point on the same curve, whose co-ordinates are $OM = x_B = OL + LM = x_A + h$ and $MB = y_B = f(x_B) = f(x_A + h)$. It follows that the gradient or slope of the chord AB of the curve is

$$\frac{BN}{AN} = \frac{BM - AL}{LM} = \frac{f(x_A + h) - f(x)}{h} \quad .. \quad (2)$$

so that Equ. (1) merely expresses that the slope of the tangent (at A) to the curve is the limit of the slope of the chord AB as the point B moves towards A along the curve.

Although Fig. 1 is helpful in making clear the meaning of Equ. (1), this equation, once established, may be freely used without reference to Fig. 1. Thus if $f(x) = x^2$, Equ. (1) gives the well-known result

$$f'(x) = \lim_{h\to 0} \frac{(x+h)^2 - x^2}{h} = \lim_{h\to 0} \frac{2xh + h^2}{h}$$
$$= \lim_{h\to 0} (2x + h) = 2x \quad .. \quad .. \quad (3)$$

and it is important to note that we can only cancel the $h$ to reduce $(2xh + h^2)/h$ to $(2x + h)$ provided that $h$ is different from zero, however small; that is why we have to talk about "taking the limit when $h$ tends to zero" instead of merely putting $h$ equal to zero.

More generally, Equ. (1) gives us that if $f(x) = x^n$, then $f'(x) = nx^{n-1}$. We only have to assume the "Binomial Theorem" discussed in the April "Mathematical Tools". This theorem tells us that when $h$ is sufficiently small,

$$\frac{(x+h)^n - x^n}{h} = \frac{1}{h}\left\{x^n\left[1 + \frac{nh}{x} + \frac{n(n-1)}{2}\left(\frac{h}{x}\right)^2 + \ldots\right] - x^n\right\} = nx^{n-1} + \frac{n(n-1)}{2}x^{n-2}h + \ldots \quad (4)$$

and the result follows, since all terms of (4) on the right-hand side except the first contain positive powers of $h$. Again, Equ. (1) enables us to deal with trigonometrical differentiation. For if $x$ is in radians,

$$\frac{\sin(x+h) - \sin x}{h} = \frac{\sin x \cos h + \cos x \sin h - \sin x}{h}$$
$$= \cos x \, . \, \frac{\sin h}{h} - \sin x \, \frac{1 - \cos h}{h} \quad .. \quad .. \quad (5)$$

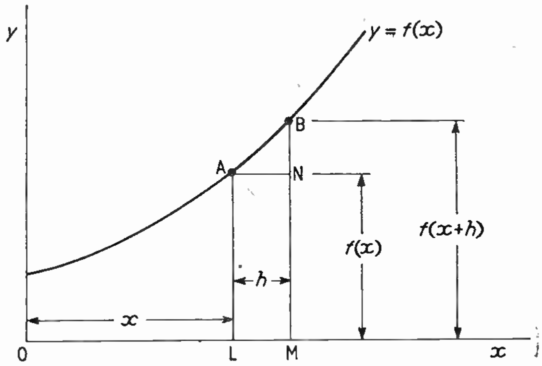


Fig. 1. *Geometrical significance of Equ.* (1)

and we can reasonably accept from Fig. 2 that

$$\lim_{h\to 0} \frac{\sin h}{h} = 1, \quad \lim_{h\to 0} \frac{1-\cos h}{h} = 0 \qquad (6)$$

for if the circle in Fig. 2 has unit radius, the chord PQ has length 2 sin $h$ and the arc PQ has length $2h$; for sufficiently small $h$ chord and arc are indistinguishable. $(1 - \cos h)$ is represented by the length NR, and there is a well-known geometrical theorem that since PNQ and ANR are chords of the circle meeting at N,

$$\text{AN} \times \text{NR} = \text{PN} \times \text{NQ} = \text{PN}^2 \qquad (7)$$

and this gives

$$\frac{1-\cos h}{h} = \frac{\text{NR}}{h} = \frac{\text{PN}^2}{h\,.\,\text{AN}} = \frac{\sin^2 h}{h\,(1+\cos h)}$$

$$= \tfrac{1}{2}\,.\,\frac{\sin h}{h}\,.\,\sin h \qquad (8)$$

Now we have already seen that $\sin h/h$ is nearly unity for small $h$; Equ. (8) shows that $(1 - \cos h/h)$ is small for small $h$ and therefore that the last term of Equ. (5) is small. It follows that if $f(x) = \sin x$,

$$f'(x) = \frac{d(\sin x)}{dx} = \cos x = \sin\left(x + \frac{\pi}{2}\right) \qquad (9)$$

The last member of Equ. (9) has a usefulness that will become more obvious later. The other important

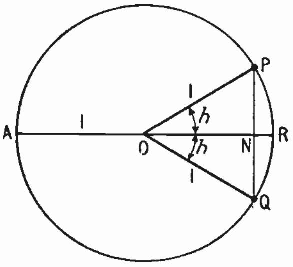


Fig. 2. *Relation between sin h, 1 — cos h and h*

simple, elementary case in which we need to know $f'(x)$ is when $f(x) = \exp x$. The result in this case is

$$f'(x) = \frac{d\,(\exp x)}{dx} = \exp x \qquad (10)$$

For engineering purposes, it is best to assume that Equ. (10) is valid where exp $x$ is $e^x$ and $e = 2{\cdot}718281828\ldots$ although, from the point of view of mathematicians, the orderly development of this part of the calculus is a matter of some importance for which several different approaches are possible. We shall also assume the 'exponential theorem', namely that

$$e^x = 1 + x + \frac{x^2}{2!} + \frac{x^3}{3!} + \ldots \qquad (11)$$

the infinite series on the right being convergent for all values of $x$.

The above remarks cover the differentiation once of powers of $x$, trigonometrical functions and exponentials, but we now need to consider general rules for differentiating which greatly extend the range of functions covered. If, for example, we want to differentiate

$$y = (a^2 - x^2)^{1/2} \qquad (12)$$

with respect to $x$, the procedure which gives us the greatest understanding is to square both sides of Equ. (12), giving

$$y^2 = a^2 - x^2 \qquad (13)$$

and then differentiate both sides of Equ. (13) with respect to $x$. We have no difficulty with the right-hand side; on the left-hand side we would prefer to differentiate with respect to $y$. The general rule which is useful in this sort of situation is

$$\frac{d(y^2)}{dx} = \frac{d(y^2)}{dy} \times \frac{dy}{dx} \qquad (14)$$

and in Equ. (14), $y^2$ could be replaced by any function of $y$. We thus find that the result of differentiating both sides of Equ. (13) with respect to $x$ is

$$2y\,.\,\frac{dy}{dx} = -2x \qquad (15)$$

so that

$$\frac{dy}{dx} = \frac{d(\{a^2 - x^2\}^{1/2})}{dx} = -\frac{x}{y} = -\frac{x}{(a^2 - x^2)^{1/2}} \qquad (16)$$

Most cases in which we have to differentiate what appears to be a complicated expression can be handled by giving names, like $y$ in Equ. (12), to the complicated parts, and then differentiating with respect to $x$, using Equ. (14) every time we would find it easier to differentiate with respect to some variable other than $x$.

The other important aid to differentiation is the 'product rule', namely that if $y = uv$, then

$$\frac{dy}{dx} = u\frac{dv}{dx} + v\frac{du}{dx} \qquad (17)$$

This rule applies in all cases, and is easy to remember because of its symmetry. There is a similar rule for finding the derivative of a quotient, say $u/w$, but this is less important because it can be deduced from Equ. (17) by putting $v = 1/w$ and applying Equ. (14) with $(1/w)$ instead of $y^2$ and $w$ instead of $y$; there is then no danger of getting a sign wrong.

Most of the functions relevant to engineering are made up of powers, trigonometrical functions, and exponentials, so that the above remarks cover all the ground essential to enable us to differentiate such functions once. We may, however, often need to differentiate several times, and this we consider next. Differentiating $x^n$ $r$ times is straightforward enough; the result is

$$\frac{d^r(x^n)}{dx^r} = n(n-1)\,(n-2)\ldots(n-r+1)\,x^{n-r} \qquad (18)$$

Whatever the values of $n$ and $r$ may be, integral or not, Equ. (18) contains the information that if $n$ and $r$ are both integers, and $r$ exceeds $n$, then one of the factors on the right-hand side will be zero and therefore the whole right-hand side will be zero. For trigonometrical expressions, the last member of Equ. (9) comes into its own if differentiating several times is involved, thus

$$\frac{d^r(\sin x)}{dx^r} = \sin\,(x + \tfrac{1}{2}r\pi) \qquad (19)$$

and, by applying Equ. (14) we could also obtain

$$\frac{d^r\cos(ax+b)}{dx^r} = a^r\cos\,(ax + b + \tfrac{1}{2}r\pi) \qquad (20)$$

and we thus have no worry about signs; after $r$ differentiations we have the same trigonometrical ratio that we started with, but the argument is increased by $\frac{1}{2}r\pi$ and there is a multiplying factor $a^r$. In the case of exponentials, it is clear from Equ. (10) that repeated differentiation presents no problem. When we seek to generalize Equ. (14) to apply to any number of differentiations, the situation becomes more difficult; we can only apply Equ. (14) repeatedly, with the help of Equ. (17). We shall, however, see later that Equ. (17) can be explicitly extended to $n$ differentiations—a result known as Leibnitz' Theorem.

Suppose therefore that we want to differentiate $y$ defined by Equ. (12) three times with respect to $x$; that is to say, we require to determine $d^3y/dx^3$ in terms of $x$. Differentiating both sides of Equ. (13) once [Equ. (13) is much more convenient than Equ. (12)] gives us Equ. (15), and Equ. (16) then gives us $dy/dx$ in terms of $x$, but we are ill-advised to worry about the fact that Equ. (15) has both $x$ and $y$ in it too early. It is better to differentiate both sides of Equ. (15) as it stands (after dividing through by 2) with respect to $x$. Again, the right-hand side presents no difficulty. For the left-hand side we have

$$\frac{d}{dx}\left\{y\frac{dy}{dx}\right\} = \left(\frac{dy}{dx}\right)^2 + y\frac{d^2y}{dx^2} \quad \ldots \quad \ldots \quad (21)$$

rom Equ. (17) with $u$ replaced by $y$ and $v$ by $dy/dx$. Thus at this stage Equ. (15) differentiated once gives

$$\left(\frac{dy}{dx}\right)^2 + y\frac{d^2y}{dx^2} = -1 \quad \ldots \quad \ldots \quad \ldots \quad (22)$$

If we now differentiate both sides of Equ. (22) with respect to $x$, we find

$$\frac{d}{dx}\left\{\left(\frac{dy}{dx}\right)\times\left(\frac{dy}{dx}\right)\right\} = \frac{d^2y}{dx^2}\frac{dy}{dx} + \frac{dy}{dx}\frac{d^2y}{dx^2}$$

$$= 2\frac{dy}{dx}\frac{d^2y}{dx^2} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (23)$$

from Equ. (17) with $u = v = dy/dx$, and

$$\frac{d}{dx}\left\{y\frac{d^2y}{dx^2}\right\} = y\frac{d^3y}{dx^3} + \frac{dy}{dx}\frac{d^2y}{dx^2} \quad \ldots \quad \ldots \quad (24)$$

from Equ. (17) with $u = y$, $v = d^2y/dx^2$, and therefore

$$3\frac{dy}{dx}\frac{d^2y}{dx^2} + y\frac{d^3y}{dx^3} = 0 \quad \ldots \quad \ldots \quad \ldots \quad (25)$$

Equ. (25) gives us the essential information about $d^3y/dx^3$, since $d^2y/dx^2$ is known from Equ. (21) in terms of $y$ and $dy/dx$; $dy/dx$ can be expressed by means of Equ. (15) in terms of $x$ and $y$, and finally $y$ can be eliminated by means of Equ. (12). We can therefore deduce $d^3y/dx^3$ in terms of $x$ if we wish by a series of eliminations of the unwanted quantities $d^2y/dx^2$, $dy/dx$ and $y$ which are known. This elimination is somewhat tedious but quite straightforward. It must be emphasized at this point that the elimination may be unnecessary. If for example we require $d^3y/dx^3$ only for a particular value of $x$ such as $a\cos\theta$, Equ. (12) tells us that $y = a\sin\theta$, Equ. (15) that $dy/dx = -\cot\theta$, and Equ. (22) that $d^2y/dx^2$ is $-1/(a\sin^3\theta)$. Substitution into Equ. (25) gives

$$\frac{d^3y}{dx^3} = -\frac{3\cos\theta}{a^2\sin^5\theta} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (26)$$

and this result is just as useful as, and easier to obtain than, a result only involving $x$.

As already mentioned, Equ. (17) can be explicitly extended to $n$ differentiations. Differentiating both sides once, we obtain

$$\frac{d^2y}{dx^2} = \frac{d^2(uv)}{dx^2} = \frac{du}{dx}\frac{dv}{dx} + u\frac{d^2v}{dx^2} + \frac{dv}{dx}\frac{du}{dx} + v\frac{d^2u}{dx^2} \quad (27)$$

the first pair of terms coming from Equ. (17) with $u$ unaltered and $v$ replaced by $dv/dx$, and the second pair from the same equation with $u$ replaced by $v$ and $v$ by $du/dx$. Equ. (27) simplifies to

$$\frac{d^2(uv)}{dx^2} = u\frac{d^2v}{dx^2} + 2\frac{du}{dx}\frac{dv}{dx} + \frac{d^2u}{dx^2}v \quad \ldots \quad \ldots \quad (28)$$

Repeating the differentiation with respect to $x$, we find similarly, after a little rearrangement,

$$\frac{d^3(uv)}{dx^3} = u\frac{d^3v}{dx^3} + 3\frac{du}{dx}\frac{d^2v}{dx^2} + 3\frac{d^2u}{dx^2}\frac{dv}{dx} + \frac{d^3u}{dx^3}v \quad (29)$$

and, at this stage, the resemblance to the Binomial Theorem (for a positive integral index) discussed in the April "Mathematical Tools" becomes clear. The result of $n$ differentiations can be written in the form known as Leibnitz' Theorem, namely

$$\frac{d^n(uv)}{dx^n} = u\frac{d^nv}{dx^n} + \frac{n}{1}\frac{du}{dx}\frac{d^{n-1}v}{dx^{n-1}} + \frac{n(n-1)}{1.2}\frac{d^2u}{dx^2}\frac{d^{n-2}v}{dx^{n-2}}$$

$$+ \ldots + \frac{n(n-1)\ \ldots\ (n-r+1)}{1.2\ \ldots\ r}\frac{d^ru}{dx^r}\frac{d^{n-r}v}{dx^{n-r}}$$

$$+ \ldots + \frac{d^nu}{dx^n}v \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (30)$$

so that any expression can be differentiated $n$ times immediately if it consists of terms each of which is the product of pairs of functions each of which can be differentiated $n$ times. In particular, if $u$ is $x^k$ ($k$ integer $>0$) the right-hand side of Equ. (30) has only $(k + 1)$ terms.

## AUTOMATION EXHIBITIONS AND CONFERENCES IN U.S.A.

The fifth international automation exposition will be held at the Trade Show Building in New York from 16th to 20th November 1959. As in the past, the exposition will be composed of three main features; an exhibition of automation equipment, a series of over one hundred technical demonstrations of operating equipment, and a programme of about sixteen technical meetings to discuss the various aspects of automation.

It has also been announced that the 14th annual instrument-automation conference and exhibition will be held at the International Amphitheatre in Chicago from 21st to 25th September 1959.

Further particulars may be obtained from the Export Publicity Fair Branch of the Board of Trade, Lacon House, Theobalds Road, London, W.C.1.

## D.S.I.R. WOLFE AWARD

It has been announced that Dr. L. Essen, O.B.E., a senior principal scientific officer at the National Physical Laboratory, becomes the first recipient of the Wolfe Award of the Department of Scientific and Industrial Research for his work on an atomic frequency standard as a basis for the future standard of time.

The caesium frequency standard that Dr. Essen designed is being used at the National Physical Laboratory to calibrate the quartz clocks and to monitor the MSF Standard-Frequency Transmissions.

# Synthesis of LC Networks

By J. T. Allanson.*

SUMMARY. *A method is outlined for the synthesis of certain voltage transfer functions by means of asymmetrical, balanced LC networks terminated at the load end by a resistance.*

In a previous article[1] a method was developed for the synthesis of RC networks. This article is concerned with the application of this method of synthesis to LC networks. It will be shown that any voltage transfer function having poles in the interior of the left-half of the $p$-plane and zeros such that the numerator polynomial of the function is either an even or an odd function of $p$, may be realized by an LC network terminated in a pure resistance.

### Outline of the Method

The voltage transfer function of the network shown in Fig. 1 is given by[2]

$$\frac{E_2}{E_1} = h\frac{N(p)}{D(p)} = \frac{-y_{12}}{1+y_{22}} \qquad (1)$$

in which $y_{12}$, $y_{22}$ are the short-circuit transfer and driving-point admittances of the network. In the

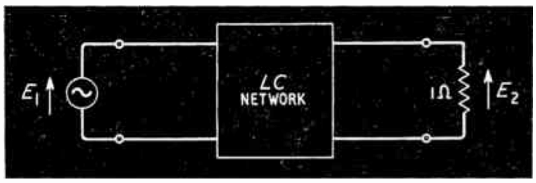


Fig. 1. *General LC network connected to a 1-Ω resistive load. The voltage transfer function is given by $E_2/E_1$*

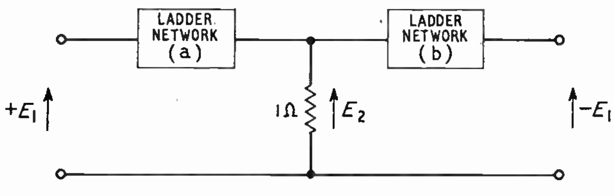


Fig. 2. *Unbalanced purely-reactive ladder networks (a) and (b) feeding a common resistive load*

general case, a realizable voltage-transfer function $E_2(p)/E_1$ must not have poles in the right-half of the $p$-plane[2], and poles on the imaginary axis must be simple. In the network shown, the output voltage is developed across a finite resistance and, therefore, $E_2(j\omega)/E_1$ cannot become infinite; i.e., the poles of $E_2(p)/E_1$ must be in the interior of the left-half of the $p$-plane.

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

The ratio of $E_1$ and $E_2$ in the network shown in Fig. 2 is given by

$$\frac{E_2}{E_1} = \frac{y_{12}^{(a)} - y_{12}^{(b)}}{1 + y_{22}^{(a)} + y_{22}^{(b)}} \qquad (2)$$

If the two networks are to be purely-reactive ladder networks, then the zeros and poles of $y_{12}^{(a)}$, $y_{12}^{(b)}$, $y_{22}^{(a)}$, $y_{22}^{(b)}$ must occur for imaginary[3] values of $p$. Suppose that

$$\frac{E_2}{E_1}(p) = h\frac{N(p)}{D(p)} \qquad (3)$$

where $N(p)$, $D(p)$ are polynomials, $D(p)$ necessarily being a Hurwitz polynomial, since its zeros must be in the left-half of the $p$-plane. Let the even and odd parts of $D(p)$ be $\alpha(p)$ and $\beta(p)$ respectively. Then the two functions $\frac{\alpha(p)}{\beta(p)}$ and $\frac{\beta(p)}{\alpha(p)}$ may both be realized as LC driving-point admittances[3]. Thus Equ. (3) may be rewritten

$$\frac{E_2}{E_1}(p) = \frac{h\cdot\frac{N(p)}{\alpha(p)}}{1+\frac{\beta(p)}{\alpha(p)}} = \frac{h\cdot\frac{N(p)}{\beta(p)}}{1+\frac{\alpha(p)}{\beta(p)}} \qquad (4)$$

Since $E_2(p)/E_1$ may not have any poles on the imaginary axis of the $p$-plane, the highest power of $p$ in the polynomial $N(p)$ may not be greater than the highest power of $p$ in $D(p)$. If the highest power in $D(p)$ is $p^n$ (i.e., having a coefficient of $+1$) then the coefficients of all lower powers of $p$ must be positive and finite, since $D(p)$ is a Hurwitz polynomial[4]. Therefore the highest powers in $\alpha(p)$ and in $\beta(p)$ may be less than the highest power in $N(p)$ by unity at the most. Thus the numerator in either of the expressions on the right-hand side of Equ. (4) is a function which has simple poles at purely imaginary values of $p$ possibly including the value $p = j\infty$. In what follows it will be assumed that $N(p)$ is an odd function of $p$.

It will always be possible to rewrite Equ. (4) as follows

$$\frac{E_2}{E_2}(p) = h\cdot\frac{\frac{N_1(p)}{\alpha(p)} - \frac{N_2(p)}{\alpha(p)}}{1+\frac{\beta(p)}{\alpha(p)}} \qquad (5)$$

where $N_1(p)$, $N_2(p)$ are polynomials with simple imaginary zeros. [There will be an equivalent form if $N(p)$ is an even function, with $\alpha(p)$ and $\beta(p)$ interchanged.] To show that such a division is possible, consider the partial fraction expansion of $\dfrac{N(p)}{\alpha(p)}$.

$$\frac{N(p)}{\alpha(p)} = a_\infty p + \frac{a_0}{p} + \sum\left(\frac{a_k}{p + j\omega_k} + \frac{a'_k}{p - j\omega_k}\right) \quad (6)$$

Since the polynomial $N(p)$ is odd, the coefficients $a_k$ and $a_k'$ will necessarily be real, and since they are the residues of the function $\dfrac{N(p)}{\alpha(p)}$ at conjugate poles, they will be equal. Therefore

$$\frac{N(p)}{\alpha(p)} = a_\infty p + \frac{a_0}{p} + \sum \frac{2a_k p}{p^2 + \omega_k^2} \quad \cdots \quad \cdots \quad (7)$$

If now, those terms on the right-hand side of Equ. (7) which have positive coefficients are grouped together, and the terms with negative coefficients also grouped together, we may write

$$\frac{N(p)}{\alpha(p)} = \frac{N_1(p)}{\alpha_1(p)} = \frac{N_2(p)}{\alpha_2(p)} \quad \cdots \quad \cdots \quad \cdots \quad (8)$$

where the roots of $N_1(p)$ and $N_2(p)$ occur in imaginary pairs and are interlaced with those of $\alpha_1(p)$ and $\alpha_2(p)$ respectively. Thus we may make the following identifications

$$-y_{12}^{(b)} = h \cdot \frac{N_2(p)}{\alpha_2(p)} \quad \cdots \quad \cdots \quad \cdots \quad (9)$$

$$-y_{22}^{(a)} = h\frac{N_1(p)}{\alpha_1(p)} \quad \cdots \quad \cdots \quad \cdots \quad (10)$$

$$y_{22}^{(a)} + y_{22}^{(b)} = \frac{\beta(p)}{\alpha(p)} \quad \cdots \quad \cdots \quad \cdots \quad (11)$$

By splitting appropriately the right-hand side of Equ. (11) it will be possible[3] to identify $y_{22}^{(a)}$ and $y_{22}^{(b)}$ separately and hence produce two LC ladder networks which will possess the transfer and driving-point admittances so defined. A similar identification would be possible if $N(p)$ were an even function of $p$.

If the two ladder networks are made balanced, it will always be possible to reconnect them to operate with a single source voltage as shown in Fig. 3.

### Illustrative Example

It is required to synthesize the voltage ratio given by

$$\frac{E_2}{E_1} = h \cdot \frac{p^4 - p^2 + 1}{p^4 + p^3 + 4p^2 + 2p + 3} \quad \cdots \quad \cdots \quad (12)$$

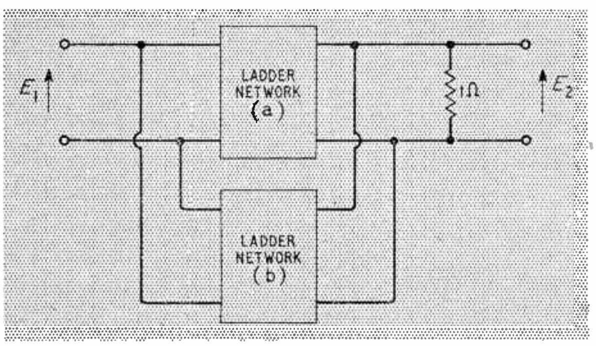


Fig. 3. *Connection of balanced ladder networks* (*a*) *and* (*b*) *with single source voltage* $E_1$

Since the numerator is an even function of $p$, the numerator and denominator are divided by the odd part of the denominator.

$$\frac{E_2}{E_1} = \frac{h \cdot \dfrac{p^4 - p^2 + 1}{p(p^2+2)}}{1 + \dfrac{p^4 + 4p^2 + 3}{p(p^2+2)}} \quad \cdots \quad \cdots \quad \cdots \quad (13)$$

$$\text{Then} \quad -(y_{12}^{(a)} - y_{12}^{(b)}) = h\left\{p + \frac{\frac{1}{2}}{p} + \frac{-\frac{7}{2}p}{p^2+2}\right\} \quad (14)$$

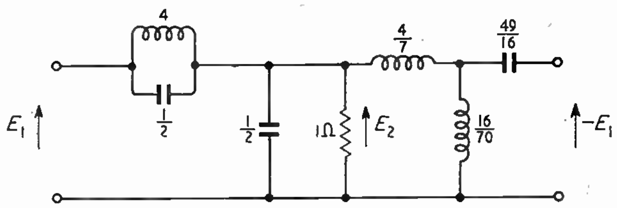


Fig. 4. *Synthesis of unbalanced networks to realize a response with* $h=0{\cdot}5$; *C in farads and L in henrys*

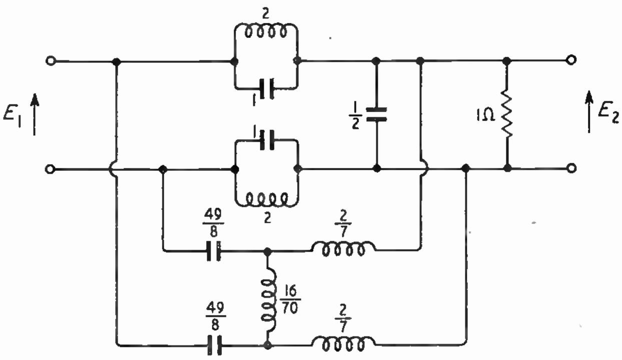


Fig. 5. *Final balanced LC network; C in farads and L in henrys*

$$\text{Thus let} \quad -y_{12}^{(a)} = h\left\{p + \frac{1}{2p}\right\} = h\left\{\frac{2p^2+1}{2p}\right\} \quad (15)$$

$$-y_{12}^{(b)} = h \cdot \left\{\frac{\frac{7}{2}p}{p^2+2}\right\} \quad \cdots \quad \cdots \quad (16)$$

$$y_{22}^{(a)} + y_{22}^{(b)} = p + \frac{3}{2p} + \frac{p}{2(p^2+2)} \quad (17)$$

The choice of $y_{22}^{(a)}$ and $y_{22}^{(b)}$ must be such that they have poles at the values of $p$ for which $y_{12}^{(a)}$ and $y_{12}^{(b)}$ respectively possess poles. Furthermore it is desirable to maximize $h$, and in this connection it has been shown[5] that for any LC ladder network $0 < \dfrac{-y_{12}(p)}{y_{22}(p)} < 1$ for any positive real value of $p$.

The choice is therefore made according to Equs. (18) and (19),

$$y_{22}^{(a)} = p + \frac{1}{4p} \quad \cdots \quad \cdots \quad \cdots \quad \cdots \quad \cdots \quad (18)$$

$$y_{22}^{(b)} = \frac{5}{4p} + \frac{p}{2(p^2+2)} \quad \ldots \quad (19)$$

The two networks shown connected together in Fig. 4 can be synthesized and will yield the desired response with $h$ equal to $\frac{1}{2}$. By making the networks balanced, and reconnecting, we obtain the final circuit shown in Fig. 5.


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# Simple Multiplex Vocoder


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



SUMMARY. *A simple time-division multiplex vocoder is described which economizes in circuit components by using a common rectifier for all channels. This vocoder appears to contravene Shannon's sampling law, but it is shown that sampling ambiguities do not produce any marked change in character or intelligibility of the synthesized speech.*


A vocoder analyser[1] provides a number of narrow-band control signals, each occupying a frequency band from zero frequency upwards, which are used to control the spectrum shape and spectrum character of synthetic speech. When used as a communication system, these control signals must be combined to form one composite signal. One method of producing this composite signal is to employ time-division multiplex and transmit the control signals as pulses into a low-pass transmission path. Once the principle of sharing the transmission path on a time basis has been accepted one attractive possibility is that of sharing some of the terminal equipment on a time basis also. This leads to a very simple form for the vocoder analyser, with a consequent saving both in cost and complexity. In order to see how this simple analyser operates, it will first be necessary to restate the mode of operation of the conventional vocoder.

## Conventional Vocoder

The conventional vocoder shown in Fig. 1 consists o an analyser and a synthesizer. The analyser is a bank of 10 adjacent band-pass filters covering the speech band from 300 c/s to 3,000 c/s, which are used to provide a crude short-term frequency analysis of the input pre-equalized speech. The power within each band is measured continuously and ten separate 'spectrum-control signals' are generated having amplitudes proportional to the square root of these powers. In addition an eleventh 'source-control signal' is generated which specifies the pitch, if any, of the speech.

The synthesizer consists of ten modulators fed from a common carrier source, which is either periodic or non-periodic, depending upon the amplitude of the source-control signal. The modulation source to the $n$th modulator is the $n$th spectrum-control signal and the output of this modulator is filtered to contain only those frequencies present in the original $n$th analyser band. The outputs of the ten modulators are added together and passed through a post-equalizer to form the synthetic speech output. Examples of the short-term analysis performed by the analyser and the spectra of the synthetic sounds subsequently produced by the synthesizer are shown in Fig. 2.

To provide intelligible speech, as opposed to natural speech, it is not necessary to generate the source-control signal. In this event, only a non-periodic carrier source is provided at the synthesizer and the synthetic speech has the character of a loud whisper. A vocoder which does not utilize a source-control signal is termed an *unvoiced vocoder* and, for simplicity, only unvoiced vocoders will be discussed in what follows.

### *Pre-Modulated Vocoder*

A slight modification to the conventional vocoder can be made which eases the design of band-pass filters. This is the inclusion of a pre-modulator which raises the spectrum to be analysed from 0–3,000 c/s up to some higher frequency band. In the vocoders shown in Figs. 3 and 4, the speech band is moved to the band 10–13 kc/s and analysis is performed in this band. There is another reason for using pre-modulation which is particular to the simple multiplex vocoder and this is discussed later.

### *Conventional Multiplex Vocoder*

The conventional method of applying time-division multiplex to a pre-modulated vocoder is shown in Fig. 3. It is assumed that the band 0–25 c/s has been allocated to each spectrum-control signal. In this system a


* *Electrical Engineering Department, University of Bristol.*

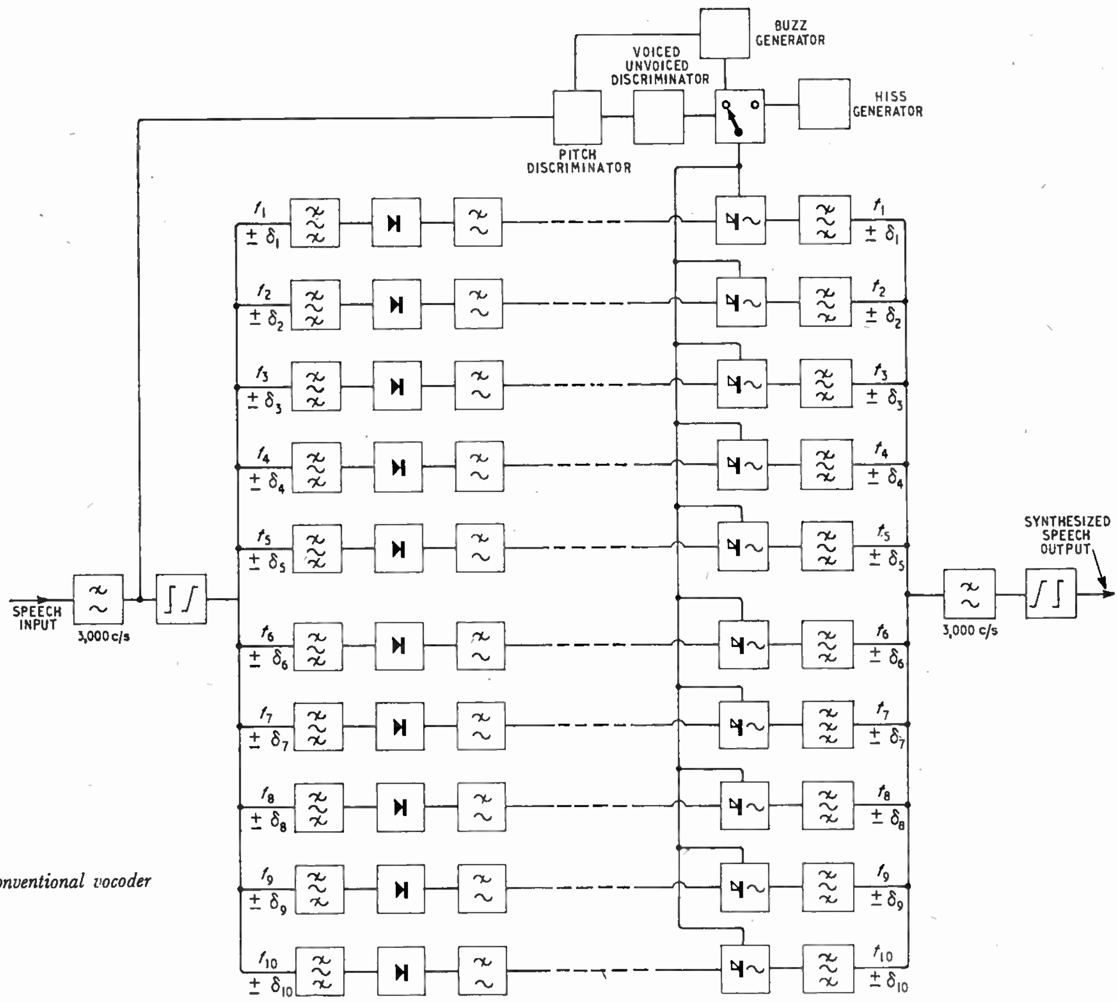


Fig. 1. *Conventional vocoder*

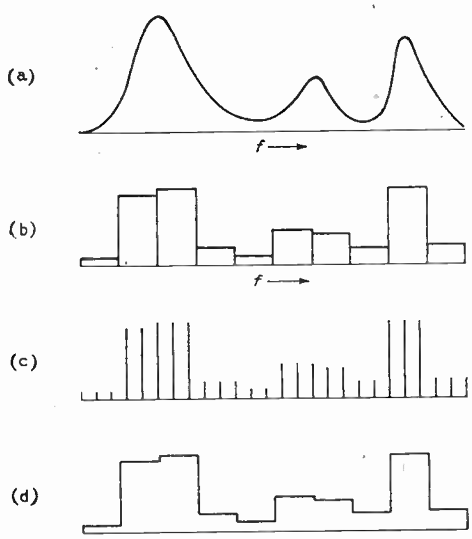


Fig. 2. *Short-term frequency analysis performed by analyser and block spectra produced by synthesizer; (a) envelope of spectrum of single sound; (b) short-term analysis provided by analyser; (c) spectrum of synthetic speech when voiced; (d) spectrum of synthetic speech when unvoiced*

rotating switch samples each of the spectrum-control signals every 0·02 second, and the pulses from the switch are passed through a low-pass filter having a bandwidth of the order of 250 c/s and thence, through the transmission path, to the synthesizer. At the synthesizer, a synchronized rotating switch samples the received waveform 500 times per second, and the pulses are sorted and distributed to the relevant modulator circuit. The original spectrum-control signals are then regenerated by applying the pulses to low-pass filters having bandwidths of 25 c/s. This system will only operate in an ideal manner if all the filters have rectangular low-pass characteristics, and if the sample pulses at each multiplex switch have infinitesimal duration. In practice, these conditions are not obtained and crosstalk is produced between the control signals, but if crosstalk is 30 dB below the wanted signal, then the system will operate adequately. It is probable that greater crosstalk can be tolerated, but it is certain that −30 dB is adequate.

## Common-Rectifier Time-Division Multiplex Vocoder

The logical extension of the conventional multiplex system is shown in Fig. 4. In this system, the outputs of the analyser bands are sampled before rectification and

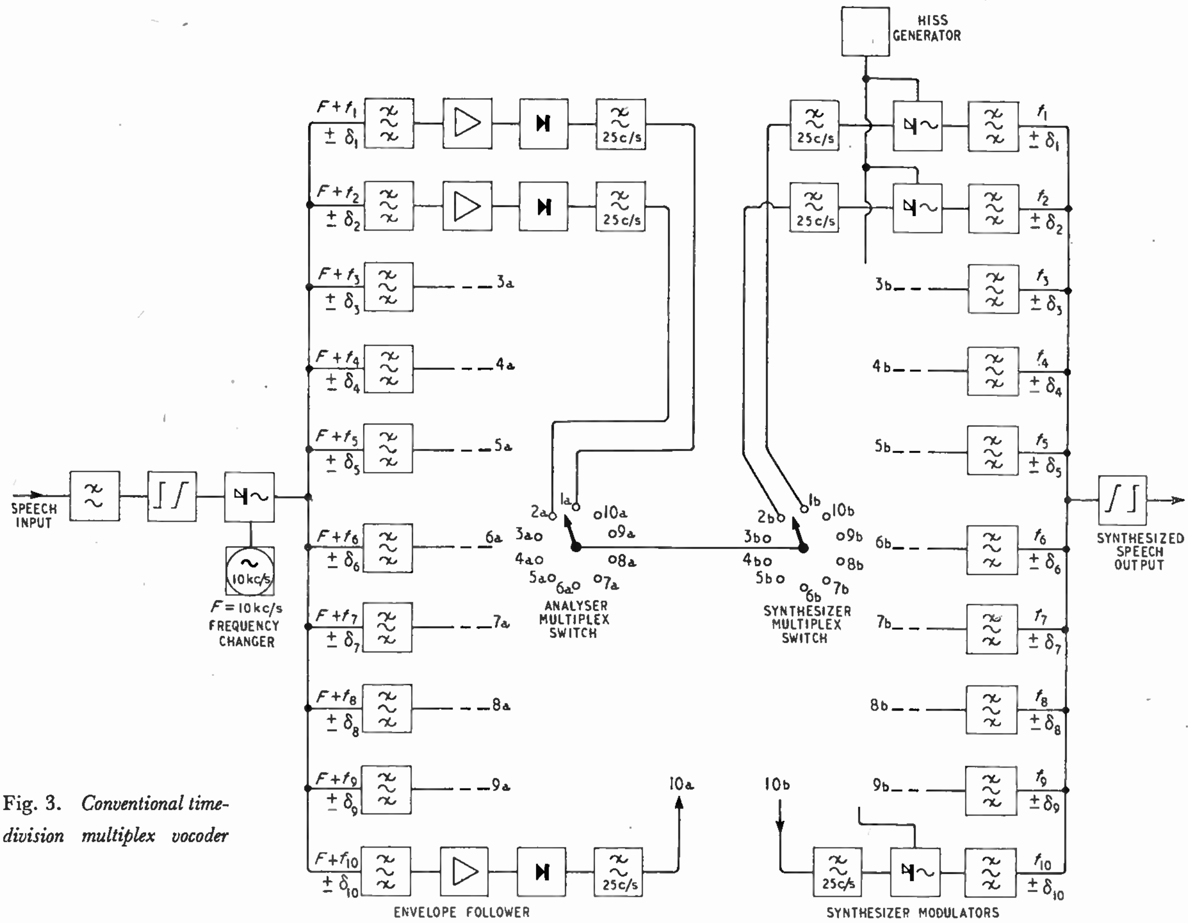


Fig. 3. *Conventional time-division multiplex vocoder*

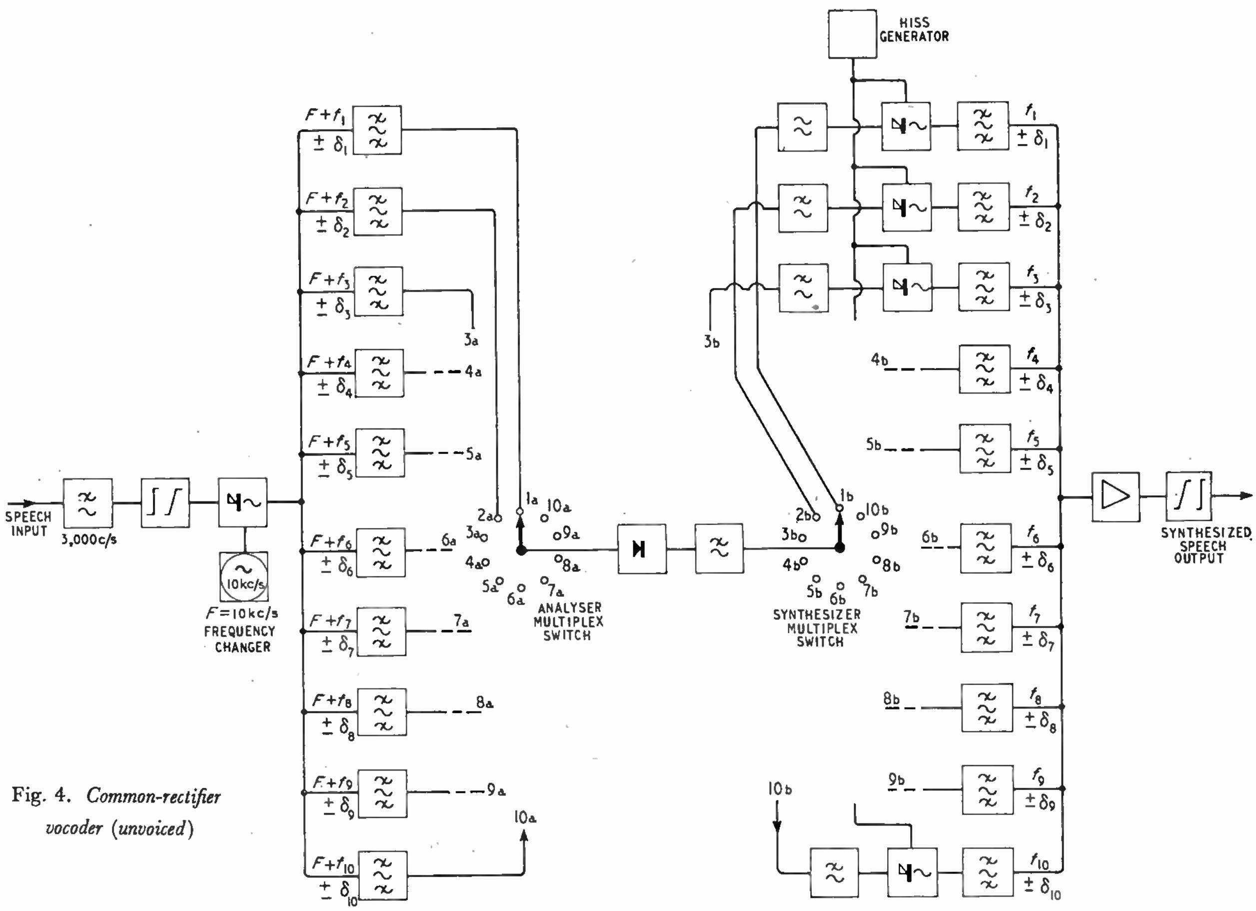


Fig. 4. *Common-rectifier vocoder (unvoiced)*

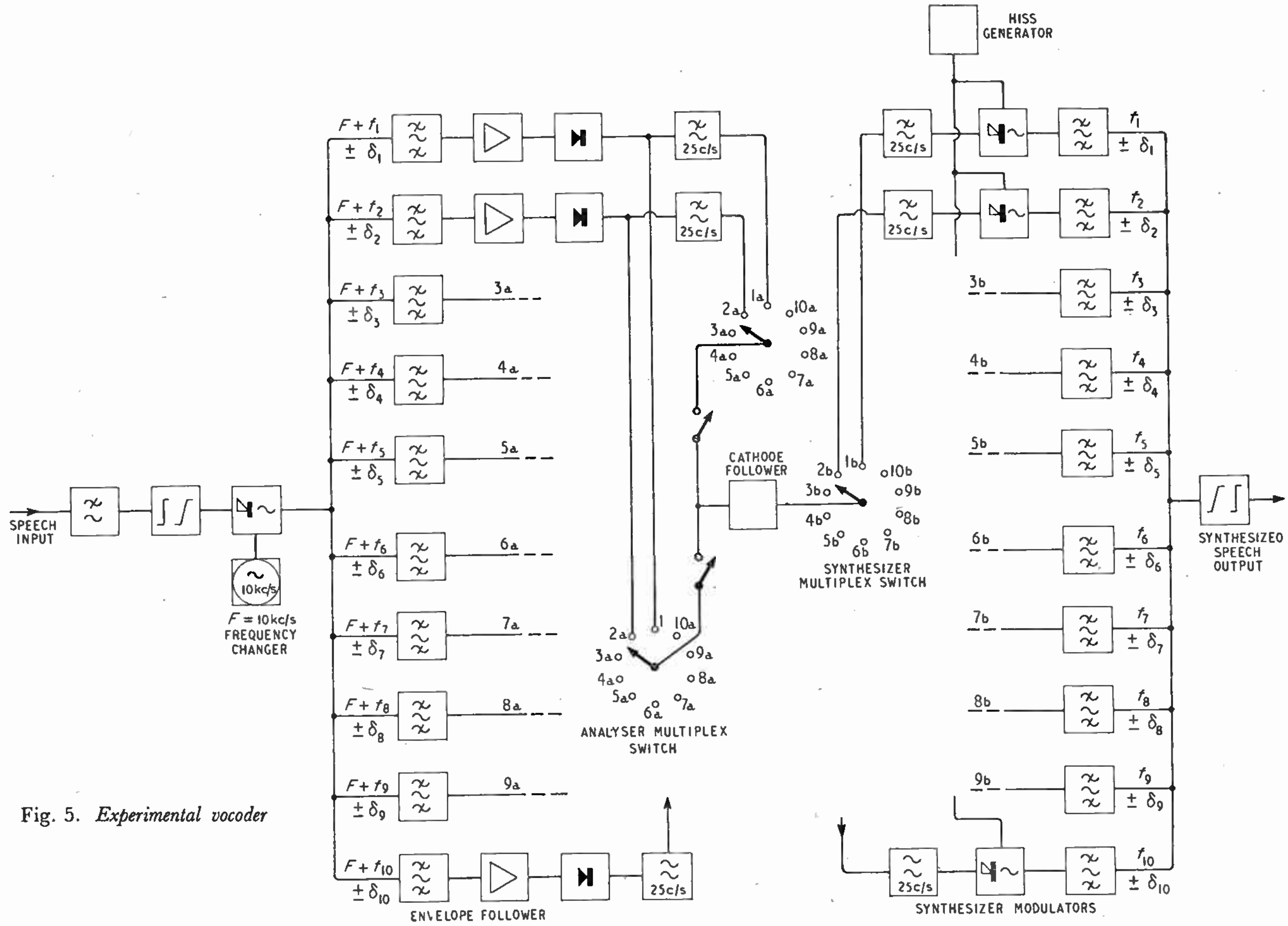


Fig. 5. *Experimental vocoder*

a single short time-constant rectifier is used for all the analyser bands. The rectified pulses are then transmitted through a low-pass filter to the synthesizer where they are dealt with in the same way as in the conventional multiplex vocoder.

A pre-modulator is essential for this type of vocoder in order that several cycles of the frequency-changed pitch harmonics shall occur during the sampling periods. If no pre-modulation is provided, much less than one cycle of low-pitch harmonics will occur during the sampling period, and the amplitude of the rectified pulses will be critically dependent upon the pitch phase at the beginning of the samples. Transfer of the speech frequencies to the band 10–13 kc/s reduces the effect of pitch phase to reasonable proportions (about 5%).

Before experiments were made with this system there appeared to be a possibility of its failing, because of the effects produced when two pitch harmonics occur within a single analyser band. In the presence of two adjacent pitch harmonics the envelope of the analyser filter output fluctuates at the pitch frequency and when there is only a single common rectifier, the multiplex switch is sampling this envelope, and is sampling it at a rate such that ambiguity is introduced. For example, if the pitch frequency is 101 c/s and the sampling frequency is 50 c/s, the rectified pulses will be amplitude modulated at 1 c/s, and this might be expected to produce undesirable beat effects. Putting it another way, the rate of sampling contravenes Shannon's sampling law[2] since the band of frequencies sampled is considerably wider than the sampling frequency.

Fortunately this apparent failing does not materialize in practice. A versatile vocoder has been constructed which has provision for a simple change-over from conventional to common-rectifier multiplex operation, and the measured syllable articulations for these two systems show no significant difference. There appear to be two reasons for the practical success of the common-rectifier multiplex system. The first is that the amplitude of envelope fluctuations only becomes comparable with the mean envelope when the amplitudes of adjacent pitch harmonics are nearly equal, and while this is not a rare occurrence, at least it is uncommon. The second reason is that the pitch fluctuates over a wide range and these fluctuations prevent the maintenance of a steady beat.

## Experimental Vocoder

As mentioned above, a versatile vocoder has been constructed which permits rapid comparisons to be made between conventional and common-rectifier multiplex operation. The circuit of this vocoder is shown in Fig. 5. In this equipment the input speech is pre-modulated before analysis and one rectifier of short time-constant is allocated to each analyser band. It can be seen that there are two alternative connections for the multiplex switch. In the first connection the rectifier outputs are sampled directly without passing through a filter, in which case the pulses in the transmission path are identical to those that would be produced by a common-rectifier vocoder. In the second connection the rectifier outputs are filtered by low-pass filters and then sampled, thereby providing a conventional time-division multiplex vocoder. No bandwidth restriction is imposed in the transmission path, in order that comparisons between systems shall not be confused by crosstalk considerations. Also a common cathode-follower is provided between analyser and synthesizer to give more power to drive the synthesizer modulators.

Measurements of articulation efficiency for both systems have been made using this versatile vocoder and values of 60·5% and 59·5% were obtained for the common-rectifier and conventional systems, respectively. It can be seen that there is no significant difference. The relatively low value of articulations is mainly due to the vocoder being unvoiced.

### Conclusions

It has been demonstrated that because of the particular nature of speech it is possible to multiplex vocoder signals in a way which appears to contravene the sampling law. The consequence of being able to do this is a considerable simplification of the analyser. With current practice tending to the use of 12- to 16-channel vocoders, this advantage is even greater than in the 10-channel vocoder described.

### Acknowledgement

The author would like to acknowledge the help he has received from Dr. J. H. Mole, who originally suggested the idea of the common-rectifier vocoder.

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# Ladder and Transformer Filters

DESIGN PROCEDURE AND CHARACTERISTICS

By **L. Kitajewski, B.Sc., Grad.I.E.E.***

While the first part of this article gives curves and formulae[1] for designing simple *LC* ladder filters having Tchebyshev response, the second part deals with the equivalent circuit of a transformer at high frequencies. A method is described for calculating the component values of the transformer's $\pi$-section, and it is shown how the transformer may be built up to give the characteristics of a filter and to provide the required matching conditions. Two examples are given, one on filter design and the other on transformer build-out design.

### Curves for Ladder Filters

The curves in Figs. 1 and 2 give the component values of ladder filters and their stop-band attenuations for three, five and seven elements, respectively. Using these curves, simple *LC* ladder filters (low-pass, high-pass and band-pass) having the well-known Tchebyshev response characteristics can be designed.

From these curves, in which the maximum insertion loss in the pass-band ($A_m$) is plotted against the return loss (R.L.), the normalized component values can be read off directly for given values of $A_m$ and R.L. The actual values of components are obtained by multiplying the normalized values of the inductances by $R_0/\omega_0$ and capacitances by $1/\omega_0 R_0$; $R_0$ is the required terminating resistance and $\omega_0$ is $2\pi$ times the cut-off frequency.

The dotted characteristic in Fig. 2 shows that Tchebyshev response gives more attenuation in the stop-band than the image prototype for the same $A_m$, which is 3 dB in this case. At frequencies much higher than cut-off, it may be shown that for three elements the attentuation difference is 12 dB, 24 dB for five elements, and 36 dB for seven elements[3], etc.

Suppose that it is required to design a high-pass ladder filter having a cut-off frequency $f_0 = 110$ kc/s, an attenuation of at least 50 dB at $f = 55$ kc/s, an input and output impedance $R_0 = 75\ \Omega$, and a return loss of of 20 dB. Then, from Fig. 2, it can be seen that for $f_0/f = (110 \times 10^3)/(55 \times 10^3) = 2$, and a return loss of 20 dB, a seven-element filter is necessary to give an attenuation of 50 dB.

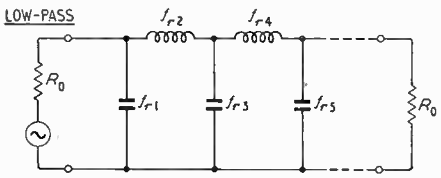
Therefore, from Fig. 1, for a seven-element filter

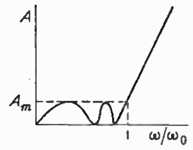
Fig. 1. *Design curves and formulae for simple LC ladder filters having Tchebyshev response. The curves show the variation of both maximum insertion loss in the pass-band ($A_m$) and normalized element values ($x$) with return loss for 3-, 5- and 7-element ladder filters. The formulae used in the design process are derived from the low-pass, high-pass and band-pass LC filter circuits[2], as shown*

* *G.E.C. Ltd., Telephone Works, Coventry*

**FIG. 1. Design Data**

$A$ = insertion loss (dB)
$A_m$ = maximum insertion loss in pass band (dB)
$r$ = number of elements
$x$ = normalized element value (read off the graphs)
$R_0$ = generator and load resistance (ohms)



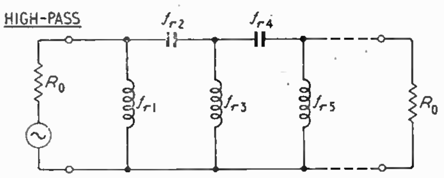



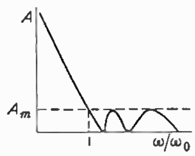

$$f_{r1} = \frac{x_{r1}}{\omega_0 R_0} \text{ farads;}$$

$$f_{r2} = \frac{x_{r2} R_0}{\omega_0} \text{ henrys;}$$

$$f_{r3} = \frac{x_{r3}}{\omega_0 R_0} \text{ farads; etc.}$$

where $\omega_0 = 2\pi f_0$, and $f_0$ = cut-off frequency (c/s).



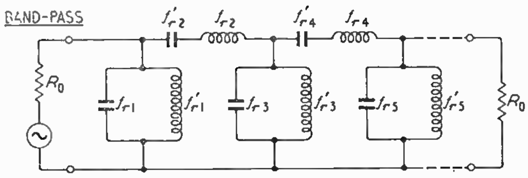



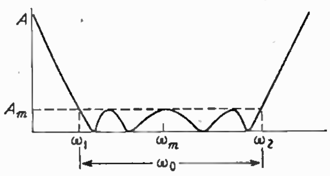

$$f_{r1} = \frac{R_0}{x_{r1}\omega_0} \text{ henrys;}$$

$$f_{r2} = \frac{1}{x_{r2}\omega_0 R_0} \text{ farads;}$$

$$f_{r3} = \frac{R_0}{x_{r3}\omega_0} \text{ henrys; etc.}$$

where $\omega_0 = 2\pi f_0$, and $f_0$ = cut-off frequency (c/s)



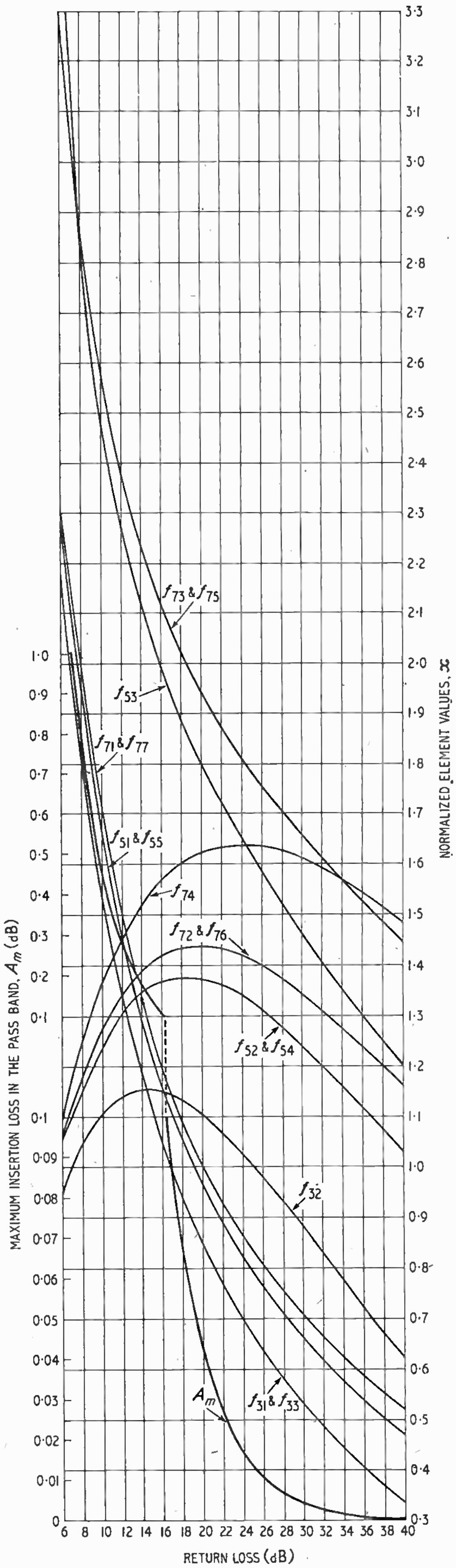

$$f_{r1} = \frac{x_{r1}}{\omega_0 R_0} \text{ farads;}$$

$$f_{r2} = \frac{x_{r2} R_0}{\omega_0} \text{ henrys;} \qquad f'_{r1} = \frac{1}{f_{r1}\omega_m^2} \text{ henrys;}$$

$$f_{r3} = \frac{x_{r3}}{\omega_0 R_0} \text{ farads; etc.} \qquad f'_{r2} = \frac{1}{f_{r2}\omega_m^2} \text{ farads;}$$

$$f'_{r3} = \frac{1}{f_{r3}\omega_m^2} \text{ henrys ; etc.}$$

where $\omega_m = \sqrt{\omega_1\omega_2}$ and $\omega_0 = \omega_2 - \omega_1$ = pass band.
$\omega_1$, $\omega_2$, $\omega_0$, $\omega_m$ in radians/second.



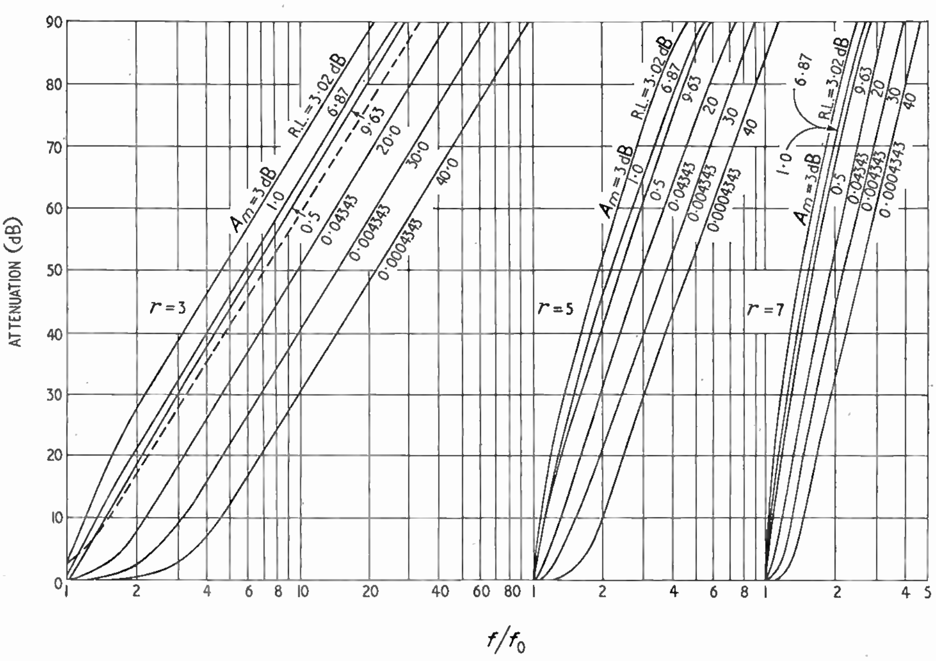



Fig. 2. *Curves showing the variation of stop-band attenuation with $f/f_0$ for 3-, 5- and 7-element LC ladder filters having different pass-band insertion loss (max.) and return-loss values. The dotted characteristic is for the image prototype (with resistive termination = $\sqrt{(L/C)}$ having an insertion loss $A_m$ of 3 dB at $f_0$; $r$ = number of elements, R.L. = return loss, $A_m$ = insertion loss, $f_0$ = cut-off frequency*

($r$ = 7) and a return loss of 20 dB, the normalized element values are

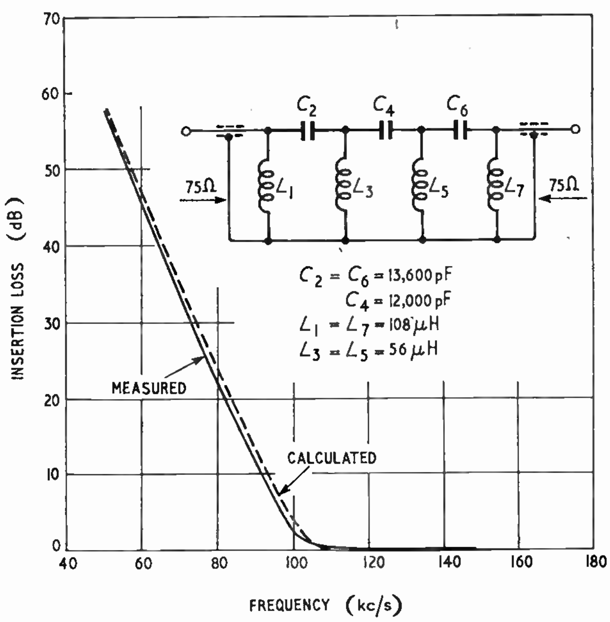
$$x_{71} = x_{77} = 1{\cdot}006$$
$$x_{72} = x_{76} = 1{\cdot}436$$
$$x_{73} = x_{75} = 1{\cdot}940$$
$$x_{74} = 1{\cdot}622$$

From the formulae given for the high-pass filter in Fig. 1, the element values can be calculated.

$$f_{71} = f_{77} = \frac{R_0}{x_{71}\omega_0} = \frac{75}{1{\cdot}006 \times 2\pi \times 110 \times 10^3} = 108\,\mu\text{H}$$

$$f_{72} = f_{76} = 1/x_{72}\omega_0 R_0 = 13{,}600 \text{ pF}$$
$$f_{73} = f_{75} = R_0/x_{73}\omega_0 = 56\ \mu\text{H}$$
$$f_{74} = 1/x_{74}\omega_0 R_0 = 12{,}000 \text{ pF}$$

Fig. 3. *High-pass filter*; $f_c$ = 110 *kc/s*




This filter has been constructed and its frequency-attenuation characteristic measured (see Fig. 3). For comparison purposes, the calculated characteristic was re-drawn from Fig. 2 and is shown as a dotted line.

It should be noticed that the filter satisfies the requirement of 50-dB minimum attenuation at 55 kc/s.

## Design of Transformer having Filter Behaviour

*Determination of the Equivalent Circuit of a Transformer at the High-Frequency End*

A transformer at the high-frequency end can be represented with a good degree of accuracy by the circuit shown in Fig. 4. To determine $L$, $C_1$ and $C_2$

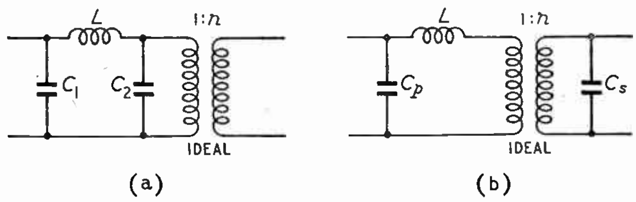



Fig. 4. *Circuit of a transformer at high frequency*

it is sufficient to take three measurements of admittance on a parallel bridge :—

(a) Admittance $Y_H$ looking into the high-impedance winding with the low-impedance winding open-circuited.

(b) Admittance $Y'_H$ looking into the high-impedance winding with the low-impedance winding short-circuited.

(c) Admittance $Y'_L$ looking into the low-impedance winding with the high-impedance winding short-circuited.

Each measurement will give an equivalent capacitance (negative for inductive impedance), and so referring to Fig 4(b), we may write

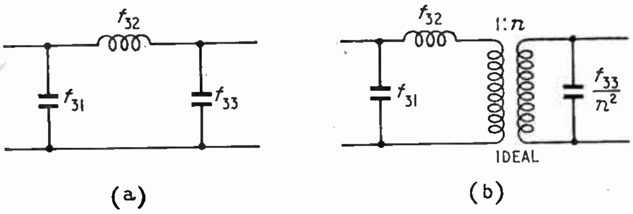



Fig. 5. *π-section low-pass filter*

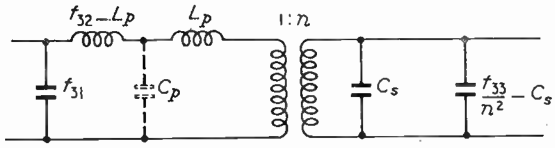



Fig. 6. *Padded transformer when $C_p \ll C_s n^2$*

$$Y_H = j\omega C_H = j\omega C_s + \frac{1}{j\omega Ln^2 + n^2/j\omega C_p}$$

$$= j\omega\left(C_s + \frac{C_p}{n^2 - \omega^2 n^2 L}\right) \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

$$Y'_H = j\omega C'_H = j\omega C_s + 1/j\omega n^2 L = j\omega(C_s - 1/\omega^2 n^2 L) \quad (2)$$

$$Y'_L = j\omega C'_L = j\omega C_p + 1/j\omega L = j\omega(C_p - 1/\omega^2 L) \quad \ldots \quad (3)$$

From Equs (1), (2) and (3), by simple algebraic eliminations, $L$, $C_p$ and $C_s$ can be expressed in terms of $C_H$, $C'_H$ and $C'_L$. They are:

$$L = \frac{1}{\omega^2 n \sqrt{C'_L (C'_H - C_H)}} \quad \ldots \quad \ldots \quad \ldots \quad (4)$$

$$C_p = C'_L + 1/\omega^2 L \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (5)$$

$$C_s = C'_H + 1/\omega^2 n^2 L \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (6)$$

*Determination of a π-Section Low-Pass Filter*

The element values of the required π-section low-pass filter can be found from Fig. 1. They are:

$$f_{31} = f_{33} = \frac{f_{31}}{\omega_0 R_0} \text{ farads}$$

$f_{32} = x_{32} \dfrac{R_0}{\omega_0}$ henrys, where $x_{31}$ and $x_{32}$ are the values read off the curves $f_{31}$ and $f_{32}$ respectively for a given return loss.

The required π-section is shown in Fig 5.

The transformer component values of Fig. 4(b) are then built up to those of Fig. 5(b).

If $L_p = f_{32}$ (a condition that could be achieved by design), then values of $C_p$ and $C_s$ only are padded to those of $f_{31}$ and $f_{33}/n^2$ respectively.

If $L_p < f_{32}$, then $L_p$ can be built up to the value of $f_{32}$, provided that $C_p \ll C_s n^2$. This case is shown ir Fig. 6 where transformer component values $L_p$, $C_p$ and $C_s$ are given together with the externally added components. $C_p$ is drawn dotted to indicate that it is negligible.

*Example of Transformer Build-Out Design*

A transformer was required to have a return loss of 30 dB minimum with reference to $R_0$ (75 Ω) over a frequency range of 100 kc/s–2 Mc/s. The load impedance was required to be 255 Ω. This necessitated the turns-ratio to be

$$\sqrt{\frac{255}{75}} = 1{\cdot}843.$$

Three admittance measurements were made on a parallel bridge (as before) at a frequency, $f = 2{\cdot}2$ Mc/s.

In order to allow for the errors in measurements and imperfections of components the design frequency was taken 10 % above the required frequency range.

$$C_H = + \quad 11 \text{ pF}.$$
$$C'_H = - \quad 333 \text{ pF}.$$
$$C'_L = - 1{,}110 \text{ pF}.$$

Resistive components are not given as they are not of direct interest. Hence, from Equ. (4),

$$1/L\omega^2 n = \sqrt{C'_L (C'_H - C_H)} = 617{\cdot}65 \times 10^{-12}.$$

$$\therefore L = \frac{1}{\omega^2 n \times 617{\cdot}65 \times 10^{-12}} = 4{\cdot}6\ \mu\text{H}.$$

From Equ. (5),

$$C_p = (-1{,}110 + 617{\cdot}65 \times 1{\cdot}843) \text{ pF} = 28{\cdot}3 \text{ pF}.$$

From Equ. (6),

$$C_s = (-333 + 617{\cdot}65/1{\cdot}843) \text{ pF} = 2{\cdot}1 \text{ pF}.$$

From the formulae given in Fig. 1 for a 3-element low-pass filter it is seen that with the leakage of 4·6 μH,

$$x_{32} = f_{32}\frac{\omega_0}{R_0} = \frac{4{\cdot}6 \times 10^{-6} \times 2\pi \times 2{\cdot}2 \times 10^6}{75} = 0{\cdot}848\,;$$

i.e., the maximum possible return loss is 31 dB. Thus

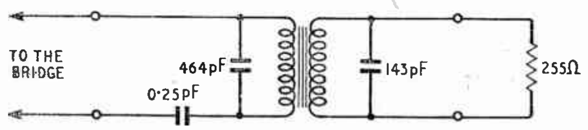
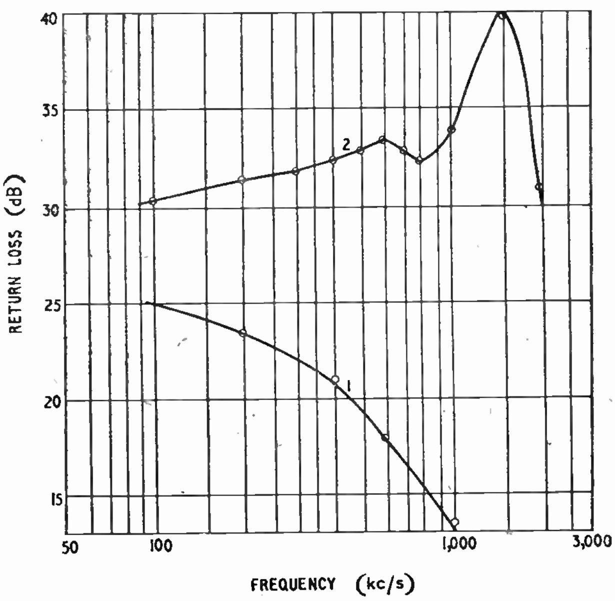



Fig. 7. *Transformer with the build-out and termination*

Fig. 8. *Curve* 1, *return loss without high-frequency end build-out. Curve* 2, *return loss with the high-frequency end build-out*



the leakage of this transformer permits the design of the build-out to give the required return loss of 30 dB. An external coil would have to be added to raise the leakage, as explained in the previous section.

It is better, however, to design the $\pi$-section low-pass filter for a return loss of 31 dB. Then the inductance required is the measured leakage of the transformer (i.e., 4·6 $\mu$H), and does not need building up.

$$\therefore f_{32} = 4{\cdot}6\,\mu\text{H}.$$

$$\text{and } f_{31} = f_{33} = \frac{x_{31}}{\omega_0 R_0} = \frac{0{\cdot}51}{2\pi \times 2{\cdot}2 \times 10^6 \times 75} = 492\,\text{pF}.$$

$$\therefore \frac{f_{33}}{n^2} = 145\,\text{pF}.$$

Comparing the transformer equivalent circuit, Fig. 4(b), with the $\pi$-section low-pass filter, Fig. 5(b), it is at once evident that the components to be added to the transformer are:

(i) On the low-impedance side a capacitor of the value of $f_{31} - C_p = (492 - 28{\cdot}3)$ pF = 464 pF.

(ii) On the high-impedance side a capacitor of the value of $(f_{33}/n^2) - C_s = (145 - 2{\cdot}1)$ pF = 143 pF.

The complete transformer with the build-out and the termination is shown in Fig. 7. A capacitor of 0·25 $\mu$F was added in order to improve the return loss at the low-frequency end. The value of this capacitor can be calculated from the low-frequency transformer equivalent circuit. It is not discussed as this article is concerned only with the high-frequency end build-out which follows filter design technique.

The return loss of the transformer with the build-out (as shown in Fig. 7) was measured and is shown in Fig. 8. It can be compared with the return loss of the transformer measured without the high-frequency end build-out; i.e., without capacitors of 464 pF and 143 pF.


### Acknowledgement

Acknowledgement is made to the General Electric Company Ltd. for permission to publish this article, and to Mr. G. Pereli of that company for his help in calculating the stop-band attenuation curves.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[1] H. J. Orchard, "Formulae for Ladder Filters", *Wireless Engr*, January 1953, Vol. 30, p. 3.
[2] J. L. Stewart, "Circuit Theory and Design", p. 135-139 J. Wiley & Sons, Inc., Publishers, New York.
[3] V. Belevitch, "Tchebyshev Filters and Amplifier Networks", *Wireless Engr*, April 1952, Vol. 29, p. 106.


# 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.*

### Cathode-Follower for a D.C. Reference Level

SIR,—It is well known that for a clipping circuit to work efficiently the source providing the reference level must have a low output impedance compared to the source of waveform. (This includes any resistance purposely introduced to increase the source impedance.) An upper limit is placed on the source resistance by considerations of the high-frequency response of the system and the unavoidable shunt capacitances in the circuits that follow this resistance. Batteries constitute an ideal source of constant-voltage reference especially because, in this application, they are not called upon to deliver any current. Where, however, the clipping level is to be variable, batteries cannot conveniently be used. A potentiometer circuit across the h.t. would answer the requirement but, if the output impedance is to be low, a large current will have to flow through the potentiometer resulting in a loss of power.

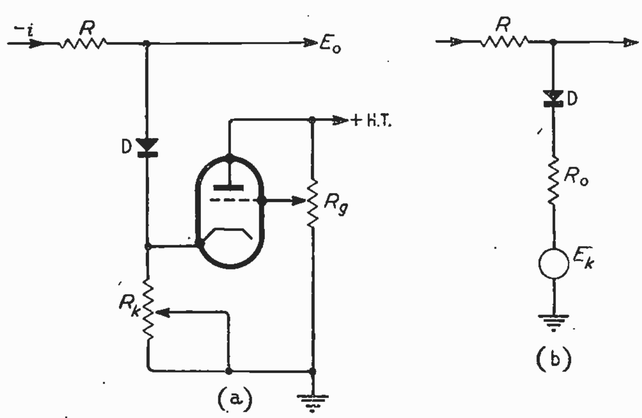
The cathode-follower with its low output impedance suggests itself as an ideal source. The cathode voltage can readily be varied by varying the grid voltage. A high-resistance potentiometer can be used in the grid circuit since the grid draws no current. In general, the current required to flow through the cathode-follower valve will be less than that for a corresponding potentiometer for the same output impedance value; this is especially true when the voltage required is only a small fraction of the available h.t. The value of the output impedance at the quiescent point of cathode-follower operation is, however, applicable only under small-signal conditions; i.e., where the height of the applied waveform is only slightly in excess of the desired clipping level.

Fig. 1 (a) gives the circuit of a cathode-follower clipper; Fig. 1 (b) is the equivalent circuit. $R$ represents the resistance of the source of the waveform; $R_k$ is the resistance in the cathode of the cathode-follower and the output impedance, $R_0$ is sensibly equal to $1/g_m$ [more accurately $r_a/(1 + \mu)$] in parallel with $R_k$. For reasonably large values of $R_k$, $R_0$ is approximately equal to $1/g_m$ itself.

When there is an input voltage in excess of the reference level $E_k$, a fraction $R_0/(R + R_0)$ of the excess voltage appears at the cathode. (The forward resistance of the diode may be included in $R$). This alters the grid–cathode voltage resulting in a change of valve current and mutual conductance leading to change of $R_0$ and the altered value has to be used in the above expression. It is clearly possible to distinguish between two different cases depending on whether $g_m$ decreases or increases with the signal.

(i) *Clipping on the Positive Side*

In this case, the excess voltage drives the cathode positive, reduces space current in the cathode-follower and thus reduces $g_m$. This results in an increased $R_0$ and less efficient clipping of the larger peaks. If an input pulse is high enough, the cathode-follower will be driven to cut-off and the output pulse will merely be the fraction



$R_k/(R + R_k)$ of the input. In the equivalent circuit, this corresponds to the condition, $E_k = 0$, and $R_0 = R_k$. Obviously, there is no clipping action involved for pulses of larger amplitude than this.

(ii) *Clipping on the Negative Side*

An argument analogous to the above (noting that the diode connections have to be reversed) indicates that $R_0$ decreases for the larger pulses reaching very low values indeed when the valve is in the grid-current region. If the resistance in the grid circuit is high, the voltage at the grid does not rise much above zero and the zero bias value of $g_m$ has to be used in the calculation of $R_0$ for large pulses.

The following general conclusions may be drawn. The cathode-follower source may be advantageous for clipping the positive side of a waveform but the probable height of the largest pulses expected should first be ascertained and the suitability of the cathode-follower decided. The cathode-follower source is ideally suited for clipping waveforms on the negative side, and considerable saving in current requirements results from the use of a cathode-follower instead of a potentiometer, especially for pulses of low duty ratio.

If a reasonably constant output impedance is desired while the voltage level is adjusted, the cathode resistance $R_k$ may be made variable [Fig. 1 (a)] and may be ganged with the potentiometer in the grid circuit to maintain the valve current almost constant.

I am grateful to Prof. R. S. Krishnan and Dr. G. Suryan for guidance and encouragement. My thanks are also due to the Council of Scientific and Industrial Research for financial aid.

*Department of Physics,* S. KRISHNAN.
*Indian Institute of Science,*
*Bangalore-12, India.*
21st March 1959.

### Sampling of Signals Without D.C. Components

SIR,—As I have noted elsewhere[1] the extension of the Sampling Theorem to bands not extending down to zero frequency was proved by Kohlenberg[2] in 1953; and contrary to the conclusion reached by Dr. Billings in the February issue, he was able to show that a mean sampling rate $2\,\Delta\, f$ still suffices. The necessary device is to split the sampling train of total rate $2\,\Delta\, f$ into two trains each of uniform rate $\Delta\, f$ but with a suitably chosen phase difference between the timing of the pulses in one train and those in the other. Kohlenberg stated that "For a function $f(t)$ in a band $(w_0, w_0 + w)$ it is shown that an exact interpolation formula is

$$f(t) = \sum_n \left[ f(n/w)\, S(t - n/w) + f(n/w + k)\, S(n/w + k - t) \right]$$

in which $k$ is subject to weak restrictions." The parameter $k$ is chosen so that the overlapping parts of the spectra cancel out between the two partial trains of sampling pulses. The interpolating function $S(t)$ is then

$$S(t) = \frac{\cos\,[2\pi(w_0 + w)t - (r + 1)\pi\, wk] - \cos\,[2\pi(rw - w_0)t - (r + 1)\pi wk]}{2\pi wt \sin\,(r + 1)\,\pi wk} + \frac{\cos\,[2\pi(rw - w_0)t - r\pi wk] - \cos\,[\,2\pi w_0 t - 2\pi wk]}{2\pi wt \sin r\pi wk}.$$

The reader is referred to Kohlenberg's paper for proof.

The instrumentation of Kohlenberg's method of sampling is not difficult. One could use an asymmetric multivibrator to generate a train of rectangular waves of differing lengths of positive and negative parts; or one could start with a combination of sine wave plus even harmonics and use a slicer to generate the equivalent waveform. Having thus obtained two interleaved sets of zero-crossings, pulses at the times of zero-crossing can be produced by suitable circuitry and used for the sampling of the signal.

D. A. BELL.

*Electrical Engineering Department,*
*The University of Birmingham, Birmingham.*
16th March 1959.

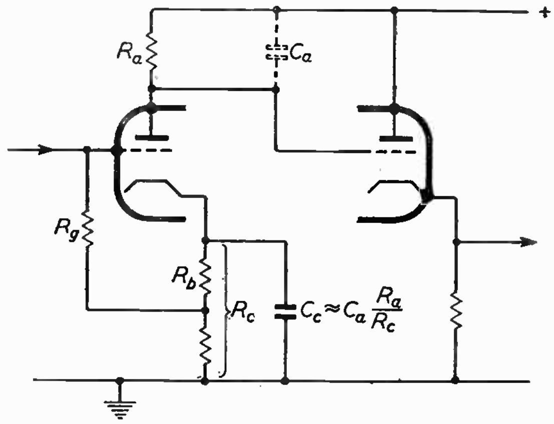
**REFERENCES**

[1] "Information Theory and its Engineering Applications", Pitman, 2nd edition 1956.
[2] A. Kohlenberg, "Exact Interpolation of Band-Limited Functions", *J. appl. Phys*, 1953, Vol. 24, p. 1432.

### Phase Inverter

SIR,—In your February issue Mr. Hajek presented (p. 76) a two-valve high input impedance phase inverter. In actual fact this circuit is equivalent to an ordinary amplifier with an anode load resistance of $r_a/(1+\mu)$. Compared to the usual anode follower, however, it has some drawbacks: the gain is necessarily a little below unity and, as a result of the lack of negative feedback, the maximum permissible input voltage is small.

The dual triode may be used in the circuit shown in the figure which does not present these disadvantages. Instead of the parallel feedback of the anode follower, series feedback is used here in order to obtain a high input impedance. If $R_b \approx 1/g_m$, $R_c \approx r_p$ and $R_a \approx r_a$ are chosen, the input resistance at low frequencies is $R_{in} \approx R_g \mu/4$.




The cathode follower assures a low value of output impedance (under $1/g_m$) and lowers the anode parasite capacitance of the first stage. The amplification is a little under $R_a/R_c$ and the bandwidth, at unity gain, is approximately that of the cathode follower.

*Bucharest,* VLAD M. PAUKER.
*Roumania.*
2nd April 1959.

# New Books

**Guide to the Literature of Mathematics and Physics including Related Works on Engineering Science.** 2nd Edition. By NATHAN GRIER PARKE III. Pp. 436 + xviii. Constable & Co. Ltd., 10–12 Orange Street, London, W.C.2. Price 20s.

The first part of this book, which is of American origin and paper-backed, occupies 74 pages and is entitled "General Considerations". It covers the principles of reading and study, self-directed education, literature search and periodicals.

The second part, "The Literature to 1956", comprises a list of books classified in subjects with some introductory matter to each main section. There are subject and author indexes.

The content is heavily over-weighted in favour of mathematics, and engineering aspects are rather cursorily covered. 'Television', for example, does not appear in the index at all, although one book on the subject is included under 'Textbooks on Communications', and 'radar' is also missing.

The literature on cathode-ray tubes is represented by 12 books of which about half are obsolete and of little but historical interest, while one is in the wrong section since it deals primarily with associated circuitry.

This is not the only example of misplacing books. The inclusion of a well-known book on a.f. amplification under the section heading of 'Noise' is a good example of unconscious humour.

In a work of this magnitude it is inevitable that there should be minor errors of this kind and too much importance should not be attached to them. The book will undoubtedly prove a useful guide to the literature. It is by no means confined to American publications; British, French and German references are frequent and there are some to the Russian.

Elementary books are rather few, the author's choice being usually the highbrow type, and there are rather too many semi-obsolete books. Eight books by Steinmetz, with publication dates ranging from 1914 to 1920, are stated to be included because of their historical interest. It is odd, however, that they should be in the section 'Textbooks on Electronics'!

It is quite evident from the arrangement of the material and the indexing that the author's subject is mathematics. Both are quite well done for this subject. They are less well done for physics and rather poorly for engineering. W.T.C.

### Electron Physics and Technology

By J. Thomson, M.A., Ph.D., D.Sc., M.I.E.E., F.Inst.P. and E. B. Callick, B.Sc., A.M.I.E.E. Pp. 527 + xiv. The English Universities Press Ltd., 102 Newgate Street, London, E.C.1. Price 50s.

When an eminent research worker and teacher combines with an eminent engineer from industry to write a book on electronic devices, the reader may well expect a feast of good things. There are many good things in this book, but neither the authors nor the publishers seem to know for whom these good things are intended. The editor of this series of books called "Physical Science Texts" talks about students and a sound general education but, on the cover, the book is described as being a standard work for professional physicists and engineers.

This uncertainty of aim is reflected in the book itself. The weakest part of it is the first section. This section contains a very tough and unpalatable review of electron physics. It might serve as a reminder of things learned elsewhere but would not be much help to a good honours student seeking for a first understanding of the subject.

However, after such an unpromising beginning, the book really gets into its stride. Conventional valves are discussed and then microwave devices, then cathode-ray tubes and a host of special-purpose devices such as image intensifiers and switching tubes. There is an excellent discussion of electron inertia effects and a very useful account of materials available and of techniques of construction. The treatment throughout the major part of the book is physical and descriptive rather than mathematical. This makes it a really useful reference book for professional physicists and engineers wishing to become acquainted with some of the more recent electronic devices. Students will find it rewarding to dip into this book, but it covers too vast a field to form an effective basis for the sound general education recommended by the editor of the series. P.H.

### Transform Method in Linear System Analysis

By J. A. Aseltine. Pp. 300 + xvi. McGraw-Hill Publishing Co. Ltd., 95 Farringdon Street, London, E.C.4. Price 66s.

This book belongs to the McGraw-Hill Electrical and Electronic Engineering Series. The author is Lecturer in Engineering at the University of California at Los Angeles. It is an engineering book, and most of the mathematics it contains is presented from the engineer's rather relaxed point of view regarding rigour. The approach is suitably heuristic.

The book is thorough, as American books so often are, and clear. There are plenty of explanatory diagrams, and where such devices as matrices have been used, they have been fully written out at each stage. This does make the argument much easier to follow, especially for a student who is trying to 'worry it out' for himself. In the reviewer's opinion, any extra space thus taken up is well used.

Laplace transforms are the main topic, but Fourier transforms and '$Z$-transforms' (for reducing difference equations to algebra in the same way as the Laplace transform or symbolic calculus reduces an ordinary differential equation to algebra) are also discussed. While the practical problems considered are mainly those associated with electrical networks, mechanical systems, systems with random input and difference equations are also mentioned.

The original work in this field was done by Fourier, a century or more ago. It is, however, by no means always convenient or appropriate to regard a function of, say, time as made up of a finite or infinite series of sinusoidal components. In practical electrical problems, we are usually concerned with the immediate results of a sudden change, caused say by the closing of a switch. Heaviside introduced his 'unit function' and his 'operational calculus' to deal with just this type of problem. It is important to note the word 'operational' in Heaviside's calculus. Heaviside (in his earlier work) used the symbol $p$ as equivalent to $d/dt$, so that $p$ was an operator, *not* a number as the corresponding symbol $s$ is in the present work. Contemporary Cambridge mathematicians disapproved of Heaviside's methods (though they were forced to accept his results), so later workers introduced 'symbolic calculus', 'Laplace transforms', etc., in a vain attempt to improve upon Heaviside. In the opinion of the reviewer and some of his colleagues, Heaviside's use of $p$ as an operator was entirely correct, though by no means clearly explained by him. If this operator is replaced by a mere number, ambiguities and even errors follow, and little progress can be made in problems such as frequency modulation, where the transform of the time function is extremely difficult to formulate explicitly.

Thus, while it is clear that the present book is good of its kind, there is some doubt as to whether it is of the right kind. J.W.H.

### Electronics Apparatus for Biological Research

By P. E. K. Donaldson, M.A. Pp. 718 + xii. Butterworth's Scientific Publications, 88 Kingsway, London, W.C.2. Price 120s.

The contents of this encyclopaedic volume range far more widely than its unassuming title would suggest. Part 1, dealing with basic theory, is in itself a textbook on electronic devices and their circuitry. Part 2, entitled "Practice", passes on the kind of information which comes as second nature after some years spent in acquiring it the hard way, but which is very difficult for the incidental user of electronics to come by. The advice on the choice of valves and tools and other equipment is up-to-date and sound and although £6 is a bit of an outlay, one feels that the worker who followed the guidance given here would save the cost of the book many times over.

In Part 3, on "Transducers, Electrodes and Indicators", the author has called in a team of specialists: Dr. J. W. L. Beament (Temperature, Humidity), Mr. F. W. Campbell (Light sources, Detectors), Dr. D. W. Kennard (Glass electrodes), Dr. R. D. Keynes (Radioactivity assay), Dr. K. E. Machin (Transducers, Relays), and Dr. I. A. Silver (Electrodes). Naturally, this is the really interesting part to the person reading the book from the electronics angle, for it shows the kind of problem the biologist meets in trying to convert his observational material into signals which can be amplified, measured and recorded. And the information given, while it could doubtless be assembled eventually from available sources of various vintages, could not be found anywhere grouped together so completely up-to-date.

Mr. Donaldson takes over again on his own for Part 4, on "Complete Apparatus", and ends the book with a chapter on Transistors—not an afterthought, but left till the end so as to be able to include as much recent material about them as possible. This is a valuable book and the care that has gone to its planning and production extends even to the binding—which is robust enough to withstand hard usage in the laboratory. G.R.N.

### The Theory and Design of Magnetic Amplifiers

By E. H. Frost-Smith, B.A., Ph.D., A.M.I.E.E. Pp. 487 + xix. Chapman & Hall Ltd., 37 Essex Street, London, W.C.2. Price 75s.

There are differences of opinion as to the best approach to the theory of magnetic amplifiers, and the fact that the present reviewer does not like this one does not necessarily mean that it is a bad book. For example, it seems a needless flight from physical fundamentals into engineering jargon to describe the energy storage in a magnetic core in terms of magnetomotive force and reluctance rather than $H$, $B$ and volume of core. On the other hand this book is fairly encyclopaedic in its coverage of the subject; it might replace the two books one has hitherto used (one on magnetic amplifiers and one on magnetic-amplifier circuits) with the advantage of a better treatment of fast-response magnetic amplifiers and of circuits incorporating transistors than is available in earlier books.

The first nine chapters give an exposition of the theory of transductors, with detailed analysis of gain and response time under various load conditions; the next two deal with balanced circuits and with low-level amplification, followed by a chapter on magnetic modulators. Chapter 13 is on construction and design, and chapter 14 on applications. The chapter title "Balanced Magnetic Amplifier Circuits" is misleading, for it does not refer to circuits which are symmetrical to the extent of balancing out standing current, but to circuits which can give an output of sign corresponding to the sign of the input. The difficulty of achieving this is insufficiently emphasized, both in this chapter and in the discussion of applications. Obviously one would need to read more than the one chapter on construction and design in this book to become a competent designer, but the book is a useful survey of the matter covered by its title. D.A.B.

**Electronic Circuits**

By E. J. Angelo, Jr. Pp. 450 + xiii. McGraw-Hill Publishing Co. Ltd., 95 Farringdon Street, London, E.C.4. Price 70s.

This book is intended to serve as "the basis for a one-year first course in electronics for juniors in electrical engineering". It covers the ideal and practical diodes and triodes in seven chapters and transistor amplifiers in two, with a further chapter on multigrid valves.

Analysis of circuits then follows, with a chapter on network theorems, and the four final chapters are Frequency dependence of single-stage amplifiers, Frequency dependence of cascade amplifiers, Non-sinusoidal signals and transient response and Feedback amplifiers.

The usual equivalent circuits for valves and transistors are developed in a straightforward and logical way. An unusual feature is the inclusion at an early stage of an equivalent circuit for a triode operating with a positive grid. This is similar to a transistor equivalent circuit and its presence does heighten somewhat the valve-transistor analogy.

The stress in the book is upon analysis and design. Mathematical expressions are used freely but the level is little above simple algebra with complex numbers. The general treatment is good and the book is one which should prove extremely useful to the serious student. W.T.C.

**Magnetic Tape Recording**

By H. G. M. Spratt, B.Sc.(Eng.), M.I.E.E. Pp. 319. Heywood & Co. Ltd., Ingersoll House, 9 Kingsway, London, W.C.2. Price 55s.

This book is intended for those engineers and technicians who, in the course of their work or leisure, are confronted with the task of building their own equipment or, at least, making modifications to existing apparatus of conventional design.

The first three chapters are devoted to the principles of magnetism, sound reproduction and electro-acoustics, and the principles of magnetic recording. Chapters 4, 5 and 6 deal with materials used in tape manufacture, the manufacture of the tape itself, and tape testing. Tape-recording machines, recording and reproducing machines for music and speech, and the testing of machines are dealt with in Chapters 9, 10 and 11, while the remaining three chapters give accounts of the application of magnetic recording, the present trends and new developments, and recording standardization. Appendixes on B.S.I. specifications and abnormal climatic effects are included and a bibliography is given at the end of each chapter.

**British Instruments: Directory and Buyers' Guide 1959**

Pp. 598. Published by the United Science Press Ltd., London, in association with the Scientific Instrument Manufacturers' Association of Great Britain, 20 Queen Anne Street, London, W.1. Price 42s.

The contents of this new publication include: The Scientific Instrument Manufacturers' Association and Other Associations Allied to the Instrument Industry; List of Specifications directly bearing on Instrument Matters by Official Bodies; List of Consultants, Engineers and Installers of Instrumentation Schemes; List of Firms Manufacturing Single or Small Batches of Instruments to a Client's Order; Classified Index of Products; Four-Language Glossary of Headings used in the Index of Products (English, French, German, Spanish); Alphabetical List of Instrument and Component Manufacturers with Overseas Agents; Trade Names; Manufacturers' Announcements; Display Advertisements.

**La Génération des Harmoniques Pairs par les Circuits de Redresseurs**

By J. Neirynck. Pp. 56. University Press, Lovanium University, P.O. Box 231, Leopoldville XI, Belgian Congo. Price 60 F.

**Investigations of the Disk-Loaded and Helical Waveguide**

By Bengt T. Henoch. Pp. 84. Transactions of the Royal Institute of Technology, Stockholm, Sweden. Price Kr. 9 (Swedish).

**The Autocorrelation and the Power Spectrum of Non-stationary Shot Noise**

By L. P. Hyvärinen. Pp. 23. Electrical Engineering Series No. 2. Published by the State Institute for Technical Research, Helsinki, Finland, and available from *Acta Polytechnica Scandanavica* Publishing Office, Box 5073, Stockholm 5, Sweden. Price Kr. 7 (Swedish).

This mathematical monograph deals essentially with the derivation of expressions for the autocorrelation function and the statistical power spectrum of non-stationary shot noise.

**Films for Industry 1959-60**

Pp. 151. Published for Her Majesty's Stationery Office. Available from the Central Office of Information, Hercules Road, Westminster Bridge Road, London, S.E.1. Price 2s. 6d.

A catalogue of 16-mm. films and filmstrips for industrial users.

**Spotlight on B.B.C. Television**

Pp. 22. B.B.C. Publications (Spotlight), 35 Marylebone High Street, London, W.1. Price 9d.

An elementary non-technical booklet which deals with the general aspects of television broadcasting, interference problems, etc.

**Radio Engineering Formulae and Calculations**

By W. E. Pannett. Pp. 200 + vii. George Newnes Ltd., Tower House, Southampton Street, Strand, London, W.C.2. Price 17s. 6d.

"The examples given in this book have been selected from everyday practice in the design and operation of radio installations, rather than for academic interest, and have been fully worked and generously illustrated by diagrams".

Intended for the practising engineer, this book will be found equally valuable to the technical assistant and the engineering student.

**International Radio Tube Encyclopaedia.** 3rd Edition. 1958–59

By Bernard B. Babani. Pp. 768. Bernards (Publishers) Ltd., The Grampians, Western Gate, London, W.6. Price 63s.

More than 27,500 radio valves of all classes are included in this new and enlarged edition.

**Principles of Electronics.** 2nd Edition

By H. Buckingham, Ph.D., M.Sc., A.M.I.E.E., and E. M. Price, M.Sc.(Tech.), A.M.I.E.E. Pp. 419. Cleaver-Hume Press Ltd., 31 Wright's Lane, London, W.8. Price 17s. 6d.

This edition includes additional chapters on transistors and magnetic amplifiers, together with a set of problems (with answers) for the reader to solve.

**Théorie et Pratique des Circuits de l'Electronique et des Amplificateurs.** Vol. 1. 3rd Edition

By J. Quinet. Pp. 235 + xviii. Dunod, Éditeur, 92 Rue Bonaparte, Paris (6e), France. Price 1,960 F.

This volume, in French, deals with the theory of complex numbers and its application to the study of electronic circuits.

**Reflex Klystrons**

By J. J. Hamilton, B.Sc.(Eng.). Pp. 260 +xi. Chapman & Hall Ltd., 37 Essex Street, London, W.C.2. Price 45s.

"The information contained in this monograph, which has been largely selected from numerous authoritative sources on velocity-modulated valves, is intended to provide a grasp of the essentials of reflex klystrons, to give an account of their history, position and scope in the field of microwave electronics, and to serve as a guide towards more vigorous study of these valves".

**Library Services and Technical Information for the Radio and Electronics Engineer**

Compiled and published by the British Institution of Radio Engineers, 9 Bedford Square, London, W.C.1. Pp. 72. Price 2s. 6d.

A library handbook which includes a catalogue of the contents of the Brit. I.R.E. library, up-to-date Institution reports on radio and electronic engineering literature and good engineering practice, information on international organizations concerned with radio and electronics, translating services, post-graduate fellowships and awards, and technical films on radio and electronics.

**Telecommunications.** 2nd Edition

By A. T. Starr, M.A., Ph.D., M.I.E.E. Pp. 470 + ix. Sir Isaac Pitman & Sons Ltd., Parker Street, Kingsway, London, W.C.2. Price 37s. 6d.

The only essential difference between this edition and the one published in 1954 is the inclusion of a number of problems set in recent examinations of the University of London.

The first edition was reviewed in the November 1954 issue of *Wireless Engineer*, so it need only be pointed out that the engineer and technician alike will find this book useful for reference.

**Encyclopédie des Isolants Electriques**

Pp. 80. Published by Swiss Electrotechnical Institution, 301 Seefeldstrasse, Zürich 8, Switzerland. Price Fr.22 (Swiss).

A handbook (in French) giving physical and chemical properties of electrical insulating materials.

**British Plastics Year Book 1959**

Pp. 644. Published by Iliffe & Sons Ltd., Dorset House, Stamford Street, London, S.E.1. Price 42s. (postage 1s. 9d.).

The contents of this 29th edition include a glossary of technical terms, tables of properties of plastics, new companies registered in 1958, specifications relating to plastics, a guide to plastics product manufacturers and plastics processors, a guide to equipment suppliers and to services, a directory of trade names, names and addresses of firms, etc., in the U.K. and overseas, technical and general data, and a 'Who's Who' section.

**A.C. Circuit Analysis**

Edited by Alexander Schure, Ph.D., Ed.D. Pp. 95 + vi. Electronic Technology Series No. 166–19. John F. Rider, Publisher, Inc., 116 West 14th Street, New York 11, N.Y., U.S.A. Price $1.80.

Contents include: Basic principles of alternating current; voltage and current values of a sine wave; resistance, inductance and capacitance; the *j* operator; series circuits; parallel circuits and series-parallel networks. Review questions are included at the end of each chapter.

## MEETINGS

**I.E.E.**

*8th May.* "Microwave Radiation Hazards", discussion to be opened by Dr. D. H. Shinn and Dr. N. L. Lloyd at 6 o'clock.

*13th May.* "The Application of Statistical Techniques to the Electronic Valve Industry", by E. G. Rowe, O.B.E., M.Sc., at 5.30.

*14th May.* Annual General Meeting followed at 6.30 by a lecture "On the Conceivable Future of Telecommunications" by Prof. E. C. Cherry, D.Sc.

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

**Brit. I.R.E.**

*13th May.* "Improving Communication Techniques—What have Engineers to learn from Information Theory?", by Prof. D. Gabor, F.R.S., at 6.30 at the London School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, London, W.C.1.

**Physical Society**

*14th May.* "High Energy Ultrasonics", by E. Neppiras, at 5.30 at Imperial College, Prince Consort Road, London, S.W.7.

*21st May.* Annual General Meeting at 5.30 followed at 5.45 by the Presidential Address on "Recent Trends in the Theory of the Ionosphere", by J. A. Ratcliffe, C.B.E., M.A., F.R.S., at the Royal Institution, 21 Albemarle Street, London, W.1.

**The Society of Instrument Technology**

*6th May.* Annual General Meeting at 5.30 followed at 6.30 by the Presidential Address, by J. F. Coales, O.B.E., M.A., to be held at Manson House, Portland Place, London, W.1.

**Institute of Navigation**

*15th May.* "Electronic Surveys in the Carribean", by Captain E. G. Irving, O.B.E., R.N., at 5.15 at the Royal Geographical Society, 1 Kensington Gore, London, S.W.7.

## M.Sc. COURSE IN INFORMATION ENGINEERING

A one-year graduate course in information engineering, which comprises electrical communications, electronic computers and automatic control systems, will be held at Birmingham University from 1st October 1959 to 30th September 1960.

Applications are invited from suitably qualified students, preferably with some industrial experience, who, on satisfactory completion of the course, will receive the degree of M.Sc.

The fee for the course is £81, and those who are interested should write to The Graduate Course Supervisor, Electrical Engineering Department, The University, Edgbaston, Birmingham 15.

## INFORMAL RESIDENTIAL CONFERENCES

The Electrical Engineering Department of the University of Birmingham is arranging two informal residential conferences in September 1959. The first, on Dielectric Devices, will be held from Monday 14th September to Thursday 17th September 1959; and the second, on Modern Network Theory, will be held from Monday 21st September to Thursday 24th September, 1959. Preliminary programmes of papers and discussions have already been arranged and those interested in attending are invited to write to the Secretary of the Electrical Engineering Department, The University, Birmingham 15, for full details. In order to preserve the informal nature of the conferences, numbers will have to be strictly limited.

## STANDARD FREQUENCY TRANSMISSIONS

(Communication from the National Physical Laboratory)
*Deviations from nominal frequency* for March 1959*

| Date 1959 March | MSF 60 kc/s 1500 G.M.T. Parts in $10^{10}$ | Droitwich 200 kc/s 1030 G.M.T. Parts in $10^8$ |
|---|---|---|
| 1 | N.M. | N.M. |
| 2 | − 196 | + 1 |
| 3 | − 195 | + 1 |
| 4 | − 193 | + 2 |
| 5 | − 193 | + 2 |
| 6 | − 193 | + 2 |
| 7 | − 194 | N.M. |
| 8 | − 194 | N.M. |
| 9 | − 192 | + 2 |
| 10 | − 192 | + 3 |
| 11 | − 190 | + 3 |
| 12 | − 189 | + 3 |
| 13 | − 190 | + 3 |
| 14 | − 190 | N.M. |
| 15 | − 189 | N.M. |
| 16 | − 185 | + 4 |
| 17 | − 189 | + 4 |
| 18 | − 185 | + 4 |
| 19 | − 186 | + 4 |
| 20 | − 187 | − 1 |
| 21 | − 191 | N.M. |
| 22 | − 189 | N.M. |
| 23 | − 190 | − 1 |
| 24 | − 188 | − 1 |
| 25 | − 187 | − 1 |
| 26 | − 186 | − 1 |
| 27 | − 185 | − 1 |
| 28 | − 186 | − 1 |
| 29 | − 185 | − 1 |
| 30 | − 185 | − 1 |
| 31 | − 185 | − 1 |

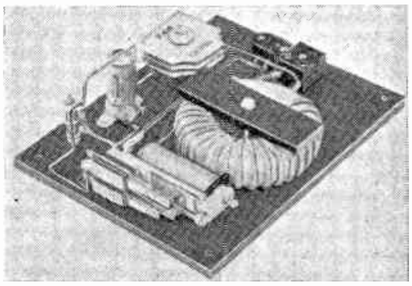
* *Nominal frequency is defined to be that frequency corresponding to a value of* 9 192 631 770 *c/s for the N.P.L. caesium resonator. NM = Not Measured.*

# New Products

### Automatic Load Indicator Unit

The Electrical Remote Control Co. Ltd. has produced a series of automatic load-indicator units, type ALI, which are capable of operating on low alternating currents and withstanding continuously heavy overloads. They are suitable for the testing of mass-produced domestic appliances (such as heater elements), contactors and motors with overload protection.

The unit, which is usually connected in series with an a.c. load on mains voltage, operates when a small alternating current saturates the choke (shown mounted alongside the relay in the photograph). The resulting voltage drop across the choke is utilized to operate the relay which then gives automatic signalling of the load. The



alternating-voltage drop across the choke is quite low and does not exceed 4 V at 100 A, while the switching-capacity rating of the relay is given as 5 A at 250 V a.c.

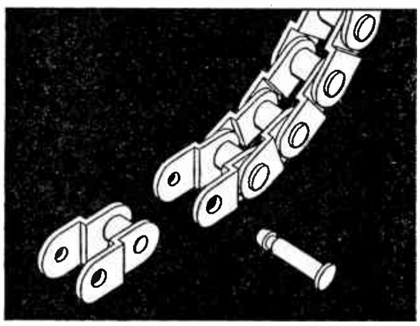
Units can be supplied for maximum loading of 20, 35, 50, 75 or 100 A at 250 V a.c., and they are claimed to be capable of detecting loads as low as 60 W at 250 V a.c.

*Electrical Remote Control Co. Ltd.,*
*Elremco Works, Harlow, Essex.*

### Nylon Chain

Nylon chain, suitable for lightweight positive drives such as on pyrometric, indicating and recording devices, is being produced by George Goodman Ltd.

Besides featuring low inertia, good electrical properties, high resistance to chemical attack and exceptional abrasion and wear resistance, the chain is also non-magnetic,



requires no lubrication and is noiseless in operation.

The drawing shows how the chain can be assembled by means of self-clinching pivot pins. These pins are easily removed from the assembled chain by cutting off the pin-head and the projecting shank at the opposite end. The arms of the link can then be freed and the remaining part of the rivet extracted.

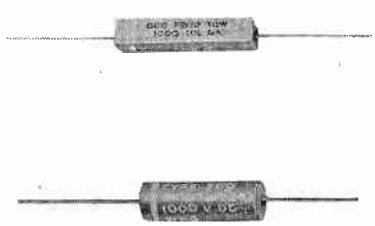
Chain can be supplied in any length (both open or closed to suit requirements), and at present is available in 8-mm pitch only with a static load rating of 5 lb. The makers, however, recommend that the driving load should not exceed 3 lb. when the chain is used for continuous or rapidly-intermittent operations.

*George Goodman Ltd.,*
*Robin Hood Lane, Birmingham* 28, *Warwicks.*

### Resistors and Capacitors

The Dubilier Condenser Co. Ltd. have extended their range of power wire-wound resistors to include 5, 7 and 10-W types, and have introduced a new series (type 560) of encapsulated paper-dielectric tubular capacitors designed to operate between −40 °C and +125 °C, and −40 °C and +70 °C on d.c. and a.c.-voltage applications, respectively.

The resistors (shown at the top of the photograph) comprise tightly and uniformly-



spaced wire, wound on silicone-processed glass-fibre cores. Solder-coated wire terminations are secured to these elements which are housed in ceramic cases (of rectangular section) and secured by means of special cement seals which mechanically bond to the ceramic cases, resistance elements and terminations. Some details from the makers' specification are given below:

| Type | PW-5 | PW-7 | PW-10 |
|---|---|---|---|
| Resistance values .. .. | 0·5 Ω–2 kΩ | 0·5 Ω–6·5 kΩ | 1 Ω–10 kΩ |
| Self-inductance (approx.) .. | 0·1–13 μH | 0·17–22 μH | 0·35–40 μH |
| Temp. Coeff. (−55 to + 275 °C) | | | |
| 0·05%/°C .. .. .. | 0·5–2·5 Ω | 0·5–8 Ω | 1–10 Ω |
| 0·03%/°C .. .. .. | 2·5 Ω–2 kΩ | 8 Ω–6·5 kΩ | 10 Ω–10 kΩ |
| Dimensions (inches) .. .. | 7/8 × 3/8 × 11/32 | 1 25/64 × 3/8 × 11/32 | 1 7/8 × 3/8 × 11/32 |

The capacitors (shown at the bottom of the photograph) are constructed from paper and foil elements (provided with inter-connections between electrodes and wire terminations) which have been impregnated with high-temperature plastics-material to produce solid capacitor elements. The formed wire terminations are inserted in the inter-connections and these are formed on and soldered to the wire terminations. The assembled elements are then housed by encapsulation in a mineral-loaded epoxy resin. The band printed on each capacitor denotes the outer-electrode termination.

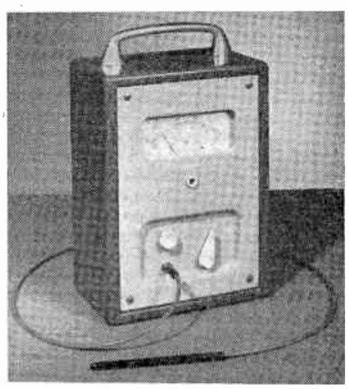
Details from the makers' data sheets include:

| | |
|---|---|
| Capacitance values and working voltage ratings .. | 0·001 μF (1,000 V a.c.)–0·1 μF (350 V d.c., 250 V a.c.) |
| Tolerances .. | ±20% (standard); ± 10% (by selection) |
| Power factor .. | <1% at 20 °C and 1·5 kc/s |
| Insulation resistance | >20,000 MΩ at 20 °C, 300 V d.c. |
| Dimensions .. | From 3/8 in. × 1 in. to 1/2 in. × 1 15/16 in. |

*The Dubilier Condenser Co.* (1925) *Ltd.,*
*Victoria Road, North Acton, London, W.*3.

### Electronic Thermometer

This battery-operated instrument, type LT100, has been designed to measure



temperature up to 100 °C (in two ranges) with an accuracy of ± 1 °C. It is particularly suitable for measuring component temperatures, the overheating of instruments, and thermal losses in solid and liquid systems.

Measurement is carried out by means of a probe unit (embodying a temperature-sensitive metallic oxide bead), connected to the instrument's sensitive d.c. bridge measuring circuit by a 3-ft moisture-sealed cable.

Two types of probe are available, immersion and contact types. The former is fitted with a glass-sealed head (suitable for immersion in liquids or gases) housed in an epoxy moulding which is sealed to a nylon-covered lead. The contact type has the oxide element sealed into the epoxide body of the probe, and a thin metallic cover acts as a thermal contact. The probes have very small heat capacities, so that errors due to the self-heating of the bead (during operation of the instrument) are negligible, and temperature readings are practically instantaneous.

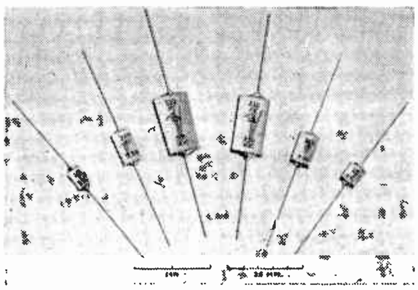
Models calibrated in °F can be supplied, if required.

*Wayne Kerr Laboratories Ltd.,*
*Chessington, Surrey.*

**Porcelain Dielectric Capacitors**

A new range of Vitramon (porcelain dielectric) capacitors has been introduced by The Plessey Co. Ltd.

Featuring close tolerances and negligible



capacitance drift characteristics, these components are available with d.c. working-voltage ratings of either 300 or 500 V.

Standard tolerances are given as $-5$ % or $0 \cdot 25$ pF (whichever is greater), and a noise level of less than 10 $\mu$V is guaranteed.

*The Plessey Co. Ltd.,*
*Ilford, Essex.*

**Circuit Magnification Meter**

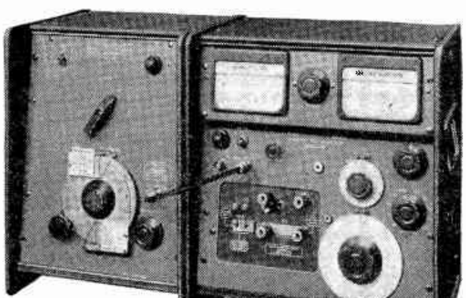
A $Q$-meter, type TF1245, covering the frequency range 1 kc/s to 300 Mc/s and capable of measuring directly $Q$ values from 5–1,000, has been produced by Marconi Instruments Ltd.

The oscillator section, which is housed in a separate unit, can be conveniently coupled to the instrument, as illustrated. Two oscillator units are available, the type TF1246 covering 40 kc/s to 50 Mc/s and type TF1247 covering 20–300 Mc/s. Below 40 kc/s, a low-frequency oscillator such as the Marconi TF1101 may be used. Simple matching transformers are available to allow the oscillators to be used independently as general-purpose signal sources.

The variable tuning capacitor of the instrument is calibrated from 500 pF down to $7 \cdot 5$ pF, and both low and high $Q$ values can be read accurately from a three-scale panel meter on which a $\Delta Q$ scale is also provided for indirect measurements and batch testing. A second meter shows $Q$ multiplying factors.

Optional accessories for use with the instrument include a wide selection of standard inductors, and test jigs for dielectric and series loss measurements.

*Marconi Instruments Ltd.,*
*St. Albans, Herts.*



**Polyester Film Thermosetting Tapes**

Permacel Tapes Ltd. have announced the addition of two new products to their range of pressure sensitive tapes. They are Permacel 62 (transparent) and 621 (orange) Melinex thermosetting electrical tapes.

Featuring high heat stability and resistance to abrasion, these tapes are suitable for use where continuous high operating temperatures up to 150 °C are encountered.

Both tapes are manufactured from 100 gauge Melinex polyester film spread with a thermosetting adhesive which, in its uncured state, has excellent pressure sensitive characteristics. After curing, the tape becomes bonded to the surface to which it has been applied, rendering it resistant to attacks from paint, varnish solvents and most transformer oils. The waterproof backing is highly resistant to acids, alkalis, etc.

*Permacel Tapes Ltd.,*
*Slough, Bucks.*

**Miniature Precision Potentiometer**

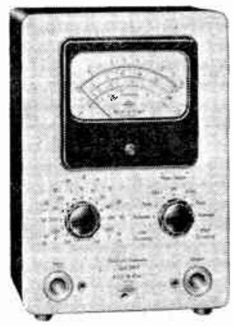
This miniature three-gang wire-wound precision potentiometer (type 8), which has an overall diameter of 0.75 in., a shaft diameter of 0.078 in. and weighing only half an ounce, has been designed for use in equipments (such as flight simulators) where it is required to provide analogue conversion from mechanical rotation to an electrical signal.

It is available with resistance values ranging from 1 kΩ to 25 kΩ (± 5% tolerance), a power rating of 1 W (no derating up to + 70 °C), a wiper pressure of about 1 gm, and an operating torque of the order of $0 \cdot 5$ gm/cm.

*Ferranti Ltd.,*
*Hollinwood, Manchester.*

**Valve Voltmeter**

The Danish firm of Brüel & Kjaer has produced an a.c. valve voltmeter, type 2409, which is suitable for peak, average and true



r.m.s. measurements ranging from approximately 1 mV up to 1 kV (in 11 ranges), and within the frequency range 2 c/s–200 kc/s.

The illuminated meter scale is calibrated in volts, dB (with reference to 1 V) and dBm (1 mV into 600 Ω). Provision is made for selecting two different meter damping characteristics so that accurate readings for both low- and high-frequency signals may be obtained.

The instrument can also be used as a calibrated amplifier having an output impedance of approximately 50 Ω.

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

**Decimal Indicator Tube**

A cold-cathode decimal indicator tube, type Z503M, suitable for use in high-speed stages of counting equipments, has been introduced by Mullard Ltd.

It comprises an anode and ten cathodes. Each cathode is brought out to a separate pin so that ten connections can be made to the counting circuit, the count being indicated by a glow discharge on the appropriate cathode. The tube gives 'end-on' viewing of the discharge, the position of which can be identified by an external numbered escutcheon.

The anode current rating is given as 60 $\mu$A, the minimum anode-to-cathode voltage necessary for ignition as 129 V (with some ambient light), and the extinguishing voltage (across the tube and a 500-kΩ resistor in series) as 105 V.

Mounted on a duodecal (B12A) base, the tube has a maximum seated height of 70 mm and a maximum diameter of 33 mm.

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

# 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

534.213.4 1422

**Influence of the Thickness of the Walls of a Resonance Tube on the Velocity of Sound in Liquids.**—C. Sălceanu & M. Zăgănescu. (*C. R. Acad. Sci., Paris*, 15th Sept. 1958, Vol. 247, No. 11, pp. 812–814.)

534.231-8-14 1423

**Theoretical Investigation of an Ultrasonic Field.**—N. Segard & J. Cassette. (*C. R. Acad. Sci., Paris*, 15th Sept. 1958, Vol. 247, No. 11, pp. 809–812.) The changes of pressure in a liquid caused by the vibrations of a piston-like quartz resonator are evaluated.

534.414 : 534.84 1424

**Investigations of Nonlinear Helmholtz Resonators.**—F. Barthel. (*Frequenz*, March 1958, Vol. 12, No. 3, pp. 72–82.) The causes of nonlinearity of the absorption coefficient in resonators as a function of sound intensity are analysed. Emphasizing these nonlinearities may be useful in improving room acoustics.

534.6 : 681.8 1425

**The Use of the Acoustic Spectrograph and the Problem of the Score in Experimental Music.**—A. Moles & V. Ussachevsky. (*Ann. Télécommun.*, Sept. 1957, Vol. 12, No. 9, pp. 299–304.)

534.75 1426

**Investigation of the Sensation of Loudness of Rhythmic Sounds.**—H. Niese. (*Hochfrequenztech u. Elektroakust.*, Jan. 1958, Vol. 66, No. 4, pp. 115–125.) Subjective tests on sinusoidal tones with sine-wave, rectangular-wave or pulse modulation show that loudness appears to increase at modulation frequencies below about 100 c/s. Results are compared with calculations of this 'inertia' effect in hearing, and conclusions are drawn for the design of objective loudness meters.

534.79 1427

**Proposal for a Loudness Meter for an Acoustically True Indication of Sounds with Peaked Waveform in Acoustic Fields of any Form.**—H. Niese. (*Hochfrequenztech. u. Elektroakust.*, Jan. 1958, Vol. 66, No. 4, pp. 125–139.)

534.84 1428

**On the Use of the Iteration Method in Room Acoustics.**—A. Moles. (*Ann. Télécommun.*, Dec. 1957, Vol. 12, No. 12, pp. 443–444.) A study of the progressive distortion of music or speech shows a separation of the relative constants of semantic and aesthetic information in each.

621.395.61 : 621.3.082 1429

**Research on Probe Microphones.**—I. Barducci & V. Degano. (*Ann. Télécommun.*, Dec. 1957, Vol. 12, No. 12, pp. 436–442.) Optimum dimensions for a probe microphone have been obtained from a study of frequency response curves plotted for various dimensions of the probe tube and cavity. The construction of the probe, experimental response curves and a formula for calculating the frequency response are given.

621.395.61.089.6 1430

**Various Methods of Absolute Calibration of Standard Microphones.**—R. Lehmann. (*Ann. Télécommun.*, Nov. 1957, Vol. 12, No. 11, pp. 393–408.) 30 references.

621.395.612.4 : 534.773.2 1431

**Technical Fundamentals and New Aspects of the Construction of Miniature Magnetic Microphones.**—W. O. Holleufer. (*Elektrotech. Z., Edn A*, 1st Aug. 1958, Vol. 79, No. 15, pp. 533–536.) The design and construction of microphones for hearing aids is discussed.

621.395.616 1432

**The Electrostatic Uniangular Microphone.**—H. F. Olson & J. Preston. (*J. Soc. Mot. Pict. Telev. Engrs*, Nov. 1958, Vol. 67, No. 11, pp. 750–753.) Description of a lightweight microphone comprising an e.s. transducer combined with an acoustic network. It has a uniform frequency response and good directivity.

621.395.623.7 1433

**The Response of Loudspeakers near the Principal Resonance.**—E. Paolini. (*Ann. Télécommun.*, Nov. 1957, Vol. 12, No. 11, pp. 387–391.) A theoretical study in which the loudspeaker is assumed to be fed by constant-current or constant-voltage signals whose frequency is compared with pressure along the loudspeaker axis.

621.395.623.8 : 621.396.721 1434

**Sound Distribution at the Brussels Exhibition.**—Martin. (See 1691.)

## AERIALS AND TRANSMISSION LINES

621.372.2 : 621.372.826 1435
**On the Propagation of Surface Waves over an Infinite Grounded Ferrite Slab.**—R. L. Pease. (*Trans. Inst. Radio Engrs*, Jan. 1958, Vol. AP-6, No. 1, pp. 13–20. Abstract, *Proc. Inst. Radio Engrs*, April 1958, Vol. 46, No. 4, p. 799.)

621.372.8.002.2 : 621.357.6 1436
**The Electroforming of Waveguide Components.**—P. Andrews. (*Electronic Engng*, March 1959, Vol. 31, No. 373, pp. 150–152.) Details are given of a simple acid-copper electroforming process for use in laboratory or small-scale production. The bath, electrical supply and mandrel materials required are described.

621.372.81.09 : 061.3 1437
**Waveguide Transmission.**—(*Wireless World*, March 1959, Vol. 65, No. 3, pp. 104–105.) A report is given of an I.E.E. Convention on 'Long-Distance Transmission by Waveguide' held in London, 29th-30th January 1959. Problems associated with the use of the $H_{01}$ mode in circular waveguides and with the single-wire surface-wave system are briefly discussed.

621.372.826 : 537.226 1438
**Excitation of a Transverse Magnetic Surface Wave Propagated on a Dielectric Cylinder.**—C. Jauquet. (*Ann. Télécommun.*, June 1957, Vol. 12, No. 6, pp. 217–233.) Detailed theoretical treatment (see 3031 of 1957) with a note of an experimental investigation of the surface-wave characteristics of a polystyrene rod.

621.372.852.323 : 621.318.134 1439
**Resonance Isolator at 70 kMc/s.**—L. C. Kravitz & G. S. Heller. (*Proc. Inst. Radio Engrs*, Feb. 1959, Vol. 47, No. 2, p. 331.) Describes a precessional-resonance waveguide isolator using an oriented Ba ferrite having an effective internal magnetization of 17 000 G. With an additional external field of 8 000 G the isolator gives an insertion loss of 1 dB and a reverse loss of 12 dB.

621.396.67 1440
**Driving Point and Input Admittance of Linear Antennas.**—T. T. Wu & R. W. P. King. (*J. appl. Phys.*, Jan. 1959, Vol. 30, No. 1, pp. 74–76.) "An infinity in the input admittance of linear antennas owing to the use of an idealized delta-function generator is investigated. It is shown that the infinity may be interpreted in terms of an infinite capacitance between the two halves of the antenna. The conclusion is reached that conventionally used iterative procedures are not invalidated by difficulties with respect to the driving point."

621.396.67 : 621.315.1 : 621.396.11.029.45 1441
**Power-Line Aerial.**—Golden, Langmuir, Macmillan & Rusch. (See 1672.)

621.396.67.012.12 1442
**On the Fresnel Approximation.**—R. B. Barrar & C. H. Wilcox. (*Trans. Inst. Radio Engrs*, Jan. 1958, Vol. AP-6, No. 1, pp. 43–48. Abstract, *Proc. Inst. Radio Engrs*, April 1958, Vol. 46, No. 4, p. 799.)

621.396.674 1443
**Four Simultaneous Transmissions from One Aerial.**—F. D. Bolt. (*Electronic Engng*, March 1959, Vol. 31, No. 373, pp. 168–170.) The aerial is a single slotted cylindrical type which radiates an effective power of 120 kW omnidirectionally on 88·1, 90·3, 92·5 and 94·7 Mc/s. The input voltage s.w.r. is not greater than 1·2.

621.396.674.3 1444
**Back-Scattering Cross-Section of a Centre-Loaded Cylindrical Antenna.**—Yueh-Ying Hu. (*Trans. Inst. Radio Engrs*, Jan. 1958, Vol. AP-6, No. 1, pp. 140–148. Abstract, *Proc. Inst. Radio Engrs*, April 1958, Vol. 46, No. 4, p. 800.)

621.396.677 1445
**The Prolate Spheroidal Antenna: Current and Impedance.**—C. P. Wells. (*Trans. Inst. Radio Engrs*, Jan. 1958, Vol. AP-6, No. 1, pp. 125–128. Abstract, *Proc. Inst. Radio Engrs*, April 1958, Vol. 46, No. 4, p. 800.)

621.396.677.32 1446
**End-Fire Echo Area of Long, Thin Bodies.**—L. Peters, Jr. (*Trans. Inst. Radio Engrs*, Jan. 1958, Vol. AP-6, No. 1, pp. 133–139. Abstract, *Proc. Inst. Radio Engrs*, April 1958, Vol. 46, No. 4, p. 800.)

621.396.677.833 1447
**An Omnidirectional Vertically Polarized Paraboloid Aerial.**—E. O. Willoughby & E. Heider. (*Proc. Instn Radio Engrs, Aust.*, Oct. 1958, Vol. 19, No. 10, pp. 554–555.) A preliminary note giving a brief description of the aerial. At 28·7 cm λ the half-power beam width is 6·6°.

621.396.677.833 1448
**Wide-Angle Scanning with Microwave Double-Layer Pillboxes.**—W. Rotman. (*Trans. Inst. Radio Engrs*, Jan. 1958, Vol. AP-6, No. 1, pp. 96–105. Abstract, *Proc. Inst. Radio Engrs*, April 1958, Vol. 46, No. 4, p. 800.)

621.396.677.833.2 1449
**Surface-Wave Beacon Antennas.**—R. E. Plummer. (*Trans. Inst. Radio Engrs*, Jan. 1958, Vol. AP-6, No. 1, pp. 105–114. Abstract, *Proc. Inst. Radio Engrs*, April 1958, Vol. 46, No. 4, p. 800.)

621.396.677.85 1450
**Experimental Test on some Microwave Configuration Lenses.**—P. F. Checcacci & V. Russo. (*Alta Frequenza*, April 1958, Vol. 27, No. 2, pp. 92–107.) Report on tests carried out with two conflection-refraction lenses and a conflection doublet [see e.g. *J. opt. Soc. Amer.*, Aug. 1955, Vol. 45, No. 8, pp. 621–624 (Toraldo di Francia)]. Radiation and wavefront diagrams are given.

621.396.679.1 1451
**The Distribution of Lightning Currents in the Earthing System of a Radio Mast.**—W. Griesinger, E. Popp & E. Schulz. (*Elektrotech. Z., Edn A*, 1st Aug. 1958, Vol. 79, No. 15, pp. 526–529.) The protection of telephone cables anchored to radio masts is considered; this can be achieved by enlarging the earthing system, particularly in mountainous regions, and by special screening of the telephone cable.

## AUTOMATIC COMPUTERS

681.142 1452
**Digital Techniques for Small Computations.**—Y. Lundh. (*J. Brit. Instn Radio Engrs*, Jan. 1959, Vol. 19, No. 1, pp. 37–44.) A special digital method of computing simple algebraic functions with one to four variables is described and analysed. The method is particularly suited to division and root extraction.

681.142 1453
**Automatic Failure Recovery in a Digital Data Processing System.**—R. J. Doyle, R. A. Meyer & R. P. Pedowitz. (*IBM J. Res. Developm.*, Jan. 1959, Vol. 3, No. 1, pp. 2–12.) A program is described which automatically compensates for computer malfunctions so that recovery from errors may be effected with a negligible loss of operational time.

681.142 1454
**Representation, Grouping and Processing of Information in Automatic Data Processing.**—H. Zschekel. (*Elektrotech. Z., Edn A*, 11th Sept. 1958, Vol. 79, No. 18, pp. 617–624.)

681.142 1455
**A Sensing System for Punched Cards or Continuous Punched Foil.**—S. Morleigh. (*Electronic Engng*, March 1959, Vol. 31, No. 373, pp. 140–141.)

681.142 1456
**Logic Synthesis of some High-Speed Digital Comparators.**—M. Nesenbergs & V. O. Mowery. (*Bell Syst. tech. J.*, Jan. 1959, Vol. 38, No. 1, pp. 19–44.) Logical schemes are derived by Boolean algebra methods. Circuits satisfying the synthesis requirements and giving either exact or approximate proportional comparison are described.

681.142 1457
**Function Generator for Sines or Cosines.**—H. Schmid. (*Electronics*, 23rd Jan. 1959, Vol. 32, No. 4, pp. 48–50.) Operation of the transistorized unit described is based on the fact that the area under a sine curve varies as a cosine function. Basic components required are a linear pulse-width modulator, an ideal switch (two *p-n-p* transistors connected emitter-to-emitter), an integrator and a sine-wave source.

681.142 : 537.311.33 : 546.281.26 1458
**An Analogue Multiplier-Divider using Thyrites.**—A. A. Maslov. (*Avtomatika i*

*Telemekhanika*, April 1957, Vol. 18, No. 4, pp. 336–348.) A new analytical method is proposed for determining quadratic elements using thyrite resistors. A description is given of a new multiplier with thyrite units which requires only two operational amplifiers. Experimental results are given.

681.142 : 621-526 **1459**

**Logic for a Digital Servo System.**—R. W. Ketchledge. (*Bell Syst. tech. J.*, Jan. 1959, Vol. 38, No. 1, pp. 1–17.) A c.r. tube beam in a photographic storage system is positioned by comparing a binary address with a digital indication of the present position. Digital servo logic circuitry is described for obtaining the sign and magnitude of the positional error.

681.142 : 621.318.5 **1460**

**An Electron Analyser of Contact Circuits.**—V. N. Rodin. (*Avtomatika i Telemekhanika*, May 1957, Vol. 18, No. 5, pp. 437–443.) A description is given of an apparatus for rapid determination of possible combinations in the operation of a circuit comprising six relays. One of the possible uses of the apparatus is the simplification of the existing circuits by removing the unnecessary contacts.

681.142 : 621.318.57 **1461**

**The Multipurpose Bias Device: Part 2—The Efficiency of Logical Elements.**—B. Dunham, D. Middleton, J. H. North, J. A. Sliter & J. W. Weltzien. (*IBM J. Res. Develpm.*, Jan. 1959, Vol. 3, No. 1, pp. 46–53.) "The efficiency of a logical element can be equated with the set of subfunctions it realizes upon biasing or duplication of inputs. Various classes of elements are considered, and optimum or near-optimum examples are presented. Some related areas of study are suggested." Part 1: 38 of 1958 (Dunham).

681.142 : 621.318.57 : 538.221 **1462**

**Millimicrosecond Magnetic Gating and Storage Element.**—D. A. Meier. (*J. appl. Phys.*, Jan. 1959, Vol. 30, No. 1, pp. 122–123.) The element consists of a round glass rod which is first chemically plated with a silver conductor and then electroplated with an Fe-Ni film. The element has an almost square saturation loop.

681.142 : 621.318.57 : 621.318.134 **1463**

**The Laddic—a Magnetic Device for Performing Logic.**—U. F. Gianola & T. H. Crowley. (*Bell Syst. tech. J.*, Jan. 1959, Vol. 38, No. 1, pp. 45–72.) The Laddic is a ladder-like structure cut from rectangular-hysteresis-loop ferrite. All magnetic paths are flux-limited. By controlling the actual switching path any Boolean function of *n* variables can be produced.

681.142 : 621.395.625.3 **1464**

**Tape Recording System speeds Data Processing.**—Way Dong Woo. (*Electronics*, 6th Feb. 1959, Vol. 32, No. 6, pp. 56–58.) A p.w.m. tape recording system is described with a capacity of 60 000 digits. The tape is 3 in. wide and carries 36 channels. The transport mechanism is electronically controlled and can start, stop and reverse within a few milliseconds.

681.142 : 621.396.962.012 **1465**

**An Analogue Computer for Evaluating Radar Performance.**—C. C. Willhite & J. W. McIntyre. (*Bell Lab. Rec.*, Jan. 1959, Vol. 37, No. 1, pp. 16–19.) Describes briefly the basic design of an analogue computer developed to evaluate the statistical information needed to assess radar tracking performance.

681.142 : 629.13 **1466**

**Application of Analogue Calculation to Flight Simulators.**—J. W. Swift. (*Rev. HF, Brussels*, 1958, Vol. 4, No. 1, pp. 1–10.) Computer elements for simulating the reactions resulting from the effects of gyration, pitch and roll are described.

## CIRCUITS AND CIRCUIT ELEMENTS

621.314.2 : 621.372.4 **1467**

**The Transformer as a Two-Terminal Network.**—W. Klein. (*Arch. elekt. Übertragung*, March 1958, Vol. 12, No. 3, pp. 133–137.) The equivalent two-terminal networks are derived for various types of transformer.

621.314.2 : 621.372.51 **1468**

**On Hybrid Transformers.**—H. O. Friedheim. (*A.T.E. J.*, July 1958, Vol. 14, No. 3, pp. 218–228.) Design formulae are derived from basic assumptions, and the properties and some common uses of these circuit elements are discussed.

621.314.2.073.3 : 621.318.124 : 621.374.3 **1469**

**Premagnetization of the Core of a Pulse Transformer by means of Ferroxdure.**—H. G. Bruijning & A. Rademakers. (*Philips tech. Rev.*, 27th July 1957, Vol. 19, No. 1, pp. 28–37.) Premagnetization to improve the loading of the core of a transformer carrying unidirectional pulse currents is examined theoretically. A practical transformer is described.

621.314.5 : 621.314.7 **1470**

**High-Power Transistor D.C. Converters.**—T. R. Pye. (*Electronic Radio Engr*, March 1959, Vol. 36, No. 3, pp. 96–105.) Circuits are considered for d.c./d.c. or d.c./a.c. converters using Ge and Si power transistors which can give power outputs of up to 100 W.

621.318.57 : 621.318.435 **1471**

**Saturable-Transformer Switches.**—B. D. Simmons. (*Electronic Radio Engr*, March 1959, Vol. 36, No. 3, pp. 82–90.) A switch using cores in a balanced saturable transformer is considered. An on-off impedance ratio adequate for switching magnetic recording heads for reading and writing operations can be obtained. Circuits are described for operation of a matrix selection system with a switching time of a few tens of microseconds.

621.319.4 : 537.227 : 621.396.662 **1472**

**Ferroelectrics tune Electronic Circuits.**—T. W. Butler, Jr. (*Electronics*, 16th Jan. 1959, Vol. 32, No. 3, pp. 52–55.) Circuits are described in which varying bias is used to change the capacitance of ferroelectric capacitors used as tuning elements.

621.319.4.015.5 **1473**

**Direct-Voltage Instantaneous Breakdown of Oil-Impregnated Paper Capacitors as a Function of Area.**—D. S. Girling. (*Elect. Commun.*, 1958, Vol. 35, No. 2, pp. 83–92.) The experimental results given show that the variation of mean breakdown voltage with increasing area is represented adequately by Milnor's equation. The coefficient of variation appears to be independent of area but decreases with increasing thickness of dielectric.

621.319.42 : 621.315.616.98 **1474**

**A Comparison of Wool Wax and Petroleum Jelly as Impregnants for Paper Capacitors.**—J. S. Dryden & R. J. Meakins. (*Proc. Instn Radio Engrs, Aust.*, Oct. 1958, Vol. 19, No. 10, pp. 551–553.) Results given show that wool wax impregnants give about 10% higher capacitance without any serious loss in performance.

621.372.412.012.8 **1475**

**The Equivalent Circuit of Oscillating Piezoelectric Crystal Rods.**—J. Tichý. (*Ann. Phys., Lpz.*, 20th May 1958, Vol. 1, Nos. 4/5, pp. 219–231.) Formulae are derived for calculating the circuit parameters for longitudinal, torsional and flexural oscillations taking account of internal damping and the air gap between electrodes and crystal.

621.372.45 **1476**

**Voltage- and Current-Controlled Negative-Resistance Two-Poles.**—L. Piglione. (*Alta Frequenza*, April 1958, Vol. 27, No. 2, pp. 138–152.) The mechanism of voltage and current control in two-pole networks is discussed. Equations for obtaining the equivalent circuits from direct measurements at the network terminals are given.

621.372.5 **1477**

**The Geometrically Simplest Form of Representation of the General Lossy Quadripole.**—J. de Buhr. (*Arch. elekt. Übertragung*, March 1958, Vol. 12, No. 3, pp. 127–132.) The transformation discussed is based on a construction of four planes perpendicular to each other in pairs in a non-Euclidean system. It can be represented in a drawing by stereographic projection.

621.372.5 **1478**

**Coupling Coefficients of Ladder Networks with Maximally Flat Amplitude Response.**—R. A. Waldron. (*J. Brit. Instn Radio Engrs*, Jan. 1959, Vol. 19, No. 1, pp. 63–71.) The coefficients are expressed in terms of the dissipations in the input and output branches, using a generalized theory of Green's method of solution (370 of 1955).

621.372.5 **1479**

**H.F. Wide-Band Electronic Integrator Design.**—H. Hodara. (*Electronic Ind.*, Oct. 1958, Vol. 17, No. 10, pp. 96–100.) Compensation for distortion of the integrated waveform due to valve output capacitances can be introduced by the addition of a capacitor in parallel with the integrating-network resistance. An expression is derived for calculating this capacitance for the basic *RC* integrator and the Miller integrator.

621.372.51 **1480**

**Impedance Converters.**—F. Molo. (*Alta Frequenza*, April 1958, Vol. 27, No. 2, pp. 120–137.) The quadripole relations and equivalent circuits of negative-impedance converters are summarized and applied to practical unbalanced converter circuits with valves and transistors.

621.372.55 **1481**

**A Laguerre Function Equalizer.**—H. Mumford & E. J. Osborne. (*A.T.E. J.*, July 1958, Vol. 14, No. 3, pp. 196–202.) A waveform corrector is described in which the input signal is successively differentiated and the differentials added to or subtracted from the input, the waveforms being given by Laguerre functions. Results are given for an experimental equalizer which need contain only passive elements.

621.373.4-523.6 **1482**

**Constant-Frequency Oscillators without Stabilized Voltage Supplies.**—W. Wisotzky. (*Elektronik*, March 1958, Vol. 7, No. 3, pp. 79–80.) Four valve oscillators controlled by thermistor bridge circuits are described.

621.373.421.13 **1483**

**The Design of Crystal-Controlled Three-Terminal Valve Oscillators.**—F. Rockstuhl. (*Telefunken Ztg*, April 1958, Vol. 31, No. 119, pp. 50–58. English summary, pp. 68–69.) Design formulae for the Pierce-Miller and Pierce-Colpitts circuits are derived taking account of the effect of crystal resistance on frequency.

621.373.421.13 **1484**

**Stable, Low-Cost 1-Mc/s Oscillator.**—J. F. Mercurio, Jr. (*Electronics*, 6th Feb. 1959, Vol. 32, No. 6, pp. 50–51.) Description of a crystal-controlled transistorized oscillator with frequency stability within 1 part in $10^9$ per day at normal room temperatures. Total weight of oven and oscillator is 2·5 lb.

621.373.421.13 : 621.396.666 : 621.396.11 **1485**

**Frequency Stepper for Radio Propagation Tests.**—E. H. Hugenholtz, A. Seljak & A. Towle. (*Electronics*, 23rd Jan. 1959, Vol. 32, No. 4, pp. 44–46.) Full circuit details are given of a stepped-frequency exciter unit controlling a pulse transmitter and receiver at widely separated locations. The range 25·05–48·95 Mc/s is covered in 100-kc/s steps at 1-sec intervals. 100-kc/s and 1-Mc/s crystals are used as reference-frequency sources, and frequency control is achieved by means of a beam-deflection tube. Transmitter and receiver circuits are briefly described: the transmitter radiates 25-$\mu$s pulses with repetition frequency 30/sec or 15/sec and output power 10–20 kW.

621.373.421.14 : 621.385.029.64 **1486**

**A Barkhausen-Kurz Oscillator at Centimetre Wavelengths.**—E. M. Boone, M. Uenohara & D. T. Davis. (*Trans. Inst. Radio Engrs*, July 1958, Vol. ED-5, No. 3, pp. 196–205. Abstract, *Proc. Inst. Radio Engrs*, Nov. 1958, Vol. 46, No. 11, pp. 1890–1891.)

621.373.421.14 : 621.396.962.23 **1487**

**Dual-Cavity Microwave Discriminator.**—M. Rudin, R. E. Shafer & B. W. Baker. (*Electronics*, 16th Jan. 1959, Vol. 32, No. 3, pp. 74, 76.) Intended for stabilizing reference klystron oscillators used in Doppler-shift radar systems. Tuning range is ±50 Mc/s, thermal drift 1 part in $10^7$ per °F, and discriminator sensitivity 1·5 V per Mc/s.

621.373.431 **1488**

**The Generation of Extremely Steep Pulse Edges in Multistage Nonlinear Amplifiers.**—G. Kohn. (*Arch. elekt. Übertragung*, March 1958, Vol. 12, No. 3, pp. 109–118.) The pulse generator described incorporates three transformer-coupled amplifier stages for sharpening the multivibrator pulses; it can supply 100-V 50-$\mu$s pulses with a rise time $<3$ m$\mu$s into a 60-Ω load.

621.373.52 : 621.376.3 **1489**

**Transistorized F.M. Oscillator.**—P. W. Wood. (*Electronics*, 30th Jan. 1959, Vol. 32, No. 5, p. 64.)

621.375.1.018.424 **1490**

**The Amplification of Very Wide Frequency Bands.**—K. H. Fischer & G. Daisenberger. (*Elektrotech. Z., Edn A*, 11th Sept. 1958, Vol. 79, No. 18, pp. 625–632.) Various techniques for amplification in bandwidths exceeding 100 Mc/s are discussed and the suitability of cascade and distributed amplifiers is investigated. Direct and indirect methods of delay-line equalization are outlined and details are given of a seven-stage distributed amplifier with 10 dB gain over a 125-Mc/s band.

621.375.121 **1491**

**Wide-Band Amplifier Design Data.**—R. H. Engelmann. (*Electronics*, 6th Feb. 1959, Vol. 32, No. 6, pp. 48–49.) Design data are tabulated for three basic types of coupling, *RC*, shunt-peaked and series-peaked. Gain is calculated using a series of approximations taking account of the gain reduction factor for a number of stages.

621.375.121.2 **1492**

**Extended-Range Distributed-Amplifier Design.**—J. J. Eichholz, C. F. Nelson & G. T. Weiss. (*Rev. sci. Instrum.*, Jan. 1959, Vol. 30, No. 1, pp. 1–6.) "A distributed amplifier employing a straight-wire transmission line is described. The amplifier has a gain of 15 ± 3 dB from 10 to 400 Mc/s, and input and output impedances of 50 Ω. Detailed electrical and mechanical design considerations are included."

621.375.132.3.029.3 **1493**

**An Inexpensive Ultralinear Output Stage.**—I. F. Barditch. (*Electronic Ind.*, Oct. 1958, Vol. 17, No. 10, p. 89.) A circuit is described which uses two cathode followers in place of a tapped output transformer.

621.375.23 : 621-52 **1494**

**Operational Amplifier without a Stabilized Power Supply.**—V. M. Evseev. (*Avtomatika i Telemekhanika*, May 1957, Vol. 18, No. 5, pp. 427–436.) A new operational amplifier is proposed in which two parallel circuits for low and high frequencies are used, with a summing amplifier and two feedback circuits. The theory of the amplifier is discussed and some experimental results are given. For a mains voltage variation of ± 10 V, the output voltage of the amplifier varies by 16 mV with a drift rate of 45 $\mu$V/sec.

621.375.3 **1495**

**On the Theory of a Half-Wave Magnetic Amplifier.**—R. A. Lipman & I. B. Negnevitskiĭ. (*Avtomatika i Telemekhanika*, April & May 1957, Vol. 18, Nos. 4 & 5, pp. 349–370 & 449–465.) A detailed theoretical analysis is given of an amplifier proposed by Ramey (see 3503 and 3507 of 1953.) Experimental results confirm the theoretical conclusions.

621.375.4 **1496**

**Differential Amplifier features D.C. Stability.**—W. T. Matzen & J. R. Biard. (*Electronics*, 16th Jan. 1959, Vol. 32, No. 3, pp. 60–62.) Drift in transistorized amplifiers is analysed and circuits for reducing drift are described for a particular amplifier. A 12-h test showed the equivalent input drift to be less than 60 $\mu$V from 70° to 80 °C.

621.375.4 (083.57) **1497**

**Nomographs for Designing Transistor Narrow-Band Amplifiers.**—L. M. Krugman. (*Electronic Ind.*, Oct. 1958, Vol. 17, No. 10, pp. 78–81.)

621.375.4.024 **1498**

**Transistor Amplifiers for D.C. Signals.**—H. Kemhadjian. (*Mullard tech. Commun.*, Dec. 1958, Vol. 4, No. 36, pp. 162–172.) Basic direct-coupled and chopper-type amplifiers are examined and compared.

621.375.4.029.3 : 534.6 **1499**

**A Low-Noise Transistor Amplifier for Acoustic Measurements.**—E. R. Hauri. (*Tech. Mitt. PTT*, 1st April 1958, Vol. 36, No. 4, pp. 142–144.) The portable equipment described has a gain of about 60 dB and a frequency range 30 c/s–15 kc/s with noise output 3·5 dB above the theoretical minimum.

621.375.9 : 538.569.4.029.6 **1500**

**The Maser: a New Form of Microwave Oscillator.**—C. M. Cade. (*J. Telev. Soc.*, Oct.–Dec. 1958, Vol. 8, No. 12, pp. 509–511.) A short review of the principles of operation of molecular-beam and solid-state masers.

621.375.9 : 538.569.4.029.6 **1501**

**Small-Signal Analysis of Molecular-Beam Masers.**—J. C. Helmer. (*J. appl. Phys.*, Jan. 1959, Vol. 30, No. 1, pp. 118–120.) A perturbation calculation gives the resonance polarization of a molecule in an electric field as a function of time. An analysis is then made of maser operation with a divergent, univelocity beam.

621.375.9 : 538.569.4.029.6 **1502**

**Three-Level Solid-State Maser.**—S. M. Bergmann. (*J. appl. Phys.*, Jan. 1959, Vol. 30, No. 1, pp. 35–36.) The maximum values of the real and imaginary components of the paramagnetic susceptibility of a three-level solid-state maser are calculated. General expressions for the gain and bandwidth of a travelling-wave maser are given.

621.375.9.029.64 : 621.3.011.23 **1503**

**Low Noise in Solid-State Parametric Amplifiers at Microwave Frequencies.**—W. E. Danielson. (*J. appl. Phys.*, Jan. 1959, Vol. 30, No. 1, pp. 8–15.) "The principles of parametric amplification are described through the use of simple low-frequency electrical circuits and their mechanical analogues. Extension of these principles to low-noise amplification at microwave frequencies is made in a qualitative way which emphasizes the physical processes involved. Amplification is only achieved when energy is transferred from a microwave oscillator or pump to the signal frequency, and it is shown why such a transfer may take place in circuits exhibiting variable capacitance or inductance but not in circuits where only a resistance is varied. Major noise sources are discussed and the special role of the image or idler frequency is noted. Finally, experimental data on four different types of parametric amplifier (3 using semiconductor diodes and 1 using ferrite) are given."

621.376.3 : 621.3.018.78 **1504**

**Calculation of Harmonic Distortion in Sinusoidal Frequency Modulation. Cases of a Waveguide of any Cross-Section and an Amplification Stage with a Tuned Transformer.**—L. Robin. (*Ann. Télécommun.*, Dec. 1957, Vol. 12, No. 12, pp. 415–418.) See also 1282 of 1953 (Robin).

## GENERAL PHYSICS

537.212 : 537.291 **1505**

**Potential of an Electrostatic Field and Trajectories of Charged Particles.**—G. Sacerdoti & R. Toschi. (*Alta Frequenza*, April 1958, Vol. 27, No. 2, pp. 108–119.) A procedure is described for calculating the electric potential in the proximity of the path of a charged particle.

537.222 : 621.314.63 **1506**

**Solutions for the Static Junction.**—L. Gold. (*J. Electronics Control*, Nov. 1958, Vol. 5, No. 5, pp. 427–431.) Discussion of certain classes of solution of the nonlinear differential equation for the potential distribution near a *p-n* junction. An inverse series solution is developed which is appropriate for diverse impurity distribution.

537.311.1 **1507**

**A New Method for the Evaluation of Electric Conductivity in Metals.**—S. F. Edwards. (*Phil. Mag.*, Sept. 1958, Vol. 3, No. 33, pp. 1020–1031.) A method is developed for evaluating the closed formal expressions for electrical conductivity which have recently been developed. See e.g. 1105 of 1958 (Kohn & Luttinger) and 2361 of 1958 (Greenwood).

537.534.8 **1508**

**Secondary Positive Ion Emission from Metal Surfaces.**—R. C. Bradley. (*J. appl. Phys.*, Jan. 1959, Vol. 30, No. 1, pp. 1–8.) Secondary positive ions ejected from surfaces of Mo, Ta, and Pt under bombardment by inert gas ions of low energy (< 1 000 eV) have been studied in high vacuum using a mass spectrometer with a 6-in. radius of curvature and a 60° sector field.

537.56 **1509**

**Current/Voltage Behaviour in a Plasma.**—L. Gold. (*J. Electronics Control*, Nov. 1958, Vol. 5, No. 5, pp. 432–434.) An exact solution for the current/voltage relation in a planar diode filled with a uniform plasma.

537.56 : 537.122 **1510**

**Electron Recombination and Negative Bands in Afterglowing Active Nitrogen.**—H. H. Brömer & V. Stille. (*Optik, Stuttgart*, June 1958, Vol. 15, No. 6, pp. 382–388.) The emission of negative bands in the auroral afterglow of nitrogen is interpreted as being due to excitation of molecular ions; this is supported by recent measurements of the decay of light intensity of these bands.

537.56 : 538.56 **1511**

**A Note on the Confinement of a Plasma by R.F. Fields.**—E. S. Weibel. (*J. Electronics Control*, Nov. 1958, Vol. 5, No. 5, pp. 435–538.) A rigorous derivation of certain results previously obtained by Boot et al. (3411 of 1958) by inferior methods.

537.56 : 538.561 **1512**

**Microwave Emission from High-Temperature Plasmas.**—D. B. Beard. (*Phys. Rev. Lett.*, 1st Feb. 1959, Vol. 2, No. 3, pp. 81–82.) Energy losses from cyclotron radiation are concluded to be negligible for plasma temperatures less than 100 keV and probably for those greater than 100 keV. Emission at the fundamental frequency and first few harmonics is detectable, and measurement of the relative intensities offers a means of determining the plasma temperature.

537.56 : 538.566 **1513**

**Excitation of Oscillations in a Plasma Layer.**—M. Sumi. (*Phys. Rev. Lett.*, 15th Jan. 1959, Vol. 2, No. 2, pp. 37–39.) Development of a linearized theory of plasma oscillations excited by an electron beam injected into a uniform plasma.

538.3 : 535.13 **1514**

**Laws of Magnetism and of Static Electricity in any Given Frame of Reference.**—H. Arzeliès & J. Henry. (*C.R. Acad. Sci., Paris*, 15th Sept. 1958, Vol. 247, No. 11, pp. 815–817.) A study of Maxwell's equations in terms of the general theory of relativity is made as a preliminary to attempting to solve practical electrical problems.

538.566 : 535.42 **1515**

**On the Diffraction of Electromagnetic Waves at Infinitely Thin Ideally Conducting Flat Screens.**—G. A. Grinberg & Yu. V. Pimenov. (*Zh. tekh. Fiz.*, Oct. 1957, Vol. 27, No. 10, pp. 2326–2339.) A new method is described based on the solution of two independent equations. As an example, the case of diffraction of a wave at an infinitely thin conducting disk is discussed.

538.566 : 535.42 **1516**

**Electromagnetic Diffraction by Dielectric Strips.**—D. C. Stickler. (*Trans. Inst. Radio Engrs*, Jan. 1958, Vol. AP-6, No. 1, pp. 148–151. Abstract, *Proc. Inst. Radio Engrs*, April 1958, Vol. 46, No. 4, p. 800.)

538.566 : 535.43 **1517**

**An Analytical Study of Scattering by Thin Dielectric Rings.**—L. L. Philipson. (*Trans. Inst. Radio Engrs*, Jan. 1958, Vol. AP-6, No. 1, pp. 3–8. Abstract, *Proc. Inst. Radio Engrs*, April 1958, Vol. 46, No. 4, pp. 798–799.)

538.566 : 535.43 **1518**

**A Statistical Model for Forward Scattering of Waves off a Rough Surface.**—L. M. Spetner. (*Trans. Inst. Radio Engrs*, Jan. 1958, Vol. AP-6, No. 1, pp. 88–94. Abstract, *Proc. Inst. Radio Engrs*, April 1958, Vol. 46, No. 4, p. 800.)

538.566 : 535.43 **1519**

**Light Scattering by Small Particles.** [Book Review]—H. C. van de Hulst. Publishers: John Wiley, New York, and Chapman & Hall, London, 1957, 470 pp., 96s. (*Nature, Lond.*, 29th Nov. 1958, Vol. 182, No. 4648, pp. 1470–1471.)

## GEOPHYSICAL AND EXTRATERRESTRIAL PHENOMENA

523.164 + 621.396.93 **1520**

**Propagation of Electromagnetic Waves, Radio Location and Radio Astronomy.**—Roessler. (See 1581.)

523.164 : 523.75 **1521**

**Ionization of the Upper Atmosphere by Low-Energy Charged Particles from a Solar Flare.**—H. Leinbach & G. C. Reid. (*Phys. Rev. Lett.*, 15th Jan. 1959, Vol. 2, No. 2, pp. 61–63.) Discussion of recordings made at Thule, Greenland, and Barrow and College, Alaska, of cosmic-noise absorption at 27·6 Mc/s at the time of a class-3 solar flare on 29th July 1958.

523.164.3 **1522**

**Radio Observations of the Planet Jupiter.**—K. L. Franklin & B. F. Burke. (*J. geophys. Res.*, Dec. 1958, Vol. 63, No. 4, pp. 807–824.) Details are given of observations outlined previously (*Astr. J.*, May 1956, Vol. 61, No. 1238, p. 177 and *Carnegie Institute of Washington Year Book*, 1955/1956, pp. 74–76), together with unpublished information from earlier observations in June 1954. Correlation of the observations with rotation, polarization, and frequency characteristics is discussed. Most of the radio noise bursts were strongly circularly polarized, and the spectrum does not appear to be continuous over the frequencies observed. Critical reflections by an ionosphere around Jupiter are discounted.

523.165 : 523.74 1523

**Cosmic-Ray Intensity Variations during Two Solar Cycles.**—S. E. Forbush. (*J. geophys. Res.*, Dec. 1958, Vol. 63, No.4, pp. 651–669.) From ionization-chamber data the decrease of cosmic-ray intensity from its maxima (near sunspot minima) is shown to lag a year or more behind the increase of solar activity following sunspot minima. The variability of daily mean values was particularly great in 1957.

523.165 : 550.38 1524

**Cosmic Rays in the Earth's Magnetic Field.**—P. Rothwell. (*Phil. Mag.*, Sept. 1958, Vol. 3, No. 33, pp. 961–970.) Discrepancies between centre dipole predictions using the Störmer equation and experimental observations of cosmic-ray intensities and cut-off phenomena are attributed to differences between the earth's real field and the dipole approximation to it, rather than to distortion of the earth's outer magnetic field by ionized interplanetary matter. An empirical expression for the cut-off phenomena is deduced which is in good agreement with experimental results over a wide range of latitude and longitude.

523.3 : 621.396.9 1525

**Comparison of Measured and Computed Values of the Rapid Fading Rate of Ultra-High-Frequency Signals Reflected from the Moon.**—S. J. Fricker, R. P. Ingalls, W. C. Mason & M. L. Stone. (*Nature, Lond.*, 22nd Nov. 1958, Vol. 182, No. 4647, pp. 1438–1439.) Observations made in U.S.A. in August 1957, during a bistatic moon reflection experiment carried out at 412·85 Mc/s are reported. They show good agreement with values calculated from the effective libration rate of the moon.

523.5 : 551.510.535 1526

**Meteors in the Ionosphere.**—L. A. Manning & V. R. Eshleman. (*Proc. Inst. Radio Engrs*, Feb. 1959, Vol. 47, No. 2, pp. 186–199.) The nature of radio reflections from the trails of ionization produced by meteors is reviewed and the principal uses of meteors as research tools are described. Some further directions in which meteor research may be pursued are suggested.

523.5 : 621.396.11 : 551.510.535 1527

**Concerning Booker's Theory of Meteoric Reflections.**—L. A. Manning & V. R. Eshleman. (*J. geophys. Res.*, Dec. 1958, Vol. 63, No. 4, pp. 737–739.) The assumption of small-scale ionospheric turbulence [see e.g. 1417 of 1957 (Booker & Cohen)] conflicts with many known facts about meteor echoes, such as the persistence of aspect sensitivity for as long as ten seconds and the known variation with time of the angular correlation function.

523.53 : 621.396.11 1528

**Electromagnetic Scattering by Low-Density Meteor Trails.**—Brysk. (See 1665.)

523.746 1529

**The Zurich Sunspot Number and its Variations for 1700 – 1957.** — E. J. Chernosky & M. P. Hagan. (*J. geophys. Res.*, Dec. 1958, Vol. 63, No. 4, pp. 775–788.) Monthly and auroral mean values of relative sunspot number are tabulated for 1749–1957. Estimates of annual values by Wolf for the period 1700–1759 are also given, together with derived data.

523.75 : 523.72 1530

**Radiation and Particle Precipitation upon the Earth from Solar Flares.**—L. Biermann & R. Lüst. (*Proc. Inst. Radio Engrs*, Feb. 1959, Vol. 47, No. 2, pp. 209–210.) A brief survey in which the energies of these emissions are estimated and their effects on the ionosphere discussed.

550.380.2 1531

**Centenary of Melbourne-Toolangi Magnetic Observatory.**—J. C. Dooley. (*J. geophys. Res.*, Dec. 1958, Vol. 63, No. 4, pp. 731–735.) Brief history of the observatory since 1858.

550.385 1532

**Possible Causes of Geomagnetic Fluctuations having a Six-Second Period.**—F. B. Daniels. (*Nature, Lond.*, 22nd Nov. 1958, Vol. 182, No. 4647, p. 1439.) The fluctuations described by Duffus et al. (3441 of 1958) may be due to small oscillations of the earth's crust ('microseisms') or, more probably, atmospheric oscillations with the same period ('microbaroms').

550.385 : 551.510.535 1533

**The Diurnal Variation of Irregular Geomagnetic Fluctuations: Part 2.**—S. B. Nicholson & O. R. Wulf. (*J. geophys. Res.*, Dec. 1958, Vol. 63, No. 4, pp. 803–806.) "Using the eight daily *K* numbers (three-hour-range indices) for six observatories in moderately low latitudes and fairly well distributed in longitude, a universal-time component of the daily variation of irregular geomagnetic fluctuations having an apparently significant amplitude in the yearly average has been found in the data for the nine years 1940–1948. It is suggested that a portion of magnetic disturbance may be produced by dynamo action in the ionosphere, and give rise to this yearly-average universal-time component." For Part 1, see 1403 of 1956.

550.385.2 : 525.624 1534

**Lunar Geomagnetic Tides at Kodaikanal.**—K. S. Raja Rao & K. R. Sivaraman. (*J. geophys. Res.*, Dec. 1958, Vol. 63, No. 4, pp. 727–730.) Tschu's method (636 of 1950) has been applied to the calculation of the lunar semi-diurnal variation of the horizontal intensity of the earth's magnetic field at Kodaikanal. The solar diurnal variation is also determined.

550.385.4 1535

**Time Constants in the Geomagnetic Storm Effect.**—C. O. Hines & L. R. O. Storey. (*J. geophys. Res.*, Dec. 1958, Vol. 63, No. 4, pp. 671–682.) An estimate is made of the delay between formation of a ring current round the earth and the occurrence of a geomagnetic storm at ground level. Parker (1422 of 1957) has estimated the delay as several months; but by taking proper account of the fluidity of the medium and the presence of the main geomagnetic field the delay is found to be small enough to be consonant with the ring-current theory of geomagnetic storms.

550.385.4 1536

**Inadequacy of Ring-Current Theory for the Main Phase of a Geomagnetic Storm.**—E. N. Parker. (*J. geophys. Res.*, Dec. 1958, Vol. 63, No. 4, pp. 683–689.) There appears to be insufficient dissipation to allow significant diffusion, during a magnetic storm, of the magnetic fields in the vicinity of the earth. A ring-current field can therefore only increase the horizontal component of the geomagnetic field and cannot account for the main phase of a geomagnetic storm.

550.385.4 1537

**Studies on Geomagnetic Storm in relation to Geomagnetic Pulsation.**—Y. Kato & T. Watanabe. (*J. geophys. Res.*, Dec. 1958, Vol. 63, No. 4, pp. 741–756.) For the 27-day recurring geomagnetic storm (M type), the 'cone of avoidance' model of Pecker & Roberts (1970 of 1955) is supported by both geomagnetic and cosmic-ray data. For the sporadically occurring storm (S type) a shock front in interplanetary space may be responsible for the sudden commencement. An exhaustive study should be made to determine whether the sudden commencement is only associated with the S type. The storm-time variation of the geomagnetic pulsation should also be measured during world-wide storms to aid the study of the shock wave.

550.389.2 1538

**The International Geophysical Year.**—L. V. Berkner. (*Proc. Inst. Radio Engrs*, Feb. 1959, Vol. 47, No. 2, pp. 133–136.) The organization which made possible the large international cooperative research effort is described and arrangements for collecting and storing the observational data are outlined.

550.389.2 1539

**The Day-to-Day Coordination of I.G.Y. Observations.**—A. H. Shapley. (*Proc. Inst. Radio Engrs*, Feb. 1959, Vol. 47, No. 2, pp. 323–327.) In addition to regular observational programs, the I.G.Y. included special series of observations made during outstanding solar and geophysical events. The organization of these series and the necessary ancillary communication facilities are described briefly.

550.389.2 1540

**The Earth and its Environment.**—S. Chapman. (*Proc. Inst. Radio Engrs*, Feb. 1959, Vol. 47, No. 2, pp. 137–141.) A general outline of the many fields of investigation included in the I.G.Y. program of observations. Particular attention is given to the earth's atmosphere and the flow of heat through it from the hot interplanetary gas.

550.389.2 : 629.19 1541

**Motion of a Satellite around an Unsymmetrical Central Body.**—R. R. Newton. (*J. appl. Phys.*, Jan. 1959, Vol. 30, No. 1, pp. 115–117.) If a central body does not have an inversion centre, the eccentricity of a satellite orbit varies periodically, with low frequency and large amplitude. Details are worked out for a central body composed of a large spherical mass and a small point mass contained somewhere within it.

530.389.2 : 629.19 **1542**

**Change of Inclination of a Satellite Orbit.**—C. H. Bosanquet. (*Nature, Lond.*, 29th Nov. 1958, Vol. 182, No. 4648, pp. 1533.) Comment on 792 of March (Merson & King-Hele).

550.389.2 : 629.19 **1543**

**Irregularities of Satellite Drag and Diurnal Variations in Density of the Air.**—G. V. Groves. (*Nature, Lond.*, 29th Nov. 1958, Vol. 182, No. 4648, pp. 1533–1534.) The theory is applied to satellites 1957$\beta$, 1958 $\delta$1 and 1958 $\delta$2.

550.389.2 : 629.19 **1544**

**Moon Rocket Tracking.**—(*Nature, Lond.*, 22nd Nov. 1958, Vol. 182, No. 4647, p. 1413.) A 108-Mc/s interferometer situated at Lasham, Hampshire, was used to track the third American moon rocket on 8th November 1958. A satisfactory record was obtained from 0747 to 0801 G.M.T.

550.389.2 : 629.19 **1545**

**Progress of the Russian Earth Satellite Sputnik III (1958$\delta$).**—D. G. King-Hele. (*Nature, Lond.*, 22nd Nov. 1958, Vol. 182, No. 4647, pp. 1409–1411.) Orbital data, based chiefly on optical observations, are given for the instrument-carrying vehicle 1958 $\delta$2 and its rocket 1958 $\delta$1.

550.389.2 : 629.19 **1546**

**The 'Explorers'.**—W. von Braun. (*Engineer, Lond.*, 5th Sept. 1958, Vol. 206, No. 5354, pp. 372–375.) Extracts from a paper presented at the congress of the International Astronautical Federation, Amsterdam, 1958. Details are given of the rocket firing procedure and satellite instrumentation as well as the tracking system used during the launching of the Explorer satellites.

550.389.2 : 629.19 **1547**

**Instrumenting the Explorer I Satellite.**—H. L. Richter, Jr, W. Pilkington, J. P. Eyrand, S. S. Shipley & L. W. Randolph. (*Electronics*, 6th Feb. 1959, Vol. 32, No. 6, pp. 39–43.) A description is given of the 10-mW ph.m. and 60-mW a.m. transistorized transmitters operating on 108 and 108·3 Mc/s respectively. Total power consumption was 5 mW obtained from four mercury-type cells. Information was transmitted on skin temperature, nose cone temperature, meteorite counts and impacts, and cosmic rays. Details are also given of the test program for the completed apparatus.

550.389.2 : 629.19 : 551.510.535 **1548**

**Earth-Satellite Observations of the Ionosphere.**—W. W. Berning. (*Proc. Inst. Radio Engrs*, Feb. 1959, Vol. 47, No. 2, pp. 280–288.) The various methods of deriving integrated electron content below a satellite are critically reviewed. Although the methods are theoretically capable of giving information of the diurnal, seasonal and latitude variations of content, interpretation of the measurements is difficult because all these variations are present simultaneously; hence some assumptions about one or two of the variables must be made in order that the third one may be studied.

550.389.2 : 629.19 : 551.510.535 **1549**

**Investigation of the Ionosphere using Signals from Earth Satellites.**—E. Woyk (Chvojková). (*Nature, Lond.*, 15th Nov. 1958, Vol. 182, No. 4646, pp. 1362–1363.) Possible effects of the ionosphere on radio signals from artificial earth satellites are discussed with reference to theoretical results noted earlier (3085 of 1958).

550.389.2 : 629.19 : 551.510.535 **1550**

**Exploration of the Upper Atmosphere with the Help of the Third Soviet Sputnik.**—V. I. Krassovsky. (*Proc. Inst. Radio Engrs*, Feb. 1959, Vol. 47, No. 2, pp. 289–296.) The instruments carried are described and some of the preliminary results of observations are given. Up to 250 km the principal ionospheric constituent is nitric oxide; above this height ions of atomic oxygen and nitrogen become more important. Electron density falls off slowly above the F region maximum. Positive-ion density at a height of 250 km is about $5 \times 10^5$ ions/cm$^3$, i.e. about half the corresponding electron density. The number of collisions with micrometeorites at heights of 150–300 km is 50/m$^2$/sec.

551.51 **1551**

**The Constitution and Composition of the Upper Atmosphere.**—M. Nicolet. (*Proc. Inst. Radio Engrs*, Feb. 1959, Vol. 47, No. 2, pp. 142–147.) A survey of the observational data and the theoretical problems involved. Dissociation of molecular $O_2$ and $N_2$, diffusion in the thermosphere, and the conduction of heat through the atmosphere are discussed.

551.510.535 **1552**

**The Distribution of Electrons in the Ionosphere.**—J. O. Thomas. (*Proc. Inst. Radio Engrs*, Feb. 1959, Vol. 47, No. 2, pp. 162–175.) The methods of deriving $N(h)$ profiles are reviewed with particular emphasis on those which include the effects of the earth's magnetic field. Attention is drawn to the use of the extraordinary ray for estimating the electron density below the peak of the E layer. Some results are given of typical diurnal, seasonal, solar-cycle and latitude variations in the electron-density distribution. 92 references.

551.510.535 **1553**

**The Normal D Region of the Ionosphere.**—J. J. Gibbons & A. H. Waynick. (*Proc. Inst. Radio Engrs*, Feb. 1959, Vol. 47 No. 2, pp. 160–161.) A discussion of low-frequency sounding of the lower ionosphere indicating the radio transmission characteristics to be satisfied. It is suggested that recent measurements of parameters, such as reaction rates, will provide an improved model of the D layer.

551.510.535 **1554**

**The Normal E Region of the Ionosphere.**—E. V. Appleton. (*Proc. Inst. Radio Engrs*, Feb. 1959, Vol. 47, No. 2, pp. 155–159.) An outline of the structure and behaviour of the E layer with particular emphasis on how it differs from an ideal Chapman layer.

551.510.535 **1555**

**The Normal F Region of the Ionosphere.**—D. F. Martyn. (*Proc. Inst. Radio Engrs*, Feb. 1959, Vol. 47, No. 2, pp. 147–155.) A review which includes comments on the physical conditions of the layer as determined from rocket and satellite observations, Bradbury's hypothesis, 'spread-F' and radio-star scintillations.

551.510.535 **1556**

**Motions in the Ionosphere.**—C. O. Hines. (*Proc. Inst. Radio Engrs*, Feb. 1959, Vol. 47, No. 2, pp. 176–186.) The theoretical factors involved in the interpretation of observational data are discussed. Particular attention is given to tidal motions and the need for theoretical advances in studies of drifts, scintillations, auroral forms, turbulence and large-scale travelling disturbances.

551.510.535 **1557**

**Horizontal Drift Measurements in the Ionosphere near the Equator.**—N. J. Skinner, J. Hope & R. W. Wright. (*Nature, Lond.*, 15th Nov. 1958, Vol. 182, No. 4646, pp. 1363–1365.) Drift of the E and F layers has been measured regularly at Ibadan, Nigeria, by the spaced-receiver method. The westward daytime drift velocity in the F layer is about 105 m/s.

551.510.535 **1558**

**The Interpretation of Night-Time Low-Frequency Ionograms.**—J. M. Watts. (*J. geophys. Res.*, Dec. 1958, Vol. 63, No. 4, pp. 717–726.) Two types of retardation of the extraordinary ray on passing through a region whose frequency is below the gyro-frequency are discussed. One is observed near the critical frequency of the ordinary ray and the other near the gyro-frequency. Information about the total number and distribution of electrons below the F layer can be deduced from them.

551.510.535 **1559**

**Rocket Observations of the Ionosphere.**—H. Friedman. (*Proc. Inst. Radio Engrs*, Feb. 1959, Vol. 47, No. 2, pp. 272–280.) A review of the electron-density profiles obtained at Fort Churchill and at White Sands. A comparison of similar data obtained in Russia up to 200 km is made. The effects of polar blackouts and of flares are discussed with particular reference to the nature of the solar ionizing radiation. Comments are also made on the radiation which can be detected at night, interplanetary hydrogen and the electron density in interplanetary space.

551.510.535 **1560**

**Summer-Day Auroral Atmospheric-Structure Measurements from 100 to 210 Kilometres.**—R. Horowitz & H. E. LaGow. (*J. geophys. Res.*, Dec. 1958, Vol. 63, No. 4, pp. 757–773.) Density and pressure determined during a rocket flight



E

at 1600 C.S.T., 29th July 1957 at Manitoba, Canada, are compared with earlier measurements.

551.510.535 (98) **1561**

**Polar $E_s$.**—R. Penndorf & S. C. Coroniti. (*J. geophys. Res.*, Dec. 1958, Vol. 63, No. 4, pp. 789–802.) Published ionosonde data are analysed over the period 1954–1957 and show three distinct types of $E_s$ for northern polar stations, each type occurring in a particular geomagnetic zone. A strong correlation between $E_s$ and magnetic activity existing along the auroral belt points to the influence of corpuscular radiation.

551.510.535 : 523.165. **1562**

**Abnormal Ionization in the Lower Ionosphere Associated with Cosmic-Ray Flux Enhancements.**—D. K. Bailey. (*Proc. Inst. Radio Engrs*, Feb. 1959, Vol. 47, No. 2, pp. 255–266.) Two separate abnormalities in ionization were recognizable during the great solar event of 23rd February 1956: the 'early effects' observed at the time of the sudden cosmic-ray enhancement and the 'late effects' which reached a maximum an appreciable time later. A difference in composition between streams of solar particles of cosmic-ray energies and ordinary cosmic rays is postulated to explain the former effect, while the latter is explained in terms of ionization at heights of 30–110 km produced by the passage or stopping of solar particles, predominantly protons. The absence of auroral and magnetic effects is consistent with these explanations. A provisional evaluation is also made of the coefficient of collisional attachment of electrons from negative ions and the negative-ion/electron ratio and effective recombination coefficient at night between 30 and 40 km.

551.510.535 : 550.385.4 **1563**

**The F Region during Magnetic Storms.**—K. I. Maeda & T. Sato. (*Proc. Inst. Radio Engrs*, Feb. 1959, Vol. 47, No. 2, pp. 232–239.) Magnetic storms are investigated using the variation of $f_0F_2$ and $h_pF_2$ over a wide range of latitude. It is shown that ionization drift theory in association with the dynamo theory is satisfactory in explaining the observed variations.

551.510.535 : 621.3.087.4 **1564**

**Automatic Sweep-Frequency Ionosphere Recorder, Model C-4.**—J. N. Brown. (*Proc. Inst. Radio Engrs*, Feb. 1959, Vol. 47, No. 2, pp. 296–300.) A description of an improved equipment for use during the I.G.Y. In addition to the 'virtual-height'/frequency records, time-lapse motion pictures are taken.

551.510.535 : 621.3.087.4 **1565**

**The I.G.Y. Three-Frequency Back-Scatter Sounder.**—A. M. Peterson, R. D. Egan & D. S. Pratt. (*Proc. Inst. Radio Engrs*, Feb. 1959, Vol. 47, No. 2, pp. 300–314.) The equipment consists of three transmitters operating at 12, 18 and 30 Mc/s, each coupled to its own horizontal Yagi aerial on a single rotating pole, and by a t.r. switch to a receiver whose tuning is interlocked with the transmitter. A camera records the plan-position displays for the three frequencies together with a short-range display. Preliminary results from 13 stations in polar, temperate and equatorial regions are discussed. Phenomena reported include sporadic-E movements, tilted-F-layer propagation, large irregularities in the F layer and echoes from field-aligned ionization.

551.510.535 : 621.3.087.4 : 523.164 **1566**

**The Riometer—a Device for the Continuous Measurement of Ionospheric Absorption.**—C. G. Little & H. Leinbach. (*Proc. Inst. Radio Engrs*, Feb. 1959, Vol. 47, No. 2, pp. 315–320.) A description of an instrument for the measurement of ionospheric absorption at high latitudes during the I.G.Y., using the cosmic-noise method (see 1152 of 1958). The circuit details of this self-balancing equipment are given and its advantages over the system of total-power measurement are discussed.

551.593.9 **1567**

**The Night Airglow.**—F. E. Roach. (*Proc. Inst. Radio Engrs*, Feb. 1959, Vol. 47, No. 2, pp. 267–271.) "A phenomenological description of the night airglow is presented, reviewing the historical background, and what is known about height, temporal and spatial variations in intensity, and movements. The very important relationship to aurora and evidence for latitude-seasonal effects are examined."

551.594.5 **1568**

**Auroral Phenomena.**—E. N. Parker. (*Proc. Inst. Radio Engrs*, Feb. 1959, Vol. 47, No. 2, pp. 239–244.) Present knowledge of the formation of the aurora is summarized. Mechanisms of particle acceleration are considered and it is emphasized that there is no consistent theory of auroral phenomena. 37 references.

551.594.5 **1569**

**A Man-Made or Artificial Aurora.**—A. L. Cullington. (*Nature, Lond.*, 15th Nov. 1958, Vol. 182, No. 4646, pp. 1365–1366.) An auroral display with which were associated radio fade-outs and a magnetic storm was observed at Apia (13° 48′ S, 171° 46′ W) on 1st August 1958. These phenomena were probably due to the explosion of a nuclear bomb over Johnston Island on the same date.

551.594.5 : 550.385 **1570**

**Auroral Ionization and Magnetic Disturbances.**—B. Nichols. (*Proc. Inst. Radio Engrs*, Feb. 1959, Vol. 47, No. 2, pp. 245–254.) The literature on radio studies of the aurora, the relation between aurora and magnetic storms, and the movements of the ionosphere and auroral forms is co-ordinated (56 references). An average density of $5 \times 10^5$ electrons/cm³ is sufficient to explain normal radar echoes. Magnetic disturbances are closely related to ionization and luminosity of the aurora. Magnetic variations are also associated with increases in the speeds of motion of the ionization.

551.594.5 : 621.396.11 **1571**

**Radio Echoes from Auroral Ionization Detected at Relatively Low Geomagnetic Latitudes.**—Leadabrand & Peterson. (See 1670.)

551.594.5 : 621.396.11 **1572**

**The Geometry of Auroral Communications.**—Leadabrand & Yabroff. (See 1671.)

551.594.5 : 621.396.96 **1573**

**U.H.F. Auroral Radar Observations.**—B. C. Blevis. (*J. geophys. Res.*, Dec. 1958, Vol. 63, No. 4, pp. 867–868.) Describes auroral Doppler spectra obtained at Ottawa with bistatic radars operating at 488 and 944 Mc/s. 10-kW c.w. klystron amplifiers with 28- and 60-ft parabolic reflectors were used, with transmitter-receiver separations of 19 and 100 km. Echoes indicating cross-sections of several thousand square metres were obtained on occasions at 944 Mc/s.

551.594.5 : 621.396.96 **1574**

**A Low-Power V.H.F. Radar for Auroral Research.**—R. S. Leonard. (*Proc. Inst. Radio Engrs*, Feb. 1959, Vol. 47, No. 2, pp. 320–322.)

551.594.6 **1575**

**The Very-Low-Frequency Emissions Generated in the Earth's Exosphere.**—R. M. Gallet. (*Proc. Inst. Radio Engrs*, Feb. 1959, Vol. 47, No. 2, pp. 211–231.) Types of noise other than whistlers have been examined using high-resolution spectograms which show the frequency distribution as a function of time. Most of these noises are excited in the exosphere by streams or bunches of high-speed ionized particles trapped in the earth's magnetic field. The excitation mechanism is similar to that of a travelling-wave valve. Most of the observations require that particle velocities be about 10 000 km/s. A model in which the ratio of electron density to magnetic field strength is almost constant along a line of force in the exosphere seems to be indicated by several types of noise.

551.594.6 **1576**

**Atmospheric Whistlers.**—R. A. Helliwell & M. G. Morgan. (*Proc. Inst. Radio Engrs*, Feb. 1959, Vol. 47, No. 2, pp. 200–208.) The historical background of the discovery of whistlers and the development of an adequate theoretical explanation of their behaviour are reviewed. The program of study during the I.G.Y. is described and some examples of results obtained are presented and discussed.

551.594.6 **1577**

**Path Combinations in Whistler Echoes.**—M. G. Morgan, H. W. Curtis & W. C. Johnson. (*Proc. Inst. Radio Engrs*, Feb. 1959, Vol. 47, No. 2, pp. 328–329.) A note describing groups of whistler echoes recorded at Unalaska (50° geomagnetic latitude) and explaining them in terms of a combination of alternative propagation paths and multiple trips over each path.

551.594.6 **1578**

**A Note on Whistler Propagation in Regions of Very Low Electron Density.**—O. K. Garriott. (*J. geophys. Res.*, Dec. 1958, Vol. 63, No. 4, pp. 862–865.) Calculations made on a model ionosphere indicate that nose whistlers may exist, although attenuation may prevent their observation.

551.594.6 : 523.75 1579

**A 27-kc/s Sudden Enhancement of Atmospherics Anomaly.**—W. A. Feibelman. (*J. geophys. Res.*, Dec. 1958, Vol. 63, No. 4, p. 866.) On 1st May 1958 two 'anomalous' solar flares caused a sharp drop in the 27-kc/s signal level recorded at Pittsburgh, Pa, instead of the usual enhancement. Enhancements were recorded elsewhere.

551.594.6 : 621.396.821 1580

**Study of the Atmospheric Radio Noise at 27 and 100 kc/s at Delhi.**—D. K. Sachdev. (*J. sci. industr. Res.*, July 1958, Vol. 17A, No. 7, pp. 262–270.) Preliminary survey of observations extending over a year, with particular reference to sudden enhancement effects.

## LOCATION AND AIDS TO NAVIGATION

621.396.93 + 523.164 1581

**Propagation of Electromagnetic Waves, Radio Location and Radio Astronomy.**—E. Roessler. (*Elektrotech. Z., Edn A*, 1st Oct. 1958, Vol. 79, pp. 737–740.) Review of recent developments. 49 references.

621.396.93 : 621.396.677.83 1582

**The Application of Metallic Reflectors for Purposes of Location.**—G. Megla. (*Hochfrequenztech. u. Elektroakust.*, Jan. 1958, Vol. 66, No. 4, pp. 107–115.) The use of stationary and rotating plane mirrors for radio beacons and other navigational aids is described. For English version see *Wescon Convention Record Inst. Radio Engrs*, 1957, Vol. 1, Part 10, pp. 29–40.

621.396.934 1583

**Radio Interferometers Track Airborne Vehicles.**—M. W. Miles. (*Electronic Ind.*, Oct. 1958, Vol. 17, No. 10, pp. 94–95, 151.) Basic problems in interferometer systems are examined.

621.396.96 1584

**Miniature X-Band Radar has High Resolution.**—C. D. Hardin & J. Salerno. (*Electronics*, 30th Jan. 1959, Vol. 32, No. 5, pp. 48–51.) The unit operates with a pulse repetition frequency of 100 kc/s and peak power 150 W. The i.f. is 400 Mc/s with a bandwidth of 100 Mc/s and gain 36 dB in four stages. A low-range altimeter with a full-scale reading of 30 ft and calibrated at 6-in. intervals has been constructed.

621.396.96 : 551.594.5 1585

**A Low-Power V.H.F. Radar for Auroral Research.**—R. S. Leonard. (*Proc. Inst. Radio Engrs*, Feb. 1959, Vol. 47, No. 2, pp. 320–322.)

621.396.96.083.7 1586

**Radar Data Transmission.**—T. E. Schilizzi. (*Proc. Instn Radio Engrs, Aust.*, Sept. 1958, Vol. 19, No. 9, pp. 467–480.) Practical methods of achieving a remote display over wide-band and narrow-band circuits are reviewed and an experimental system using wide-band radio links is outlined. Image-converter and bright-image storage tubes for large-screen projection equipment are described. See also 2770 of 1957 (Dixon & Thomas).

621.396.962.012 : 681.142 1587

**An Analogue Computer for Evaluating Radar Performance.**—Willhite & McIntyre. (See 1465.)

621.396.963 1588

**Dynamic Compression for Radar Receivers.**—D. Levine (*Electronic Ind.*, Oct. & Nov. 1958, Vol. 17, Nos. 10 & 11, pp. 102–106 & 82–84.) Various types of receiver are examined in terms of c.r. tube brightness for direct observation and for recording on film. Graphs are given to assist in the selection of the required dynamic compression curve for the system in which the receiver is to be used.

621.396.967 1589

**The Rotterdam Harbour Radar System.**—B. H. G. Prins & J. M. G. Seppen. (*Philips Telecommun. Rev.*, Sept. 1958, Vol. 20, No. 1, pp. 16–30.) A chain of seven radar stations working in the 3-cm band provides accurate positional information to ships with the aid of leading lines and cursor lines which are superimposed electronically on display screens.

621.396.967 : 621.372.413 : 621.317.799 1590

**A Radar Echo Box with Remote Control.**—G. van Gelder & E. Scholten. (*Philips Telecommun. Rev.*, Sept. 1958, Vol. 20, No. 1, pp. 33–38.) A description of the construction of a high-$Q$ resonant cavity for the 8·5- or 10-cm band and its tuning mechanism. It can be used for the measurement of the overall performance of a radar installation and for obtaining the power spectrum of a magnetron pulse.

621.396.967.029.65 1591

**An 8-mm, High-Definition Radar Set.**—J. M. G. Seppen & J. Verstraten. (*Philips Telecommun. Rev.*, Sept. 1958, Vol. 20, No. 1, pp. 5–15.) The design of the equipment is discussed and general circuit features and photographs of the radar display are given.

621.396.967.2 1592

**Development of the DEW Line.**—G. R. Frantz. (*Bell Lab. Rec.*, Jan. 1959, Vol. 37, No. 1, pp. 2–6.) A general outline of the radar warning system is given.

## MATERIALS AND SUBSIDIARY TECHNIQUES

535.215 : 546.482.21 1593

**Photochemical Effects and the Effect of Oxygen on Photoconducting Cadmium Sulphide Crystals.**—J. Woods. (*J. Electronics Control*, Nov. 1958, Vol. 5, No. 5, pp. 417–426.) The photochemical effects and the effects of heat treatment in oxygen on a number of differently activated crystals are described and discussed.

535.215 : 546.482.21 1594

**Growth of Photoconductivity of Single Crystals of Cadmium Sulphide from Irradiation in an Atomic Pile.**—M. Martineau. (*C. R. Acad. Sci. Paris*, 11th Aug. 1958, Vol. 247, No. 6, pp. 639–643.)

535.37 1595

**Luminescence and Luminescent Materials.**—D. G. Anderson. (*J. Electronics Control*, Nov. 1958, Vol. 5, No. 5, pp. 457–470.) "A general review of luminescent materials is given, with some emphasis on the more recent applications. The theoretical aspects of the absorption emission processes are discussed briefly."

535.37 : 546.472.21 1596

**Electron Traps in Zinc-Sulphide Phosphors.**—W. Hoogenstraaten. (*Philips Res. Rep.*, Dec. 1958, Vol. 13, No. 6, pp. 515–693.) An attempt is made to clarify the chemical and physical nature of electron traps in ZnS phosphors, including those based on mixed crystals of ZnS with CdS or ZnSe.

535.376 1597

**Electroluminescence and Image Intensification.**—G. Diemer, H. A. Klasens & P. Zalm. (*Philips tech. Rev.*, 27th July 1957, Vol. 19, No. 1, pp. 1–11.) The mechanism of electroluminescence and the application of the effect in solid-state image intensifiers is discussed.

535.376 : 539.234 1598

**Electroluminescent Thin Films.**—W. A. Thornton. (*J. appl. Phys.*, Jan. 1959, Vol. 31, No. 1, pp. 123–124.) Thin luminescent films of ZnS-Cu,Cl and ZnS-Cu, Mn,Cl have been prepared by a two-step evaporation/firing process similar to that described by Feldman & O'Hara (3494 of 1957) but using finished electroluminescent powder phosphors as the starting material.

537.226/.227 : 546.431.824-31 1599

**On Growing $BaTiO_3$ Single Crystals.**—A. M. Cherepanov. (*Zh. tekh. Fiz.*, Oct. 1957, Vol. 27, No. 10, pp. 2280–2284.) Triangular crystals with a hypotenuse up to 15 mm long are obtained after heating $1BaCl_2.0{\cdot}53BaCO_3.0{\cdot}26TiO_2$ to a temperature of 1 300–1 450° C. These crystals have lattice characteristics $a$ = 3·986 Å, $c$ = 4·0263 Å, and a Curie point at 122°–123° C.

537.226 : 546.212-16 1600

**Dielectric Properties of Ice Crystals.**—(*Helv. Phys. Acta*, 30th Dec. 1957, Vol. 30, No. 7, pp. 553–610. In German, with English summaries.)

Part 1—Dynamic Theories of Dielectric Constants.—A. Steinemann & H. Gränicher (pp. 553–580).

Part 2—Dielectric Investigations on Ice Crystals with Occluded Impurity Atoms.—A. Steinemann (pp. 581–610).

537.226 : 546.431.824-31 **1601**

**Dielectric Properties of Barium Titanate at High Frequencies and Low Temperatures.**—H. Rabenhorst & J. Melichercík. (*Ann. Phys., Lpz.*, 20th May 1958, Vol. 1, Nos. 4/5, pp. 261–263.) Dielectric constant and loss factor have been measured in the temperature range −180° to + 20° C at a frequency of 9·1 kMc/s.

537.226 : 621.319.2 **1602**

**Contribution to the Phenomenological Theory of Electrets.**—A. N. Gubkin. (*Zh. tekh. Fiz.*, Sept. 1957, Vol. 27, No. 9, pp. 1954–1968.) Five dielectrics, carnauba wax, naphthalene, steatite, nylon and magnesium titanate, were prepared under fields ranging from 5 to 25 kV/cm and observed for as long as 3 months. An expression is derived for the lifetime of these electrets and experimental and calculated results are tabulated.

537.226 : 621.319.2 **1603**

**The Anomalous Stability of New Inorganic Polycrystalline Electrets.**—A. N. Gubkin & G. I. Skanavi. (*Zh. tekh. Fiz.*, Sept. 1957, Vol. 27, No. 9, pp. 1969–1970.) Experiments show that the properties of $CaTiO_3$ electrets of specific conductivity $10^{-12}$—$10^{-14}$ $\Omega^{-1}$ cm$^{-1}$ are similar when kept open-circuited or short-circuited by metallic foils. See also 3164 of 1957.

537.311.33 **1604**

**Contribution to the Theory of Semiconductors with Excited Impurity Zone.**—M. I. Klinger & Yu. I. Zozulya. (*Zh. tekh. Fiz.*, Oct. 1957, Vol. 27, No. 10, pp. 2285–2290.) The variations of conductivity, Hall effect and thermo-e.m.f. as functions of temperature in *n*-type semiconductors are discussed.

537.311.33 : 546.23 **1605**

**Self-Diffusion in Selenium.**—B. I. Boltaks & B. T. Plachenov. (*Zh. tekh. Fiz.*, Oct. 1957, Vol. 27, No. 10, pp. 2229–2231.) Results of an investigation of the diffusion of impurities in crystalline and amorphous Se are given. The difference between the diffusion constants for the two types increases with increasing temperature.

537.311.33 : 546.23 : 536.2 **1606**

**The Influence of Bromine Additives on the Thermal Conductivity of Selenium.**—G. B. Abdullaev & A. A. Bashshaliev. (*Zh. tekh. Fiz.*, Sept. 1957, Vol. 27, No. 9, pp. 1971–1975.) Amorphous and crystalline Se samples with Br content varying from 0·008 to 0·5 % were tested at 27·5° C; their thermal conductivity coefficients were respectively $3{\cdot}08 \times 10^{-3}$ and $7{\cdot}02 \times 10^{-3}$ cal/deg. cm. sec.

537.311.33 : 546.24 : 538.214 **1607**

**Magnetic Susceptibility in Semiconductors of the Tellurium Type.**—Yu. A. Firsov. (*Zh. tekh. Fiz.*, Oct. 1957, Vol. 27, No. 10, pp. 2212–2228.) A mathematical analysis of zone junctions. A method is proposed for the investigation of the zone structure based on the angular dependence of susceptibility in strong magnetic fields.

537.311.33 : 546.28 **1608**

**Lattice Absorption Bands in Silicon.**—F. A. Johnson. (*Proc. phys. Soc.*, 1st Feb. 1959, Vol. 73, No. 470, pp. 265–272.) Detailed measurements are described of the absorption spectrum of pure vacuum-grown Si crystals, for wavelengths 2μ–30μ and at temperatures of 20, 77, 290 and 365° K. Some new absorption bands were found. The positions and temperature dependence of all the principal absorption peaks are explained in terms of multiple phonon interactions.

537.311.33 : 546.28 **1609**

**The Effect of Heat Treatment on the Breakdown Characteristics of Silicon *p-n* Junctions.**—A. R. Plummer. (*J. Electronics Control*, Nov. 1958, Vol. 5, No. 5. pp. 405–416.) Soft breakdown, a more gradual breakdown than the normal avalanche characteristic, can be due to unsatisfactory bulk properties, which can be induced by heat treatment. An explanation for the effect is suggested.

537.311.33 : 546.281.26 : 537.533 **1610**

**Electron Emission from Breakdown Regions in SiC *p-n* Junctions.**—L. Patrick & W. J. Choyke. (*Phys. Rev. Lett.*, 15th Jan. 1959, Vol. 2, No. 2, pp. 48–50.) The maximum emission was found to range from $10^{-12}$ A to $10^{-6}$ A, the emission depending strongly on sample preparation.

537.311.33 : 546.289 **1611**

**A Note on the Theory of Diffusion of Copper in Germanium.**—M. D. Sturge. (*Proc. phys. Soc.*, 1st Feb. 1959, Vol. 73, No. 470, pp. 297–306.)

537.311.33 : 546.289 **1612**

**The Diffusion of Boron in Germanium.**—M. D. Sturge. (*Proc. phys. Soc.*, 1st Feb. 1959, Vol. 73, No. 470, pp. 320–322.)

537.311.33 : 546.289 **1613**

**Electrical Properties of Germanium Doped with Zinc.**—S. G. Kalashnikov, E. Yu. L'vova & V. V. Ostroborodova. (*Zh. tekh. Fiz.*, Sept. 1957, Vol. 27, No. 9, pp. 1925–1930.) Zn has little effect on recombination velocity and appears to be suitable for doping Ge to give a low specific resistance and long electron lifetime.

537.311.33 : 546.289 **1614**

**The Influence of Elements of Groups III and V on the Recombination Velocity of Electrons and Holes in Germanium.**—V. G. Alekseeva, S. G. Kalashnikov, L. P. Kalnach, I. V. Karpova & A. I. Morozov. (*Zh. tekh. Fiz.*, Sept. 1957, Vol. 27, No. 9, pp. 1931–1939.) Shorter electron and hole lifetimes were obtained with Bi and Tl than with Sb and Ga. Elements possessing a small distribution coefficient such as Bi, Tl, Cu, Ni and Fe strongly accelerated the electron-hole recombination but elements such as Sb and Ga with a larger coefficient proved much less active. Co, Mn and Au seemed also to accelerate this recombination in Ge.

537.311.33 : 546.289 **1615**

**Valley-Orbit Splitting of Arsenic Donor Ground State in Germanium.**—G. Weinreich, W. S. Boyle, H. G. White & K. F. Rodgers. (*Phys. Rev. Lett.*, 1st Feb. 1959, Vol. 2, No. 3, pp. 96–98.) Investigation of the far-infrared excitation spectrum of bound electrons in an elastically strained sample verifies that, of the two states into which the donor ground state is split, the triplet is the lower one.

537.311.33 : 546.289 **1616**

**Edge Breakdown of *p-n* Junctions in Germanium.**—B. M. Vul & A. P. Shotov. (*Zh. tekh. Fiz.*, Oct. 1957, Vol. 27, No. 10, pp. 2189–2194.) Investigation shows that the permittivity of the medium influences appreciably the breakdown voltage of $n^+p$ junctions but affects only slightly the $p^+n$ and diffusion junctions. This can be explained by assuming a negative charge on the Ge surface which has the effect of altering the thickness of the junction near the surface.

537.311.33 : 546.289 **1617**

**Ambipolar Transport of Carrier Density Fluctuations in Germanium.**—J. E. Hill & K. M. van Vliet. (*Physica*, Sept. 1958, Vol. 24, No. 9, pp. 709–720.) A theoretical study is made of the spectrum of generation-recombination noise at relatively high field strengths. Experimental results for near-intrinsic crystals confirm that if the ambipolar drift velocity is sufficiently large the noise spectrum is quite different from that at low field strengths.

537.311.33 : 546.289 **1618**

**The Diffusion Constant, Mobility and Lifetime of Minority Carriers in Germanium containing Parallel Arrays of Dislocations.**—J. B. Arthur, A. F. Gibson, J. W. Granville & E. G. S. Paige. (*Phil. Mag.*, Sept. 1958, Vol. 3, No. 33, pp. 940–949.) Measurements of the diffusion constant *D* show that for *n*-type Ge *D* is anisotropic; for *p*-type Ge *D* is isotropic, and the carrier lifetime anisotropic. Measurements of drift mobility of holes in *n*-type Ge at high electric fields show this to be anisotropic with respect to the dislocation array, no comparable effect occurring in *p*-type material. A qualitative interpretation of the data is given. See also 494 of 1958 (Bell & Hogarth).

537.311.33 : 546.289 **1619**

**An Interpretation of certain Transport Properties in Germanium containing Parallel Arrays of Edge Dislocations.**—A. F. Gibson & E. G. S. Paige. (*Phil. Mag.*, Sept. 1958, Vol. 3, No. 33, pp. 950–960.) Using a model similar to that considered by Read (457 of 1955), a quantitative interpretation is given of the anisotropic effects observed by Arthur et al. (1618 above). The diameter of the space-charge cylinder surrounding the dislocations ($1{\cdot}6 \times 10^{-4}$ cm) and the fraction of time (about one half) that an injected hole spends within the space-charge region are deduced from the analysis.

537.311.33 : 546.289 : 537.32 **1620**

**Thermoconductivity of Germanium.**—E. D. Devyatkova & I. A. Smirnov. (*Zh. tekh. Fiz.*, Sept. 1957, Vol. 27, No. 9, pp. 1944–1949.) The thermoconductivity of eight $p$-type and $n$-type samples was examined in the temperature range 80°–300°K. Below 200°K the thermoconductivity for similar types of Ge depended on the charge-carrier concentration. The $p$-type Ge showed a greater thermoconductivity than the $n$ type.

537.311.33 : 546.289 : 538.632 **1621**

**The Temperature Dependence of the Hall Coefficient in Semiconductors with Constant Carrier Concentration.**—E. I. Kaplunova & K. B. Tolpygo. (*Zh. tekh. Fiz.*, Oct. 1957, Vol. 27, No. 10, pp. 2246–2251.) Mathematical treatment with reference to Ge. Results are shown graphically.

537.311.33 : 546.482.21 **1622**

**Space-Charge Limited Currents in Insulating Materials.**—G. T. Wright. (*Nature, Lond.*, 8th Nov. 1958, Vol. 182, No. 4645, pp. 1296–1297.) The steady $I/V$ characteristic of a plate of CdS about $3 \times 10^{-3}$ cm thick provided with a cathode of In metal and an anode of colloidal graphite is shown. In the reverse direction the crystal was, as expected, an insulator.

537.311.33 : 546.561-31 **1623**

**Diamagnetic Zeeman Effect and the Exciton Structure in Cuprous Oxide Crystals.**—E. F. Gross & B. P. Zakharchenya. (*Zh. tekh. Fiz.*, Sept. 1957, Vol. 27, No. 9, pp. 1940–1943.) See also 1499 of 1957.

537.311.33 : 546.682.19 **1624**

**Preparation of Indium Arsenide.**—R. H. Harada & A. J. Strauss. (*J. appl. Phys.*, Jan. 1959, Vol. 30, No. 1, p. 121.)

537.311.33 : 546.682.86 **1625**

**Electrical Conduction in *n*-Type InSb between 20°K and 300°K.**—E. H. Putley. (*Proc. phys. Soc.*, 1st Feb. 1959, Vol. 73, No. 470, pp. 280–290.) Measurements are reported of the electrical conductivity and Hall coefficient for samples of InSb containing from $5 \times 10^{13}$ to $10^{18}$ conduction electrons per cm$^3$. The intrinsic carrier concentration is calculated from the results obtained above 180°K. The Hall mobility results are explained as due to a combination of acoustic lattice and ionized-impurity scattering.

537.311.33 : 621.314.7 **1626**

**Multiplication of Minority-Carrier Current in the Nonideal *p-n* Junction.**—V. I. Stafeev. (*Zh. tekh. Fiz.*, Oct. 1957, Vol. 27, No. 10, pp. 2195–2211.) The possibility of increasing minority-carrier current by means of a nonideal $p$-$n$ junction is examined. Alloy transistors of $p$-$n$-$p$ and $n$-$p$-$n$ type with $\alpha > 1$ and a region of negative resistance in the collector circuit are considered. The disruptive voltage can be adjusted from a few volts to 150–250 V and current after breakdown may reach 150–300 mA. The time of passage from one state to another is $0 \cdot 1$–$0 \cdot 2$ $\mu$s. See also 1893 of 1956 (Schenkel & Statz).

538.22 : 538.569.4 **1627**

**Paramagnetic Spectra of Substituted Sapphires: Part 1—Ruby.**—E. O. Schulz-DuBois. (*Bell Syst. tech. J.*, Jan. 1959, Vol. 38, No. 1, pp. 271–290.) Resonance properties of $Cr^{+++}$ ions in $Al_2O_3$ have been investigated theoretically and experimentally for three-level solid-state maser application. Energy levels and associated eigenvectors are presented as functions of applied magnetic field, and transition probabilities at certain orientations are discussed. Paramagnetic spectra for signal frequencies between 5 and 24 kMc/s are shown.

538.22 : 538.569.4 **1628**

**Paramagnetic Resonance Spectrum of Cr+++ in Emerald.**—J. E. Geusic, M. Peter & E. O. Schulz-DuBois. (*Bell Syst. tech. J.*, Jan. 1959, Vol. 38, No. 1, pp. 291–296.) Spectra observed in the X, K and M bands give the spectroscopic splitting factors for this material. The large value of zero-field splitting observed suggests an application as a solid-state maser for higher microwave frequencies.

538.22 : 538.569.4 **1629**

**Paramagnetic Resonance in the 10 000-Mc/s Band of Europium and Gadolinium subjected to a Cubic Crystalline Field.**—C. Ryter. (*Helv. phys. Acta*, 15th Oct. 1957, Vol. 30, No. 5, pp. 353–373. In French.)

538.22 : 538.569.4 **1630**

**Theory of Paramagnetic Resonance of Europium and Gadolinium subjected to a Cubic Crystalline Field.**—R. Lacroix. (*Helv. phys. Acta*, 15th Oct. 1957, Vol. 30, No. 5, pp. 374–394. In French.)

538.221 **1631**

**Some Magnetic Properties of Dilute Ferromagnetic Alloys: Part 2.**—B. W. Lothian, A. C. Robinson & W. Sucksmith. (*Phil. Mag.*, Sept. 1958, Vol. 3, No. 33, pp. 999–1012.) Part 1: 3667 of 1955 (Bate et al.).

538.221 : 621.318.134 : 538.614 **1632**

**Faraday Effect and Birefringence in Ferrites at Microwave Frequencies.**—F. Mayer. (*Ann. Télécommun.*, July–Oct. 1957, Vol. 12, Nos. 7–10, pp. 279–288, 305–332 & 334–342.)

538.221 : 621.318.134 : 548.0 **1633**

**Some Properties of Mixed Gadolinium - Erbium and Gadolinium - Yttrium Garnets.**—G. Villers, J. Loriers & C. Claudel. (*C. R. Acad. Sci., Paris*, 25th Aug. 1958, Vol. 247, No. 8, pp. 710–713.)

538.221 : 621.318.134 : 621.318.57 **1634**

**Observations of Rotational Switching in Ferrites.**—W. L. Shevel, Jr. (*IBM J. Res. Developm.*, Jan. 1959, Vol. 3, No. 1, pp. 93–95.) Experimental data on switching times as a function of applied field for square-loop ferrites suggest three mechanisms of flux reversal, each being dominant over a certain region of the curve of inverse switching time against applied field.

621.315.61 : 621.318.4 **1635**

**Special-Purpose Magnet-Wire Insulation.**—G. Sideris. (*Electronics*, 13th Feb. 1959, Vol. 32, No. 7, pp. 60–61.) A brief review of wires available in U.S.

## MATHEMATICS

512 : 621.316.5 **1636**

**Ternary Switching Algebra.**—E. Mühldorf. (*Arch. elekt. Übertragung*, March 1958, Vol. 12, No. 3, pp. 138–148.) A switching algebra is developed for use in systems with a ternary code.

517.949.8 : 681.142 **1637**

**The *Z* Transformation.**—H. A. Helm. (*Bell Syst. tech. J.*, Jan. 1959, Vol. 38, No. 1, pp. 177–196.) "The Stieltjes integral is used to develop a rigorous derivation of the $z$ transform. Sufficient properties of the transformation are included to form a reasonably complete basis for the operational solution of constant-coefficient, linear, finite-difference equations."

519.251.7 : 53.088 **1638**

**Analysis of Errors in the Determination of the Mean Value of a Random Quantity and of its Mean Square Error due to the Finite Time of Observation.**—A. E. Kharybin. (*Avtomatika i Telemekhanika*, April 1957, Vol. 18, No. 4, pp. 304–314.) Formulae are derived and nomograms are plotted by means of which it is possible (*a*) to estimate whether the interval for the observation of a random quantity is sufficient, and (*b*) to find the assumed mean-square errors in the determination of the mean value and its dispersion for a typical case.

519.2 **1639**

**The Advanced Theory of Statistics. Vol. 1: Distribution Theory.** [Book Review]—M. G. Kendall & A. Stuart. Publishers: Griffin, London, 1958, 433 pp., 84s. (*Nature, Lond.*, 29th Nov. 1958, Vol. 182, No. 4648, p. 1470.)

## MEASUREMENTS AND TEST GEAR

621.3.018.41 (083.74) **1640**

**Standard-Frequency Transmissions.**—(*Electronic Radio Engr*, March 1959, Vol. 36, No. 3, pp. 117–118.) Details are given of a new method of adjusting the MSF standard-frequency transmission with reference to the second of Ephemeris Time (E.T.), to be operated from March 1959. The MSF frequency corrections published monthly in *Electronic Radio Engr* will be given to $\pm$ 1 part in $10^{10}$, and the form of presentation will be changed.

621.3.018.41 (083.74) : 538.569.4 **1641**

**Theory of the Cavity Microwave Spectrometer and Molecular Frequency Standard.**—Y. Beers. (*Rev. sci. Instrum.*, Jan. 1959, Vol. 30, No. 1, pp. 9–16.) The theory predicts that a considerable improvement in signal/noise ratio and sensitivity can be obtained in the cavity spectrometer. A fractional stability of about $4 \times 10^{-12}$ can be achieved in a frequency standard using the 3,3 ammonia line.

621.317.3 : 621.372.412 **1642**

**Quartz Crystals require Testing for Spurious Response.**—A. N. Silverstein. (*Electronic Ind.*, Oct. 1958, Vol. 17, No. 10, pp. 85–88.) The test equipment described is a modified form of the low-frequency spectrum analyser discussed by McDuffie (202 of 1956). It is used for detecting interfering spurious responses in quartz crystals operating in the frequency range 20–60 Mc/s.

621.317.361 + 621.317.373 **1643**

**A Pulse-Beat Method for Accurate Frequency and Phase Measurements and Phase-Locked Frequency Changing.**—G. Becker. (*Frequenz*, March 1958, Vol. 12, No. 3, pp. 82–90.) A method is described for accurate short-term comparison of two standard frequencies, particularly if their relation is rational, even if they differ considerably in magnitude. A differentiation method for accurate determination of phase coincidence, and the principle of phase-locking a frequency changer are outlined.

621.317.42 : 538.569.4 **1644**

**Measurement of Magnetic Fields by Nuclear Resonance.**—G. C. Lowe. (*Electronic Engng*, March 1959, Vol. 31, No. 373, pp. 138–140.) A simple feedback circuit is described for the accurate measurement of magnetic fields over a wide range with little readjustment of circuit elements.

621.317.6 : 621.3.001.4 **1645**

**Sorting Components by Measuring Waveforms.**—B. Agusta. (*Electronics*, 13th Feb. 1959, Vol. 32, No. 7, pp. 56–59.) Waveform characteristics of circuit components are obtained by sampling at discrete time intervals. A pulse whose amplitude is proportional to that of the waveform at the sampling time is produced and a digital output reading is obtained.

621.317.7 : 621.314.7 **1646**

**Measurement of Junction-Transistor Equivalent-Circuit Parameters.**—J. J. Sparkes. (*A.T.E. J.*, July 1958, Vol. 14, No. 3, pp. 176–187.)

621.317.7 : 621.314.7 **1647**

**A Transistor D.C.-A.C. Beta Tester.**—T. P. Sylvan. (*Electronic Ind.*, Oct. 1958, Vol. 17, No. 10, pp. 90–92.) Details are given of a tester for measuring both the d.c. and a.c. common-emitter current gain and the collector-to-emitter leakage current.

621.317.733 : [621.314.63 + 621.314.7 **1648**

**Capacitance Bridges for Semiconductor Measurements.**—N. F. Blackburne. (*A.T.E. J.*, July 1958, Vol. 14, No. 3, pp. 166–175.) Two bridges are described. The first is an admittance bridge for measurement of the effective parallel resistance and capacitance of *p-n* junctions under forward, reverse and zero bias in the frequency range 1 kc/s–1 Mc/s. The second bridge measures collector capacitance and extrinsic base resistance of junction transistors at frequencies up to 10 Mc/s. Measurements can be made at elevated temperatures.

621.317.734 **1649**

**On the Accuracy of the Ohmmeter.**—R. Braae. (*Engineer, Lond.*, 10th Oct. 1958, Vol. 206, No. 5359, pp. 563–565.) The classical theory of errors is used to analyse the capabilities and limitations of measuring equipment, particularly of ohmmeters.

621.317.75 **1650**

**The Recording and Collocation of Waveforms: Part 1.**—R. J. D. Reeves. (*Electronic Engng*, March 1959, Vol. 31, No. 373, pp. 130–137.) The basic principles and history of stroboscopic oscillographs are given. Modern methods of strobe pulse generation, synchronization and time delay are discussed.

621.317.77 **1651**

**Measurement of Phase and Amplitude at Low Frequencies.**—R. J. A. Paul & M. H. McFadden. (*Electronic Engng*, March 1959, Vol. 31, No. 373, pp. 142–149.) Description of a l.f. oscillator and phasemeter for testing feedback control systems. The range extends from below 0·01 c/s to at least 10 kc/s.

621.317.794 : 537.324 **1652**

**Thermocouples and Bolometers for Radiation Measurements in the Infrared Spectral Region.**—G. Grave & W. Heimann. (*Elektronik*, March 1958, Vol. 7, No. 3, pp. 65–69.) The construction of sensitive radiation measuring equipment is described with brief details of apparatus for medical applications.

621.317.794 : 537.324 **1653**

**Noise in Radiation Thermocouples.**—V. Schley & F. Hoffmann. (*Optik, Stuttgart*, June 1958, Vol. 15, No. 6, pp. 358–371.) Measurements indicate that solder joints to the couple may be a source of thermal noise.

## OTHER APPLICATIONS OF RADIO AND ELECTRONICS

535.376.07 **1654**

**Solid-State Panels for Display or Storage.**—R. K. Jurgen. (*Electronics*, 30th Jan. 1959, Vol. 32, No. 5, pp. 46–47.) The use of photorectifier matrices with packing densities of 256/in$^2$ for character generation and storage is described.

621-52 : 621.395.625.3 **1655**

**Magnetic Drum provides Analogue Time Delay.**—H. L. Daniels & D. K. Sampson. (*Electronics*, 6th Feb. 1959, Vol. 32, No. 6, pp. 44–47.) The use of a magnetic drum to provide delays of between 5 and 20 sec is described. A recording range of $\pm 50$ V and an accuracy within 0·1% for frequencies between 0 and 1 c/s are achieved.

621-52 : 681.142 **1656**

**Digital System positions Shafts over Phone Line.**—R. B. Palmiter. (*Electronics*, 13th Feb. 1959, Vol. 32, No. 7, pp. 62–66.) Description of a carrier system by which data describing the position of three master shafts as well as all necessary synchronizing and auxiliary information are transmitted over a telephone line for controlling slave shaft positions.

621.384.6 : 621.319.339 **1657**

**An Accelerator with an 800-kV Cascade Generator.**—K. Simonyi. (*Acta tech. Acad. Sci. hungaricae*, 1958, Vol. 19, Nos. 3/4, pp. 353–362. In German.) Description of an installation of the Central Physical Research Institute, Budapest, with details of the rectifier-valve heating and ion focusing arrangements.

621.396.969 : 533.6.011.7 **1658**

**Radio Observations of Hypersonic Shock Waves.**—J. S. Hey, J. T. Pinson & P. G. Smith. (*Nature, Lond.*, 1st Nov. 1958, Vol. 182, No. 4644, pp. 1220–1221.) Application of the Doppler technique described earlier (3625 of 1957).

621.398 : 621.376.5 **1659**

**A Static Transmitting Device for Pulse-Frequency Telemetry Systems.**—A. M. Pshenichnikov. (*Avtomatika i Telemekhanika*, May 1957, Vol. 18, No. 5, pp. 444–448.) Description of a magnetic-modulator/multivibrator circuit with compensating feedback network. The frequency of the multivibrator output is a linear function of the measured quantity. Advantages over existing types of transmitting device are noted.

## PROPAGATION OF WAVES

621.396.11 **1660**

**On the Spectrum of a Passive Scalar Mixed by Turbulence.**—A. D. Wheelon. (*J. geophys. Res.*, Dec. 1958, Vol. 63, No. 4, pp. 849–850.) A discussion of 1527 and 1533 of 1958 (Bolgiano). Previous analysis (2881 of 1957) is extended to show that removal of spectral content by convective transfer is more important than diffusion damping throughout the inertial range, whatever the spectrum may be. See also 1661 below and *ibid.*, pp. 854–855.

621.396.11 **1661**

**On the Role of Convective Transfer in Turbulent Mixing.**—R. Bolgiano, Jr. (*J. geophys. Res.*, Dec. 1958, Vol. 63, No. 4, pp. 851–853.) The extended theory given by Wheelon (1660 above) is not necessarily valid, since additional mechanisms of transfer (rather than dissipation) are introduced. The differences between the two theories are due to conceptually distinct methods of treating the convective transfer process.

621.396.11 **1662**

**Propagation of Electromagnetic Pulses Around the Earth.**—B. R. Levy & J. B. Keller. (*Trans. Inst. Radio Engrs*, Jan. 1958, Vol. AP-6, No. 1, pp. 56–61. Abstract, *Proc. Inst. Radio Engrs*, April 1958, Vol. 46, No. 4, p. 799.)

621.396.11 **1663**

**Scattering of Electromagnetic Waves in Beyond-the-Horizon Radio Transmission.**—D. I. Paul. (*Trans. Inst. Radio Engrs*, Jan. 1958, Vol. AP-6, No. 1, pp. 61–65. Abstract, *Proc. Inst. Radio Engrs*, April 1958, Vol. 46, No. 4, p. 799.)

621.396.11 **1664**

**Downcoming Radio Waves.**—J. R. Wait. (*Electronic Radio Engr*, March 1959, Vol. 36, No. 3, pp. 106–107.) A method of measuring the angle of arrival, azimuth and polarization of a downcoming radio wave using a crossed-loop direction finder with a four-element Adcock aerial.

621.396.11 : 523.53 **1665**

**Electromagnetic Scattering by Low-Density Meteor Trails.**—H. Brysk. (*J. geophys. Res.*, Dec. 1958, Vol. 63, No. 4, pp. 693–716.) A uniform underdense line of electrons is considered and the model is then extended to include diffusion and to take account of the fast initial movement of the particles before they are slowed to thermal velocities. The effect of aerial gain is discussed. Various limiting cases are examined and expressions are given for specular and nonspecular scattering.

621.396.11 : 551.510.52 **1666**

**Wavelength Dependence in Trans-horizon Propagation.**—R. Bolgiano, Jr. (*Proc. Inst. Radio Engrs*, Feb. 1959, Vol. 47, No. 2, pp. 331–332.) An experiment to determine the wavelength dependence of the scattering coefficient in tropospheric scatter propagation is described. Scaled aerials at 417 Mc/s and 2 290 Mc/s were used, and a wide range found for the wavelength dependence. The variation is considered to be statistically significant and to correspond to a variation in the meteorological processes responsible for the scattering.

621.396.11 : 551.510.535 **1667**

**On the Reciprocity of H.F. Ionospheric Transmission.**—M. Balser, W. B. Smith & E. Warren. (*J. geophys. Res.*, Dec. 1958, Vol. 63, No. 4, pp. 859–861.) Describes preliminary simultaneous two-way tests with pulses over a 1 685-km path in Canada, using the same aerial at each terminal for both receiving and transmitting. Sample records show nonreciprocal effects in the fading, even though aerials insensitive to Faraday rotation were used.

621.396.11 : 551.510.535 **1668**

**Polarization Fading over an Oblique-Incidence Path.**—D. A. Hedlund & L. C. Edwards. (*Trans. Inst. Radio Engrs*, Jan. 1958, Vol. AP-6, No. 1, pp. 21–25. Abstract, *Proc. Inst. Radio Engrs*, April 1958, Vol. 46, No. 4, p. 799.)

621.396.11 : 551.510.535 : 537.56 **1669**

**Equivalence Theorems of Wave Absorption in Plasma.**—K. Rawer & K. Suchy. (*Ann. Phys., Lpz.*, 20th May 1958, Vol. 1, Nos. 4/5, pp. 255–260.) Using wave and ray theory and neglecting the earth's magnetic field it is shown that Martyn's theorem of ionospheric absorption is valid only if attenuation is mainly due to collisions and is proportional to the number of collisions.

621.396.11 : 551.594.5 **1670**

**Radio Echoes from Auroral Ionization Detected at Relatively Low Geomagnetic Latitudes.**—R. L. Leadabrand & A. M. Peterson. (*Trans. Inst. Radio Engrs*, Jan. 1958, Vol. AP-6, No. 1, pp. 65–79. Abstract, *Proc. Inst. Radio Engrs*, April 1958, Vol. 46, No. 4, p. 799.)

621.396.11 : 551.594.5 **1671**

**The Geometry of Auroral Communications.**—R. L. Leadabrand & I. Yabroff. (*Trans. Inst. Radio Engrs*, Jan. 1958, Vol. AP-6, No. 1, pp. 80–87. Abstract, *Proc. Inst. Radio Engrs*, April 1958, Vol. 46, No. 4, pp. 799–800.)

621.396.11.029.45 : 621.396.67 : 621.315.1 **1672**

**Power-Line Aerial.**—R. M. Golden, R. V. Langmuir, R. S. Macmillan & W. V. T. Rusch. (*Electronic Radio Engr*, March 1959, Vol. 36, No. 3, p. 116.) A note on propagation experiments carried out in California using an 8-mile section of medium-voltage single-phase power transmission line as a radiator at 8·4 kc/s. Parallel-resonant circuits tuned to the operating frequency were used to isolate the line, and the power supplied to the aerial terminals was 10 kW. Measurements of extremely strong ionospheric reflections have been made at near-vertical incidence, and satisfactory signals have been detected 250 km away.

621.396.11.029.64 **1673**

**Radio Attenuation at 11 kMc/s and some Implications affecting Relay System Engineering.**—S. D. Hathaway & H. W. Evans. (*Bell Syst. tech. J.*, Jan. 1959, Vol. 38, No. 1, pp. 73–97.) Measurements have been made of attenuation and rainfall over paths of length 27 and 12 miles. The results are compared with theoretical expectations of attenuation, and the effect of attenuation on usable path length is discussed.

## RECEPTION

621.376.23 : 621.396.822 **1674**

**The Response of Nonlinear Devices to Band-Limited High-Frequency Signals and Noise.**—N. W. W. Smith. (*J. Electronics Control*, Nov. 1958, Vol. 5, No. 5, pp. 385–401.) "The envelope detection model is used to describe the response of nonlinear devices (e.g. detectors and mixers) to band-limited high-frequency signals. Results obtained for discrete sinusoidal signals are shown to be applicable to the continuous spectra of high-frequency noise without recourse to probability theory."

621.396.3 **1675**

**A Modern Frequency-Shift Telegraph Receiver.**—E. J. Allen. (*Electronic Engng*, March 1959, Vol. 31, No. 373, pp. 161–164.) In this system the 'mark' and 'space' signals are separated. Since diversity reception is employed two 'mark' and two 'space' signals are available, each pair of which are combined in a ratio squarer. The resultants are converted to double-current signals and added. The system will function with only one of the four signals present.

621.396.62 + 621.397.62] : 658.5 **1676**

**Some Uses of Statistical Methods in the Manufacture of Radio and Television Receivers.**—A. I. Godfrey. (*J. Brit. Instn Radio Engrs*, Jan. 1959, Vol. 19, No. 1, pp. 15–28.)

621.396.621 **1677**

**Receivers with Zero Intermediate Frequency.**—J. C. Greene & J. F. Lyons. (*Proc. Inst. Radio Engrs*, Feb. 1959, Vol. 47, No. 2, pp. 335–336.) Measurements made on a frequency-sweep receiver covering the range 500–930 Mc/s at a sweep rate of 10 c/s and using a low-pass video amplifier in place of a normal i.f. stage, indicated an average noise figure of 8 dB.

621.396.662 **1678**

**Some Aspects of Permeability Tuning.**—W. D. Meewezen. (*J. Brit. Instn Radio Engrs*, Jan. 1959, Vol. 19, No. 1, pp. 47–60.) Reprint. See 3622 of 1958.

621.396.662 : 534.76 **1679**

**F.M. Tuner Adapter for Multiplexed Stereo.**—L. Feldman. (*Electronics*, 6th Feb. 1959, Vol. 32, No. 6, pp. 52–54.) Description of a 4-valve converter unit for the reception of a multiplex-type two-channel stereophonic transmission.

621.396.821 : 551.594.6 **1680**

**Study of the Atmospheric Radio Noise at 27 and 100 kc/s at Delhi.**—Sachdev. (See 1580.)

621.396.822 **1681**

**The Spectrum of Limited Gaussian Noise.**—F. L. H. M. Stumpers. (*Philips Res. Rep.*, Dec. 1958, Vol. 13, No. 6, pp. 509–514.) "The energy spectrum of the output of a nonlinear device with an input of Gaussian noise can be expressed directly in terms of the Laplace transform of its characteristic and of convolutions of the input bandpass form. The expression is derived and the result applied to several forms of limiter characteristic. The same method can be applied if a carrier signal is also present."

621.396.822 **1682**

**Some Aspects of Noise in Communications and Servo Systems.**—R. M. Huey. (*Proc. Instn Radio Engrs, Aust.*, Sept. 1958, Vol. 19, No. 9, pp. 486–493.) Methods of system design involving studies of the system response to random signals, as opposed to sinusoidal signals, are discussed.

## STATIONS AND COMMUNICATION SYSTEMS

621.391 **1683**

**On the Mathematical Theory of Error-Correcting Codes.**—H. S. Shapiro & D. L. Slotnick. (*IBM J. Res. Develop.*, Jan. 1959, Vol. 3, No. 1, pp. 25–34.)

621.396.3 : 621.376 1684

**An Experimental Modulation-Demodulation Scheme for High-Speed Data Transmission.**—E. Hopner. (*IBM J. Res. Develop*m., Jan. 1959, Vol. 3, No. 1, pp. 74–84.) A description is given of a low-cost system which was designed to determine speed and reliability limitations on transmitting binary data over private telephone lines.

621.396.324 1685

**An Electronic Coder and Decoder for Teleprinter Signals.**—J. Das. (*Electronic Engng*, March 1959, Vol. 31, No. 373, pp. 156–160.)

621.396.41 : 621.396.62 1686

**The Development of Radio Telegraphy Systems on Short Waves and its Influence on Receiver Techniques.**—R. Tastenoy. (*Rev. HF, Brussels*, 1958, Vol. 4, No. 1, pp. 11–23.) A review of the principal multiplex systems and of the problems of selectivity and stability in receivers associated with these systems. Diversity reception is briefly discussed.

621.396.5 1687

**Radio Link Installations for the Transmission of Telephony and Television in the 4-kMc/s and 2-kMc/s Bands.**—K. Christ, O. Laaff & K. Schmid. (*Elektrotech. Z., Edn A*, 1st Oct. 1958, Vol. 79, No. 19, pp. 687–693.) The equipment of two f.m. systems is described. The 4-kMc/s system has a capacity of 600 telephony channels or one 625-line television channel, and the 2-kMc/s installation has 120 carrier-frequency channels; both conform to C.C.I.T.T. and C.C.I.R. recommendations.

621.396.5.029.62 1688

**Radio Transmission into Buildings at 35 and 150 Mc/s.**—L. P. Rice. (*Bell Syst. tech. J.*, Jan. 1959, Vol. 38, No. 1, pp. 197–210.) The e.m. field on the ground floor of a building was found to be 20–25 dB less than the median field in city streets at the same distance from the transmitter. It is shown that the effective coverage range in buildings is greater for the higher frequency.

621.396.65 : 621.396.933 1689

**Radio Links for the Control of Aeronautical Air-Ground-Air Equipment.**—W. S. McGuire. (*Proc. Instn Radio Engrs, Aust.*, Oct. 1958, Vol. 19, No. 10, pp. 541–550.) A multichannel f.m. system between Melbourne and outlying stations for the control of aircraft communication equipment is described. Frequency bands used are 160 Mc/s and 450 Mc/s; equipment is duplicated, and automatic change-over switching and test facilities are provided.

621.396.712 1690

**Common-Channel Common-Programme Operation of Medium-Wave Broadcasting Stations.**—S. F. Brownless. (*Proc. Instn Radio Engrs, Aust.*, Oct. 1958, Vol. 19, No. 10, pp. 529–541.) Two experimental systems are described, one using a low-power booster transmitter, the other using two manually synchronized crystal-controlled high-power transmitters. Conclusions are drawn from the test results reported. 30 references.

621.396.721 : 621.395.623.8 1691

**Sound Distribution at the Brussels Exhibition.**—A. V. J. Martin. (*Audio*, Feb. 1959, Vol. 43, No. 2, pp. 26-28 . . 80.) Five 250-W f.m. transmitters were used to supply about 450 sound sources, each consisting of one receiver feeding four loudspeakers. The receivers distributed over the exhibition grounds were in continuous operation for the six months' duration of the World Fair 1958. Details of circuitry and special installations are given.

621.396.74 + 621.397.7] (434.7) 1692

**The Network of Broadcast and Television Transmitters in Württemberg.**—H. Rupp. (*Elektrotech. Z., Edn A*, 1st Oct. 1958, Vol. 79, No. 19, pp. 670–673.)

## SUBSIDIARY APPARATUS

621-526 : 621.314.7-555.621 1693

**A Simple Temperature-Control System for Transistors.**—H. Kemhadjian. (*Mullard tech. Commun.*, Dec. 1958, Vol. 4, No. 36, pp. 186–190.) A description of a closed-loop servomechanism in which a power transistor, which supplies the current for a heating coil, is controlled by an error signal produced by a temperature-sensing a.f. transistor.

621-526 : 621.396.6 1694

**Loop controls Scatter Power to offset Fading.**—L. P. Yeh. (*Electronics*, 30th Jan. 1959, Vol. 32, No. 5, pp. 60–62.) A closed-loop servo system is described whereby the transmitted power of an u.h.f. tropospheric scatter link is reduced under conditions of good reception and increased under fading conditions. A statistical analysis of the system is given.

621.3.087.6 1695

**Converting Recorders to Rectilinear Outputs.**—N. D. Diamantides. (*Electronic Ind.*, Oct. 1958, Vol. 17, No. 10, pp. 82–84.) A computer circuit generating variable transport time delays is described for transforming pen recordings from arcs to straight lines. See also 1914 of 1957 (Massa & Massa).

621.311.6 : 621.317.7.089.6 1696

**Stabilized Variable-Frequency A.C. Instrument Calibration Source.**—C. A. Master & W. L. Mandrell. (*Rev. sci. Instrum.*, Jan. 1959, Vol. 30, No. 1, pp. 38–40.) A network is described which renders a 20 c/s–20 kc/s amplifier insensitive to variations of signal input, power supply and load.

621.311.62 : 621.316.722.1 1697

**High-Stability Mains-Operated Valve Heater Supply.**—C. T. Murray & R. E. Aitchison. (*Proc. Instn Radio Engrs, Aust.*, Sept. 1958, Vol. 19, No. 9, pp. 494–495.) Details are given of a circuit using a high-gain tuned amplifier with feedback controlled by a thermistor bridge.

621.314.57 : 621.314.7 1698

**A Four-Transistor D.C. Converter Circuit for Use with Relatively High-Voltage Supplies.**—W. L. Stephenson. (*Mullard tech. Commun.*, Dec. 1958, Vol. 4, No. 36, pp. 191–192.) An experimental bridge circuit is described with a power output of 40 W and conversion efficiency 90 %.

## TELEVISION AND PHOTOTELEGRAPHY

621.397.5 1699

**Television Techniques.**—E. Schwartz. (*Elektrotech. Z., Edn A*, 1st Oct. 1958, Vol. 79, No. 19, pp. 743–746.) Review of recent developments. 69 references.

621.397.5 : 535.623 1700

**A Simple and Compatible System for Colour Television.**—L. Chrétien & R. Aschen. (*TSF et TV*, Oct. 1957, Vol. 33, No. 348, pp. 323–324.) The system outlined is based on transmitting the luminance signal in a bandwidth of 5·5 Mc/s and the chrominance signals on two subcarriers of different frequency, all within the 14-Mc/s channel normally allotted for 819-line monochrome transmissions.

621.397.5 : 535.623 : 535.417 1701

**Applications of the Interference of Light in Thin Films.**—P. M. van Alphen. (*Philips tech. Rev.*, 24th Aug. 1957, Vol. 19, No. 2, pp. 59–67.) The theory of optical interference and its application to dichroic mirrors for colour television are briefly discussed. The construction and production of the mirrors are described.

621.397.5 : 621.395.625.3 1702

**Eight Papers on Video Tape and Recording.**—(*J. Soc. Mot. Pict. Telev. Engrs*, Nov. 1958, Vol. 67, No. 11, pp. 721–745.) Problems in recording and editing video signals in the Ampex system are described and discussed. The mechanical design of the tape transport system and head is not described. The electronic system for recording and playback and the processing of the recovered signal to restore the synchronization and gating pulses is described together with the use of magnetic powders to enable splices to be located accurately. The problem of the development of high-quality tape for use with rotating heads and the importance of head alignment are discussed.

621.397.611.2 : 535.215 1703

**Semiconducting Materials in Vidicon-Type Television Pickup Tubes.**—V. A. Babits. (*J. Telev. Soc.*, Oct.-Dec. 1958, Vol. 8, No. 12, pp. 498–502.) A summary of the target materials used in the vidicon-type tube, and the physical principles underlying their performance. Possible increases in sensitivity and temperature range are suggested as a result of proper choice of material for the various layers.

621.397.621.2 **1704**

**The Current Characteristic of TV Picture Tubes.**—W. F. Niklas. (*J. Telev. Soc.*, Oct.-Dec. 1958, Vol. 8, No. 12, pp. 512–515.) The value of the exponent in the cathode current characteristic of c.r. tubes increases from 2·5 to 3·5 with increasing current values for space-charge-limited emission.

621.397.621.2 : 535.623 **1705**

**The Faraday Cell in Colour Television.**—R. W. Wells. (*J. Telev. Soc.*, Oct.-Dec. 1958, Vol. 8, No. 12, pp. 503–506.) A summary of the advantages and limitations of a projection c.r. tube with a Faraday cell and a cellophane filter.

621.397.7 **1706**

**Isle of Wight I.T.A. Station.**—(*Brit. Commun. Electronics*, Nov. 1958, Vol. 5, No. 11, pp. 850–851.) An outline is given of the transmitting equipment at Chillerton Down and the microwave radio-relay system linking London and Southampton. For a similar account see *Engineer, Lond.*, 29th Aug. 1958, Vol. 206, No. 5353, pp. 340–341.

621.397.7(4) **1707**

**European Television Stations.**—(*Wireless World*, March 1959, Vol. 65, No. 3, pp. 109–116.) A comprehensive survey of European networks including summaries of services available in each country and reproductions of test cards. World television standards and European channel allocations in bands I and III are tabulated. Transmitters, links, and conversion centres for Eurovision links are indicated on a map.

## VALVES AND THERMIONICS

621.314.63 : 546.289 **1708**

**Blocking Junction Process in Planar Germanium Diodes Type DG-Ts.**—Yu. K. Barsukov. (*Zh. tekh. Fiz.*, Oct. 1957, Vol. 27, No. 10, pp. 2252–2261.) An investigation of the first stage of the blocking process, corresponding to limitation of the reverse current through the diode by the resistance of the external circuit. The results for five diodes are tabulated and presented graphically.

621.314.63.002 **1709**

**The Manufacture of Germanium Diodes.**—C. F. Hühn. (*Telefunken Ztg*, April 1958, Vol. 31, No. 119, pp. 11–20. English summary, p. 66.) A description of the complete manufacturing process.

621.314.632 **1710**

**High-Frequency Gallium Arsenide Point-Contact Rectifiers.**—W. M. Sharpless. (*Bell Syst. tech. J.*, Jan. 1959, Vol. 38, No. 1, pp. 259–269.) Recent work is described using single crystals as frequency converters at frequencies as high as 60 kMc/s and as switching diodes for switching times of the order of $10^{-10}$s. Satisfactory operation is obtained over a considerable range of temperature.

621.314.632 : 621.316.722.1 **1711**

**Applications for Zener Diodes.**—G. Porter. (*Electronic Ind.*, Oct. 1958, Vol. 17, No. 10, pp. 108, 110.) A list is given of the manufacturers of various types of Zener diode, and applications are tabulated.

621.314.7 **1712**

**New Transistor works at Cryogenic Temperatures.**—S. Weber. (*Electronics*, 23rd Jan. 1959, Vol. 32, No. 4, pp. 34–35.) A 'grain-boundary' transistor capable of operating at temperatures as low as 2°K is described. Its operation is based on the characteristics of the boundary formed between two crystal lattice structures of different grain orientation.

621.314.7 **1713**

**Some Criteria for the Thermal Stability of Transistors.**—F. Weitzsch. (*Frequenz*, March 1958, Vol. 12, No. 3, pp. 65–71.) The conditions giving rise to thermal instability are analysed and formulae are derived to determine whether a given circuit requires stabilization.

621.314.7 **1714**

**An Analysis of Base Resistance for Alloy-Junction Transistors.**—A. J. Wahl. (*Trans. Inst. Radio Engrs*, July 1958, Vol. ED-5, No. 3, pp. 131–139. Abstract, *Proc. Inst. Radio Engrs*, Nov. 1958, Vol. 46, No. 11, p. 1889.)

621.314.7 **1715**

**Physical Mechanisms Leading to Deterioration of Transistor Life.**—G. C. Messenger. (*Trans. Inst. Radio Engrs*, July 1958, Vol. ED-5, No. 3, pp. 147–151. Abstract, *Proc. Inst. Radio Engrs*, Nov. 1958, Vol. 46, No. 11, p. 1890.)

621.314.7 : 621.317.7 **1716**

**Measurement of Junction-Transistor Equivalent-Circuit Parameters.**—J. J. Sparkes. (*A.T.E. J.*, July 1958, Vol. 14, No. 3, pp. 176–187.)

621.314.7 : 621.317.7 **1717**

**A Transistor D.C.-A.C. Beta Tester.**—Sylvan. (See 1647.)

621.314.7.012.8 **1718**

**Transistor Equivalent Circuit.**—D. A. Green. (*Electronic Radio Engr*, March 1959, Vol. 36, No. 3, pp.108–114.) A circuit is derived which is valid at all frequencies at which alloyed-junction transistors give useful gain. The circuit may be used to calculate the performance of h.f. amplifiers.

621.314.7.012.8 **1719**

**The Junction Transistor as a Network Element at Low Frequencies: Part 1—Characteristics and *h* Parameters.**—J. P. Beijersbergen, M. Beun & J. te Winkel. (*Philips tech. Rev.*, 27th July 1957, Vol. 19, No. 1, pp. 15–27.)

621.314.7.012.8 : 530.17 **1720**

**The Thermal Equivalent Circuit of a Transistor.**—P. R. Strickland. (*IBM J. Res. Developm.*, Jan. 1959, Vol. 3, No. 1, pp. 35–45.) It is shown that an exact electrical analogue can be given for the thermal system between the collector junction and the constant-temperature environment of a transistor. An experimental method is given for obtaining the parameters of the equivalent circuit, and its application in circuit design is discussed.

621.383 : 546.289 : 535.61-1 **1721**

**The Frequency Characteristic of a Germanium Infrared Diode Modulator.**—Yu. I. Ukhanov. (*Zh. tekh. Fiz.*, Sept. 1957, Vol. 27, No. 9, pp. 1950–1953.) Infrared rays passing through a Ge diode modulator were received on a PbS photocell. The modulation coefficient was found to be constant in the frequency range 20 c/s–20 kc/s.

621.383.27 **1722**

**Stroboscopic Operation of Photomultiplier Tubes.**—C. F. Hendee & W. B. Brown. (*Philips tech. Rev.*, 24th Aug. 1957, Vol. 19, No. 2, pp. 50–58.) A technique is described for analysing a periodically repeated low-intensity flash which is synchronized with a phase-delayed pulse to a photomultiplier tube. The tube can be triggered by a pulse as short as $10^{-7}$ sec to act as a light shutter, and the tube gain is much higher than that under d.c. operation. Circuit details and experimental results are given.

621.383.5 **1723**

**Grain-Boundary Photovoltaic Cell.**—R. K. Mueller & R. L. Jacobson. (*J. appl. Phys.*, Jan. 1959, Vol. 30, No. 1, pp. 121–122.) A photocell is described which is sensitive to light-spot movement in two dimensions. It comprises a rectangular rod of *n*-type Ge containing a grain boundary perpendicular to its main axis. Ohmic contacts are applied at the ends of the sample and In contacts are alloyed on opposite sides covering the grain boundary.

621.385 : 621.374.32 **1724**

**The Trochotron.**—N. P. R. Sherry. (*Brit. Commun. Electronics*, Nov. 1958, Vol. 5, No. 11, pp. 842–843.) A description of the mode of operation of a hot-cathode high-vacuum valve with a pulse counting rate in the region of $10^6$ per sec. See also 3079 of 1954 (Björkman & Lindberg).

621.385.029.6 **1725**

**On the Application of Harmonic Vibrations of Electrons for the Generation of Ultra High Frequencies.**—P. A. Borodovskiĭ. (*Zh. tekh. Fiz.*, Oct. 1957, Vol. 27, No. 10, pp. 2353–2355.) A brief description of results obtained with an experimental valve in which variations of the accelerating voltage from 150 to 1 000 V produce frequency changes from 310 to 600 Mc/s. See 3398 of 1954 (Alfvén & Romell).

621.385.029.6 **1726**

**Effect of Electron Lenses on Beam Noise.**—R. C. Knechtli. (*Trans. Inst. Radio Engrs*, April 1958, Vol. ED-5, No. 2, pp. 84–88. Abstract, *Proc. Inst. Radio Engrs*, July 1958, Vol. 46, No. 7, p. 1440.)

621.385.029.6 **1727**

**New Mechanism of Noise Reduction in Electron Beams.**—M. R. Currie & D. C. Forster. (*J. appl. Phys.*, Jan. 1959, Vol. 30, No. 1, pp. 94–103.) Experiments have demonstrated that the basic noise quantities of an electron beam can be transformed and optimized by varying the field configuration and flow characteristics in the multivelocity region near the cathode. A detailed investigation of the conditions for minimum beam noisiness is presented.

621.385.029.6 **1728**

**Reduction of Electron-Beam Noisiness by means of a Low-Potential Drift Region.**—A. W. Shaw, A. E. Siegman & D. A. Watkins. (*Proc. Inst. Radio Engrs*, Feb. 1959, Vol. 47, No. 2, pp. 334–335.)

621.385.029.6 **1729**

**Ballistic Analysis of a Two-Cavity Finite-Beam Klystron.**—S. E. Webber. (*Trans. Inst. Radio Engrs*, April 1958, Vol. ED-5, No. 2, pp. 98–108. Abstract, *Proc. Inst. Radio Engrs*, July 1958, Vol. 46, No. 7, p. 1440.)

621.385.029.6 **1730**

**Principle of Operation and Working Data for the Power Reflex Klystron TK7.**—F. Möhring. (*Tech. Mitt. PTT*, 1st April 1958, Vol. 36, No. 4, pp. 145–149.) The klystron has a maximum h.f. output >5 W for a 35-Mc/s bandwidth in the 4-kMc/s range.

621.385.029.6 **1731**

**Propagation in a Crossed-Field Periodic Structure.**—A. Kiel, M. Scotto & P. Parzen. (*Trans. Inst. Radio Engrs*, April 1958, Vol. ED-5, No. 2, pp. 76–84. Abstract, *Proc. Inst. Radio Engrs*, July 1958, Vol. 46, No. 7, p. 1440.)

621.385.029.6 **1732**

**Characteristics of Travelling-Wave Tubes with Periodic Circuits.**—R. W. Gould. (*Trans. Inst. Radio Engrs*, July 1958, Vol. ED-5, No. 3, pp. 186–195. Abstract, *Proc. Inst. Radio Engrs*, Nov. 1958, Vol. 46, No. 11, p. 1890.)

621.385.029.6 **1733**

**A Hybrid-Type Travelling-Wave Tube for High-Power Pulsed Amplification.**—E. J. Nalos. (*Trans. Inst. Radio Engrs*, July 1958, Vol. ED-5, No. 3, pp. 161–166. Abstract, *Proc. Inst. Radio Engrs*, Nov. 1958, Vol. 46, No. 11, p. 1890.)

621.385.029.6 **1734**

**Conditions for Minimum Noise Generation in Backward-Wave Amplifiers.**—M. R. Currie & D. C. Forster. (*Trans. Inst. Radio Engrs*, April 1958, Vol. ED-5, No. 2, pp. 88-98. Abstract, *Proc. Inst. Radio Engrs*, July 1958, Vol. 46, No. 7, p. 1440.)

621.385.029.6 : 537.533 **1735**

**Space-Charge-Wave Excitation in Solid-Cylindrical Brillouin Beams.**—W. W. Rigrod & J. R. Pierce. (*Bell Syst. tech. J.*, Jan. 1959, Vol. 38, No. 1, pp. 99–118.) The voltage and current modulation of ideal cylindrical electron beams in Brillouin flow and in beams of zero magnetic field are studied by means of Laplace transforms. The problems of field modulation by an annular gap in a drift tube and noise excitation of a beam are discussed.

621.385.029.6 : 537.533 **1736**

**Space-Charge-Wave Harmonics and Noise Propagation in Rotating Electron Beams.**—W. W. Rigrod. (*Bell Syst. tech. J.*, Jan. 1959, Vol. 38, No. 1, pp. 119–139.) The higher-order space-charge waves on solid-cylindrical electron beams are considered. The properties of such waves are derived from slow-wave small-signal analysis.

621.385.029.6 : 621.316.726.078 **1737**

**Nonvacuum Devices control Klystrons.**—M. C. Harp. (*Electronics*, 13th Feb. 1959, Vol. 32, No. 7, pp. 68–70.) Close frequency control of transmitter and receiver local-oscillator klystrons in a 6-kMc/s microwave link is achieved by the use of magnetic amplifiers and transistors.

621.385.029.6 : [621.372.2+621.372.8 **1738**

**Electron Waves in Periodic Structures.**—L. A. Vaĭnshteĭn. (*Zh. tekh. Fiz.*, Oct. 1957, Vol. 27, No. 10, pp. 2340–2352.) Relations derived earlier (338 of 1957) for retarding systems are generalized, and an expression is obtained for calculating the linear properties of travelling-wave and backward-wave valves.

621.385.029.6 : 621.376.3 **1739**

**Linearization of the Frequency-Modulation Characteristic of a Reflex Klystron.**—E. Schuon & H. J. Butterweck. (*Arch. elekt. Übertragung*, March 1958, Vol. 12, No. 3, pp. 99–108.) The characteristic can be straightened and the frequency swing increased by applying a coupled-resonator load with band-filter characteristics.

621.385.029.64/.65 **1740**

**Two Backward-Wave Oscillator Tubes for the 29 000 to 74 000 Megacycle Frequency Range.**—D. J. Blattner & F. Sterzer. (*RCA Rev.*, Dec. 1958, Vol. 19, No. 4, pp. 584–597.) The characteristics and performance of two experimental backward-wave oscillator valves are described. Their wide frequency range and milliwatt-level power output make them suitable for signal-generator and local-oscillator applications.

621.385.029.64 **1741**

**The Reflex Klystron as a Negative-Resistance-Type Amplifier.** — C. F. Quate, R. Kompfner, & D. A. Chisholm. (*Trans. Inst. Radio Engrs*, July 1958, Vol. ED-5, No. 3, pp. 173–179. Abstract, *Proc. Inst. Radio Engrs*, Nov. 1958, Vol. 46, No. 11, p. 1890.)

621.385.029.64 **1742**

**A 20- to 40-kMc/s Backward-Wave Oscillator.**—R. W. Grow, D. A. Dunn, S. W. McLaughlin & R. P. Lagerstrom. (*Trans. Inst. Radio Engrs*, July 1958, Vol. ED-5, No. 3, pp. 152–156. Abstract, *Proc. Inst. Radio Engrs*, Nov. 1958, Vol. 46, No. 11, p. 1890.)

621.385.029.65/.66 **1743**

**Dielectric Slow-Wave Structures for the Generation of Power at Millimetre and Submillimetre Wavelengths.**—R. H. Pantell, P. D. Coleman & R. C. Becker. (*Trans. Inst. Radio Engrs*, July 1958, Vol. ED-5, No. 3, pp. 167–173. Abstract, *Proc. Inst. Radio Engrs*, Nov. 1958, Vol. 46 No. 11, p. 1890.)

621.385.832 **1744**

**Cathode-Ray Storage Tubes for Direct Viewing.**—A. S. Kramer. (*Electronics*, 23rd Jan. 1959, Vol. 32, No. 4, pp. 40–41.) Physical and electrical characteristics, performance data and applications of 17 types of tube are tabulated.

621.385.832 **1745**

**Survey of Half-Tone Image Storage Tubes.**—H. G. Lubszynski. (*Nachrichtentech. Z.*, March 1958, Vol. 11, No. 3, pp. 115–124.) See 3362 of 1957.

621.385.832 **1746**

**Characteristics and Applications of the Iatron Storage Tube.**—D. W. Davis. (*Commun. & Electronics*, March 1957, No. 29, pp. 47–53; *Elect. Commun.*, 1958, No. 2, pp. 93–102.)

621.385.832 **1747**

**Cathode-Ray Tube Adds Third Dimension.**—E. L. Withey. (*Electronics*, 23rd May 1958, Vol. 31, No. 21, pp. 81–83.) Details are given of the 'peritron', an experimental c.r. tube in which the fluorescent screen, of 18 cm diameter, is displaced harmonically along the Z-axis using a drive motor and crank assembly. A sinusoidal signal relating to the instantaneous position of the screen and derived by means of a magnet mounted in the push-rod and a fixed coil, is used to provide beam gating and focusing correction. Applications in air-traffic control systems are discussed.

621.385.832.087.6 **1748**

**An Electron-Beam Tube for 'Writing' Directly on Special Paper.**—(*Elektronik*, Feb. 1958, Vol. 7, No. 2, p. 48.) The prototype tube described has numerous short lengths of wire incorporated in its glass screen with the bare wire ends protruding slightly from the screen to form a raster. The electron beam impinging on the inner end of the wires will leave a record of its trace on current-sensitive paper (Type L, teledeltos) placed in contact with the tube screen.

## MISCELLANEOUS

061.4 : 621.3 **1749**

**Physical Society's Exhibition** [1959].—(*Wireless World*, March 1959, Vol. 65, No. 3, pp. 126–134.) Brief descriptions are given of selected exhibits.

621.3-71 **1750**

**Prediction of Temperatures in Forced-Convection Cooled Electronic Equipment.**—L. Fried. (*Trans. Inst. Radio Engrs*, June 1958, Vol. CP-5, No. 2, pp. 102–107. Abstract, *Proc. Inst. Radio Engrs*, Aug. 1958, Vol. 46, No. 8, p. 1553.)

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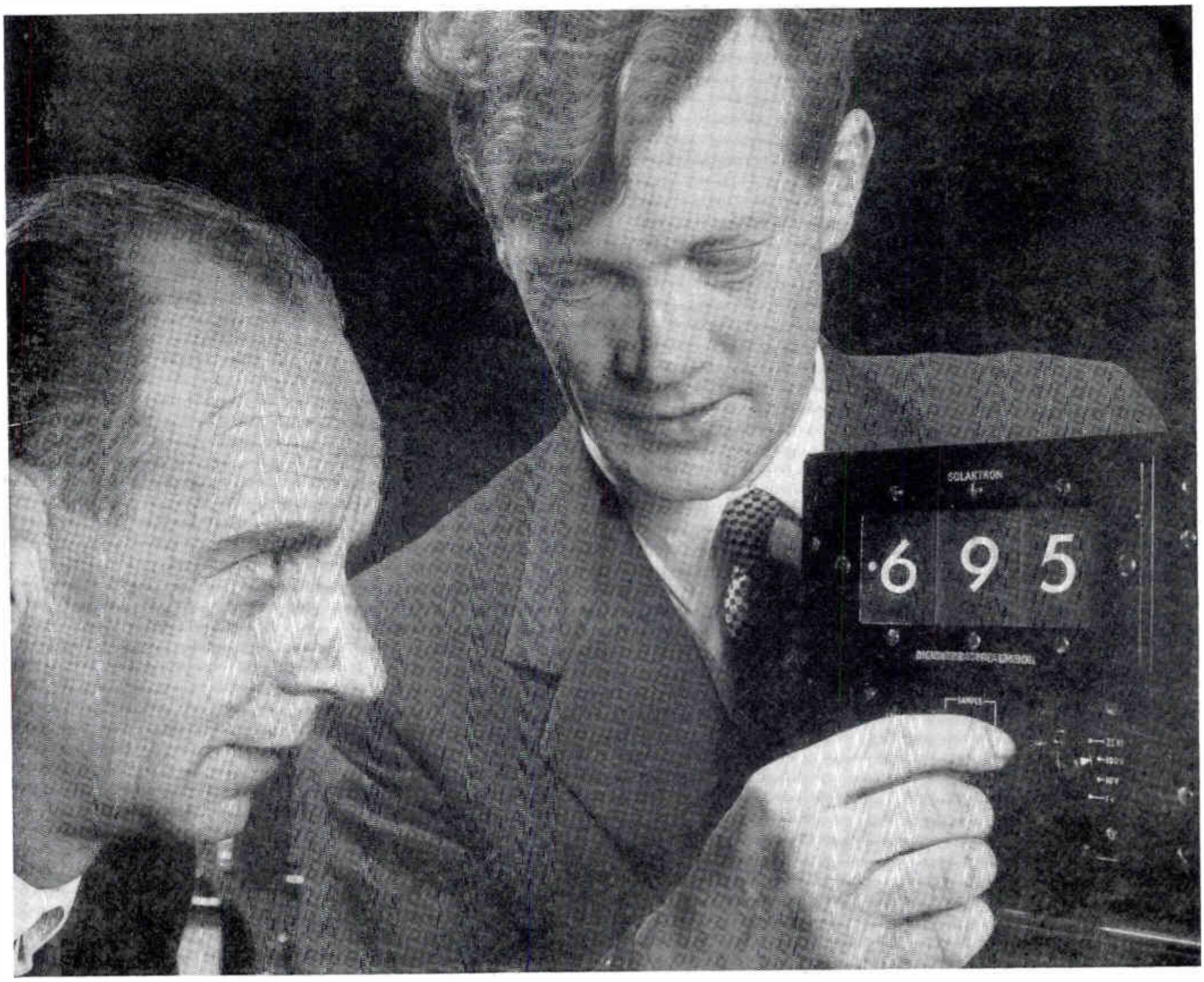


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