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Commentary

THE Monopolies and Restrictive Practices Commission's report on the supply of electronic valves and cathode-ray tubes which has recently been published, has created little stir within the valve making industry or with the principal users of valves and cathode-ray tubes; and the main criticism concerning the B.V.A.—the British Radio Valve Manufacturers' Association—seems to be directed at the high cost of replacement valves and cathode-ray tubes for the domestic market.

The Commission set about its investigation towards the end of 1954 and following the passing of the Restrictive Trade Practices Act in 1956 the Commission modified its original terms of reference and submitted a factual report only, setting forth instances of restrictive practices on the part of the B.V.A., including the following.

(1) Common prices were fixed and maintained for valves and cathode-ray tubes sold by retail that were considerably higher than the prices for valves and tubes sold for first equipment.

(2) Differential prices and discounts were allowed to various classes of customers.

(3) Restrictions were placed on the freedom of B.V.A. members and others to import valves and tubes.

(4) Members agreed on common forms and periods of guarantee.

To these and the other allegations contained in the report the British Radio Valve Manufacturers' Association has produced in reply a statement which appears largely to negative the Commission's report. The B.V.A. states that while the period from 1951 to 1954, chosen by the Commission to investigate the activities of the B.V.A. and examine the profits of its members, was the most prosperous in the history of the valve making industry, it was preceded by a period, immediately after the war, during which there was extensive reorganization from a war time to a peace time basis and it was followed by another period in which the industry was involved in considerable capital outlay, rising wages and costs of materials.

And so the dust has settled. The Monopolies and Restrictive Trades Practices Commission has produced a report which the B.V.A. says is largely a historical document covering only one period of its post war history, and in no way an indictment of its activities.

On both sides, therefore, honour seems to be satisfied.

The exhibition season is now in full swing and this year the electronic and allied industries are provided with a programme sufficient to daunt even the most avid of exhibition goers. In March the Television Society and the Physical Society held their exhibitions. In April there will be the Radio and Electronic Component Manufacturers Federation's Exhibition, the Association of Supervising Electrical Engineers' Exhibition and the London Audio Fair, while in May we have the Instruments, Electronics and Automation Exhibition. In addition one or two firms are staging private exhibitions of their own.

While it is obviously desirable, and indeed, necessary to show other members of the profession, and particularly those from overseas, what has been achieved and what is available, six major exhibitions plus several private ones in the course of three months seems, to say the least, a little much. And yet, even so, there are still sections of the industry which have not been adequately represented, and this applies particularly to the manufacturers of communications equipment.

How this long list of exhibitions can be shortened without impairing any firm's opportunity adequately to exhibit its wares is not easy to see and is a problem that can only be resolved by close co-operation between the various manufacturers' associations and, perhaps the scientific associations, with the lead coming from the Radio Industries Council.

The idea of one large Annual Electronics Exhibition is in some ways, attractive, but, with the present size of the industry and its many facets, it might prove to be a somewhat cumbersome affair that could only be viewed by a marathon walker; and even then, only at the risk of severe mental indigestion. However, for the time being we have the exhibition programme as already organized and, from the advance information available, this year's exhibitions should prove to be of outstanding interest.

This year, for the first time, the R.E.C.M.F. exhibition is to be split between two buildings, Grosvenor House and Park Lane House, and elsewhere in this issue a brief preview is given of some of the components and accessories which will be on view.

The May issue will contain a preview of the Instruments, Electronics and Automation Exhibition together with a description of some of the highlights of the Physical Society's Exhibition.

Dynamic Methods of Testing Semi-Conductor Rectifier Elements and Power Diodes

(Part 1)

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Measurement of static (d.c.) rectifier characteristics has many limitations which are overcome by dynamic test methods. Practical dynamic testing requires special instruments for accurate measurement of dynamic forward voltage and dynamic reverse current. Suitable electronic instruments are fully described. In Part 2 various approximate methods of dynamic testing not requiring special instruments will be reviewed and their errors considered.

THE d.c. (static) forward and reverse characteristics of a semi-conductor diode are easily measured by the ammeter-voltmeter method. They are readily understood and, apparently, unambiguous. It should be possible to calculate the a.c. performance of a rectifier at power frequencies in any given circuit with any desired degree of accuracy from a knowledge of its d.c. characteristics. Why, then, should it be necessary to consider methods of test under actual rectifying conditions? The reasons are as follows:

(a) D.C. characteristics taken at a series of steady voltage and current values are misleading owing to the stepped variations in the temperature of the rectifying junction which occur during such measurements. When the diode is driven cyclically over the same range of current and voltage values at power supply frequency the junction temperature is prevented from following the range of steady state values which would have been reached under d.c. conditions.

(b) For rating purposes it is necessary to specify forward and reverse limits. Such limits cannot conveniently be applied to the whole characteristic but are usually restricted to one measurement in the forward and one in the reverse direction. If these test limits are to be of practical use they must be strictly related to the actual rectifying performance. Single point d.c. limits cannot meet this requirement.

(c) When actually rectifying, the diode characteristics may change synchronously during the whole excursion of the a.c. cycle, for various reasons. D.C. tests cannot indicate such behaviour.

(d) Forward current affects the reverse characteristic and reverse voltage stress may affect the forward characteristic. D.C. testing cannot reveal these factors.

(e) As rectifiers of higher efficiency are evolved, greater accuracy in loss measurement and calculation becomes necessary. Losses cannot be accurately predicted from single-point d.c. measurements or even from complete d.c. characteristics for reasons (a), (c) and (d).

(f) In a.c. operation, the peak diode current may be many times the mean diode current. It is undesirable to measure the characteristics up to these high values with steady d.c., apart from the errors caused for the above reasons, as it is not desirable to tolerate the continuous dissipation of losses which, in service, only occur at the peaks of alternate half cycles.

Advantages of Full Dynamic Testing

To overcome the above limitations of d.c. testing, a method of testing under actual rectifying conditions is necessary. This is known as full dynamic testing. The diode is operated as a rectifier and measurements of the reverse and forward characteristics are taken while in operation. In this way the interdependence of forward and reverse loading, high peak current, cyclic thermal variation and other dynamic effects are allowed for. The over-riding advantage is that the test is realistic with the result that the dynamic characteristics thus obtained (if correctly defined and measured) are directly related to performance in service.

There are, however, other methods of dynamic testing which differ from the 'full' method described above. These are approximate methods and can appear in different forms, but they are similar in principle and are sometimes liable to give inaccurate results. The two basic methods 'full' and 'approximate' are therefore defined below.

Two Basic Forms of Dynamic Testing

It is desirable to define the two basic forms commonly used, i.e. Full Dynamic Testing and Approximate Dynamic Testing.

Full Dynamic Testing

The diode is operated on a.c. as a rectifier and experiences alternate and consecutive periods of forward current and reverse voltage. For standardization of test procedure and equipment these alternate periods are normally made consecutive half-cycles of a sine wave (e.g. the diode is operated in a half-wave circuit, with pure resistive load and energized from a sinusoidal supply). If essential, the periods may be modified to correspond to conditions of operation in other circuits. The forward and reverse characteristics are measured in operation. Specialized test instruments are necessary.

Approximate Dynamic Testing

The forward and reverse characteristics of the diode are examined dynamically, e.g. swept by half-cycles of current or voltage, but the forward and reverse tests are made independently of one another. In other words, the forward characteristic is examined without the application of reverse voltage and the reverse characteristic is examined without the passage of forward current. Specialized test instruments are not usually necessary but in some cases auxiliary means of generating special waveforms may be required.

Definitions of Dynamic Characteristics

The advantage of the simple direct relation between the dynamic characteristics of the diode and the operational performance of the complete arrangement can be lost if the dynamic characteristics are incorrectly defined.

The following definitions are, therefore, suggested. Unless otherwise specified these apply to measurements made in a sine-wave driven single-phase half-wave circuit with resistive load.

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(a) *Mean Forward Voltage Drop*

The mean value of the forward voltage drop in one diode or element integrated over the whole cycle.

(b) *Mean Forward Current*

The mean value of the forward current in one diode or element integrated over the whole cycle.

} Dynamic Forward Characteristic

(c) *A.C. Reverse Voltage*

The r.m.s. value of the input a.c. voltage applied to the complete rectifying circuit.

(d) *Mean Reverse Current*

The mean value of the reverse current in one diode or element integrated over the whole cycle.

} Dynamic Reverse Characteristic

Full Dynamic Testing

A full dynamic test to the definitions already given is achieved by operating the rectifier in the circuit shown in Fig. 1. The supply must be sinusoidal and of low impedance and precautions against d.c. magnetization of the supply transformer are usually necessary. The best method is to use a second load and rectifier connected in anti-phase, as shown, but a primary series connected rectifier can be used if suitable precautions are taken to avoid waveform distortion.

SOURCES OF ERROR IN THE CIRCUIT OF FIG. 1

It will be immediately evident that the above circuit is liable to error in various ways and that extremely stringent requirements are placed on the performance of the forward reading voltmeter V_f and the switching diodes A and B.

(1) The forward reading voltmeter (V_f) must be capable of registering mean forward voltages of the order of 0·3V with considerable accuracy and at the same time it must be completely insensitive to the reverse voltage across the diode under test, which may reach values of several hundred volts. It is clearly not possible to achieve this performance by the simple expedient of connecting the voltmeter in series with either a thermionic diode or a semi-conductor diode.

(2) The forward switching diode A must be capable of carrying the full forward current of the test diode, but on the reverse half cycle it must not by-pass any of the reverse current of the test diode from its correct path through switching diode B and the reverse current meter I_r. Even at the comparatively low voltages which are developed across I_r and diode B by the reverse current, this requirement is very difficult to achieve since diode A must be large and will pass appreciable reverse current even at low voltages. This leakage may not be so serious when testing selenium rectifiers.

(3) The reverse switching diode B must not by-pass any of the forward current from diode A, not because any appreciable error in the forward current reading (I_f) would result, but for the reason that any such current flowing on the forward half-cycle will produce an incorrectly low reading of the reverse current meter (I_r). This is not difficult to achieve since diode B can be of small area, but the requirement clearly conflicts with the aforementioned need to keep the voltage drop in diode B and the meter I_r low.

(4) The voltage drop in the reverse switching diode B and the reverse current meter (I_r) is subtracted from the supply voltage during the reverse half cycle. This effect may produce an appreciable error at the peak of the applied voltage wave, where the diode may be particularly sensitive to the magnitude of the reverse voltage, and where the reverse current and the instrument voltage drop are both at their greatest. Therefore, for this reason (in addition to (3) above) it is desirable to keep the voltage drop in diode B and the meter I_r low.

The above are the main sources of error in this circuit which, apart from (4), become more troublesome as the quality of the diode under test improves. It therefore becomes more difficult to make consistent measurements on high-quality diodes.

OVERCOMING ERRORS

To avoid these difficulties it has been proposed to use synchronous switches for diodes A and B, but although accuracy might thereby be improved under ideal conditions it is not likely to be maintained in practice by such a method owing, in particular, to the difficulty of maintaining precise phase adjustment.

The following electronic instruments were therefore designed for use in the circuit of Fig. 1. These will enable consistent dynamic measurements to be made without difficulty on a wide range of diodes of all types. These instruments are:

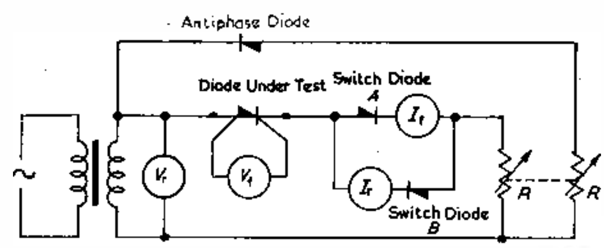

Fig. 1. Basic circuit for full dynamic testing

In the above circuit:—
Vr reads the 'A.C. Reverse Voltage'
Vf reads the 'Mean Forward Voltage Drop' and ignores the reverse half-cycle
Ir reads the 'Mean Reverse Current'
If reads the 'Mean Forward Current'

(a) A 'unipolar' low range forward reading voltmeter, completely insensitive to the reverse half-cycle, for V_f.

(b) A 'unipolar' reverse current ammeter of substantially zero impedance, for I_r.

Error (1) is eliminated by the new voltmeter, error (3) is eliminated by the new reverse current ammeter which also, by virtue of its substantially zero impedance, eliminates errors (2) and (4).

These instruments are fully described below.

'Unipolar' Voltmeter

THE 'IDEAL' INSTRUMENT

Fig. 1 shows a voltmeter V_f which is used to measure the mean forward voltage drop of the rectifier under test. The requirements of a satisfactory instrument for this purpose are:

(a) The indication should be proportional to the mean value of the positive potential applied to the input terminals.

(b) The indication should be completely insensitive to negative potentials applied to the input terminals.

(c) The input impedance should be high. The minimum permissible value depends upon the characteristics of the rectifier under test, but in general the current taken by the instrument for positive input potentials must be small compared with the rectifier forward current and for negative input potentials it must be small compared with the rectifier reverse current.

(d) The instrument should have a flat frequency response extending from d.c. over the range of frequencies to be used for dynamic testing.

From a theoretical point of view these requirements would be met by the circuit of Fig. 2 which presupposes that a mean reading voltmeter of suitable sensitivity and sufficiently high impedance is available for use as V and that an 'ideal' rectifier is available for MR.

Such an 'ideal' rectifier would have zero voltage drop in the forward direction and pass zero current in the reverse direction and by definition its forward and reverse characteristics would therefore meet at the origin.

In practice it would be possible to obtain a suitable voltmeter for inclusion in the circuit of Fig. 2, but it is not possible to obtain a rectifier for MR with characteristics which are sufficiently close to the 'ideal' to give anything approaching the necessary accuracy.

Practical Rectifiers

The choice of rectifiers actually available lies between semiconductor and thermionic types and each of these shows a departure from the 'ideal'.

The semiconductor rectifier in general shows imperfections in both the forward and the reverse directions and while it would perhaps be possible to choose a rectifier with a sufficiently low reverse current, such a rectifier in practice will always be found to have an inconveniently high forward voltage drop.

The thermionic diode departs from the 'ideal' in a somewhat different way. The characteristics are of the general form shown in Fig. 3, and it can be seen that as no appreciable reverse current flows, the characteristic is virtually 'ideal' in reverse. However, a considerable departure from the 'ideal' forward characteristic is exhibited in that a significant forward voltage drop occurs, although the thermionic diode differs from the semiconductor diode in that this voltage drop is negative for small currents and positive for large currents. (For one particular forward current value, of course, where the curve crosses the zero voltage axis, the diode exhibits no forward voltage drop). The thermionic diode is thus equally unsuitable for direct inclusion in the circuit of Fig. 2.

Comparing semi-conductor and thermionic rectifiers with the 'ideal' rectifier characteristic, it is seen that the thermionic rectifier shows a departure from the ideal in respect of one quantity only, namely forward voltage drop, whereas the semiconductor rectifier may show departures both in respect of forward voltage drop and finite reverse current.

Negative Feedback Amplifier

In attempting to make a circuit which will behave similarly to the circuit of Fig. 2 which requires an 'ideal' rectifier, it is convenient in practice to use the thermionic diode in place of MR and to provide means for correcting the diode characteristic to the 'ideal' form by, in effect, inserting into the circuit a compensating element having the complementary characteristics shown by the dotted line in Fig. 3. This can, in fact, be achieved by using rectified negative feedback with a d.c. amplifier. Within the limits set by the gain and zero stability of the d.c. amplifier the overall performance of the circuit may be made to approximate as closely as is required to that of the ideal circuit[1,2] of Fig. 2.

A simple form of rectified negative feedback circuit to give the desired result is shown in Fig. 4.

If the gain of the amplifier is large, the voltage across the meter V will be substantially equal to the input voltage to the instrument for all positive values. The small difference that will actually exist between the two is equal to

$$V_e = -\frac{V_i + V_d}{G}$$

where V_i is the indicated voltage, V_d is the voltage drop of the diode (which may be positive or negative) and $-G$ is the voltage gain of the amplifier.

This error voltage may be made as small as desired by suitably increasing G, within the limit of zero drift in the amplifier.

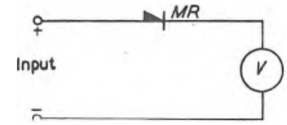

Fig. 2. Theoretical 'unipolar' voltmeter circuit assuming 'ideal' components

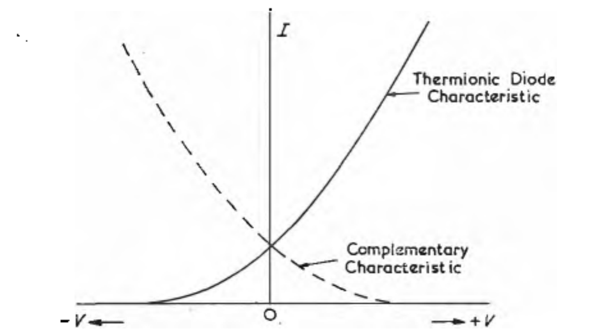

Fig. 3. General form of thermionic diode characteristic. Dotted curve shows complementary characteristic required to produce an 'ideal' overall characteristic

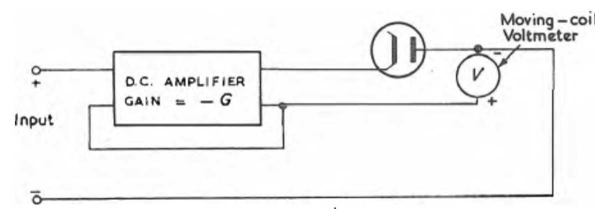

Fig. 4. Simple rectified negative feedback unipolar voltmeter circuit

Zero drift appears as a small voltage source apparently in series with the instrument input terminals giving rise to an additional error of this magnitude. This error may be positive or negative but the diode will prevent negative meter indications.

With zero voltage input to the instrument and neglecting zero drift an indicated voltage $-V_c/(G+1)$ will result, where V_c is the voltage necessary to cut off the diode. V_c will be negative and the error will be positive, but again may be made as small as desired by increasing G.

For negative input voltages the diode will be on reverse and virtually zero current will flow in the moving-coil voltmeter. This condition will not be obtained, however, unless the amplifier input impedance is high, as otherwise there will be a direct feed from the instrument input terminals through the amplifier input impedance to the meter.

In practice, by using a suitable valve amplifier, this input impedance can be made very high, so that negligible errors result.

When a large negative input voltage is applied it appears across the amplifier input terminals because the diode breaks the negative feedback path. This results in the generation of a very large amplifier output voltage which is impressed across the diode in reverse and may cause the amplifier to saturate, with attendant disadvantages when rapid recovery of the circuit is required. In practice it is convenient to avoid this condition and various means of doing so are available depending upon the detailed design of the amplifier. This point is further considered below in the design of a practical instrument.

Practical Instrument

The circuit arrangement shown in Fig. 4 is inconvenient because the common amplifier connexion is floating. This may be avoided by using a differential amplifier input stage and applying the feedback voltage to one input grid and the voltage to be measured, to the other.

It is essential that the polarities of the input voltage and the diode in the meter circuit are correctly chosen so that the instrument is sensitive to input voltages corresponding to positive swings on the grid of the input valve. In this way, the large negative input voltages to which the instrument must be insensitive, appear as negative voltages on this grid. With the incorrect polarity, these voltages would appear as positive grid voltages and cause grid current to flow. This grid current would have a disturbing effect upon the dynamic test circuit and would appear as a spurious reverse current in the rectifier under test.

The circuit of Fig. 5 shows a simple practical instrument using a two-stage d.c. amplifier having a voltage gain of about 30. The amplifier is based on a circuit described by Scroggie[3].

The instrument incorporates three ranges of 0·5, 2·5 and 10V f.s.d. and gives an overall accuracy of better than 2 per cent of full-scale deflexion on all ranges.

Means are provided for checking and setting the zero of the d.c. amplifier (S_1 and VR_2 respectively). The rather limited voltage gain of the amplifier makes it necessary to use somewhat less than 100 per cent negative voltage feedback to achieve an overall circuit gain of unity. This is effected by the potentiometer formed by VR_1 and resistor R_6. For maximum accuracy it is preferable to adjust VR_1 to the correct setting on each range, although only small errors are introduced by making the adjustment on the middle range and leaving it unchanged for the other two. The difference between settings required on each range is due to the different load resistances presented to the amplifier by the moving-coil voltmeter. Provision is made for checking the adjustment of the potentiometer VR_1 using the moving-coil voltmeter as a voltage standard. The switch S_2 enables a suitable direct voltage derived from the rectifier MR_3 to be applied successively first to the moving-coil voltmeter directly, and then to the amplifier input terminals with the voltmeter replaced in the amplifier output circuit. The potentiometer VR_1 should be adjusted to give equal meter indications in both switch positions.

The rectifier MR_1 prevents saturation of the amplifier when large negative potentials are applied to the input grid.

With zero input voltage to the instrument, valves V_1 and V_4 take approximately equal current and there is substantially zero voltage across MR_1. When a positive input potential is applied, the current in V_1 increases and that in V_4 decreases. The potentials of the anodes of V_1 and V_4 change correspondingly and MR_1 is driven on to its reverse characteristic. The copper oxide type rectifier chosen has a very high reverse resistance and under these conditions its effect on the circuit is negligible.

For negative input voltages, however, there is a tendency for the anode potentials of V_1 and V_4 to change in the direction to drive MR_1 on to its forward characteristic. When this happens, the rectifier conducts and prevents the anode of V_1 rising significantly in potential above that of V_4. The amplifier operating conditions are therefore maintained at a condition similar to that of zero input potential and saturation is avoided.

If this precaution is not taken, it is found that the resulting amplifier saturation produces grid current in V_4, some of which flows as a small error current through the meter. A further disadvantage is that if MR_1 is omitted, the recovery time of the amplifier limits the frequency response of the instrument. With MR_1 fitted, operation is satisfactory up to 2kc/s.

Because of unbalance which may exist in the valves or

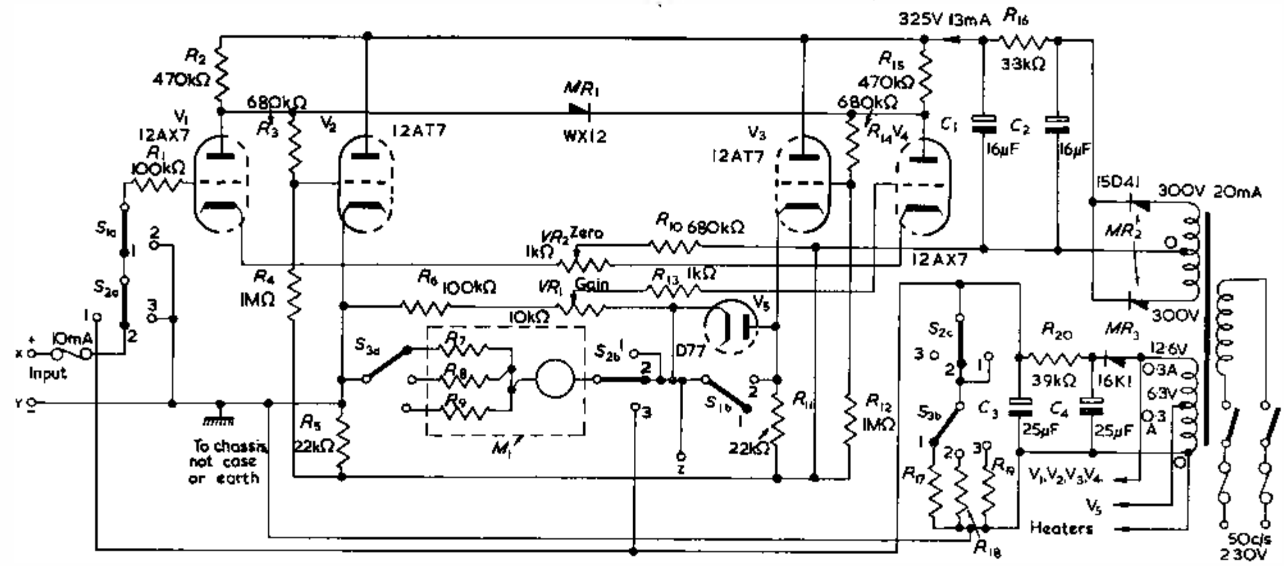

Fig. 5. Unipolar voltmeter

R_1 R_{13} ± 10% carbon ¼ watt
R_2 R_3 R_4 R_{10} R_{12} R_{14} R_{15} R_{20} ± 5% high stability carbon ½ watt
R_6 R_{11} ± 5% high stability carbon 1 watt
R_7 R_8 R_9 series resistors for M_1 (see M_1)
R_{16} ± 10% wire wound 2 watt
R_{17} equal to R_7 plus the resistance of the moving coil instrument
R_{18} equal to R_8 plus the resistance of the moving coil instrument
R_{19} equal to R_9 plus the resistance of the moving coil instrument

Potentiometers
VR_1 ± 10% wire wound (gain control)
VR_2 ± 10% wire wound (zero control)

Capacitors
C_1 C_2 450V D.C. working electrolytic
C_3 C_4 25V D.C. working electrolytic

Rectifiers
MR_1 Westinghouse copper oxide
MR_2 2 units type Westinghouse selenium
MR_3 Westinghouse selenium

Switches
S_1 2-pole change over key switch. Spring-loaded normally in position 1 (set zero)
S_2 3-pole position key switch. Spring-loaded normally in position 2 (check gain switch: position 1—adjust; position 2—normal; position 3—check)
S_3 2-pole 3-position rotary switch (meter range switch)
All switches with break-before-make contacts

Meter
3-range moving coil voltmeter 2000 ohms/volt
Series resistors (R_7 R_8 R_9) to give ranges of 0·5, 2·5 and 10 volts f.s.d.

inter-stage coupling resistors, a number of series elements are used in rectifier MR_1 so that several volts change in potential at the anodes of V_1 and V_4 is necessary before the rectifier is driven on to the low resistance portion of its forward characteristic. This obviates any possibility of MR_1 reducing the amplifier gain below the normal level for small positive inputs.

The dynamic range of the instrument is sufficient to permit operation up to full scale deflexion on each range with an input waveform comprising sinusoidal positive half cycles alternating with half cycles of zero or negative voltage. In general, the forward voltage drop of a rectifier in a single-phase dynamic test circuit will be rather more flat topped than this, but care must be taken in other types of dynamic test circuit (e.g. multi-phase circuits) that the instrument is not overloaded by the peaks of the positive input voltage waveform.

The voltage appearing across the moving-coil voltmeter is made available at the terminal marked Z and can conveniently be used in conjunction with an oscilloscope to display the dynamic forward characteristic of the rectifier under test.

'Unipolar' Reverse Current Ammeter

The 'Ideal' Instrument

Fig. 1 shows a series combination of a mean reading ammeter I_r and a switching diode B, as a means of indicating the reverse current of the rectifier under test. The use of practical components such as a moving-coil ammeter and either a thermionic or semiconductor diode, in such a circuit, may result in unacceptable errors as pointed out previously.

In attempting to design measuring equipment to overcome these errors, the requirements of a satisfactory instrument may be stated as follows:

(a) The indication should be proportional to the mean value of negative input current flowing through the input terminals.

(b) The indication should be completely insensitive to positive potentials applied to the input terminals.

(c) The input impedance should be low for negative input currents. The value required depends upon the rectifier under test but in general it should be sufficiently low to prevent the flow of appreciable reverse current through diode A.

(d) The input impedance should be high for positive input potentials. The value required depends again upon the rectifier under test but in general the current taken by the instrument should be low compared with the forward current in diode A.

(e) For negative input currents, the voltage drop between the input terminals should also be low compared with the supply voltage V in the dynamic test circuit. This is normally a less stringest requirement than (c).

(f) The instrument should have a flat frequency response extending from d.c. over the range of frequencies to be used for dynamic testing.

Negative Feedback Amplifier Circuits

As with the unipolar voltmeter, rectified negative feedback techniques can be employed to achieve a practical approximation to an 'ideal' instrument.

A simple form of such circuit is shown in Fig. 6 where it is assumed that the input impedance of the amplifier is high.

Because of the rectifying action of MR, the feedback path through MR and A is operative for negative inputs only, for which it has the effect of making the input impedance appear very low and causing the input current to flow through the mean reading meter A. The circuit operation is therefore consistent with requirements (a) and (e) above.

For positive inputs, the rectifier MR is operated on its reverse characteristic which is chosen to be of very high impedance, so that the input impedance of the instrument also appears to be very high and negligible current flows through the meter A. The circuit operation is therefore also consistent with requirements (b) and (d) above.

If the gain $-G$ of the amplifier is large, the voltage drop between the input terminals will be very small for negative input currents, and the voltage drop across the ammeter A and the rectifier MR will be supplied by the output of the amplifier. Ignoring zero drift effects, the actual voltage drop existing at the input terminals will be.

$$V_{in} = \frac{V_a + V_m}{(G + 1)}$$

where V_a is the voltage drop of the ammeter A and V_m that of the rectifier MR.

The maximum error current that can flow in the shunt

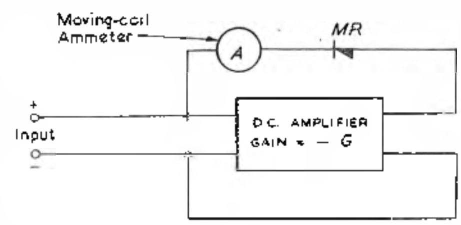

Fig. 6. Simple rectified negative feedback unipolar reverse current meter circuit

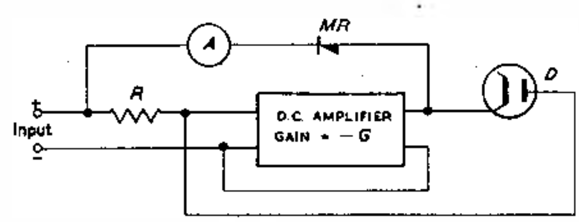

Fig. 7. Modification of Fig. 6 to prevent saturation of d.c. amplifier

path produced by the switching diode A (Fig. 1) is therefore

$$V_{in}/R_{ar}$$

where R_{ar} is the reverse resistance of diode A at very low voltages.

Within the limits of gain and freedom from zero drift which can be achieved in the design of a practical amplifier, this current error can be made as small as desired by increasing the value of G. Requirement (c) above may therefore be satisfied.

A practical circuit must, however, exhibit some zero drift in the amplifier and this zero drift appears as an apparent source of potential in series with the instrument input terminals. If this is of the appropriate polarity it can produce an error current which flows in reverse through diode A even in the absence of a genuine reverse current in the test rectifier. This current flows from the amplifier output and gives an error indication on the meter A.

The positive error current produced due to a negative zero drift voltage is approximately

$$i_e = \frac{-V_z}{2\,R_{ar}}$$

where V_z is the zero drift voltage of the amplifier referred to its input terminals.

The factor of 2 in the denominator occurs because the positive forward voltage drop in switching diode A during the forward half-cycle of the rectifier under test, is applied to the reverse current instrument input terminals and causes MR to be biased on reverse so that no current flows in meter A.

Positive zero drift voltages do not produce an error current directly in meter A in the absence of true reverse current as the flow of such an error current is prevented by MR, but in fact they appear as small potentials in series with the instrument input terminals. These potentials must be overcome by the external circuit when negative input currents are to be measured, so that the zero drift potential is effectively added to the dynamic input voltage V_{in}, to form the reverse stress applied to the switching diode A. This negative error also has a maximum value of $I_e = -V_z/2\,R_{ar}$ with the proviso that the actual reading of A must always be positive.

Thus, the error current due to zero drift in the amplifier places a limit on the extent to which the amplifier gain G may usefully be increased.

In practice, an instrument may be designed to give short term zero drift voltages of below 10mV although periodic correction of long-term drifts is necessary. Such an instrument may usefully employ an amplifier with sufficient gain to reduce V_{in}, the negative dynamic voltage drop across the input terminals, to a similar level. Suitable rectifiers may then in practice be chosen for the switching diode A, which cause negligible current error due to reverse leakage.

Referring again to Fig. 6, for positive input potentials the reverse resistance of the rectifier MR prevents the flow of appreciable input current and the full applied potential appears at the amplifier input terminals, causing a very large reverse voltage to be applied to MR. Such a condition may overstress MR as well as causing the amplifier to saturate and it is convenient in practice to avoid it. Fig. 7 shows a suitable circuit.

It will be seen that the circuit is similar to Fig. 6 except that a resistor R has been added in series with the high impedance input to the amplifier and an additional feedback path has been incorporated through the diode D.

For negative input currents, the circuit operation is identical to that of Fig. 6. For positive input potentials, however, there is now a voltage feedback path through D which prevents the amplifier output voltage building up appreciably above that required to make D conduct. The instrument, therefore, shows an apparent input resistance approximately equal to R for positive applied potentials.

In a practical instrument used in the dynamic test circuit of Fig. 1, this resistance appears in shunt with the forward current meter I_f and switching diode A. Values of R may however be chosen in practice such that no significant error occurs in the reading of I_f.

In practice it is necessary to add a small bias voltage in series with diode D to prevent conduction under the condition of zero amplifier output voltage.

Some advantage in respect of freedom from reverse leakage would result from using a thermionic diode for MR but except for instruments of very low maximum current indication, the high forward voltage drop of the thermionic diode is a disadvantage and a copper oxide type rectifier is to be preferred.

Practical Circuit

Fig. 8 shows a practical reverse current measuring ammeter based on the principles described. The instrument is suitable for measurement of rectifier reverse currents up to 100mA peak in a dynamic test circuit and has three ranges of 1, 10 and 50mA full-scale.

The d.c. amplifier has been designed to minimize zero drift but a 'zero' control is incorporated to enable the maximum possible accuracy to be obtained.

When the zero control is correctly set, the maximum negative voltage drop occurring at the input terminals is only 5 to 10mV.

Shunt resistors (R_1, R_2 and R_3) are included in the feedback path and these can be used to supply a suitable signal to a curve tracer. Current flows in the feedback path for negative input currents only, so that the reverse characteristic of the rectifier under test may be displayed independently of forward loading conditions. Further details of characteristic display circuits are given later. The instrument is suitable for use in test circuits operating at frequencies up to 600c/s.

The high gain of the d.c. amplifier requires the use of gain/phase correcting networks to avoid high frequency instability in the circuit. This is provided by the networks C_2, R_{24}, C_6, R_{27} and the capacitors C_3, C_4 and C_5.

Unfortunately the transient performance of the instrument is not entirely independent of reactance in the external circuit which may be introduced in practice by the self-capacitance of the switching diode A (Fig. 1). When this capacitance is high, as for example when A comprises a selenium rectifier rated to carry currents in the 10 to 100A range, the transient performance of the instrument is improved by omitting the correcting network C_2R_{14}. When the capacitance of A is small, however, as in the case of a smaller selenium rectifier or a silicon diode for example, the network will be required. A switch S_3 is included in the circuit to enable the correction network to be switched in or out.

In a practical test circuit, it is always possible that the amplifier may fail, e.g. due to a failure of its mains supply. In this event, the instrument input terminals could present a very high impedance which would possibly result in undesirably high reverse voltages appearing across the switching diode A (Fig. 1). To avoid this, the rectifier MR_5 is added to the circuit to enable current to flow directly through the meter without the amplifier in operation. In normal operation, MR_5 has no function and it is chosen to have three series elements so that it does not provide a short-circuit across the amplifier output at very low negative output voltages. In this case conduction through V_8 occurs before sufficient voltage is built up to allow MR_5 to conduct appreciably.

It is also desirable to provide some protection for the instrument against the heavy current overloads which could occur if the rectifier under test were to break down in reverse and this is provided by fuses (F_1, F_2 and F_3). The feedback path through the diode V_9 prevents high reverse voltages from being developed across MR_5 if the fuses blow. The relay A may be included if required, to operate a contactor to interrupt the supply to the test circuit. This operates only when the fuses are blown.

In the event of an overload causing a fuse to blow, high reverse voltage may be applied to switching diode A during the short interval before the contactor drops out. Where this is undesirable, it may be avoided by connecting a further rectifier across the input terminals PQ, in the opposite polarity to switching diode A. By suitably choosing the number and type of series elements in this rectifier in relation to the diode A, the latter may be effectively protected against over-voltage while the effective resistance of the additional rectifier at low forward voltages corresponding to the normal negative voltage drop between terminals PQ can be maintained sufficiently high to prevent any serious shunting effect.

Instrument Errors

In addition to the errors mentioned previously which, it was pointed out, could be reduced to acceptable levels in practice, there are other possible sources of error in a practical test circuit, which should be considered.

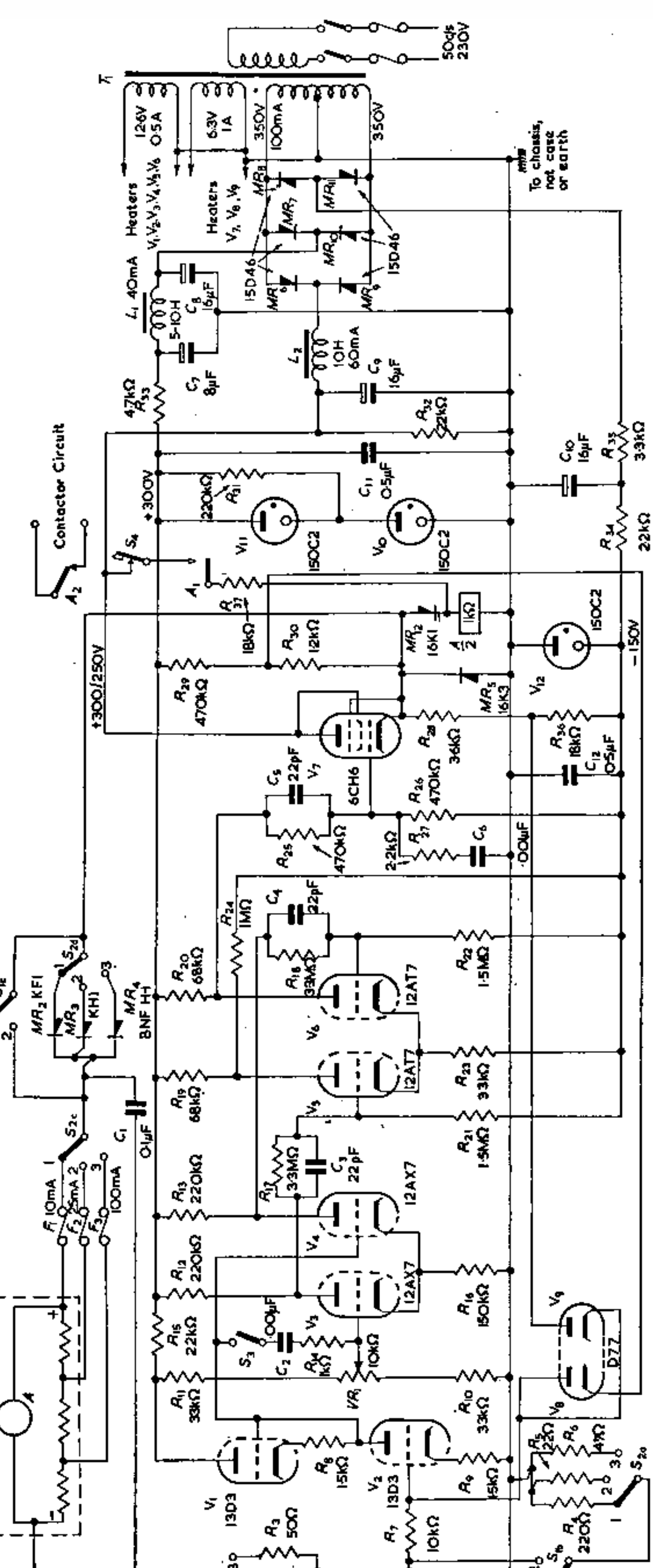

Fig. 8. Unipolar reverse current meter

Resistors
R_1 R_2 R_3 ± 1% high stability carbon ½ watt
R_8 R_9 R_{12} R_{13} R_{14} R_{19} R_{20} R_{22} R_{24} R_{25} R_{26} R_{29} ± 5% high stability carbon ½ watt
R_{10} R_{11} R_{15} ± 5% high stability carbon 1 watt
R_{17} R_{18} R_{21} R_{22} R_{23} R_{28} ± 5% high stability carbon ¼ watt
R_4 R_5 R_6 R_7 R_{34} R_{37} R_{31} ± 10% carbon ¼ watt
R_{32} R_{34} R_{35} ± 5% wire wound 5 watt
R_{33} ± 5% wire wound 10 watt
R_{37} ± 10% wire wound 5 watt
R_{36} ± 10% carbon 1 watt
Potentiometer
VR_1 ± 10% wire wound (zero control)
Capacitors
C_1 C_2 C_3 C_4 C_5 C_6 C_{12} 350V working paper
C_7 C_8 C_9 C_{10} 450V working electrolytic
C_{11} 500V working paper
Rectifiers
MR_1 MR_2 MR_3 MR_4 Westinghouse copper oxide
MR_5 MR_6 MR_7 MR_8 MR_9 MR_{10} MR_{11} MR_{12} Westinghouse selenium
Switches
S_1 3-pole, 2-way key switch: make-before-break action; spring-loaded normally in position 1. 50mA rating (set zero switch)
S_2 4-pole 3-way rotary switch; make-before-break action; 50mA rating (meter range switch, position 1—1mA; position 2—10mA; position 3—50mA)
S_3 single-pole on-off switch
S_4 push-button single pole. Normally closed
Meter
A 3-range moving coil milliammeter. One 10 and 50mA full-scale deflexion. Maximum voltage drop less than 250mV on all ranges
Relay
A P.O. type 3000
1 pair normally open contacts (A_1)
1 pair normally closed contacts (A_2)
Pick-up level approximately 9mA

As mentioned before, the instrument shown in Fig. 8 is suitable for measurement of currents not exceeding 100mA peak and it is important that higher peak currents should not be employed. This would result in excessive negative peak voltages appearing across the instrument input terminals with corresponding errors in current reading due to possible shunting effects in switching diode *A* (Fig. 1). The presence of such high peak currents is not immediately obvious from the indication of the reverse current meter as the mean current may well be of low value. To guard against these conditions it has been found to be convenient to use a unipolar voltmeter on the 0·5V range to monitor the negative potential across the terminals PQ. The reading will normally be substantially zero, but in the presence of high peak currents, a marked increase in indication will appear on the voltmeter. In practice, a single, unipolar voltmeter with a changeover switch may be used to combine this function with the normal function of measuring the forward voltage drop of the rectifier under test.

The reverse leakage of the switching diode *A* (Fig. 1) is, of course, a fundamental source of error and can never be made entirely zero because the gain of the d.c. amplifier in the reverse current meter can never be infinite nor can its zero drift be eliminated completely.

With the circuit of Fig. 8 the maximum negative potential appearing across the terminals PQ is of the order of 10mV or less assuming that long term zero drift effects are corrected by means of the zero control. Switching diode *A* must therefore be chosen to pass negligible reverse current at this potential. In practice, using the instrument on its 1mA range, a selenium rectifier may be successfully used for diode *A* for tests on rectifiers carrying forward currents of up to 50A mean because the reverse current of a selenium rectifier is extremely low at very low reverse voltages. A silicon junction rectifier could also be used for diode A and would enable a rectifier with an even higher ratio of forward to reverse current to be tested. In this case it would be possible to include a further reverse current range of a few hundred microamperes which could be used to measure the reverse current of high quality power diodes carrying forward currents exceeding 50A.

Since the amplifier successfully reduces the undesirable voltage drop in the milliammeter I_f and diode B in Fig. 1 to about 5mV, a germanium junction diode is inferior to a selenium rectifier for diode A, since at this extremely low voltage a germanium diode usually passes a higher reverse current than a selenium rectifier of the same forward rating, owing to the saturation effect in the reverse characteristic. This effect is less marked however with silicon junction rectifiers which, it has been found in practice with large junctions, do not saturate in reverse current below a level of approximately 250mV.

The self-capacitance of switching diode A may also be a source of error in the reverse current measurement. During the passage of forward current, this capacitance becomes charged to a voltage equal to the forward voltage drop, but when the current decays at the end of the conducting half cycle, any charge left in the capacitance, must discharge through the non-linear resistance of the rectifier. As the capacitor discharges and its voltage falls, the value of the resistance increases so that complete discharge of the capacitance is very slow unless current of the reverse polarity flows in the circuit.

The reverse current of the rectifier under test does, in fact, fulfil this function, but until the potential across the self-capacitance has been reduced to zero, the voltage across the input terminals of the reverse current meter is positive since the voltage drop in the meter I_f is negligible and so the reverse current meter is maintained in a high resistance condition. Thus the charge which is removed each cycle from the forward capacitance of diode A represents an error current, not indicated by the reverse current meter. This error, of course, becomes more significant, the lower the reverse current to be measured.

Hole storage effects in switching diode A will also behave in a similar way.

When the instrument is used with an oscilloscope, as described later, these effects can be observed as a shortening of the reverse current conduction angle due to a small part of the reverse current waveform being removed at the beginning of the reverse half cycle.

Hole storage or capacitance effects in the rectifier under test also have an effect upon the operation of the reverse current meter. For example, hole storage shows up in a dynamic test circuit, as a short pulse of heavy reverse current, lasting perhaps for a few microseconds at the beginning of the reverse half cycle but of comparable value to the previous forward current. Such current will generally have a peak value in excess of the 100mA peak current that can be handled by the reverse current meter and will therefore flow instantaneously at least in part through the reverse resistance or capacitance of switching diode A and a high voltage drop will be built up across the reverse capacitance of diode A.

After the pulse of hole storage current has terminated this capacitance will be discharged by the reverse current meter, but as its current handling capacity is limited to about 100mA peak, the capacitance may take considerably longer to discharge than the duration of the original hole storage pulse.

If the reverse characteristic is displayed on a curve tracer (Fig. 8) the reverse current will show a large pulse of hole storage current at the beginning of the reverse half cycle but this pulse will appear to have a peak value of only about 100mA and to last for considerably longer than a few microseconds.

If the reverse leakage effects in diode A could be ignored the area under the observed pulse would be the same as the area under the true pulse of hole storage current. In practice, however, errors are to be expected and in any case this effect and the effect of capacitance in diode A, described above, will be present simultaneously.

Complete Circuit Including Facilities for Curve Tracing

The dynamic test circuit using the unipolar voltmeter and unipolar reverse current meter described above, may

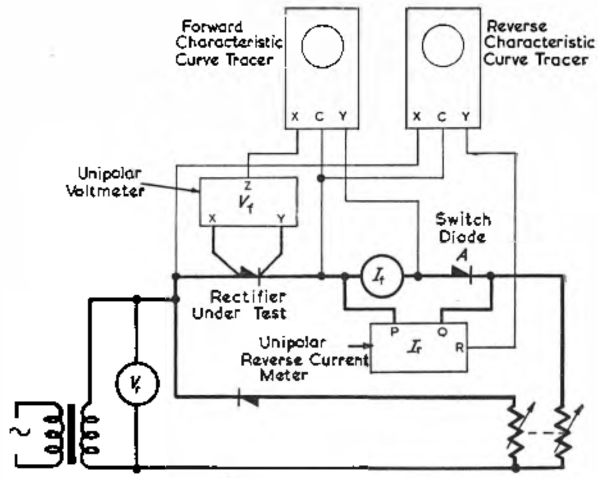

Fig. 9. Complete dynamic test circuit including facilities for curve tracing

conveniently have d.c. oscilloscopes incorporated to display the dynamic forward and reverse characteristics of the rectifier under test. The complete circuit is shown in Fig. 9.

It will be observed that for display of the rectifier forward characteristic, the oscilloscope is supplied with an input to the Y amplifier obtained from the voltage drop across the forward current meter I_f, together with an input to the X amplifier obtained from the unipolar voltmeter. Thus the forward characteristic can be displayed electrically independently of conditions in the reverse half cycle, leaving only the desired physical effects at the junction revealed.

For the display of the rectifier reverse characteristic the oscilloscope is supplied with an input to the Y amplifier obtained from the reverse current meter together with an input to the X amplifier or plates obtained directly across the rectifier under test. Thus the reverse characteristic can be displayed electrically independently of the conditions in the forward half cycle, leaving only the desired physical effects at the junction revealed.

The oscilloscopes to be used should employ d.c. coupling to the plates and in the amplifiers and care must be taken that the oscilloscope input resistances are sufficiently high to avoid shunting effects. In particular, the X circuit input resistance must be high compared with the reverse resistance of the rectifier under test in the case of the reverse characteristic display.

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(To be continued)

A High-Speed Data Processing System

By M. L. Klein*, R. B. Rush*, and H. C. Morgan*

A high-speed digital data system has been constructed which holds up to 4 800 000 eighteen-bit words on magnetic tape. These data are obtained from 100-input analogue signals at a rate of 10 000 words/sec. The information is recorded digitally on the tape along with source identification and time. This tape can be played back through the system into two IBM 727 tape units and is compatible with the IBM EDPM 704. System accuracy is 0·1 per cent with a 100mV full-scale input.

THE overall requirements for a high speed, high density, all electronic data reduction system are known. It is generally required that not less than 100 separate inputs be recorded at as high a conversion rate as possible with as low an input level as is feasible. There should also be reasonable latitude in assigning the input channels in various arrangements. In the IDIOT system use is made of an intermediary tape on which all pertinent information is stored permanently. This is shown in Fig. 1. This magnetic tape holds about eight minutes of digital information obtained at a 10kc/s conversion rate in the form of 18-bit binary words. When information is required from the tape, it is obtained by running this tape through the playback convertor which translates the information into IBM language and dubs it on to two IBM 727 tape units. These latter tape units permit direct access into an IBM EDPM. In this dubbing operation, editing can be accomplished and inter-record gaps inserted to simplify programming the computer. Only one playback unit is necessary for each EDPM no matter how many record units are used.

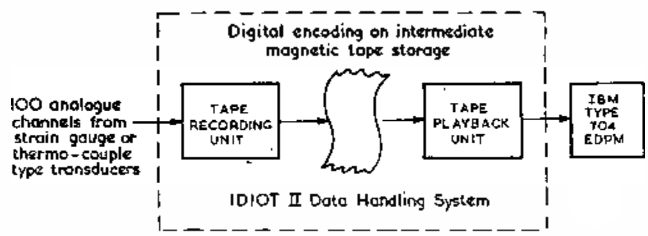


Fig. 1. Idiot II digital data handling system

Digital Recording Unit

The entire digital recording unit is shown in Fig. 2 in block form. Data from as many as 100 independent channels and as few as 20 channels are presented to the multiplexor at a full-scale level of 100mV. The multiplexor steps from one channel to the next at a rate of 10kc/s, passing the independent analogue signals to the clamp in fixed sequence. After amplification, the signals are clamped to the average value of a sample taken near the beginning of each multiplexor step as soon as the transients subside, and this value is maintained as a fixed d.c. level during the balance of the 100μsec interval. After the value is clamped or held as a d.c. level, it is presented for conversion to the analogue-to-digital convertor, a fixed programme ten-step digital encoder which produces a binary-code representation of the d.c. level. This information, along with a binary coding of the multiplexor position, is fed into a buffer storage in the tape code transcriber, and the analogue-to-digital convertor is released to begin the next conversion cycle. In the tape code transcriber, the 18-bit half-word produced is read out in the subsequent cycle in sequence of six parallel bits into the tape recorder. Simultaneously, two timing mark channels are added and the total of eight bits is presented to the tape recorder. The tape recorder records this information on tape producing an eight-channel binary tape with a pulse density of 500 pulses/in at a speed of 60in of tape/sec. The resultant tape, 2 400ft in length, is the intermediary tape and holds up to 4·5 million 18-bit half-words. This tape becomes the permanent storage for the information. The entire unit is keyed by pulses produced at the multiplexor so that in the event of a random drop-out, the entire unit pulses into step again at the next half-word and an error of only a single half-word is made. A checking loop is placed around the clamp and convertor. This is a low-order check of the two units within a loop. When a significant error is made within the loop, an error mark in the form of a bit is carried forward on to the tape. This is accomplished by comparing the digital output of the convertor with the analogue value held in the clamp by reconverting the former back into an analogue value. This is not essential as a low-order check, since this can be made part of the computer programme, but it can be set up to a relatively high value of sensitivity and provides some measure of protection against conversion inaccuracies. The intermediary tape, Fig. 3, is now available for the playback unit and is transported to the location of the IBM EDPM for further processing.

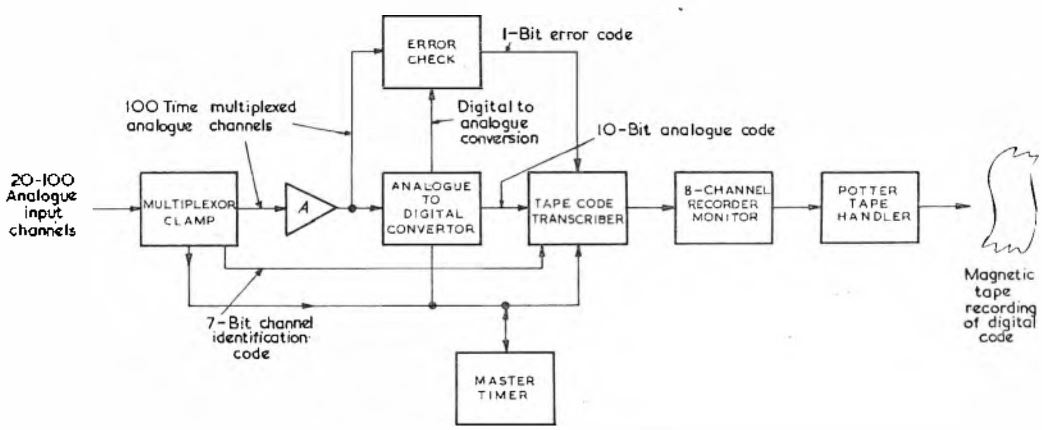


Fig. 2. Idiot II digital recording unit

* *Rocketdyne, a Division of North American Aviation, Inc., California.*

The Multiplexor

The multiplexor is a 100-pin mercury jet switch manufactured by the Detroit Controls Corporation of Redwood City, California. The particular switch used is made of two mechanically linked switches running in tandem from a common shaft. One switch is used to produce the input information from the 100 channels serially. The tandem switch produces a keying pulse at each step of the multiplexor, and this keying pulse drives the balance of the circuit. With nominal input impedance, the switch produces less than $10\mu V$ of noise. When the switch is driven by a synchronous motor, the front-end jitter of the multiplexing step is less than $10\mu sec$. Since the keying is obtained from the multiplexor itself and since the jitter is relatively low, no synchronizing system is needed. Jitter ultimately

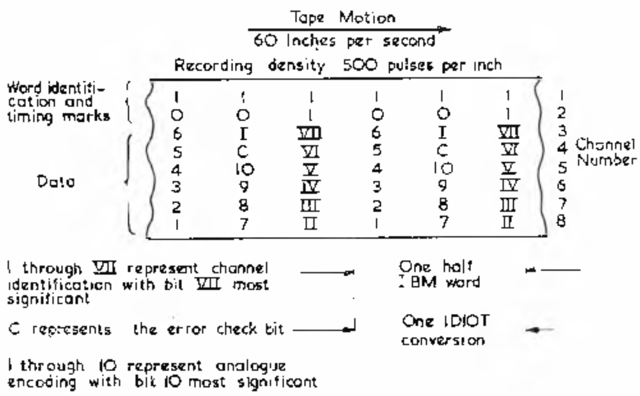


Fig. 3. Idiot II intermediate magnetic tape store

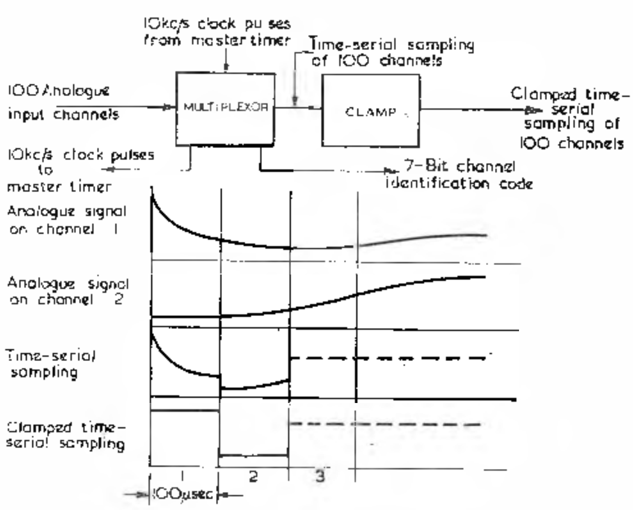


Fig. 4. Multiplexor clamp

manifests itself as slight displacement of the bits on the tape, but well within the limits of the IBM EDPM. This multiplexor was chosen over an all-electronic system because of its simplicity and limited space requirements.

Clamping Circuit

The status of the input information after clamping can be seen in Fig. 4. The information received from, say, two channels of the multiplexor are admitted serially to the clamping circuit and the d.c. levels established and held. This is done using the circuit shown in Fig. 5. The clamp consists of an input cathode-follower, a switch, and an amplifier, all of which are enclosed within a feedback loop. The switch in the forward-going direction is a diode array which is electronically opened and closed, isolating the integrating amplifier from the input. With such a circuit, it is not difficult to maintain clamped d.c. levels to an accuracy of 0·1 per cent for a conversion cycle. Once converted, the clamped signal is rejected and the integrator is reconnected to the multiplexor to establish the next d.c. level to be clamped.

Analogue-Digital Convertor

The d.c. levels produced by the clamp are converted to the binary code in a programmed trial voltage encoder. This

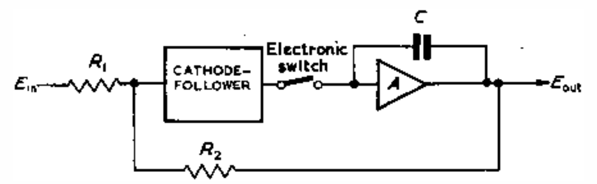


Fig. 5(a). Clamp circuit, simplified diagram

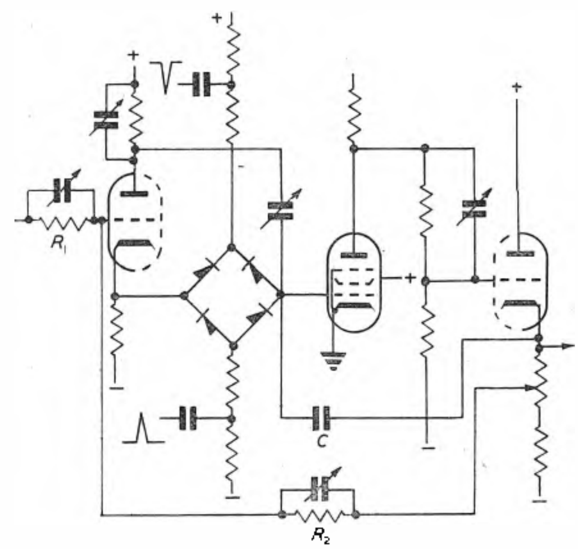


Fig. 5(b). Clamp circuit, schematic diagram

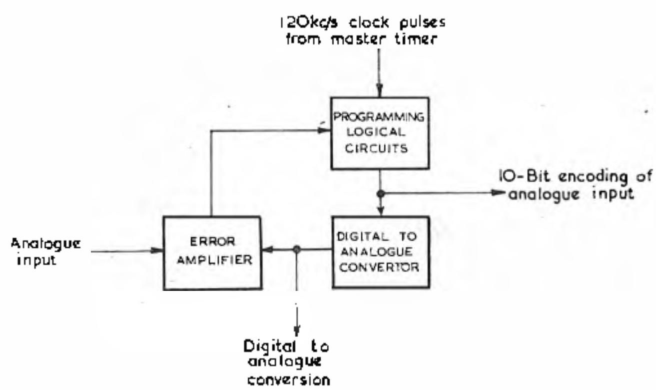


Fig. 6. Analogue to digital convertor

is shown in block form in Fig. 6. The analogue input, the clamped levels, are fed into an error amplifier. The programmed logical circuits execute a fixed programme of successively smaller binary voltages, the largest of which is half the full-scale value. These logical circuits are driven by a train of eleven 120kc/s pulses keyed off by the multiplexor.

The trial voltages are obtained from a highly regulated voltage standard. The logic produces a ten-bit coding of the clamped voltage while minimizing the error between the clamped voltage and the standard voltages generated. This is shown in Fig. 7. The timing diagram of the trial voltages and their magnitudes is shown in Fig. 8. The solid lines indicate the state retained if the sum of the trial voltages exceeds the analogue voltage, while the dotted line shows the resetting of the trial voltage if the trial voltage sum is less than the analogue signal in the clamp. This programme generates the binary code representing the digitizing of the signal. The programme logic is executed by the circuit shown in Fig. 9. Twelve driving pulses are provided, keyed by the multiplexor, of which eleven are used by the logical circuits. The states to be held are retained or rejected by the flip-flops which enable or disable the standard-voltage gates. These gates provide the standard binary voltages and the outputs are summed for the error amplifier which also receives the clamped analogue voltage. It can be seen that the largest voltage is tried first, and then successively smaller voltages are added to this. To follow through a single encoding, a pulse is produced through pulse-shaper *PS1*. This sets the left-most flip-flop and resets the others. Having set the flip-flop, the largest binary trial voltage (512A) is enabled and reaches the difference amplifier. If this voltage is less than the analogue voltage, *PS*2 opens gate 256*R* and adds this to gate 512*R*. If, however, gate 512*R* exceeded the analogue voltage, a pulse would have been enabled from *PS*2 resetting flip-flop 1. This proceeds through the entire conversion cycle. The binary coding stands in these flip-flops at the end of the conversion cycle and is triggered into the buffer storage of the transcriber. The entire conversion is accomplished in 100μsec, $8\frac{1}{3}\mu$sec being allowed for each trial voltage.

TRANSCRIBER

Since the analogue voltage has been digitized, the transcriber, Fig. 10, is entirely a digital circuit. The eleventh keyed pulse, of the twelve produced for each encoding cycle, resets the buffer storage flip-flops. The twelfth pulse reads the state of the convertor flip-flops and the position of the multiplexor. This is accomplished by using the flip-flops of the convertor and the multiplexing circuits to enable a reading pulse, the twelfth pulse of the chain. This flip-flop buffer storage now retains the half-word of the previous cycle and releases the convertor and multiplexor for the next encoding cycle. It is now necessary to read this buffer storage in groups of six pulses. To achieve this, the first reading is executed by the first pulse of the chain of keyed pulses. This is passed through gates 1 to 6 simultaneously if the count in the buffer flip-flops enables the gate. Pulse 5 reads flip-flops 7 to 12, and pulse 9 reads out flip-flops 13 to 18. It should be noted that flip-flops 1, 7, and 18 all pass through a common output and all eighteen channels are reduced in this way to only six outputs and the eighteen bits are presented serially in three readings. It should also be noted that by using pulses 1, 5, and 9 from the master timer, the spacings in time between read-outs are a fixed interval of $33\frac{1}{3}\mu$sec. This permits even spacing of the digits on the intermediary tape.

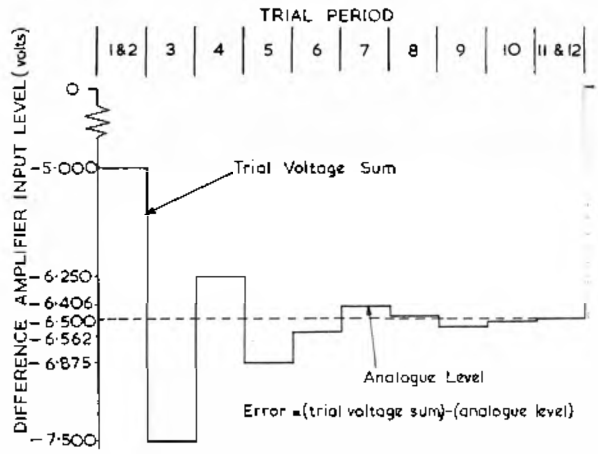


Fig. 7. Trail voltage summation

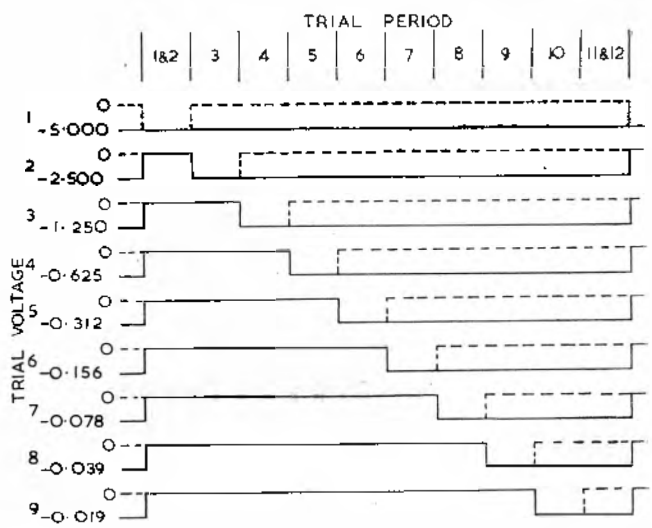
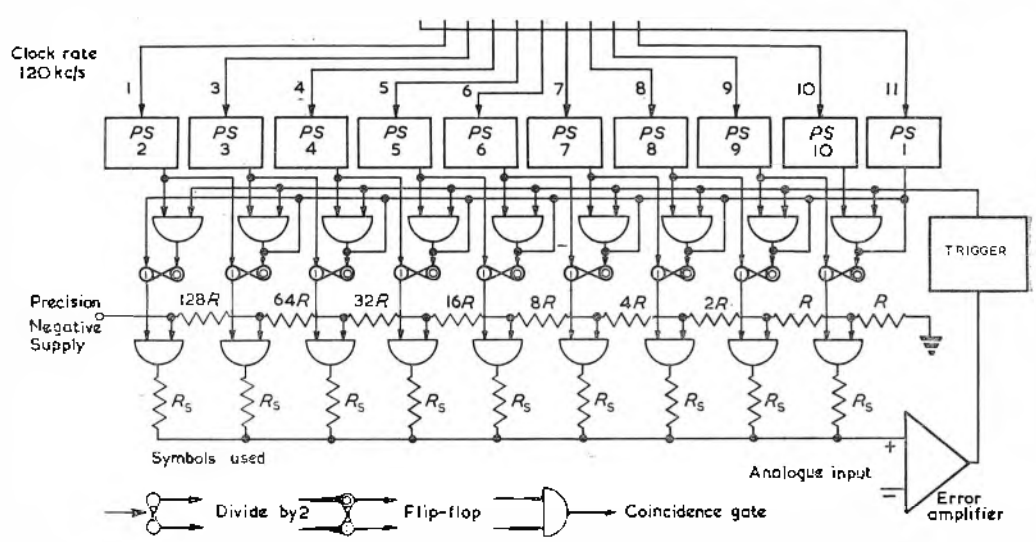


Fig. 8. Trail voltage time diagram

Fig. 9. Analogue to digital convertor logical diagram



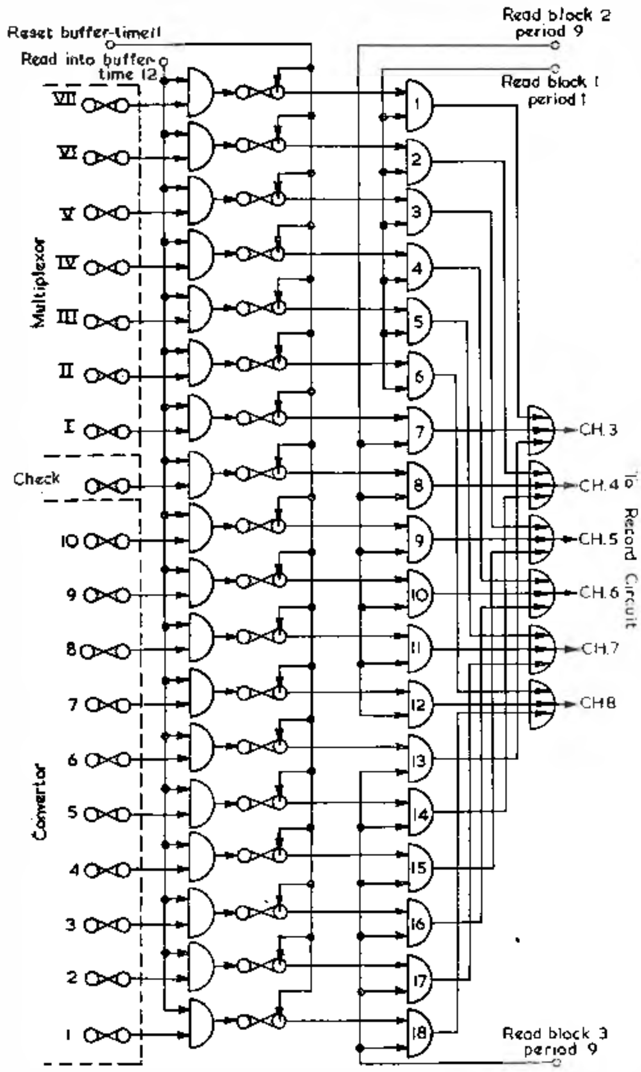


Fig. 10. Transcriber logical diagram

Tape Recording

The tape recorder, Fig. 11, is particularly simple in design and permits pulse densities of 500 pulses/channel/in of tape. Recordings are made at a tape speed of 60in/sec. The six outputs of the transcriber are used to drive input flip-flops of the tape recorded. These flip-flops in turn bias cathode-followers across which each head coil is mounted. Each side of each flip-flop biases a single cathode-follower to conduction or cut-off depending upon its state and, thus, depending on the presence or absence of a digit, a positive magnetization or negative magnetization at saturation is obtained. In addition to the six data inputs, two additional channels receive pulses from the ring of twelve pulses and these are recorded as timing markers and playback key pulses so that on playback the system is driven entirely by the information recorder on the tape. This eliminates the need for close control of the playback tape recorder speed and the two IBM 727 tape units into which the data is re-recorded.

To assist in the field use of the equipment, a selector switch system and single playback channel are located on the recording chassis. This permits a visual monitoring of the recorded information at any time in the field. This is accomplished by switching the heads off the cathode-follower outputs and connecting them one at a time to the playback circuit. The information is first amplified through two conventional stages of a.c. amplification, and then is used to drive a phase-splitter. Two trigger tubes, both driven by negative pulses, trigger the output flip-flop to its proper state, reproducing the original input to the tape recorder without ambiguity.

Physical Construction Details

The equipment for recording fits into three standard telephone racks and includes the circuits previously described, all of the associated power supplies, and input patching board. The power requirement for this equipment is 50A at 115V. Extensive use is made of plug-in valve circuits manufactured by the EECO Production Company of Santa Ana, California. Some of the circuits are theirs, in particular the digital circuits, and some are North American Aviation, Inc. design. Regulated d.c. power is obtained from a standard Kay Lab power supply. Digital circuit power is obtained from three specially designed 1A regulated power supplies.

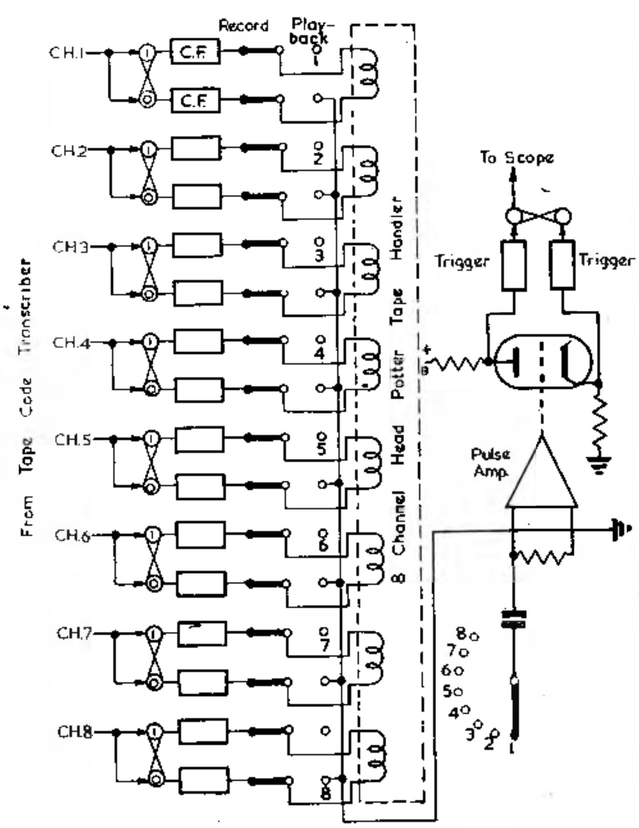
Playback Circuit

The playback circuit, Fig. 12, is the controlled re-recording transcribing system explained previously. The intermediate tape storage of eight minutes duration is re-recorded on to two IBM 727 tape units preparatory to entering the IBM EDPM. This requires that the intermediate information be placed in IBM language and be presented in conformance with the logical requirements of the IBM EDPM. This would be necessary for any digital computer manufacture. In the case of the IBM EDPM, the requirements reduce to:

(a) A six-channel code of 36-bit words.

(b) A recording rate of 200 pulses/in at a tape speed

Fig. 11. 8 channel tape record and monitor circuits



of 75in/sec at the appropriate levels of voltage and times.

(c) A lateral parity check mark.

(d) The insertion of gaps of 10msec in the data after blocks of words not exceeding 4 096 full words and without loss of recorded data.

When the re-recording cycle is completed, a manual switch returns the IBM 727 units to the IBM EDPM console for control and data processing. This plan permits the use of relatively inexpensive peripheral equipment, the two IBM 727 units, and uses only the EDPM during the actual process of data reduction.

Tape Playback Unit

The eight tape channels are played simultaneously into eight playback units, (Fig. 13). These are identical to the unit, previously described, located on the record chassis for monitoring, and consist of two a.c. amplifiers, a phase-splitter, two triggers and a flip-flop, per channel. Since the record rate is 30kp/s and the IBM requirement is 15kp/s, the tape is played back at half the record speed. The playback units will operate satisfactorily at speed reductions up to 1 : 4. The playback tape deck, manufactured by Davies Manufacturing Corporation, Riverdale, Maryland, has a special head arrangement. Six of the channels are in line and read the data. The two channels that read the timing marks are displaced forward so that the timing marks anticipate the corresponding data by 5msec. This is used in keying the blocking of data.

Time Filter

In data reduction, it is often the case that only a portion of the data obtained is to be used. To reduce machine time, a time filter or slicer is provided in the playback circuit. This filter, shown in Fig. 14, enables the user to preset the start of re-recording and to preset the interval of recording desired in decimal switches. This is done by establishing a preset count into the counter circuits. The count from the timing tracks is logged in the counter until the preset count is established. The gates are enabled, allowing the data to pass through the filter. These gates remain open. At the same time the gates are enabled, the opening pulse establishes the preset count into the counters representing the elapsed time interval chosen. This logging continues until the preset count is reached, at which time the gates are closed. The maximum count is 9 999 999 eighteen-bit words which exceeds the recording time. The resolution is a single word, and thus a single word can be sliced out of the run. The time filter is essentially a simple preset counter.

Redundancy Generator

To be compatible with the IBM EDPM input, the tape on the IBM 727 unit requires a lateral parity check mark. This requires, in binary, that there always be an odd number of bits across the seven IBM 727 channels, six of which are data and the seventh the parity check-mark channel. This is accomplished in the redundancy generator, Fig. 15. The logic in the redundancy generator is performed with two diode matrices which examine two sets of three bits simultaneously, thereby looking at all six bits at once. Each matrix emits a pulse when there is an odd number of bits presented to it. The two pulses are appropriately gated so

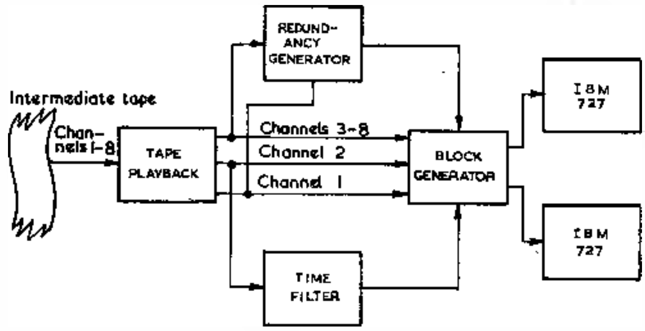


Fig. 12. Idiot II tape playback unit block diagram

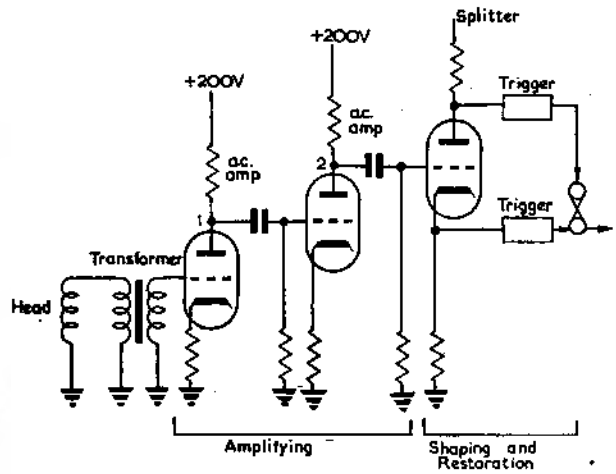
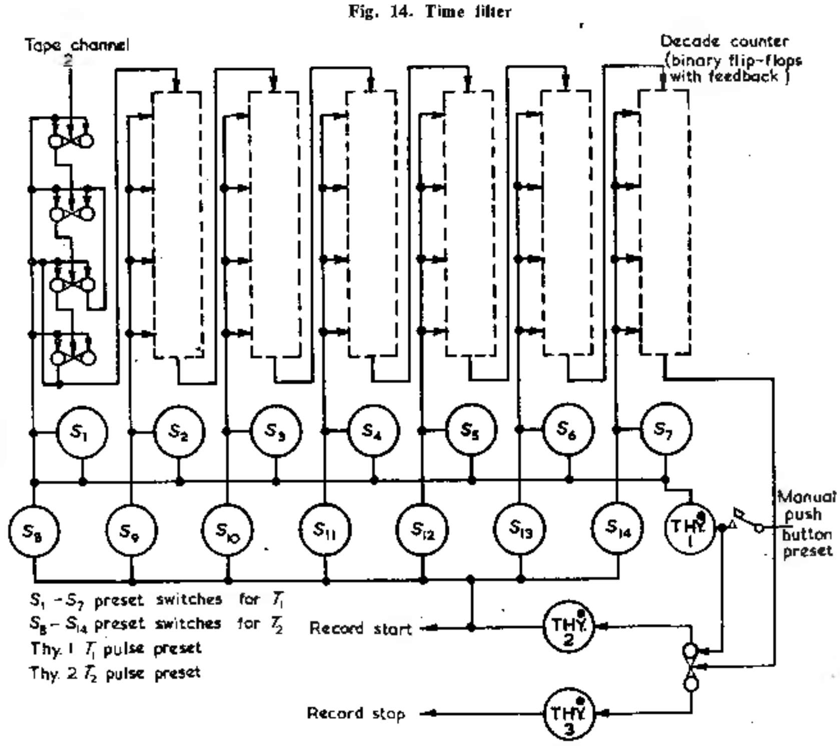


Fig. 13. Typical playback channel

Fig. 14. Time filter



that two odds (which means an even number of bits) and two evens generate a parity mark in the seventh channel An odd from one matrix and an even from the other (no pulse) mean an odd and no parity mark is generated. This produces an odd number of bits across the seven IBM 727 channels as required, providing the lateral parity check mark.

WORD-BLOCKING GENERATOR

To provide for blocking of the data on the IBM 727 tape, a logical chassis is provided in the playback circuits. This is shown in Fig. 16 and alternately turns on and off each of two IBM 727 units, putting all of the odd blocks on one tape recorder with a gap inserted between each block and all of the even blocks on a second recorder. This is accomplished by presetting the block length chosen into the decimal switches. Up to 33 333 words can be placed in a block and as few as 100. The presetting is pulsed into the counters which start counting timing marks only during the time slice. The timing marks are delivered 5msec in anticipation of the corresponding data, allowing the tape recorders to start and come up to speed before data recording begins. A 5msec delay is inserted at the end of a block to keep the tape recorder running and recording at the end of the block. At the same time the second tape recorder is turned on and it starts coming up to speed. At the completion of the 5msec delay, the data is switched without loss of any bits from one tape recorder to the other and a gap has been inserted. Compared with an in-line head arrangement, the displaced head technique reduces the number of valves needed to accomplish the logic. It can be seen that in this operation all of the odd blocks will appear on one tape recorder and all of the even blocks on the second tape recorder. As an alternate procedure, a single tape unit can be used by first recording all of the odd blocks and then all of the even blocks. This increases the re-recording time.

PHYSICAL CONSTRUCTION DETAILS

The playback equipment requires a power supply of 25A at 115V. The IBM 727 units are separate and receive the output of the blocking generator after adjustment to the correct biasing levels. The recording pulses for the IBM 727 unit are produced by the playback unit as well as the bits themselves. Power is supplied by the high-current regulated power supplies previously mentioned. Only one playback unit is required for each IBM EDPM and is considered peripheral equipment irrespective of the number of record units in use.

Other Applications

The system described is quite general in application. While the particular unit operates at ten thousand conversions per second, slower speeds can be obtained by reducing the tape speed appropriately. Similarly, single scans can be used, allowing the equipment to operate for a considerable time, limited only by the long-term stability of the over-all system. This is limited by the analogue circuits to one week. Single scans can be played back at high speed without using the blocking generator, and the data-reduction is considerably less than the data-recording time. Faster conversion rates than 10kc/s have not been attempted for the over-all system, but the limitation appears to be in the pulse density of the tape. Interlacing the data

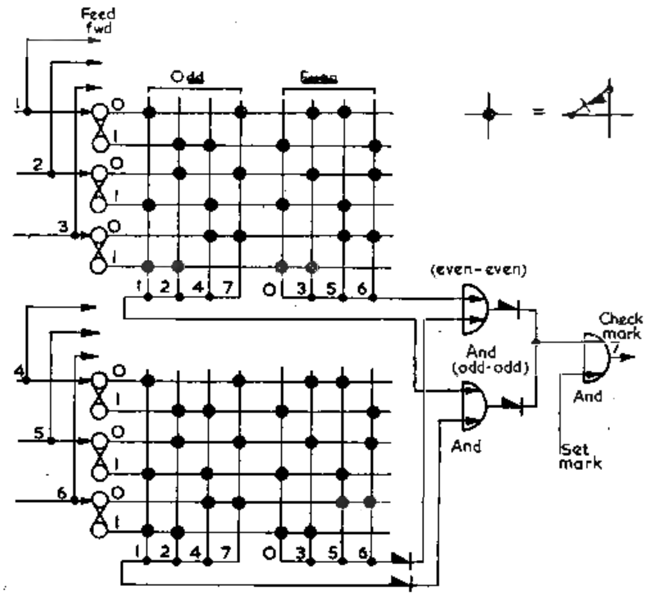


Fig. 15. Lateral parity check mark generator

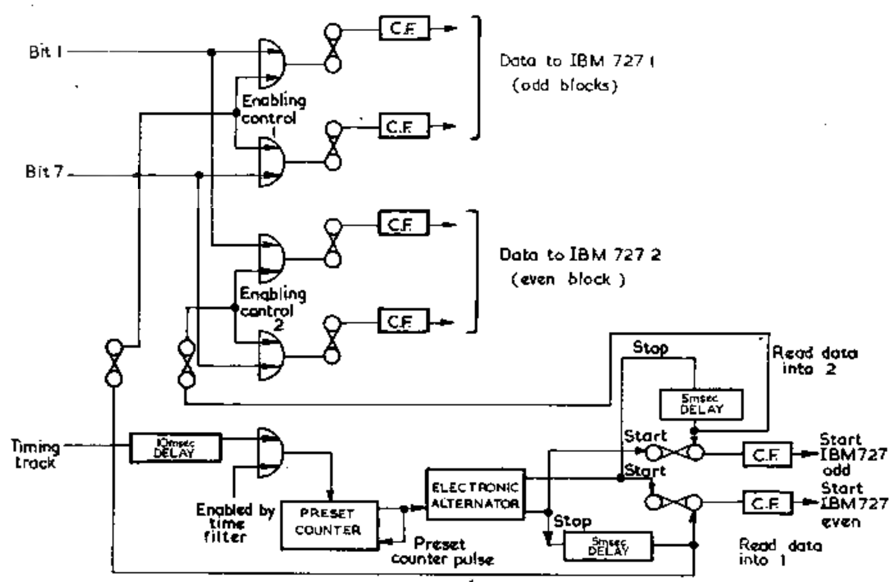


Fig. 16. Block length generator

on several tape recorders is possible to increase the conversion rate, but has not been attempted.

In other applications, data is presented in p.c.m. or p.w.m. from telemetering installations. In the case of p.c.m., the system can be simplified, eliminating the analogue-to-digital convertor. Since 100 inputs are available, absolute time can be coded into one of the channels as an input if the timing marks of the system itself are not sufficient. In the case of p.w.m. input, conversion to binary code is relatively straightforward and from this point on the system is similar to straight logical operation as with p.c.m. In fact, it is generally simpler to remain in digital form and record directly than to reproduce the analogue signals and then multiplex the analogue inputs through the entire system.

A Two-Phase Low Frequency Oscillator

(Part 1)

By E. F. Good*, M.A.

There is no difficulty in designing an RC tuned oscillator circuit so that at the required frequency the phase shift round the loop is zero, but methods so far disclosed of trying to ensure that simultaneously the loop gain is exactly unity for an oscillation of some chosen amplitude have not been altogether satisfactory, especially for frequencies below the audio band. The new circuit arrangements to be described overcome this difficulty, and provide means of generating an oscillation of stable amplitude and at the same time of low harmonic content. An incidental advantage is that two outputs are available with 90° phase difference†.

CONVENTIONAL *RC* oscillators are of the type which Edson[1] classifies as linear; the waveform at all points in the circuit is substantially sinusoidal and the loop gain is adjusted to unity by some device such as a lamp, thermistor, or a.v.c. system, which responds relatively slowly to the amplitude of oscillation. If a very low frequency of oscillation is required (say 1c/s) the time-constant of the gain adjusting device must be very long, since if it is not considerably longer than the period of oscillation it will follow the waveform of the oscillation and not only the average power or amplitude. It will then act as a non-linear device at the oscillation frequency, and waveform distortion will result. It has been usual, therefore, in oscillators for very low frequencies, to do without the gain adjusting device and rely on non-linearity in the amplifiers to limit the amplitude of oscillation, some sort of reaction control being provided for setting the loop gain for small amplitudes to a value only a little greater than unity. Since there is little or no selectivity after the non-linear part of the circuit, only a little non-linearity can be tolerated; and the oscillator when working is poised precariously between failure of the oscillation and serious deterioration of waveform and shift in frequency. Only by very careful circuit design and the use of closely matched and stable components can such an oscillator give a reasonably satisfactory performance, especially when the frequency is variable over a considerable range.

A way out of these difficulties is to design an oscillator of a type which Edson would classify as non-linear, one containing a limiter giving an output which is essentially a constant amplitude square wave, the frequency determining networks having sufficient selectivity to reconvert the square wave into a practically pure sine wave. But when adjusted for high selectivity, orthodox *RC* feedback circuits such as the Wien-bridge or parallel-T types are the equivalent of an almost balanced bridge, and small changes in component values can cause much larger changes in peak gain (gain at resonance); indeed comparatively small changes in component values can turn the selective circuit into an oscillator. Consequently some of the disadvantages mentioned above remain. What is needed is a selective circuit which gives a known and stable peak gain, and in which errors in component values give no more than proportionate changes in performance. That is, a circuit which needs only normal-tolerance components, a circuit which is ' designable '.

The Integrator

An integrator is a device whose output is proportional to the time integral of the input, and hence conversely a device whose input is proportional to the rate of change of the output. That is,

$$V_{in} = k \cdot d\,(V_{out})/dt$$

or, as often written,

$$V_{in} = pT \cdot V_{out}$$

where $p = d/dt$, and $T = k$

(T because the constant has the dimensions of time).

It follows that if

$$V_{in} = \sin \omega t,$$

$$V_{out} = (1/pT)\sin \omega t = -(1/\omega T)\cos \omega t + \text{constant} = (1/\omega T)\sin[\omega t - (\pi/2)] + \text{constant}$$

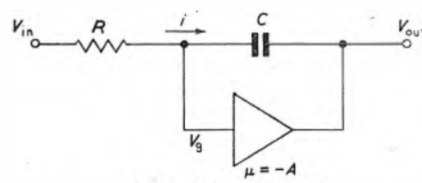


Fig. 1. Miller integrator

This means that the frequency response of an integrator is inversely proportional to frequency (i.e., on logarithmic scales, a straight line of slope −20dB/decade), that the frequency at which the output and input amplitudes are equal is given by $\omega T = 1$, and that the phase shift is −90° at all frequencies.

Among electronic circuits the most usual integrator is the Miller circuit, Fig. 1, consisting of an input resistor, a feedback or Miller capacitor, and a high-gain amplifier. To be ideal the amplifier gain must be infinite, and the behaviour of the integrator is then as given above except that there is a change of sign, so that

$$V_{in} = -pT \cdot V_{out} \quad \text{.............. (1)}$$

where the constant T is equal to the product RC.

The phase shift is now −90° + 180° (= +90°) at all frequencies, and the frequency at which the output amplitude is equal to the input amplitude is given by

$$\omega = (1/T) = (1/RC) \quad \text{........... (2)}$$

Two Integrators in a Loop

For two integrators in cascade the frequency response, or gain, falls at a rate of −40dB/decade, and the phase shift at all frequencies is 180°. The constant phase shift distinguishes such a cascaded arrangement of integrators from frequency dependent systems having a varying phase shift, and, as will be seen, is of great importance.

If now overall feedback is applied (Fig. 2), we have a system which at low frequencies has a very high forward gain, and consequently will have a gain with the loop closed

* *R.R.E., Malvern.*

† *The methods and arrangements described in this article, are the subject of a Patent application, Provisional Specification 35,472 53.*

of unity. But at the frequency at which the forward gain and hence the loop gain has fallen to unity, since the loop phase shift (at all frequencies) is $180° + 180° = 0°$, the fed-back signal is exactly equal to the signal at the input of the first integrator, and no external input is required. Thus the external gain is infinite, and the system is just regenerative and will maintain an oscillation of this frequency at constant amplitude. The shape of the external frequency response is indicated in Fig. 3(a) and is identical with that of the infinite-Q passive network shown in Fig. 3(b). To alter the resonant frequency it is necessary only to alter the T of one of the integrators, for because of the constant loop phase shift there is always one frequency at which the fed-back signal is correct for maintaining oscillation. In most practical cases, however, it is preferable to have the two T's equal and vary them simultaneously, so that the amplitude of oscillation is the same at all points round the loop.

A simple mathematical demonstration that the two-integrator loop will maintain a sine-wave oscillation proceeds as follows. If the T's of the integrators are T_1 and T_2, the motion at S (Fig. 2) is given by $pT_2\theta_{out}$, and the motion at P by $p^2T_1T_2\theta_{out}$. Consequently when $\theta_{in} = 0$,

$$p^2T_1T_2\theta_{out} = -\theta_{out} \quad \ldots\ldots\ldots\ldots\ldots \quad (3)$$

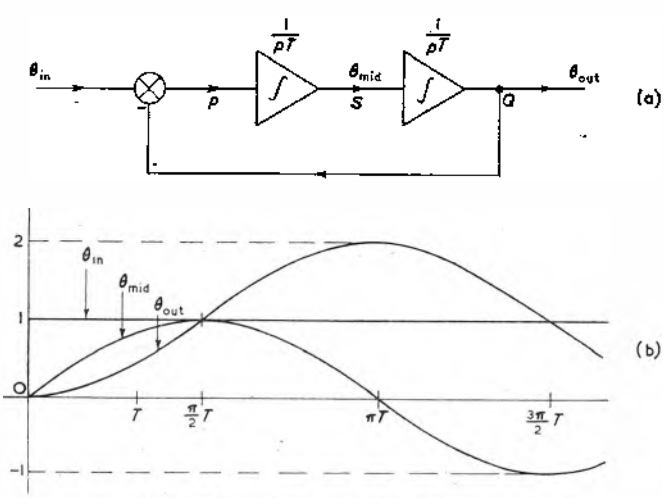


Fig. 2. Feedback system with two integrators

the solution of which is simple harmonic motion at a frequency given by

$$\omega_0 = 1/\sqrt{(T_1T_2)} \quad \ldots\ldots\ldots\ldots\ldots \quad (4)$$

When θ_{in} is not zero,

$$\theta_{in} - \theta_{out} = p^2T_1T_2\theta_{out},$$

or in transfer ratio form,

$$\theta_{out}/\theta_{in} = G(p) = \frac{1}{1 + p^2T_1T_2} \quad \ldots\ldots\ldots \quad (5)$$

an equation defining the response of the system in terms of the differential operator p.

To obtain the response to sine-wave inputs $j\omega$ is written in place of p. Thus

$$\theta_{out}/\theta_{in} = G(\omega) = \frac{1}{1 - \omega^2T_1T_2} \quad \ldots\ldots\ldots \quad (6)$$

which shows straight away that infinite response occurs when $\omega^2 = 1/T_1T_2$.

These properties of the two-integrator loop are a well known part of servo theory; but are not often included in works on electronic circuits, where the integrator is usually treated only as a time-base, and where feedback loops are treated in terms of lags and gain.

Fig. 4 shows an electronic version of the two-integrator loop consisting of two Miller integrators and an anode-follower phase invertor (or sign-changer). If the integrators were perfect and the phase invertor gave an exact phase inversion, this arrangement would behave exactly as the ideal system already described, except for sign changes due to the inherent sign change in each amplifier, and would give infinite gain at the resonance frequency. Normally $R_1C_1 = R_2C_2 = T$, the phase invertor gives unity gain (i.e., $R_5 = R_4 = R_3$ (approx.)), and the transfer ratio for the system is

$$V_{out}/V_{in} = G(p) = -\frac{1}{1 + p^2T^2} \quad \ldots\ldots\ldots \quad (7)$$

With general values of components

$$V_{out}/V_{in} = G(p) = -(R_3/R_5)\frac{1}{1 + p^2(R_3/R_4)C_1R_1C_2R_2} \quad \ldots\ldots\ldots\ldots \quad (8)$$

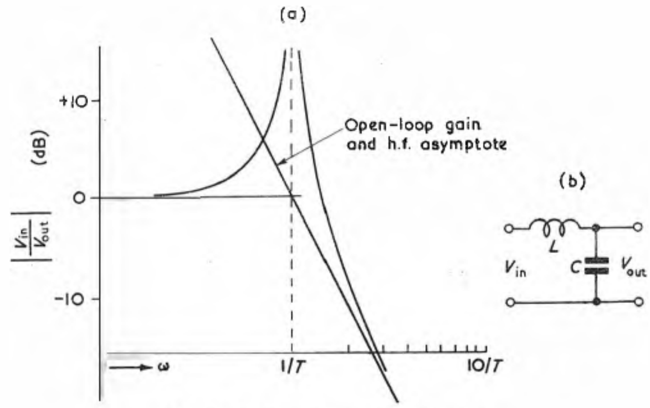


Fig. 3. Undamped second-order system

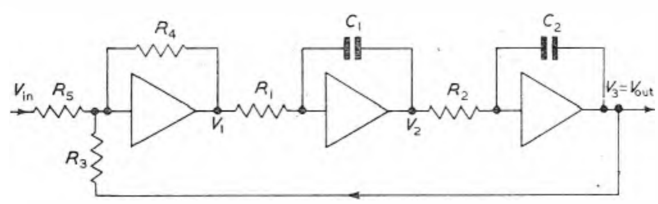


Fig. 4. Electronic two-integrator loop

which shows that

$$\omega_0 = (1/T) = \sqrt{\left[\frac{R_4}{R_3} \cdot \frac{1}{C_1R_1C_2R_2}\right]} \quad \ldots\ldots\ldots \quad (9)$$

that is, that the resonance frequency can be varied by varying any of the C's and R's except R_5, which is not in the loop.

However, the requirement is not infinite gain at the resonant frequency, but a known and finite gain. This means that the system must be given a known degree of damping, the equations for the system being modified to the well known forms for a loop containing an integrator and a lag

$$V_{out}/V_{in} = G(p) = -\frac{1}{1 + \alpha pT + p^2T^2} \quad \ldots\ldots \quad (10)$$

and

$$V_{out}/V_{in} = G(\omega) = -\frac{1}{1 + \alpha j\omega T - \omega^2T^2} \quad \ldots\ldots \quad (11)$$

When α is small, the resonant frequency (frequency of maximum gain) is almost the same as the undamped natural frequency ($\omega T = 1$). Consequently the gain at resonance

$$V_{out}/V_{in(max)} = (1/\alpha) \text{ (approx).} \quad \ldots\ldots\ldots \quad (12)$$

and the frequency response is as shown in Fig. 5(a). This response is identical with that of the *LCR* network shown in Fig. 5(b); and by analogy the constant α may be written $1/q$, q corresponding to $\omega_c L/R$, where $\omega_c = 1/\sqrt{(LC)} = 1/T$.

Methods of Damping

Damping is obtained by phase advance, and for present purposes is conveniently obtained by reducing by a few degrees the 90° phase lag of one or both integrators (it being understood that a Miller integrator gives a 90° phase lag plus a phase inversion or sign change). The loop phase shift at frequencies near resonance then differs from 360° by a small angle as shown in the vector diagrams of Fig. 6 and at resonance, V_{in} has a minimum but not zero value.

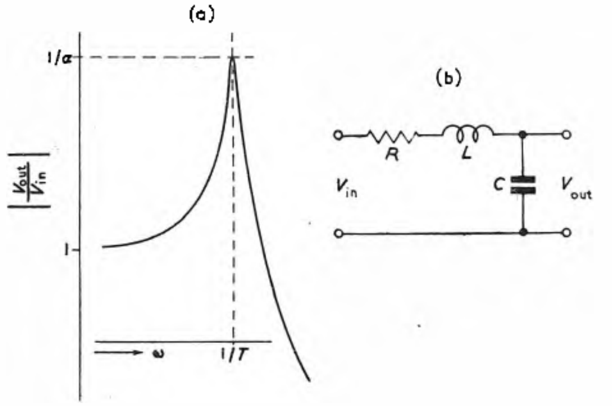


Fig. 5. System with damping

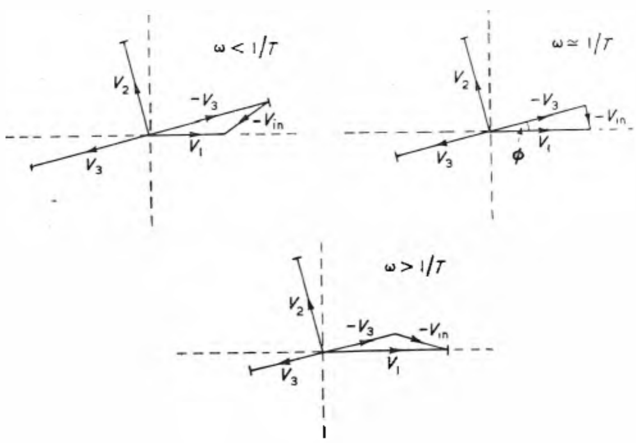


Fig. 6. Vector diagrams of system with damping

It can be seen from these diagrams also that this small angle, ϕ, is approximately equal to the minimum value of $|V_{in}/V_3|$. That is,

$$\phi = (1/q) = \alpha \text{ (approx.)} \quad \ldots\ldots\ldots\ldots (13)$$

A feedback method of advancing the phase of one of the integrators is to make the phase-angle difference between Z_f and Z_i, Fig. 7(a), less than 90°, and three simple arrangements are shown in Figs. 7(b), (c) and (d). Assuming as before that the integrator amplifiers have infinite gain, and that the phase invertor gives unity gain from *Q* to *P* (Fig. 4), the values of q obtained are

$$q = (1/\alpha) = R'/R \quad \ldots\ldots\ldots\ldots (14)$$

$$C/C' \quad \ldots\ldots\ldots\ldots (15)$$

$$\text{and } R/r \quad \ldots\ldots\ldots\ldots (16)$$

In each case q is determined by the ratio of two components, and this must be remembered when the resonant frequency is varied.

Another method of obtaining damping is to arrange for one or both of the integrator amplifiers to have a finite (and known) gain. For with finite amplifier gain the response or gain of a Miller integrator to a sine-wave input is

$$-\frac{A}{1 + (A + 1)j\omega T} \quad \ldots\ldots\ldots\ldots (17)$$

and at the frequency at which input and output amplitudes are equal, which is given by $\omega T = A/(A + 1)$ approximately, the phase lag is less than 90° by a small amount given by

$$\phi = (1/A) \text{ (approx.)} \quad \ldots\ldots\ldots\ldots (18)$$

If both integrators have finite gain, A_1 and A_2, both contribute a small angle, and since $\phi = (1/q)$ (equation (13)), q is given by

$$(1/q) = \phi = \phi_1 + \phi_2 = (1/A_1) + (1/A_2) \text{ (approx.)} \quad \ldots\ldots (19)$$

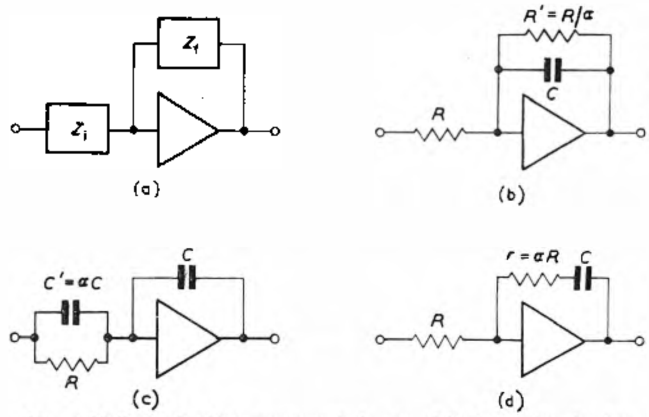


Fig. 7. Methods of adding components to one of the integrators to give damping

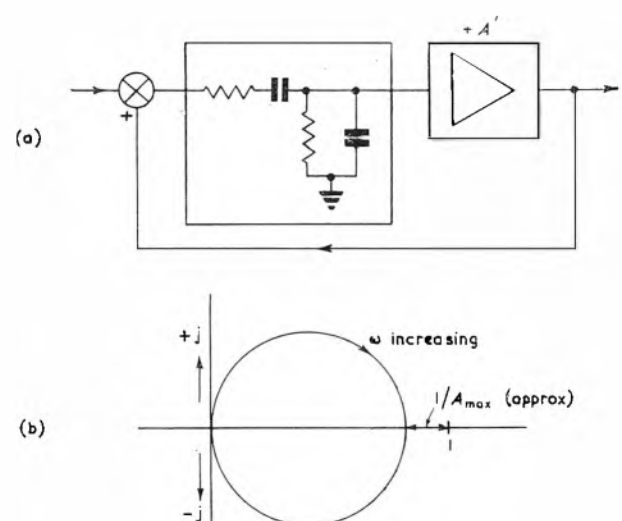


Fig. 8. Wien-bridge-type selective amplifier
(a) Block diagram
(b) Nyquist diagram

Thus if $A_1 = A_2 = A$,

$$q = \tfrac{1}{2}A \text{ (approx.)} \quad \ldots\ldots\ldots\ldots (20)$$

and the frequency of resonance is given by

$$\omega_c = A/(A + 1)T \text{ (approx.)} \quad \ldots\ldots\ldots (21)$$

Unless feedback is used to determine A_1 and A_2 this method of obtaining damping will not be as precise as the first methods described, but it will often be adequate in applications where accuracy of amplitude and frequency are not important. It should be noted, however, that it is implicit in the derivation of the above equations that A_1 and A_2 are 'real' numbers, i.e., that the integrator amplifiers have no phase shift, and this should be considered in the design.

Comparison With Other Selective Amplifiers

Fig. 8(a) shows a Wien-bridge type of selective amplifier. Although not shown, the other two arms of the bridge are formed by the negative feedback or β-network in the amplifier. In a circuit of this type the low natural selectivity of the frequency-dependent network is boosted up by positive feedback. The Nyquist plot for the system is of the form shown in Fig. 8(b), and for high selectivity must pass close to the point 1, j0. In this condition small changes in loop gain, which may be caused by errors in the frequency-dependent network, or by changes in the value of A', will cause large changes in the minimum distance between the locus and the point 1, j0, and so will cause large changes in

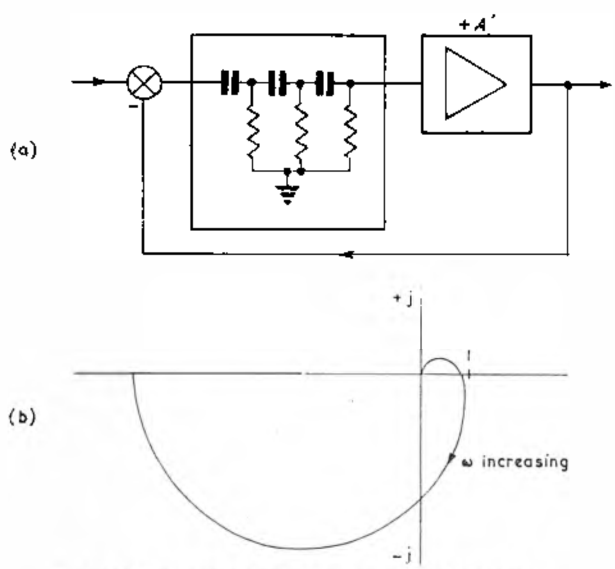


Fig. 9. Phase-shift ladder-network selective amplifier

the value of A_{max}, the peak gain with the loop closed; indeed only a small change is needed to bring the loop gain at the peak frequency up to the value unity, and so make the system an oscillator. Similar considerations apply for the type of circuit shown in Fig. 9.

In the parallel-T feedback circuit, Fig. 10(a), there are three feedback paths, and a simple understanding of the working of the circuit may be obtained from a vector diagram of the currents fed back to the virtual earth point, Fig. 10(b). Ideally the parallel-T network is balanced, i_1 is equal and opposite to i_2, and the net current fed back is i_3. For high selectivity, however, i_1 and i_2 must be of much greater magnitude than i_3 and a small unbalance in i_1 and i_2 can easily be comparable with i_3, and cause a large change in the total current fed back, and so in the gain of the circuit. Again, relatively small errors can turn the system into an oscillator.

For the two-integrator circuit, the Nyquist plot (Fig. 11) runs almost horizontally above the 1, j0 point. A change in loop gain, which may be caused by an error in one of the tuning components, makes the loop-gain vector for that frequency lengthen or shorten; but the distance between the Nyquist locus and the 1, j0 point at the point of nearest approach is altered little or not at all, and not even gross errors in circuit values can make the loop phase shift greater than 360° and move the Nyquist plot to the other side of the 1, j0 point. Thus, although errors in component values can cause a shift in the resonant frequency, there is little change in the gain at resonance (or q), and the requirement for a selective circuit with a known and stable gain at resonance has been met.

Summing up, it may be said that in the two-integrator circuit changes in loop gain are transformed mainly or

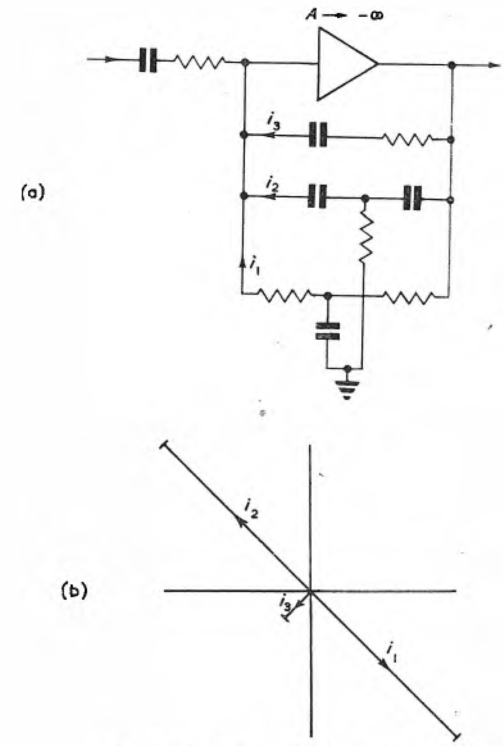


Fig. 10. Parallel-T selective amplifier

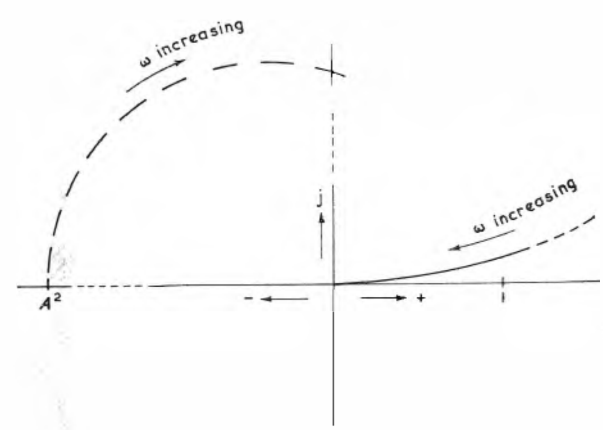


Fig. 11. Main features of Nyquist diagram of two-integrator loop with light damping

entirely into changes of resonant frequency; while in circuits of the varying phase-shift type changes in loop gain may have no effect on the resonant frequency, but have a very great effect on the gain at resonance, as may be expected in a positive feedback system (small changes in loop gain being magnified approximately q times).

For completeness it should be mentioned, however, that unwanted phase shift in the two-integrator loop does move the Nyquist locus nearer to or further from the 1, j0 point, and so does change the gain at resonance. Above a certain frequency, depending on the design of the circuit, the effect of stray capacitances will become appreciable, and experience has shown that it is capacitance to earth from intermediate points on the input resistors of the integrators that is most troublesome (Fig. 12). This gives additional phase lag and an increased q. Clearly, for satisfactory performance at high frequencies, low values of resistance are indicated. It is also possible for stray capacitances to give unwanted phase shift in the invertor stage.

At low frequencies (especially below 50c/s) a different imperfection is found—all available solid-dielectric capacitors showing an appreciable power factor (3 per cent is typical), even though they may have a negligible power factor at higher frequencies*. This makes the integrators as shown in Figs. 7(b) or 7(d), and reduces the q of the loop. The

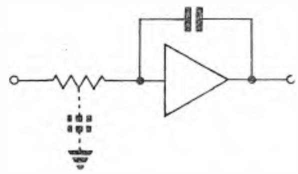


Fig. 12. Integrator with stray capacitance

effect is most troublesome in a circuit with variable tuning, since the power factor is not constant, generally increasing with decreasing frequency. Associated (presumably) with the effect is a small increase in capacitance.

Using the Two-Integrator Circuit as an Oscillator

To make the selective circuit an oscillator a point must be found where there is an amplified signal in phase with the input; and Fig. 6 shows that, at a frequency near resonance, although the input voltage V_{in} is in quadrature with the output voltage V_3, it is in phase with V_2, the voltage at the intermediate point S. Consequently the proposed limiter may be fed from V_2, giving the arrangement shown in Fig. 13. This diagram shows straight away the most characteristic feature of the new oscillator, the two feedback paths. The main feedback path, which already existed in the selective amplifier, carries the output oscillation V_3, while the auxiliary feedback path through the limiter carries an oscillation in quadrature with V_3.

This quadrature component is automatically adjusted to be just that fraction of V_2 needed to maintain oscillation,

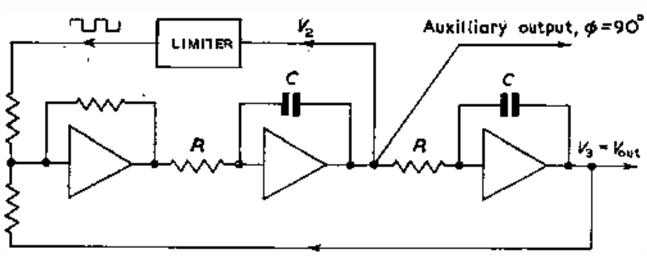


Fig. 13. Oscillator arrangement

i.e., to make the total feedback vector just touch the 1, j0 point. For if the amplitude of oscillation is too great, the fraction of V_2 appearing at the output of the limiter is too small to satisfy the condition for zero damping, the net damping is positive, and the amplitude of oscillation decreases; if the amplitude of oscillation is too small the fraction of V_2 at the output of the limiter is too great for the condition of zero damping, the net damping is negative, and the oscillation builds up.

For the limiter, any standard arrangement such as that shown in Fig. 14 is suitable. The output of such a limiter when driven by a sine wave of sufficient amplitude and balanced with respect to earth is approximately a square wave, given by

$$y = (4E/\pi)\,(\sin \omega t + (1/3) \sin 3\omega t + (1/5) \sin 5\omega t + \dots) \qquad (22)$$

That is, the amplitude of the harmonics (odd only) is inversely proportional to n, the order of the harmonic.

Now the analysis already given in equations (11) and (12) shows that the amplification given to the fundamental is q, and to the harmonic frequencies is

$$\frac{1}{n-1} \text{(approx)} \qquad (23)$$

Consequently, combining these results and the information contained in equation (22), the percentage of each harmonic at the output is given by

$$\frac{1}{qn(n^2-1)} \times 100 \ (n \text{ odd only}) \qquad (24)$$

which with a reasonably high value of q (say 10 or greater) represents a low harmonic content, (3rd harmonic less than 0·42 per cent).

In a real circuit there may be some lack of symmetry in the limiter, which will give a small even-harmonic output; and because of non-linearity of valve characteristics, harmonics may be generated in the amplifiers. But that such

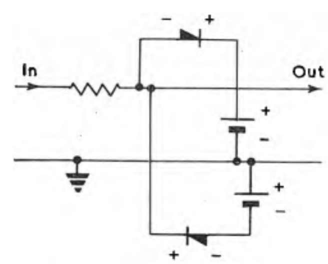


Fig. 14. Limiter

imperfections need not be at all serious in practice is shown by the figures for the first experimental oscillator, which had a measured q of 28.

Harmonic	*Calculated (Percentage)*	*Measured*
3rd	0·15	0·14
5th	0·03	0·03

Content of all other harmonics, less than 0·02 per cent.

At the output from the first integrator the amount of each harmonic may be expected to be n times greater, giving for the theoretical expression for the percentage of the harmonics at this, the auxiliary or 90° output.

$$\frac{1}{q(n^2-1)} \times 100 \ (n \text{ odd only}) \qquad (25)$$

and again the measured values show good agreement:

Harmonic	*Calculated (Percentage)*	*Measured*
2nd	0	0·12
3rd	0·45	0·42
4th	0	0·04
5th	0·15	0·13
6th	0	0·02
7th	0·075	0·055

Content of all other harmonics, less than 0·02 per cent.

To obtain even lower percentages of harmonics a higher q may be used; or at audio frequencies it seems clear that great purity of waveform could be achieved by reverting to a lamp or thermistor etc. for amplitude stabilization. So

* *Polystyrene-dielectric capacitors, now available, seem to be free from this trouble.*

far, however, no development in either direction has been undertaken.

Some Analogies

It has already been shown that the natural motion of the ideal undamped two-integrator loop is simple harmonic,

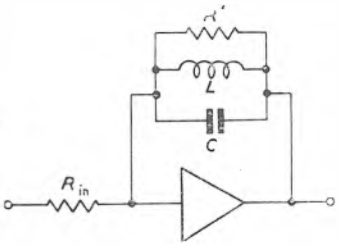


Fig. 15. Theoretical arrangement for tuned amplifier

and consequently that the loop is an analogue of any two-energy-store system of the general class which includes such well-known devices as a simple pendulum, a mass and spring, and an undamped LC circuit, for all of which in the absence of damping, and for small amplitudes of oscillation, the differential equation is of the form

$$d^2\theta/dt^2 + k\theta = 0 \quad \ldots\ldots\ldots\ldots\ldots \quad (26)$$

The two energy stores are the two integrating capacitors, and it is interesting to note that by adopting an active system it has been possible to make them of the same kind.

The new oscillator may, therefore, be thought of as a clock. The main loop is a resonant system with a small decrement, the analogue of the pendulum or balance wheel and hair spring; and its natural motion is a decaying oscillation. To keep the amplitude constant, energy is supplied from the limiter, which acts synchronously with the oscillation and is analogous to the escapement.

In addition to the general physical equivalence between the two-integrator system and an LC circuit etc., it can be shown in a more detailed manner how the action of inductance is simulated.

Fig. 15 shows a theoretical arrangement for a tuned amplifier. In terms of the virtual-earth concept, C feeds back to the virtual earth point a leading current, R' an in-phase current, and L a lagging current. At very low frequencies the use of inductance is impractical; but any arrangement which feeds back an equal lagging current will

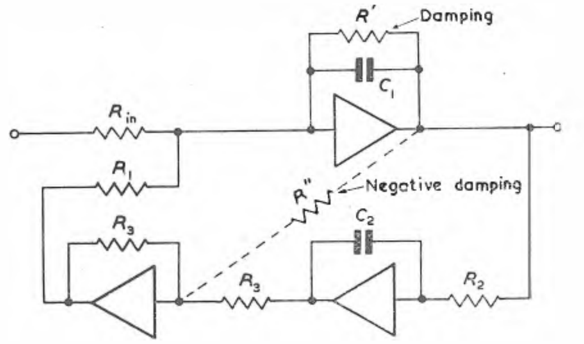


Fig. 16. Equivalent circuit of oscillator

give the same response, and this function is performed by the second integrator and phase invertor of the slightly rearranged two-integrator system shown in Fig. 16. To maintain a steady amplitude of oscillation the positive damping given by R' must be neutralized, i.e., an equal antiphase current must be fed back to the virtual earth point. In principle this requirement may be met by a resistor, R'', equal to R_3R'/R_1 connected as shown. Although such a linear system with fixed parameters does not make a practical oscillator, since oscillation would be maintained at constant amplitude only when there is exact balance between the positive and negative damping, the limiter which replaces R'' must, in the steady state, be equivalent to a resistor of this value.

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(To be continued)

New Zealand Trunk Telephone Network

The provision of a trunk telephone service comprehensive in itself, yet admitting of ready extension, is the aim of the New Zealand Posts and Telegraphs Department which has recently installed a 4-tube coaxial cable between Auckland and Hamilton zone centres in the North Island, providing multi-channel telephone facilities.

This represents the first stage of a project to establish a complete trunk telephone network eventually linking Auckland with Wellington in the extreme south of the Island.

For the second stage of the scheme, Hamilton to Palmerston North zone centre, the New Zealand Post Office, taking into account the nature of the terrain to be covered decided that the installation of a broadband radio relay system would offer definite advantages.

The contract for the supply and installation of the whole of the s.h.f. radio equipment, towers, and ancillary equipment, has been awarded to Standard Telephones and Cables Pty. Ltd., Wellington, and the equipment will be designed and manufactured in England by Standard Telephones and Cables Ltd.

The radio transmission path as envisaged, will cover a route-distance of some 240 miles and embrace terminal stations at Hamilton and Palmerston North, with eight intermediate repeater stations. A spur-route will extend from the repeater station at Mt. Tuahu to New Plymouth in the west, a distance of approximately 22 miles. As telephone channel dropping facilities are required at Mt. Tuahu this station will be equipped for main route and spur-route working. It is expected that in the first instance the system will be loaded with four telephone super-groups comprising 240 two-way speech channels between Hamilton and Palmerston North, with one super-group of 60 circuits teed into the New Plymouth zone. At terminal stations Standard frequency-modulated s.h.f. radio transmitting and receiving equipment will be installed, capable of ultimately providing six two-way broadband radio channels in the frequency range of 3 800 to 4 200Mc/s. Initially, the system will be equipped for two radio channels each able to handle ten super-groups, i.e. 600 telephone circuits, or the video signal for a television programme. Through-repeater stations will each be provided with s.h.f. repeater cubicles, one for each direction of transmission per radio channel.

S.h.f. equipment at all stations will incorporate travelling-wave tubes and associated circuits to achieve a high-grade transmission system fully capable of forming an integral part of New Zealand's trunk telephone service. The two radio channels will function as completely operative bearer circuits, and will normally be fed with the total telephone traffic. One channel will carry the multi-telephone signal while the other acts as standby. High-speed switching will be provided to change over to stand-by and vice versa.

Directional aerials will be employed consisting of 10ft diameter aluminium-alloy paraboloids mounted on self-supporting steel towers sited to give adequate beam clearance between the various sections of the route. The same station transmit and receive aerials will be used for both radio channels, but at Mt. Tuahu the tower will mount additional paraboloids to cover the spur-route working. As the s.h.f. system will carry the main trunk traffic, supervisory facilities will be provided to give early warning of any fault which may develop in the equipment or associated power plant. These, together with remote control facilities for repeater stations operating on an unattended basis, will be extended to control points over a single radio channel provided by v.h.f. transmitting and receiving equipment, which will be installed at all stations on the main and spur-routes. Corner reflector aerials will be mounted on the same towers as the s.h.f. reflectors to serve this v.h.f. radio channel.

A Square Wave Convertor

With Feedback Control of Mark-to-Space Ratio

By J. B. Earnshaw*, B.Sc.

The article describes a variable mark-to-space ratio square wave convertor in which the mark-to-space ratio is controlled by feedback. The device will operate with repetitive input waveforms, which are not necessarily sinusoidal, and it is extremely stable under variable operating conditions.

A MULTITUDE of square wave generators are available for normal use and these range from overloaded pentode amplifiers to flip-flop circuits of the multivibrator type. However, in most of these circuits the mark-to-space ratio is dependent upon the operating conditions and although this is sometimes a disadvantage it is often tolerated for the sake of simplicity.

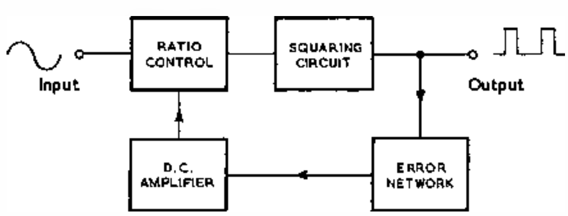


Fig. 1. Block diagram of convertor

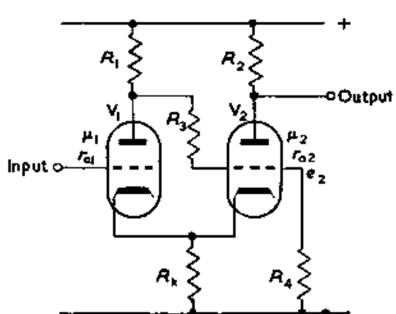


Fig. 2. Basic Schmitt trigger circuit

General Principle

The convertor produces a square wave output from a repetitive input signal and has the characteristics that the mark-to-space ratio of the output depends solely upon the ratio of two resistances in the feedback circuit. Because of the nature of the feedback, stability against changes of valve parameters and operating voltages is an inherent feature. The operating range (which can be extended by component changes) is 30c/s to 100kc/s and within this range the performance is frequency-independent.

Fig. 1 is a block diagram of the convertor showing the basic method by which control is achieved.

The squaring circuit is designed so that the mark-to-space ratio is dependent upon the average d.c. level of the input signal. This d.c. level is adjusted by the ratio control to produce an output with the pre-set mark-to-space ratio. Any deviation from this value results in a signal being developed in the error network. After amplification this error signal is fed into the ratio control to produce the voltage shift necessary to obtain the desired mark-to-space ratio and to reduce the error signal to zero.

* *Auckland University College, New Zealand.*

Squaring Circuit

The direct coupled Schmitt trigger, Fig. 2, is commonly used as a simple voltage discriminator, but can also be used as a squaring circuit for repetitive waveforms.

Normally V_2 is held 'on' by the resistor coupling chain R_1, R_3, R_4, but when the grid potential of V_1 exceeds a certain value ('on' level) the positive feedback loop causes a regenerative reaction which rapidly switches off V_2 and switches on V_1. For this trigger action to take place the loop gain must exceed 1, i.e.,

$$\frac{1}{2} \cdot \frac{\mu R_1}{R_1 + r_1} \cdot \frac{R_4}{R_3 + R_4} > 1 \qquad \ldots\ldots (1)$$

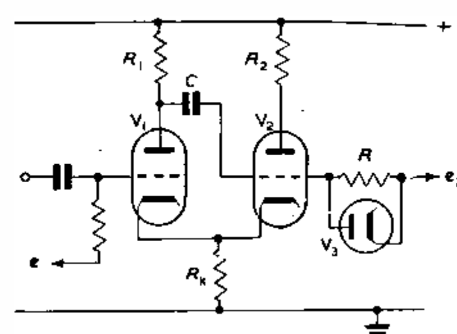


Fig. 3. A.C. coupled trigger circuit

For the circuit to revert to its original state, the grid potential of V_1 must fall to a voltage somewhat below the 'on' level. ('off' level). The difference between the 'on' and 'off' levels is known as hysteresis or backlash.

Greater flexibility in design parameters and a higher loop gain are afforded by the a.c.-coupled version of the trigger circuit, Fig. 3. A resistance capacitance coupling of long time-constant is used with a diode to ensure that the grid potential of V_2 does not exceed e_2 when the circuit resets[2]. (The resistor-diode combination may be replaced by a crystal diode with a sufficiently high back-resistance). Satisfactory operation can be achieved only when the duration of the 'on' period of V_1 is much less than the time-constant RC. This places a limitation on the maximum width of the positive-going output pulses.

The voltage swing of the output, taken from the anode of V_2 is $e_2 \cdot (R_2/R_k)$.

Backlash

A fundamental design feature in trigger circuits is the relationship between backlash and loop gain. To obtain a fast and reliable trigger action it is desirable to make the loop gain in the positive feedback loop as high as possible. This means a large resistance R_1 and a correspondingly large backlash. Normally this is considered a disadvantage and methods to reduce the backlash have been developed[3]. However, in the present application of this circuit, the backlash has special significance, being used to assist the mark-to-space ratio control.

Although the measurement of the backlash in the a.c.-coupled trigger cannot be made directly, the following simple method has been found to be satisfactory.

A sinusoidal wave having a peak-to-peak voltage greater than the backlash is applied to the input and the grid bias voltage, e of V_1 is adjusted until a 1 : 1 square wave appears at the output. (Fig. 4(a)). The amplitude of the input is then reduced until the output waveform begins to 'jitter' at which stage an increase in e will leave V_1 always 'on' and a decrease will leave V_1 always "off'. The situation is shown in Fig. 4(b) and the peak-to-peak input voltage is then equal to the backlash. The relationship between triggering levels and R_1, for a.c. coupling is shown graphically in Fig. 5. Measurements were made at 1kc/s.

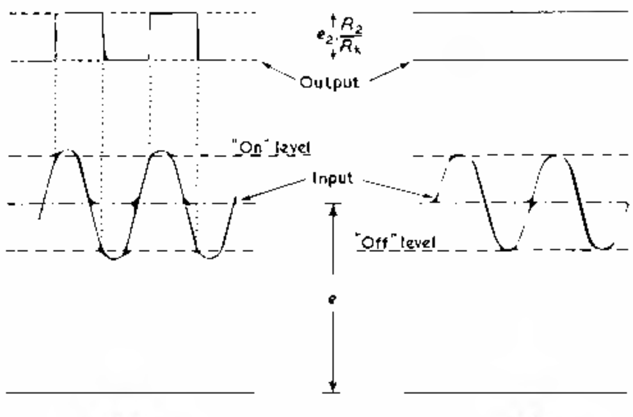


Fig. 4. Waveforms for backlash determination

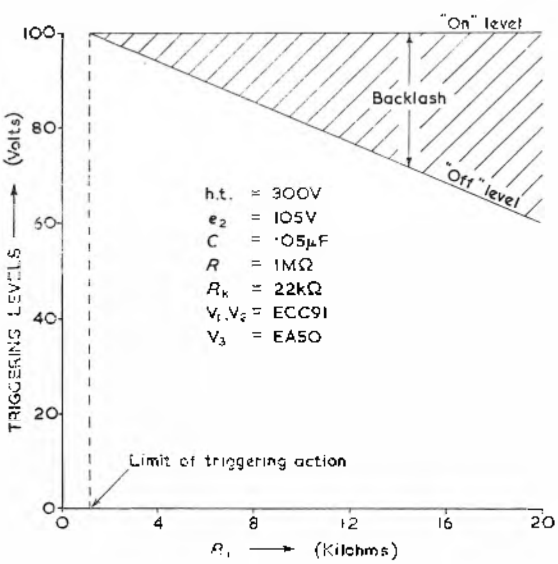


Fig. 5. Variation of triggering levels with R_1

Ratio Control

If the mark-to-space ratio is denoted by s, then, using the notation of Fig. 6,

$$s = \frac{\tau}{T - \tau} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

while the mark-to-period ratio

$$p = (\tau/T) \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

Inspection of Fig. 6 will immediately show that the mark-to-space ratio can be altered by variation of both input voltage amplitude and grid bias voltage e. There are, however, limitations on the ratios obtainable, determined by the magnitude of the input signal; for example, when the peak input voltage is only equal to the backlash, $3 \geqslant s \geqslant \frac{1}{3}$. With an input signal of constant amplitude ($\frac{1}{2}$ × the backlash) the Schmitt trigger circuit alone will operate as a satisfactory squaring device in which the mark-to-space ratio is independent of frequency. However, in common with other circuits, this simple convertor is dependent upon the operating conditions and it is for this reason that feedback is introduced.

It can be seen from Fig. 6 that the change $\delta\tau$ in τ brought about by a change, δe in the grid bias voltage is

$$\delta\tau = \delta e\,(\cot\psi_1 - \cot\psi_2) \quad \ldots\ldots\ldots\ldots \quad (4)$$

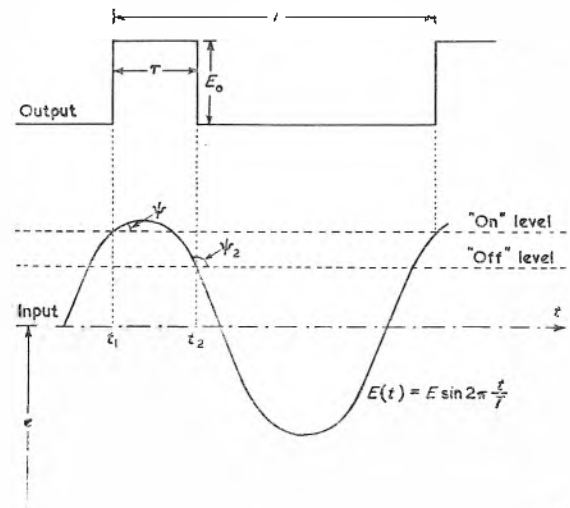


Fig. 6. Typical input signal with corresponding output

Thus, for a constant amplitude input signal, the rate of change of mark-to-period ratio with grid bias voltage

$$dp/de = (1/T)\ .\ (\cot\psi_1 - \cot\psi_2) \quad \ldots\ldots\ldots \quad (5)$$

The bias has no control when $\cot\psi_1 - \cot\psi_2 = 0$ and this happens only when $\psi_1 + \psi_2 = 180°$, i.e., no backlash, or when the input wave has vertical sides and $\psi_1 = \psi_2 = 90°$.

With the sinusoidal input shown,

$$\tan\psi_1 = (2\pi/T)\ .\ E\ .\ \cos(2\pi t_1/T)$$

hence

$$dp/de = (1/2\pi E)\ .\ [\sec(2\pi t_1/T) - \sec(2\pi t_2/T)] \quad \ldots\ldots \quad (6)$$

Error Network

The error network must be such that the sign of the output error voltage is dependent upon whether the actual mark-to-space ratio is greater or less than the pre-set value. In addition it must be independent of frequency.

The circuit of the error network is drawn in Fig. 7. It consists essentially of two diode clamping circuits, which ensure that the potential of point A never falls below earth and the potential of point B never rises above earth. The input to the network is taken from the output of the convertor (see Fig. 10) and the waveforms appearing at points A and B are illustrated on Fig. 8, E_a and E_b being the mean voltage levels of these points. E_e, the error signal, is taken from the junction of R_a and R_b, the two ratio control resistances (see equation (10)) and it fulfills the stated requirements if the clamping time-constants are long compared with T, and R_a and R_b are much greater than the output impedances of the clamping circuits.

With these conditions

$$\frac{E_a - E_e}{R_a} = \frac{E_e + E_b}{R_b} \quad \ldots\ldots\ldots\ldots (7)$$

hence

$$E_e = \frac{E_a R_b - E_b R_a}{R_a + R_b} \quad \ldots\ldots\ldots\ldots\ldots (8)$$

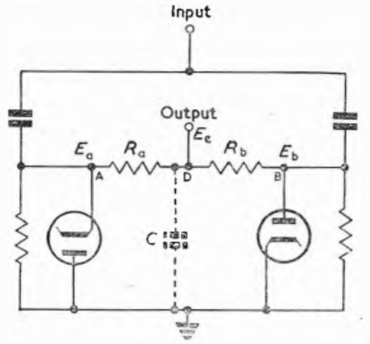


Fig. 7. Error network

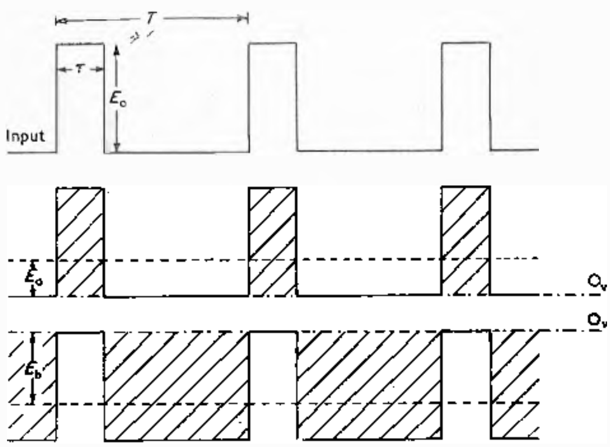


Fig. 8. Waveforms in error network

Consequently the output will be zero when

$$(E_a/R_a) = (E_b/R_b) \quad \ldots\ldots\ldots\ldots\ldots (9)$$

however, since $E_a = E_o \,.\, (\tau/T)$ and $E_b = E_c \,.\, (T - \tau)/T$, equation (9) reduces to the form

$$s = \frac{\tau}{T - \tau} = (R_a/R_b) \quad \ldots\ldots\ldots\ldots (10)$$

Thus the mark-to-space ratio will be determined solely by the ratio of the two resistances R_a and R_b.

Substituting for E_a and E_b equation (8) can be rewritten

$$E_e = E_o \,.\, (\tau/T) - E_o \,.\, \frac{R_a}{R_a + R_b} \quad \ldots\ldots\ldots (11)$$

and as $p = (\tau/T)$

$$E_e = E_o p - E_o \frac{R_a}{R_a + R_b} \quad \ldots\ldots\ldots (12)$$

Differentiating with respect to p, the rate of change of error voltage with mark-period ratio is

$$(dE_e/dp) = E_o \quad \ldots\ldots (13)$$

Smoothing of the error voltage can be achieved simply by the addition of a capacitor C, (shown dotted in Fig. 7) between D and earth.

The time-constant introduced is

$$C \,.\, \frac{R_a R_b}{R_a + R_b} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (14)$$

Feedback Loop

Equivalent transfer functions (e.t.f.) of the various units of the convertor are:

(a) ratio control	(e.t.f.) $= dp/de$
(b) squaring circuit	(e.t.f.) $= 1$
(c) error network	(e.t.f.) $= dE_o/dp$
(d) d.c. amplifier	(e.t.f.) $= A$

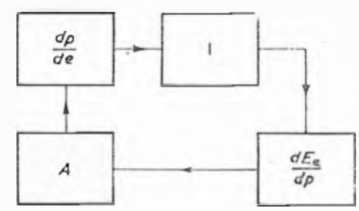


Fig. 9. Feedback loop

The situation is shown in Fig. 9 where the block diagram of Fig. 1 has the relevant e.t.f. values inserted.

The loop 'gain' is

$$(dE_e/dp)\; A \,.\, (dp/de) \quad \ldots\ldots\ldots\ldots (15)$$

and from normal feedback principles the stability factor is

$$1 + (dE_e/dp)\; A \,.\, (dp/de) \quad \ldots\ldots\ldots\ldots (16)$$

For high stability $(dp/de)\; A \,.\, (dE_e/dp) \gg 1$ and making the appropriate substitutions from equations (5) and (13), this can be rewritten

$$AE_o/T\,(\cot\psi_1 - \cot\psi_2) \gg 1$$

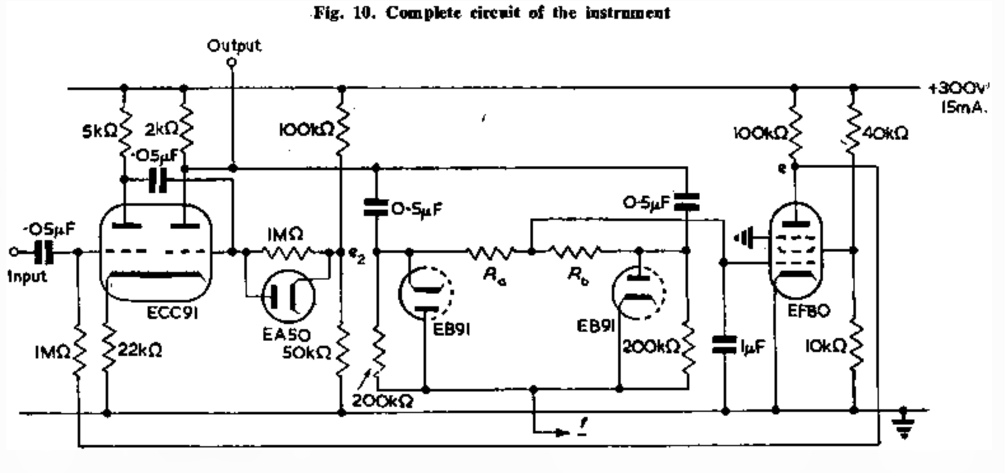
The above results have been calculated for the case of a change in e with all other factors constant. Similar equations can be developed for variations in other factors contributing to a change in mark-to-space ratio.

Circuit Details

Fig. 10 shows the complete circuit designed to produce an output square wave of 10V amplitude, (E_o = 10V). The backlash of the trigger is 10V so that with a sinusoidal input of 10V amplitude, mark-to-space ratios between 3:1 and 1:3 can be obtained.

The gain, A of the d.c. amplifier, V_3 is 200 and this is limited by the facts that (a) the output impedance must be much less than the grid leak of V_1, and (b) the anode

Fig. 10. Complete circuit of the instrument



voltage e must be approximately equal to 90V with a correspondingly low screen voltage.

Adjustments of the bias voltage f of V_3 brings e into the range of operation and the values of R_a and R_b, then determine the mark-to-space ratio of the output.

Variation of the ratio R_a/R_b can be achieved in two ways. Fig. 11(a) shows a step control using high stability resistors and giving seven ratios between 3 : 1 and 1 : 3; while Fig. 11(b) shows how the same range can be covered continuously.

In the latter method the 1MΩ resistors ensure that impedance relations are unimpaired at extreme settings. By decreasing the backlash of the trigger or increasing the amplitude of the input signal, other mark-to-space ratios may be obtained.

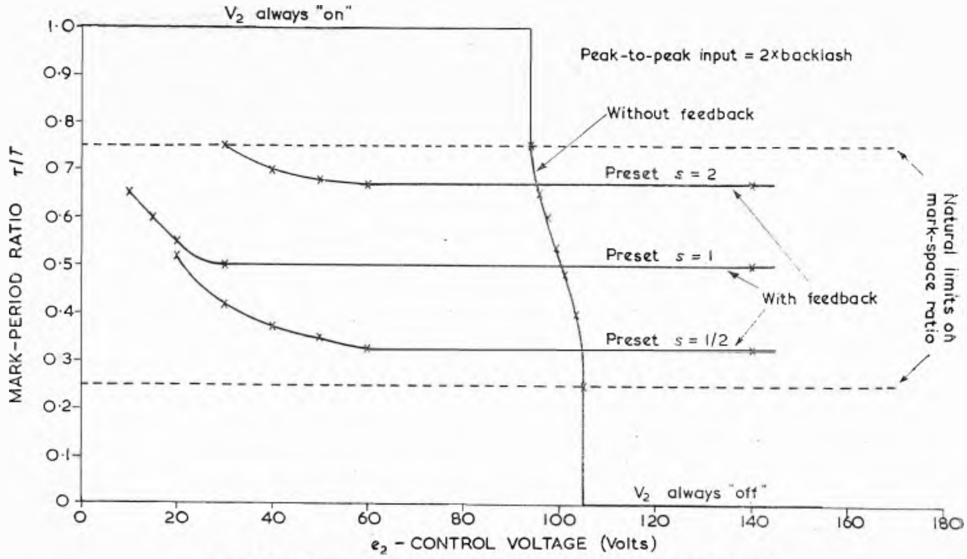
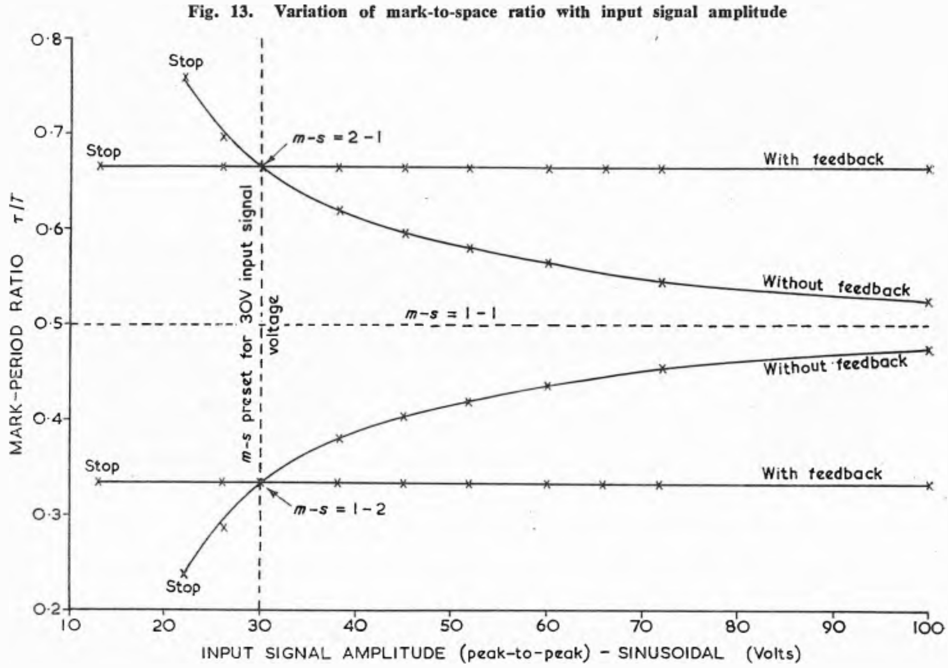


Fig. 12. Variation of mark-to-space ratio with control voltage

Fig. 13. Variation of mark-to-space ratio with input signal amplitude



Performance

Tests of the convertor's performance fall into two classes, parameter changes and input signal changes.

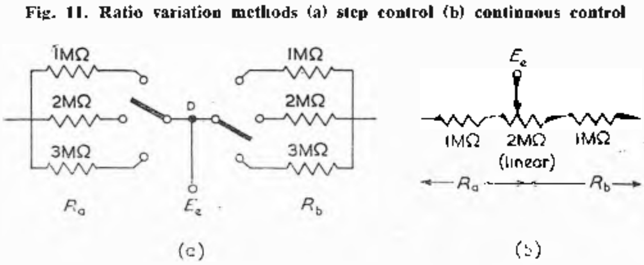
Parameter changes can be simulated by variation of e_2 and graphs in Fig. 12 show the effect of such a variation on the mark-to-space ratio, both with and without feedback control. Three mark-to-space ratios were investigated and in each case the input was sinusoidal with an amplitude of 10V. With a parameter variation of ±40 per cent, mark-to-space ratio remains independent of parameter value. This is a considerable improvement over the operation without feedback where a variation of ±5 per cent is sufficient to traverse the whole range of mark-to-space ratios available.

The effect of input signal amplitude on mark-to-space ratio is illustrated by the graphs of Fig. 13. Mark-to-space ratios were first pre-set with a 30V peak-to-peak input signal. Without feedback the mark-to-space ratios tended to 1 : 1 as the input signal amplitude was increased, but with feedback no variation occurred.

Tests with sawtooth and triangular input signals produce similar results.

The convertor showed complete independence of frequency within the range 30c/s to 100kc/s. Extension of the lower range can be achieved by increasing the coupling and smoothing time-constants, while the upper range can be increased by the introduction of a cathode-follower between the output and the error network.

Fig. 11. Ratio variation methods (a) step control (b) continuous control



Acknowledgments

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The 'Bizmac' Digital Data Processing System

By J. C. Hammerton*, M.A.

The article describes the data-handling activities at the central control agency for American military supply depots and the machines employed in the 'Bizmac' system to perform them. Special reference is made to the integration and operation of the system.

IN February 1956 the Radio Corporation of America formally disclosed details of its 'Bizmac' System. The first installation of this system was designed to perform the data-handling activities at the Ordnance Tank-Automotive Command, Detroit.

The Data-Handling Problem

The Ordnance Tank-Automotive Command is the central American control agency for all military supply depots throughout the world which issue tank and automotive parts and it keeps records of 250 000 stock items. Its principal functions are supply control and stock control. To perform these functions an accurate, up-to-date knowledge of the activity and inventory of each stock item at the issuing depots is necessary. This means the maintenance of a perpetual inventory record which is modified in accordance with the information received from the depots.

With this basic reference data available it is possible, for example, to take the necessary action on items which have dropped below their re-ordering level at any particular depot (supply control) or arrange for the transfer of items from an overstocked depot to a depot with a shortage (stock control).

The supply organization performs other functions like the making of catalogue changes and the preparation of reports. Its principal functions, however, are those named:

(1) Maintenance of daily inventory data,

(2) Supply control,

(3) Stock control.

At present the issuing depots are not equipped with the electronic apparatus necessary to integrate their procedures with those existing at OTAC. Reports to OTAC are made daily from the depots on punched cards.

The daily volume of work can be divided into three categories:

(a) Processing Input Information

Input information is either in the form of punched cards or punched paper tape produced from a manually operated keyboard device. It is expected that some 84 000 punched cards will be processed daily to supply the bulk of the input information. In addition, procurement action reports and catalogue changes will require some 150 000 key strokes per day.

(b) Maintenance of Reference Data

The reference and cross-reference data occupy ninety reels of magnetic tape each 2 400ft long. An operation aimed at modifying the reference data in accordance with current information requires the inspection of thirty to forty of these reels. The actual running time required is 3 to 4 hours at a tape speed of 80in/sec.

(c) Output Information

The types of information which result from a day's operation and which are required in printed form are queries arising from inventory data processing, supply control procurement orders, stock control shipping orders and printed copies of catalogue changes for the visual file. The expected output arising from these activities is 9 000 printed pages per day. Other reports are required on a monthly or quarterly basis. For example, a quarterly study of authorized items is made to determine whether the predicted activity for these items is in general agreement with the actual activity experienced.

The Bizmac System as a Solution

The OTAC installation consists of a number of machines with special functions. They are interconnected through a switching unit and operated as an integrated whole from a centralized location, the system central (Fig. 1), through a control unit.

The system central and the method of operation which is implemented through it constitute an advance in existing techniques of control. The Bizmac system includes a diversity of special purpose machines. Adequate integration of these can only be obtained by controlling their operation from one location. Given the necessary integration the system becomes extremely flexible. Because several machines are available, distinct activities which require the use of more than one machine can be interlaced by the operators according to established priorities.

Before describing system central and the method of operation the function of the machines in the system will be outlined in order to indicate the extent of the integration problem.

The machines can be classified according to function as:

(1) storage (filing),

(2) input (entries),

(3) organizational (operation on a filing system),

(4) computing (calculations by human operator),

(5) output (typewritten reports).

The correlation with existing accounting systems founded on the handling of information by people, is indicated in parentheses.

Storage Machines

All the data in the system are stored in binary coded form on reels of magnetic tape. (Length of reel, 2 400ft, tape speed, 80in/sec, 125 characters/in).

The number of reels of tape used is dependent on the storage requirements of a particular installation. Each tape is housed in a tape station which is capable of moving the tape in accordance with orders given to the station. No hand-carrying of tapes is required. Each tape station is associated with an amplifier and control unit which contains the circuits for amplifying the output of the magnetic reading heads and for interpreting the incoming orders. In order to effect some economy in equipment the association is not on a one-to-one basis in every case. Some of the amplifier and control units are shared between a maximum of five tape stations.

* *The Radio Corporation of America.*

The tape stations allocated to an installation function either as storage tapes or working tapes, the functions being interchangeable during any operating cycle.

Input Machines

The system uses two methods for introducing new information.

Card Transcriber

The card transcriber converts information contained on 80-column punched cards into data recorded on magnetic tape at the rate of 400 cards/min. Many organizations keep their inventory and transactions on punched cards. It is possible that in the future punched cards will be rendered obsolete and that new information will be introduced directly to the system through a teletype transmission system. At the present time, however, the use of punched cards is sufficiently widespread to make the inclusion of a card transcriber essential in a versatile system.

Paper Tape Transcriber and Tapewriter

Input information which is in conventional typescript is processed by an operator using a tapewriter. The tapewriter is a keyboard machine which has keys similar to those of a typewriter, but with the addition of some extra ones. The machine punches paper tape in accordance with the Bizmac code and prints the characters in conventional typescript on paper for the guidance of the operator. The paper tape has 10 characters/in.

The paper tape transcriber transfers the information to a magnetic tape in a special two-speed tape station. A photo-electric reader reads the characters on the tape at 200 characters/sec and they are transferred to magnetic tape at this rate. In order to obtain the standard character spacing of 125 characters/in, the magnetic tape is run at slow speed (1·6in/sec). Subsequently the information is transcribed to a standard tape machine at 10 000 characters/sec.

Organizational Machines

An organizational machine is one by means of which the data are rearranged but otherwise unaltered. The data are organized on the tape in 'messages'. Thus inventory records are stored on a tape as a number of messages, each of which contains the stock number of a particular tank or automotive part and in addition, other pertinent information like quantity on hand, re-ordering level and location of parts. An organizational operation results in re-arranging the individual messages but does not in any way alter the contents of them.

Sorter

The principal organizational machine in the Bizmac system is the sorter.

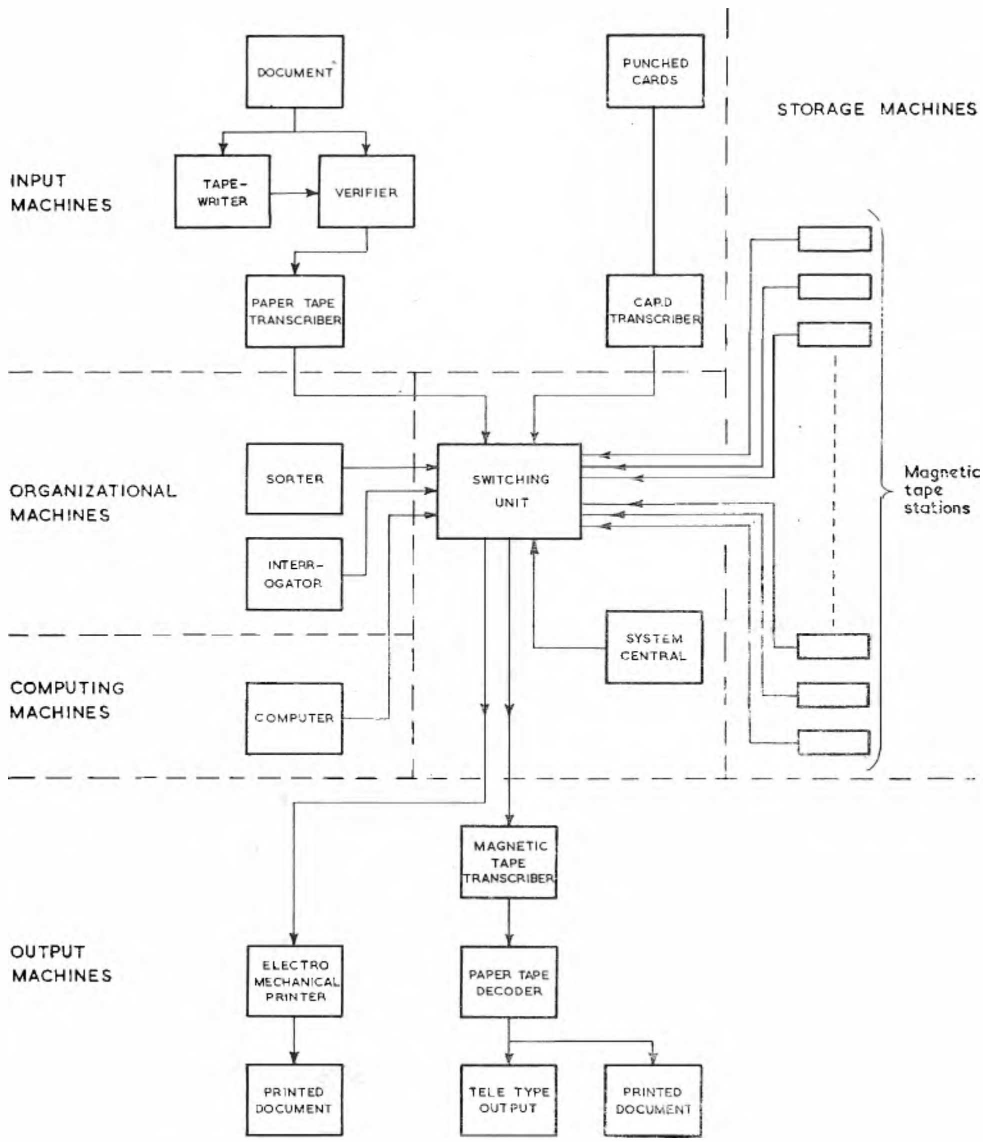

Fig. 1. Outline of the Bizmac system

The underlying principle of operation is the direct transcription of selected messages from one magnetic tape to another. The machine itself is a special purpose data-handling device which can be employed full-time on certain pre-determined modes of operation. It is therefore possible to build the necessary programming instructions into the machine. An indication of the operations which the sorter performs can be satisfactorily conveyed providing a magnetic tape is pictured as a chain of separate messages of the type described above. The first part of each message contains all the information normally used for filing purposes, e.g. stock number. Such information is used by the sorter to identify the messages and is referred to as a 'criterion'.

Most of the operations depend on having magnetic tapes in which the messages are recorded in ascending order according to the identifying criterion. For example, in the case of a supply depot, the messages will be ordered according to stock number.

(a) *Sort*

The messages introduced to the system from the card transcriber or the paper tape transcriber are in random order. The first organizational operation is to 'sort' the messages into an ascending sequence because this is a pre-requisite for most of the operations performed by the system.

In general terms the method of sorting utilizes four magnetic tapes, two as input tapes and two as output tapes. After splitting the information contained on the initial tape between two tapes, the sorting process continues by selective transcription from the input to the output tapes. Messages from both input tapes which are in ascending sequence are transcribed to the first output tape. When the ascending sequence cannot be maintained because the next messages on the two input tapes have criteria of value less than that of the last message transcribed to the output tape, the same process is repeated on the second output tape. At the next break in the ascending sequence transcription continues to the first output tape. When the information on the input tapes is exhausted all the tapes are rewound and another 'pass' is commenced. At each successive pass the length of the 'strings' of messages which are in ascending order increases. At the conclusion of the last pass there is only one string, i.e. the messages have been sorted. The number of passes required depends on the number of messages and the way in which they are ordered initially.

(b) *Merge*

The merging operations consist of re-transcribing the messages from two tapes already in ascending sequence on to a third tape so that the messages remain in ascending sequence. This type of operation is used, for instance, in introducing new catalogue items into a perpetual inventory file. If the file is ordered by catalogue number, the new entries are positioned in the file according to their numbers. The operation contains variations which enable two messages having the same criterion to be handled in one of three ways:

(1) the messages are transcribed one after the other (straight merge)

(2) one message is transcribed and the other is suppressed (merge substitute)

(3) neither message is transcribed (merge substitute delete).

A straight merge is required, for instance, when information concerning new issues from the stores depots are merged together to form a transaction tape. If two or more issues of the same stock item have been made, all the transaction data are required in the output of the operation.

A merge substitute operation is used in revising a store depot's inventory file when more recent information about particular catalogue items becomes available. It is required to locate the old entries and replace them by the new ones.

A merge substitute delete operation can be used to eliminate information from the files in the case, for example, of catalogue deletions. In these instances neither the message in the inventory file nor the message which was used to locate it is transcribed on to the output tape.

(c) *Extract.*

Extracting operations are performed by the transcription from an input to an output tape of certain messages which are selected with reference to information supplied to the machine. The variations of the extract mode are:

(1) extract by list,

(2) extract to a preset value,

(3) extract by class, equal to,

(4) extract by class, less than.

The extract by list operation makes it possible to obtain from the reference files the information about certain specific stock items. For example information about daily issues from a stores depot is incorporated into the inventory file by first making a 'list' tape. The list tape contains messages detailing recent issues from the depot. The list tape is used to extract from the perpetual inventory file the recorded information about the items issued. In order that this operation can be completed in a single 'pass' of the file tapes, both the file and the list tape must be ordered in ascending sequence. This condition is a prerequisite for the operation.

The extract to a preset value operation enables every message up to the one with a certain specified criterion to be transcribed from the reference tapes to an output tape. The specified criterion is inserted into the sorter by a special input operation and held there for the duration of the operation. This mode of operation enables a block of stock items to be extracted from the reference file in the event, for example, that a review of the inventory file is undertaken. For such a review the extraction will be performed with respect to the criterion by which the messages are ordered in the reference file. By making this a prerequisite for the operation it can be completed without inspecting the entire reference file.

Extract by class operations differ from the other two extracting operations in that the reference data may be in random order with respect to the criterion by which the extraction is effected. For example, prior to printing out, shipping instructions and procurement orders are assembled by the computer on a magnetic tape. They are identified by different 'transaction codes.' Since they require printing out on different forms the shipping instructions and the procurement orders must first be separated on to two tapes. This is achieved by an extract by class (equal to) operation using a transaction code as the criterion.

An extract by class (less than) operation can be used to obtain from the file all procurement orders which are overdue in order to print them out for initiating follow-up action.

Because, in general, the input data are randomly ordered with respect to the criteria used neither of the extract by class operations is completed until the entire input file has been searched. Since the input file may consist of many reels of tape a considerable saving in time is effected by using the extract to a preset value operation where possible.

It will be evident from the description of these operations that they are all fundamentally similar. A selected portion, known as the criterion, of each of the messages on a tape is compared with like portions on the other input tapes. As a result of the comparison, orders are given to the input and output tapes connected to the sorter. By means of this selective running of tapes information is transcribed according to the desired pattern without the use of any intermediary storage. The transcription is performed without any alteration in the content of the information and the operations are therefore classed as organizational.

Interrogation Unit

The purpose of this machine is to make particular messages in the tape files readily accessible for review by a human being. For example, since the perpetual inventory record file may consist of as many as 40 reels of tape, it is considered advisable to index the individual tapes. This is done as a routine operation by the interrogation unit.

Indexing in this context means finding and printing out the stock number of the first message on each tape.

Alternatively it may be important to know the quantity on hand of a particular stock item. The interrogation operation consists of inserting the required stock number into the machine and inspecting the appropriate part of the inventory file until an equality occurs. The required information is then printed out.

The interrogation unit does not fall readily into the machine classification given above. Its function could be performed by the sorter so that it can be called an organizational machine. On the other hand it is capable of printing out information and to this extent it is an output machine. The interrogation unit is, in fact, a hybrid arising from a special need in data-handling with serial magnetic tape files. As will be seen when the first Bizmac installation is described, the interrogation unit is not integrated with the rest of the system principally because its operations by their nature are not subject to a regular schedule.

Computing Machines

The computer in the Bizmac System (Fig. 2) is a multi-purpose machine specifically designed for handling the problems which arise in the course of business operations.

Two classes of operation can be distinguished. The first class comprises those problems in which the information content of messages requires alteration. The adjustment of the levels of stock items in accordance with issues and receipts, i.e. inventory recording, is an operation of this kind.

The computer is the only machine in the system capable of making these alterations.

The second class of problem handled by the computer is organizational in character. The making of routine or special reports in which the required information is lodged in the tape files, but has to be extracted according to some special criterion is an operation of this type. For example, in a stores depot a routine check is made for those catalogue items whose actual activity does not conform with the activity predicted for them.

The computer by its nature is a versatile machine since the provision of an intermediary storage (Fig. 2) allows any part of a message to be located and modified. Since a maximum of five input tapes and ten output tapes are handled, the computer can perform any of the operations described as characteristic of the sorter. The computer can also perform the function of the interrogation unit since it includes a printer for the production of hard copy.

The maintenance of the daily inventory data involves the adjustment of the perpetual inventory record in accordance with the daily transactions. The task is to locate the records of the relevant catalogue items and to adjust the quantity of each in accordance with the transaction data.

Supply control involves the location of that part of the message which details the quantity of the catalogue item in hand and the location of another part which contains the re-ordering level for the item. Comparison of these two provides information for a decision to re-order. In the case of catalogue items which are to be re-ordered, the computer extracts the relevant parts of the message and transfers them to a special output tape in an edited form suitable for printing out as a procurement order.

Stock control involves a 'levelling' of the quantities of any particular catalogue item available at the different stores depots and entails the location within the file information of the quantities of the catalogue items available at each of the depots and a prediction of the demand for them. Where such action is appropriate, movement of determined quantities of the catalogue items between the depots can be initiated on the basis of established priorities. The computer originates 'messages' which when printed are used as the shipping orders to effect the levelling action.

In operation, the messages relating to the different catalogue items are presented to the computer serially in time. The computer performs all the main functions cited and any supplementary ones which are required on each item as it is presented.

The principal component parts of the computer are as follows (Fig. 2):

(a) High speed memory

(b) Arithmetic unit

(c) Auxiliary memory (primarily for instruction storage)

(d) Programme control unit.

The high speed memory can store 2 048 characters each of seven bits. The system is designed so that it can handle either one or two memories as required; hence the maxi-

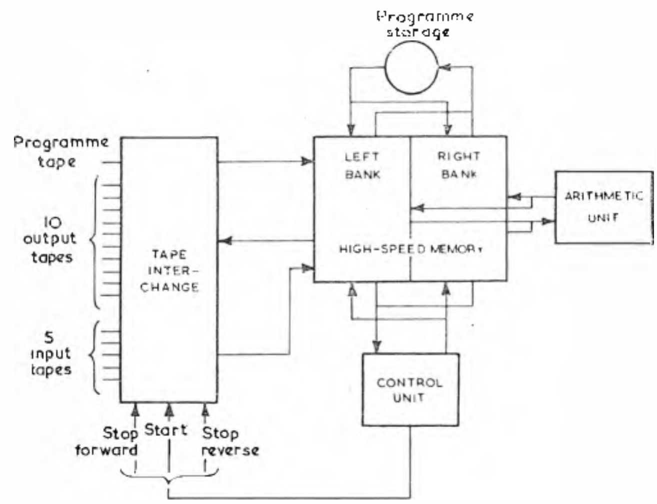

Fig. 2. The computer

mum storage available is 4 096 characters. The memory is a random access, magnetic core matrix with an access time of 20μsec imposed by the associated logic.

The programming of an operation includes the allocation of the storage space in the high speed memory to the various phases of the operation, the retention of the input information and of the instruction surges, working space for the arithmetic unit and so on.

Data in the system are organized in 'items' or words of variable length. It is necessary to allocate sufficient storage space to each item to cope with its maximum length. Each item has a specified maximum length which may be different from that of the other items in the standard message. This feature of the message format is referred to as a 'non-standard maximum' and is responsible for more effective use of the available storage space.

The component parts of the computer are interconnected through the high speed memory. The routine programmes which the computer uses are stored on a special magnetic tape. At the start of an operation the required programme is located and transferred to the high speed memory and thence to the cyclic auxiliary memory. Throughout the operation instructions are transferred from the auxiliary memory back into the memory in groups, or 'surges,' in order to reduce the time wasted in searching for the next instruction in the auxiliary memory.

Input information is introduced to the computer on as many as five input tapes. It is read from the tapes into the high speed memory, one or more messages at a time. Once recorded in the memory any item of the message can be located and transferred to the arithmetic unit for comparison with or modification by another item.

The programme control unit governs the accessibility of instructions and hence controls the operation.

The information resulting from the computer's operations is fed back into the system through ten output trunks.

INSTRUCTIONS

Operations in the computer are controlled by the use of 22 basic instructions each of which may have one or more variations. Thus, for example, 'write-out to tape' is an instruction and enables a block of information between two addresses to be transferred from the high speed memory to a magnetic tape. By stipulating 'variations' on this basic instruction the programmer can either stop the magnetic tape when the transfer is complete or allow it to continue running.

In addition from one to three addresses in the high speed memory are specified in an instruction. For example, when an 'addition' instruction is used it is necessary to specify where each of the two numbers to be added are to be found and also where the answer is to be recorded.

The basic format of any instruction comprises eight characters of which the first is the code number of the operation, the second specifies the variation of the operation and the three remaining pairs of characters specify the three addresses.

The instructions can be classified according to function as either:

(a) a data-handling instruction,

(b) an arithmetic instruction,

(c) a decision and control instruction.

A data-handling instruction is used for the transfer of information from one part of the storage system to another as, for instance, in transcribing data in the high speed memory on to the output magnetic tapes or in surging instructions from the auxiliary memory into the high speed memory.

The arithmetic instructions are few because accounting problems entail only very simple arithmetic. Addition and subtraction are the principal arithmetic operations. Multiplication which is required for example in the preparation of dollar value accounts is performed by repetitive addition. Subtraction is used for the adjustment of inventory totals and for making comparisons between groups of characters in order to determine their relative magnitudes. This enables the computer to be used to sort information into a specified sequence.

A decision and control instruction is used when the next step in an operation is dependent on some decision just made. For example, in the case of supply control if the quantity of a catalogue item still held in stock exceeds the re-ordering level for that item the operation continues by reading the next message from the input tape. If, however, the stock on hand has fallen below the re-ordering level, control of the operation is transferred to a sub-routine which is used for initiating procurement action.

Decision and control instructions are principally concerned with making it possible to establish regular and conditional sub-routines. This permits considerable saving in the space required for storing instructions.

Summary of characteristics. The computer is characterized by:

(a) simple arithmetic,

(b) efficient use of storage capacity made possible by assigning different maximum lengths to the individual 'items' in any one input message,

(c) efficiency in data-handling measured by the number of instructions required to effect the transfer of a quantity of information,

(d) ability to handle complex operations made possible by the provision of five input and ten output tapes.

The flexibility of the system is achieved through the computer. In a particular installation any type of operation which involves only a small amount of machine time can be done by the computer. Special purpose machines such as the sorter and the interrogation unit can be considered for inclusion in the installation if the volume of work which can be handled by them is sufficiently great.

OUTPUT MACHINES

Information can be obtained from the system either in a form which is intelligible to human beings with a conventional education or as punched paper tape suitable for transmission through a teletype network.

ELECTRO-MECHANICAL PRINTER

The electro-mechanical printer accepts information from magnetic tape and prints it out in documented form. It is capable of printing 10 lines/sec, each containing up to 120 characters. Customarily information is printed in accordance with a standard format, the horizontal and vertical tabulation for which is set up in the machine. The electro-mechanical printer is the principal output device of the system in its present state of development. It is responsible for printing shipping orders and procurement orders.

MAGNETIC TAPE TRANSCRIBER

The magnetic tape transcriber converts information recorded on magnetic tape in the Bizmac code into punched paper tape without change in the coding and is included in the system for three principal reasons.

Having punched paper tape containing Bizmac characters enables hard copy to be prepared by a document printer. The latter contains a Flexowriter for this purpose operating at a maximum speed of 10 characters/sec and capable of printing both capital and lower case letters.

Secondly an IBM card punch is used to obtain output information on punched cards. This machine operates from paper tape punched in the five-bit code common to communication systems. The system includes a paper tape coder which converts the seven-bit Bizmac code to the five-bit code.

Thirdly, the coder can provide information from the system in a form suitable for transmission through a standard teletype network.

The magnetic tape transcriber effects the conversion from magnetic tape to punched paper tape by transcribing the input information to an intermediate storage in segments. The further transcription from the storage to the punched paper tape takes place at 20 characters/sec.

The System Central

The extent of the integrating problem in the Bizmac system can be judged from the following equipment complement for the OTAC installation which covers a floor area of 18 000ft^2.

Storage

Tape stations	183

Input machines	
Card transcriber	1
Paper tape transcriber	1
Tape-writers and verifiers	17
Organizational machines	
Sorter	3
Interrogation unit	1
Computing machines	
Computer	1
Output machines	
Electro-mechanical printer	2
Paper tape coder	2
Magnetic tape transcriber	2
Document printer	2

In order to control the operation of these machines

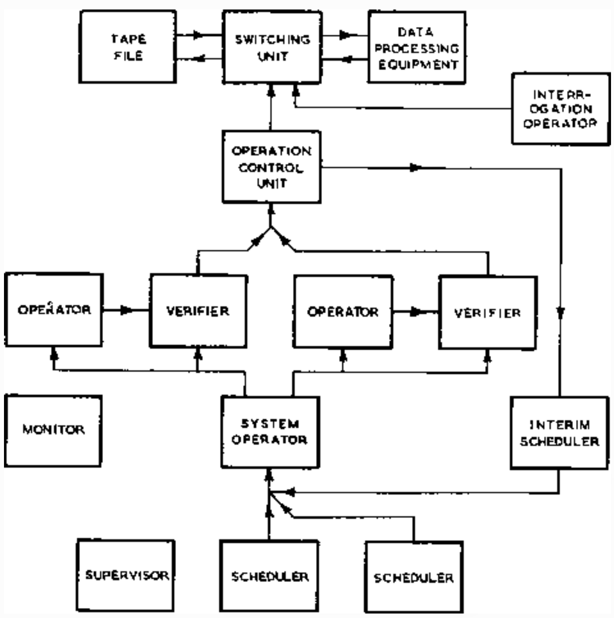

Fig. 3. Operating team

system central has a team of ten men (Fig. 3) who have the following duties:

Schedulers

The two schedulers interpret the required data-processing operations in terms of machine functions and prepare a 'consolidated flow chart' which details these functions. They are responsible for the schedule which governs the employment of the tape stations as temporary working storage for intermediary data or as permanent storage for reconstituted file information.

Interim scheduler

The interim scheduler is acquainted with the condition of each machine including the tape stations and it is his job to circumvent potential blocks in the execution of the master schedule due to unavailability of machines.

Operator and Verifier

The operator and verifier work as a team. They have identical consoles which enable them to set-up the required machine conditions at the instigation of the system operator and to connect the necessary machines and tape stations. When they have pressed the prescribed number of buttons, the status of the two consoles is automatically compared in the control unit and, if identical, the system operator is informed that the set-up is complete. The operator and verifier perform relatively unskilled jobs. Some effort has been expended to make their work as completely repetitive as possible in order to reduce the chance of introducing errors into the system.

System Operator

The system operator has a console which provides the following functions:

(a) control of one or more operator-verifier teams,

(b) machine status indications ("available", "selected", "operating", "out" and "local") for the computer and the sorters,

(c) buttons for controlling the computer and the sorters,

The control exercised by the system operator over the machines is limited to:

(1) Start Machine

(2) Stop Machine

(3) Release All Tapes

(4) Release Machine

(5) Transfer to Local Control

The system operator handles the assignment of machines to specific operations, a function which he can perform because his console indicates current machine availability.

Monitor

The Monitor works at a console which, like the system operator's console, provides indication of machine status. In addition the status of each of the tape stations is displayed. The progress in each activity which is being processed through the system is shown by lights governed by the following conditions:

(1) Machine Operating

(2) End of Operation

(3) Equipment Failure

(4) Tape Exhausted on trunk indicated.

Interrogator Operator

The interrogation unit is not fully integrated into the system central because it operates on a demand basis and hence is not scheduled. Its primary purpose is to make available information about certain specific stock items with little or no delay. The interrogator operator's console provides him with the means for connecting the interrogation unit to certain tape stations under direction from the system operator and for controlling the unit.

Supervisor

The operations team is under the general direction of the Supervisor.

During a day's routine operation at OTAC over 100 machine set-ups are made from the system central, involving 1 000 assignments of tape stations to machine trunks.

Method of Operation

The schedulers prepare a 'consolidated flow chart' on which they detail the individual machine functions necessary to perform a specified activity. Fig. 4 is part of such a chart. The chart contains different symbols representing the machines and indicates the flow of data from operation to operation. Each symbol details the trunks of the machine to which tape stations are connected. Of the other two numbers within a symbol, the upper designates the number of an operation for that particular machine, the most significant digit designating the type of machine. The lower number indicates the priority which the operation carries.

The component operations of an activity are detailed on operation cards which give the following information:

(a) the machine or machines required for an operation

(b) the set-up of the machine

(c) the pre-requisites which must be fulfilled before commencing the operation.

The allocation of tape stations to the various component operations is contained in a separate instruction. Where a tape is used at any point in an activity as a temporary storage, it can be re-scheduled at a later time in the same activity. By this scheme of 'chain scheduling', maximum economy in the allocation of working tapes to an activity is effected.

With the integrated control of the system provided by system central it is possible to engage concurrently in any number of distinct activities. For instance, the revision of the perpetual inventory record at OTAC requires the following operations:

(1) the transcription of the daily load of item detail cards

(2) the sorting of the resulting magnetic tapes

(3) the extraction from the reference file of that information which requires modification because of the incoming data on the item detail cards (an 'extract-by-list' using the sorted tape resulting from (2) as the list tape)

(4) the modification of the reference information in accordance with the new information on the sorted tape (a computer operation resulting in an up to date reference tape)

(5) the merging of the up to date reference tape back into the main reference file while removing the old information (a 'merge-substitute').

These operations are planned to last two days. Operations (1) through (3) or (4) are executed on one day and the remainder on the second day.

Nevertheless, the revision of the perpetual inventory record is a daily operation which means that on any one day the operation on yesterday's transaction data is being completed while the initial operations on the latest date are being started.

This dove-tailing of activities is made possible by a special sorter operation. According to this operation the sorter can perform a merge-substitute and an extract-by-list simultaneously. This enables the complete revision of the perpetual inventory record to be effected with only one search of the many tapes which constitute it.

Since one search takes of the order of 3 to 4 hours, the saving is considerable.

The operations listed above are detailed on the consolidated flow chart shown in Fig. 4.

(1) Transcription of the item detail cards: operations 010, 011, 012, and 013

(2a) Sorting of the resulting magnetic tapes; operations 201, 202, 203 and 204.

(2b) Merging the sorted tapes to complete the sort: operations 230, 231, 232 and 238.

(3) Extraction from the Perpetual Inventory Record: operation 250, using input trunks 01 and 03 and yielding an output 05.

(4) Modification of information in the computer: operation 101.

(5) Substitution of new data for old in the Perpetual Inventory File: operation 250, using inputs 01 02 and yielding an output on trunk 04.

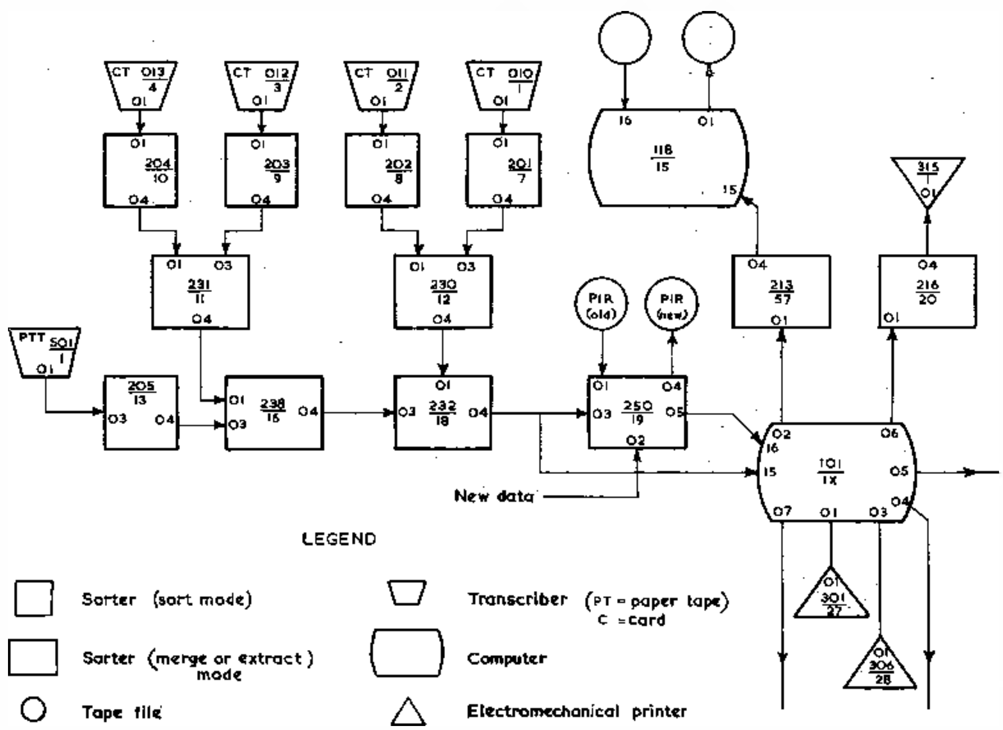

Fig. 4. Part of flow chart

The operation 250 is the simultaneous merge-substitute and extract-by-list referred to above.

In addition to the overlap of daily routine activities of the type described, monthly and quarterly investigations can be initiated as required. Since all these activities can be handled concurrently, the system operator is guided in his work by the priority numbers of the component operations in any activity and also by the general rule that operations in the activity which has been in progress the longest have priority over all others.

This method of operation and the flexibility it provides are made possible by the control which is inherent in the concept of a system central.

Acknowledgements

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Microwave Helical Aerials

By T. G. Hame*

Helical aerials are of particular value in u.h.f. systems where a narrow beam of circularly polarized waves is required. In this article some of the problems involved in the design of this type of aerial are considered with particular reference to the dielectric enclosed helix.

HELICAL aerials of the general form shown in Fig. 1 were first described by J. D. Kraus[1] and have been used for u.h.f. transmission and reception. They are of particular value for systems in which a high gain aerial is required to produce a narrow beam of circularly polarized waves. These characteristics require an aerial in which the diameter of the helix and of the conductor of which it is made, the number of turns and the pitch angle or the spacing between the turns are critically controlled. Nevertheless, these aerials possess many advantages which make it profitable to investigate the possibility of using them at microwave frequencies.

The problem of designing a helical aerial for microwave use resolves itself into a scaling-down operation and the first difficulty is that the conductor becomes so fine that it requires to be supported along its entire length if it is to be used at say 4kMc/s while at 10kMc/s the difficulty is intensified.

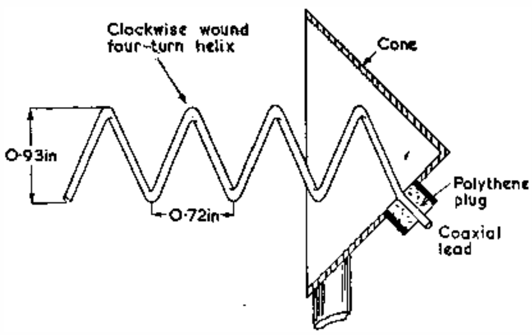

Fig. 1. 4 000Mc/s helix aerial

The Dielectric-Enclosed Helix

Since the helix must be supported, the material used for this purpose must be a low loss dielectric to prevent loss of power and, as its dielectric constant will differ from that of air, the velocity of propagation will be altered; this results in distortion of the radiation pattern and loss of circularity of polarization (axial ratio). This effect may often be ignored at 500Mc/s where the supporting structure is small compared with the wavelength but even at 4kMc/s it is comparable with the wavelength and cannot be ignored. It is apparent, therefore, that, if optimum performance is to be obtained, the supporting medium must be carefully chosen and its effect must be included in the design of the helix.

A helical aerial radiates along the axis of the helix, i.e., it is an endfire aerial. The effect of enclosing it within a dielectric is to cause it to behave partially as a polyrod aerial which is also an endfire aerial. The velocity of propagation along the dielectric and the ratio of the power guided inside to that guided outside the dielectric are functions of the rod diameter, the wavelength of the radiation and the dielectric constant (K) of the material. It can be shown that if the diameter of the dielectric is of the order of half a wavelength, the phase velocity within it is nearly the same as an unbounded dielectric medium.

It appears, therefore, that to ensure that the rate of change of phase along the dielectric-enclosed helix is the

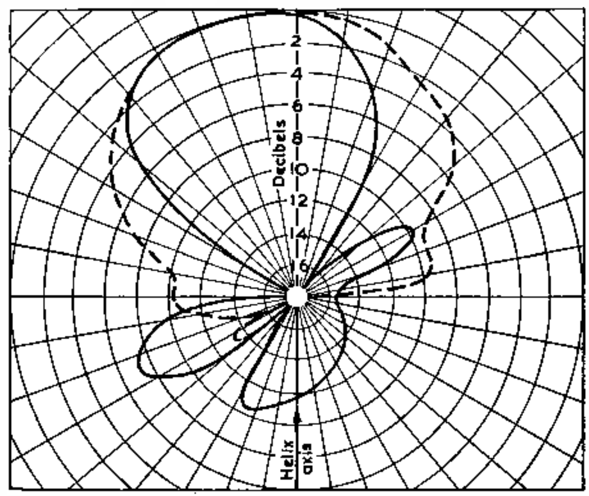

Fig. 2. Radiation pattern of helix with polythene cover and core (4 000Mc/s)

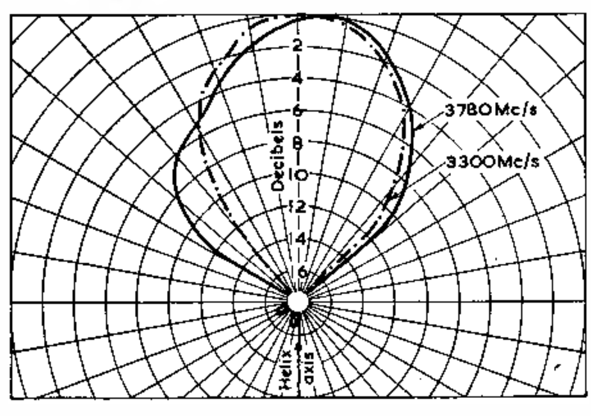

Fig. 3. Radiation pattern of 4 000Mc/s helix with polythene cover and core at various frequencies

same as that along a helix operating in air, compensation for the effect of the changed medium must be made. This may be done by reducing the dimensions of the helix in the ratio $\sqrt{K}$: f.

Measurements on the Helix

Measurements of radiation patterns and axial ratio were made by using a horn radiating linearly polarized waves as the transmitting aerial and a helix mounted on a turntable as the receiving aerial.

* *E.M.I. Engineering Development Ltd.*

The helix used for the initial experiments is shown in Fig. 1. It has been designed for a frequency of 4kMc/s, the helix being assumed to be operating in free space. When a polythene cover and core were fitted to the helix of Fig. 1 the radiation pattern obtained was quite poor, the main beam being deflected and distorted and side lobes of large amplitude being produced as indicated by Fig. 2. The radiation patterns are shown in two orthogonal planes of the

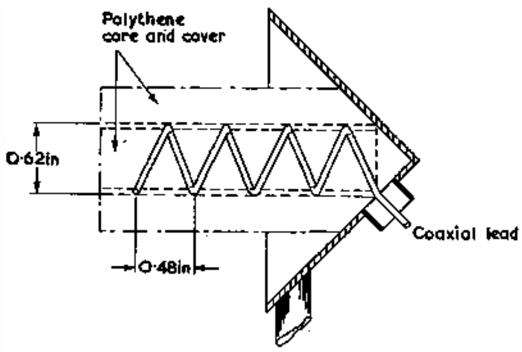

Fig. 4. Scaled down helix with polythene cover and core

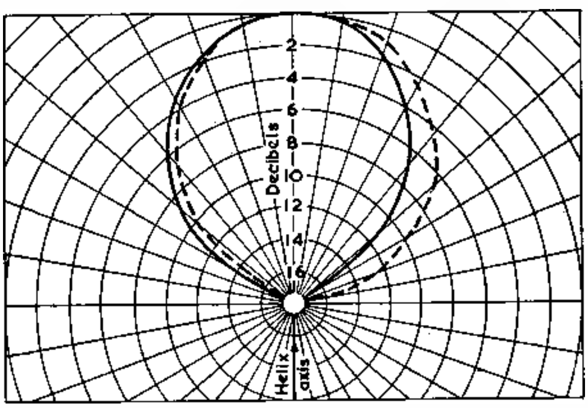

Fig. 5. Radiation pattern of scaled down helix with polythene cover and core

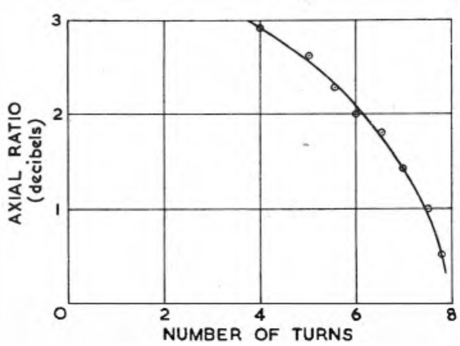

Fig. 6. Variation of axial ratio with number of turns

polarization ellipse and are normalized along the forward axis of the helix. The axial ratio on the axis of the helix was 5dB. Both these effects showed that the detuning effect of the dielectric was quite severe.

The dielectric increases the effective electrical path length between the turns of the helix, the effect of which is to lower the optimum frequency of operation. Further radiation patterns were made at 3 780 and 3 300Mc/s in order to find how much variation in the optimum frequency arose as a result of adding the polythene. Fig. 3 shows the improvement in one plane as the frequency was decreased.

To compensate for this effect and so to restore the optimum frequency to 4kMc/s, the linear dimensions of the helix were reduced in the ratio $\sqrt{K}:1$; the new dimensions being shown in Fig. 4. This resulted in an overall improvement in the radiation patterns and the disappearance of any side lobes greater than 20dB (Fig. 5); the axial ratio was also improved to its original value 3dB.

The effect of varying the thickness of the outer polythene cover of the scaled-down helix and also that of a hollow polythene core has been determined. These changes produce little effect on the radiation patterns although the

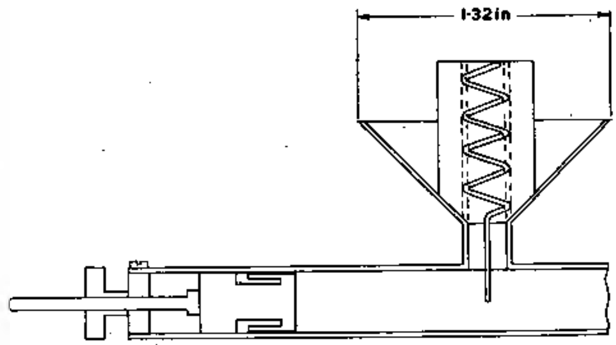

Fig. 7. X-Band helix

Helix diameter—0·264*in*
Turn spacing—0·204*in*
Diameter of wire—0·040*in*
Diameter of core—0·224*in*
Sleeve thickness—0·090*in*

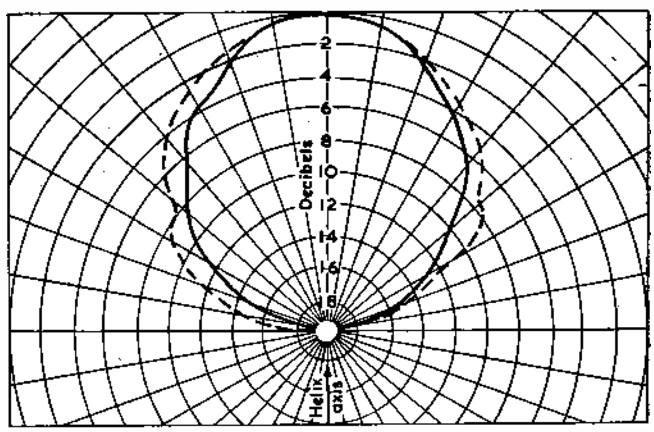

Fig. 8. Radiation pattern of X band helix at 9 400Mc/s

axial ratio changes to 4dB for some arrangements. It appears from measurements with various combinations of core and cover that the effect of variation in the thickness of the outer cover is greater than that of variations of the inner core.

The axial ratio of the radiation on the main beam axis of a scaled-down helix, plotted against the number of turns, is shown in Fig. 6. An 8-turn helix will give an axial ratio which is better than 0·5dB.

An X-Band Helix

The higher frequency operation of the helix is achieved by reducing the linear dimensions of the helix, the cone and the surrounding polythene dielectric in the ratio of the operating wavelengths. The resultant dimensions for an X-band helix are shown in Fig. 7. In view of the small size of the cone it becomes necessary to modify the lead to the helix where it passes through the cone. The cone is directly mounted on WG16 waveguide, the helix feeding straight into the guide through a polythene plug at the apex of the cone. A movable piston at one end of the guide is used to match the probe from the helix to the guide.

Fig. 8 shows the radiation patterns obtained at a frequency of 9 400Mc/s in two orthogonal planes. The beam width at half-power points is 62° in one plane and 50° in the other. The gain of the aerial is approximately 7. The axial ratio is 3dB but this can be improved by increasing the number of turns as indicated by the 4kMc/s measurements.

Conclusions

The use of the dielectric-enclosed helix extends the high frequency range of the helical aerial throughout the microwave region without loss of performance.

Acknowledgments

The author wishes to express his thanks to Mr. J. Bass who carried out the experimental measurements and to E.M.I. Engineering Development Ltd, for permission to publish this article.

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ELECTRO-OCULOGRAPHY

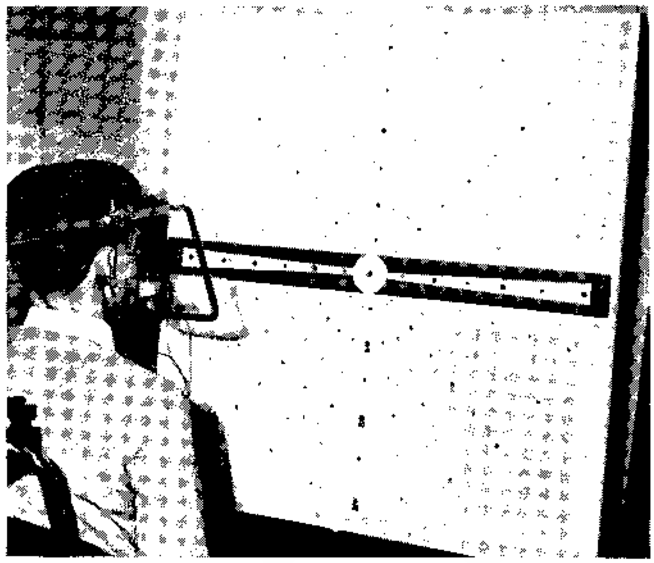
For some time past, the Psychological Research Laboratory of E.M.I. Electronics Ltd., has been carrying out research and development in electro-oculography: the technique of electrically recording eye position and eye movements by detecting the resulting small d.c. potentials from the skin surface around the eye sockets.

As a result, they evolved an improved technique and have developed a practical and complete system of eye movement measuring apparatus, the first of which will be used by the Naval Motion Study Unit of the Admiralty Research Laboratory.

Although the technique has been known and investigated intermittently by various research workers for more than 20 years, little progress has been made so far mainly because other voltages are detected from the skin at the same time which greatly exceed the eye position voltage, or which cause excessive drift of the zero point.

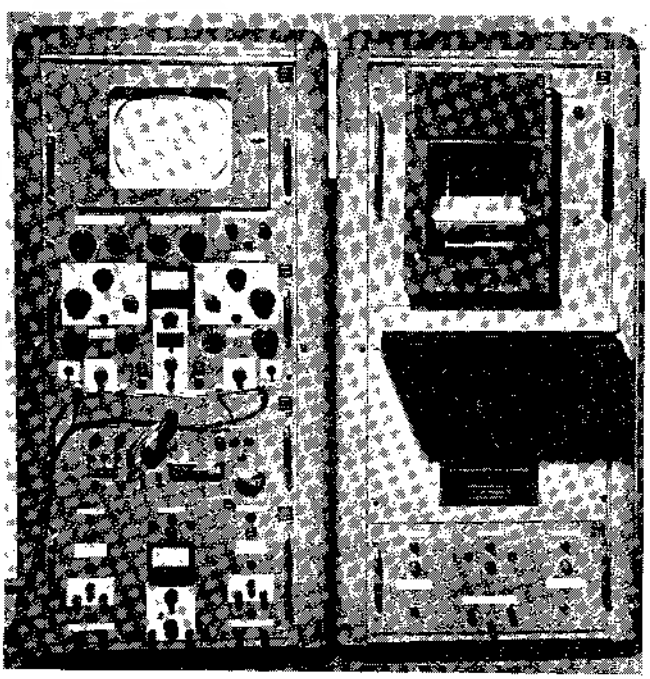
In their new system, E.M.I. have succeeded in reducing very considerably the unwanted skin (g.s.r.) potentials; they have also found both the need and the way to make very pure silver electrodes, since as much zero drift can come from the electrodes themselves as from the skin.

To describe the operation of the system very simply and briefly: the eye acts as though it were a tiny battery, with a positive voltage at the front (the cornea) and a negative voltage at the back (the retina). With the eye looking straight ahead, these voltages are in balance, and thus an electrode placed on the skin at the side of the eye socket would register zero.



A subject under test, sitting in front of the target board. Each spot represents a 5° movement in any direction, with the subject at a fixed distance from the target. A positive transparency of the pattern is placed in front of the cathode-ray display tube, where the eye movements are plotted by the electron beam.

Part of the eye movement measuring apparatus. On the left is the high-stability, high gain d.c. amplifier and the cathode-ray tube on which the eye movements of the person being tested are displayed. On the right are the pen recorders which produce a continuous trace of the vertical and horizontal movements.



As soon as the eye moves in any direction, the voltages are out of balance and the resulting sum or difference voltage can be picked up by the electrode, amplified by the equipment and either displayed on a cathode-ray tube or used to drive pen recorders to produce a continuous trace of the horizontal and vertical movements.

Different people give different amounts of voltage per degree of eye movement; accuracy can therefore be expressed only in statistical and not in absolute terms.

With an average subject tested in one minute spells, one can now be sure of recording horizontal eye movements to better than $\pm 1{\cdot}5°$, and vertical eye movements to $\pm 2°$ for 70 per cent of the testing time. For shorter spells—e.g. 20 to 30sec—the accuracy is better than $\pm 1°$ for at least a similar percentage of the testing time.

With selected subjects in one minute spells, an accuracy can be assured of $\pm 1{\cdot}5°$ for more than 90 per cent of the time, and better than $\pm 1°$ for at least 70 per cent of the time.

These figures assume that all results are plotted from an arbitrary zero level. It has been found, however, that the residual zero drifts are usually almost linear, so that by using a pen recorder and interpolating the zero level from the zero points at the beginning and end of the recording spells (whether they be one, two or more minutes), it is possible to make a reliable analysis of the record to better than $\pm 1°$ of eye movement for an entirely satisfactory percentage of the total recording time.

The cathode-ray tube display is a two-dimensional type of eye movement display which was originated by Dr. N. H. Mackworth, of the M.R.C. Applied Psychology Research Unit, Cambridge.

MILLIMICROSECOND BLOCKING OSCILLATORS

By J. MacDonald Smith*, M.A.

In this article the design of millimicrosecond blocking oscillators is described. Suitably designed circuits will deliver pulses of up to 200V amplitude into coaxial cables of normal impedance. The theory of the circuit is outlined and expressions for the pulse width and rise-time are derived.

BENJAMIN[1] has given a full analysis of the mode of operation of the blocking oscillator in the microsecond region, and design techniques for such circuits are by now standard. In the following paragraphs the design of millimicrosecond blocking oscillators is discussed; it is shown that pulses 20 to 100mμsec in duration can be generated which are some 200V in amplitude when the circuit is properly matched into a low impedance load, such as a coaxial cable.

A simple theory of the circuit is possible, since the assumption can be made that the transformer is ideal. The theory enables simple expressions for the rise-time and pulse width to be derived.

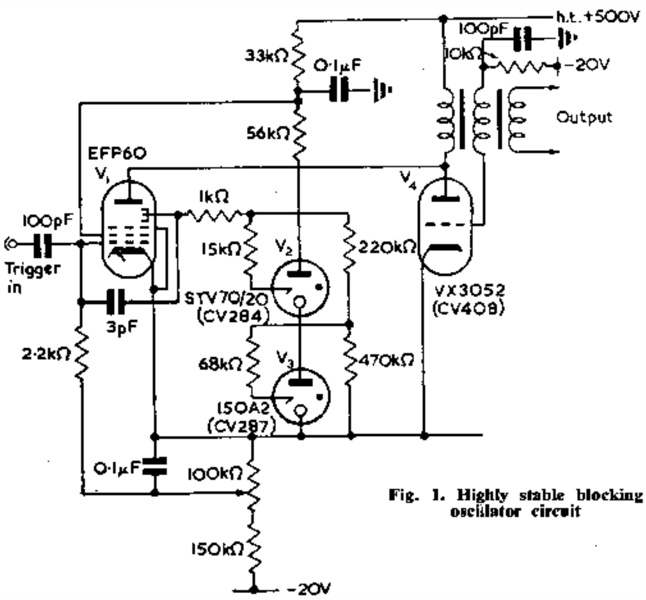


Fig. 1. Highly stable blocking oscillator circuit

Design Techniques for Blocking Oscillators

A suitable valve for use in a fast blocking oscillator circuit should have low interelectrode capacitances, a high mutual conductance, and high peak current under pulse conditions.

The valve capacitances should be as small as possible, since at millimicrosecond orders of time their impedances will be comparable with those of the coils. Thus, increasing the anode-earth or grid-earth capacitance increases the rise-time of the output pulse, and increasing the anode-grid capacitance increases the negative feedback from anode to grid, and will thus have the same effect. Increasing the mutual conductance increases the positive feedback from anode to grid, and so will decrease the rise-time.

Since the output of the circuit is a highly damped oscillation, its duration depends on the inductance of the coils and on the capacitance associated with them. Thus, if narrow pulses are desired, the valve capacitances should be as small as possible.

The rise-time of the output pulse is therefore controlled by the mutual conductance and by the interelectrode capacitance, while the pulse duration is controlled by the inductance of the coils and, by the interelectrode capacitance.

Increasing the peak current will increase the peak output voltage.

The most important requirement of the core is that it shall have high permeability for millimicrosecond pulses. Cores have been developed with permeabilities of the order of several hundreds under these conditions, and among these are the 0·001in Mumetal strip toroid manufactured by Telcon Ltd., and the 0·0006in Permalloy 'C' strip toroid core manufactured by Standard Telephones and Cables Ltd.

Good results are obtained using pulse transformers wound on these cores in the circuit of Fig. 1. This is illus-

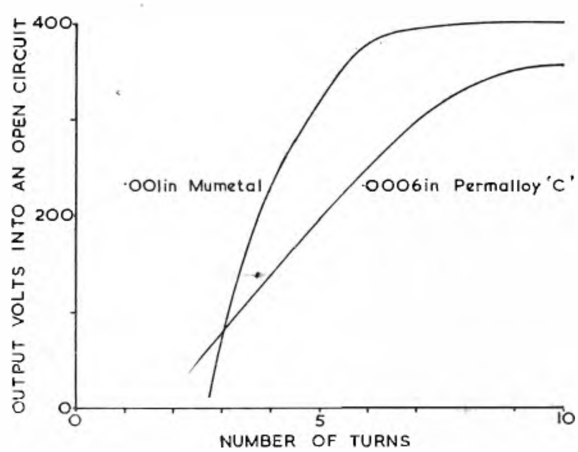


Fig. 2. Peak output voltage plotted against the number of turns on the primary, secondary and tertiary windings for a fast blocking oscillator

trated by Figs. 2, 3, and 4, which show peak output voltage, 10 to 90 per cent rise-time and width at half peak voltage, as a function of the number of turns wound on the core for typical toroids of each type. The 'spread' of the results taken from a batch of toroids is small enough to make it possible to use these curves as design charts when the pulse transformer is used in the circuit of Fig. 1 and using the theory to be outlined, it is possible to correct these results when different valve types are used.

The best results are obtained when the core is wound with equal numbers of turns on the primary and secondary windings. By varying the number of turns on the tertiary winding, it is possible to match the output into low impedances between 30 and 300Ω. The windings are best placed on top of each other, as this arrangement gives maximum coupling.

The interwinding insulation should be two turns of Polythene tape; in the case of Mumetal one turn of Nylon tape should be put between the core and the windings but this is not necessary in the case of Permalloy 'C', since the toroid is supplied in a moulded nylon box.

The circuit of Fig. 1 will be found extremely useful in many applications, since the input-output time 'jitter' is well under 1mμsec. This circuit has been used as a brighten-

* *The Theological College, Wells: formerly Atomic Weapons Research Establishment, Aldermaston.*

ing pulse generator and as a time-base valve trigger circuit in a time-base unit which generates a 5mμsec scan, and by means of it the problem of 'jitter' on the display has been solved. For applications where 'jitter' presents no problems, a CV138 (EF91) amplifier may be substituted for the secondary emission pentode trigger shown in Fig. 1.

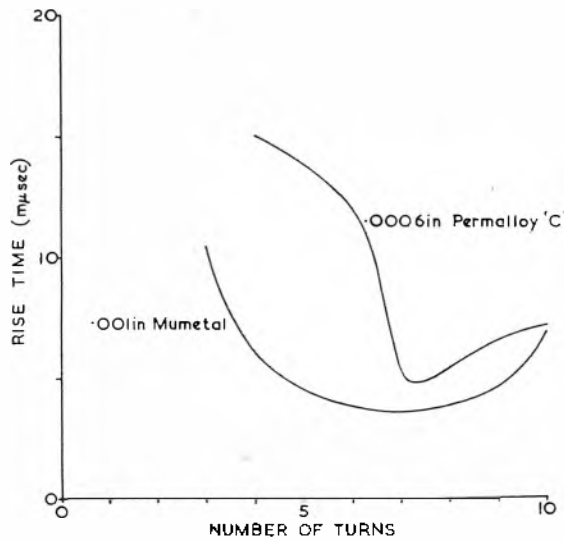


Fig. 3. Ten per cent to 90 per cent rise-time of blocking oscillator output plotted against number of turns on the core

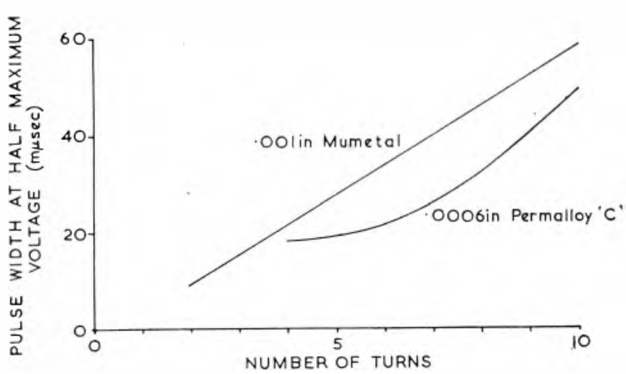


Fig. 4. Width at half maximum voltage of blocking oscillator output plotted against number of turns on the core

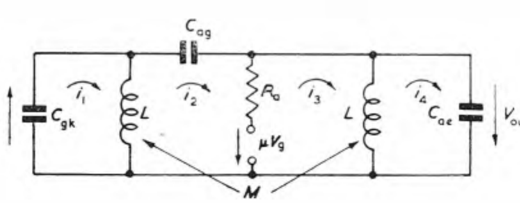


Fig. 5. Equivalent circuit of Fig. 1

Theory of Operation

In this section a simple theory of millimicrosecond blocking oscillators is outlined.

The theory of these oscillators is comparatively simple compared with that of slower speed circuits, since it may be assumed that the pulse transformer is ideal, that is, the leakage inductance is negligible, because the transformer coupling is high and the number of turns small. This assumption is confirmed by experiment.

The circuit of Fig. 1 has the equivalent circuit shown in Fig. 5, where C_{ae}, C_{gk}, and C_{ag} represent the total capacitance in circuit, i.e. the valve capacitance plus that of the wiring and transformer.

The analysis is performed only for the case of a 1:1 transformer, since experiment shows the best results are obtained in this case.

The analysis of Fig. 5 results in the differential equation:

$$\begin{aligned}\Big\{ & p^4[R_a(L^2-M^2)(C_{ae}C_{ag}+C_{ae}C_{gk}+C_{ag}C_{gk})] \\ & - p^3[(L^2-M^2)(C_{gk}+(\mu-1)C_{ag})] \\ & - p^2[2(L-M)C_{ag}+L(C_{gk}-C_{ae})]R_a \\ & + p[(L-M)+(\mu+1)M]+R_a \Big\}\, i_4 = 0 \quad \ldots\ldots\ldots\ldots (1)\end{aligned}$$

Where p is the differential operator d/dt, R_a and μ are the usual valve parameters, L is the inductance of the primary and secondary windings, and M is their mutual inductance.

Now in an ideal 1:1 transformer, $L = -M$; thus equation (1) reduces to

$$\left[p^2 + \frac{p(1-\mu)}{R_a(C_{gk}+4C_{ag}-C_{ae})} + \frac{1}{L(C_{gk}+4C_{ag}+C_{ae})}\right] i_4 = 0 \quad \ldots\ldots\ldots\ldots (2)$$

therefore

$$pi_4 = \frac{(\mu-1)}{2R_a(C_{gk}-4C_{ag}+C_{ae})} \pm \sqrt{\left[\frac{(\mu-1)^2}{4R_a^2(C_{gk}+4C_{ag}+C_{ae})^2} - \frac{1}{L(C_{gk}+4C_{ag}+C_{ae})}\right]}$$

putting

$$\frac{\mu-1}{2R_a(C_{gk}+4C_{ag}+C_{ae})} = \alpha_0$$

$$\sqrt{\left[\frac{(\mu-1)^2}{4R_a^2(C_{gk}+4C_{ag}+C_{ae})^2} - \frac{1}{L(C_{gk}+4C_{ag}+C_{ae})}\right]} = \alpha_1$$

equation (2) gives

$$pi_4 = \alpha_0 \pm \alpha_1 \quad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Therefore:

$$i_4 = A_1 \exp[(\alpha_0+\alpha_1)t] + A_2 \exp[(\alpha_0-\alpha_1)t]$$

(A_1, A_2 arbitrary constants)

At $t = 0$, $i_4 = 0$, $\therefore A_1 = -A_2$

Therefore the output voltage =

$$V_{out} = \frac{B}{\alpha_0^2 - \alpha_1^2}[(\alpha_0 - \alpha_1)\exp(\alpha_0 + \alpha_1)t - (\alpha_0 + \alpha_1)\exp(\alpha_0 - \alpha_1)t] \quad \ldots\ldots (4)$$

(B is a constant)

Now α_1 may be real or imaginary, and there are three possible cases to be considered for each of these alternatives, i.e. α_1 very much larger than α_0, α_1 of the same order as α_0, and α_1, very much less than α_0. The output voltage functions corresponding to each of these alternatives are given in Table 1, and are derived from equation (4).

Consider first case 1: the condition for case 1 is given by:

$$\frac{(\mu-1)^2}{4R_a^2(C_{ae}+4C_{ag}+C_{gk})} \sim \frac{g_m^2}{4(C_{ae}+4C_{ag}+C_{gk})} \sim 1/L \quad \ldots\ldots (5)$$

Typical values for $\Sigma C = C_{ae} + 4C_{ag} + C_{gk}$, g_m, and L will be of the order of 30pF, 10mA/V, and 10μH respectively. It is easily verified that with these values it is impossible to fulfil condition (5), and so Case 1 can be ruled out.

Case 3 for α_1 real is obviously impossible to fulfil. Case 3 for α_1 imaginary is only possible if $L \ll 1\mu$H, and as this does not apply to the circuits under consideration in this article, Case 3 can be ruled out.

For Case 2 to apply, the condition is:

$$\frac{\mu-1}{2R_a\Sigma C} \simeq \sqrt{\left[\frac{g_m^2}{4(\Sigma C)^2} - \frac{1}{L\Sigma C}\right]} \quad \ldots\ldots\ldots (6)$$

TABLE 1

CASE NUMBER	α_1 REAL	α_1 IMAGINARY
(1) $\alpha_1 \ll \alpha_0$	V_{out} VERY SMALL	V_{out} VERY SMALL
(2) $\alpha_1 \sim \alpha_0$	$V_{out} \sim \frac{B}{\alpha_0 + \alpha_1} \exp [(\alpha_0 + \alpha_1) t]$	$V_{out} \sim \frac{B}{\alpha_0 - \alpha_1} \exp (\alpha_0 - \alpha_1) t$
(3) $\alpha_1 \gg \alpha_0$	$V_{out} \sim \frac{2B}{\alpha_1} \operatorname{Sinh} \alpha_1 t$	$V_{out} \sim \frac{4B}{\alpha_2} \operatorname{Sin} \alpha_2 t$ $\alpha_1 = j\alpha_2$

Putting

$$\left.\begin{aligned} \frac{\mu - 1}{2R_a\Sigma C} &= x \\ \frac{1}{L\Sigma C} &= y \end{aligned}\right\} \quad \ldots\ldots\ldots\ldots (7)$$

Equation (6) becomes

$$x \simeq \sqrt{(x^2 - y)} \quad \ldots\ldots\ldots\ldots\ldots\ldots (8)$$

The condition α_1 imaginary may be dismissed at once, for it implies:

$$g_m^2/2\Sigma C \sim 1/L$$

and the analysis of case 1 shows that this is impossible. There remains for consideration the condition α_1 real. This condition implies that:

$$\sqrt{\left[\frac{g_m^2}{4(\Sigma C)^2} - \frac{1}{L(\Sigma C)}\right]} < g_m/2\Sigma C \text{ or } \sqrt{(x^2 - y)} < x. \quad (9)$$

and for Case 2 to apply this means that $\sqrt{(x^2 - y)}$, though less than x, shall not be much less than x, for $\alpha_1 \sim \alpha_0$. It remains to be shown that this is possible with typical circuit values. The condition α_1 real implies:

$$\left.\begin{aligned} x &\sim (x^2 - y)^{\frac{1}{2}} \\ \text{i.e. } 1 &\sim 1 - (y/2x^2) \\ \therefore\ y/2x^2 &\ll 1 \end{aligned}\right\} \quad \ldots\ldots\ldots\ldots (10)$$

Now:

$$y/2x^2 = (2\Sigma C)/Lg_m^2 \quad \ldots\ldots\ldots\ldots (11)$$

Using the typical values already quoted, the value of the function in equation (11) is 0·06. Thus with normal circuit values, the condition in equation (10) is satisfied.

It has been shown that Case 2, α_1 real describes the initial operation of the circuit. In the typical case α_1 and α_0 are equal to within a few per cent of each other; hence the leading edge of the output is an exponential $V_o\exp(at)$ with $a = g_m/(C_{ae} + C_{gk} + 4C_{ag})$, to within a few per cent.

It should be noted that the above analysis assumes g_m is a constant, which is not strictly true. Thus, while the cathode current is space charge limited, the output of the blocking oscillator is approximately exponential, departures from this being due to the variations in effective g_m. However, after a time the cathode current will become temperature limited, and the g_m will gradually fall to zero. After this the output voltage will turn over and fall to zero in a time dependent only on L and ΣC. In fact, putting $g_m = 0$ in equation (3) shows that the width of the pulse will be equal to half the period of the resonant frequency of L and $(C_{ae} + 4C_{ag} + C_{gk})$. This is the condition shown in Table 1 as Case 3, α_1 imaginary.

The above theory is easily substantiated experimentally. If the circuit of Fig. 1 is constructed, and capacitors added between anode and earth, anode and grid, and grid and earth, it will be found that the square of the pulse duration is linear with respect to the added capacitance. Let the pulse duration be T, then the change in T^2 for a given change in C_{ae} will be equal to the change in T^2 for the same change in C_{gk}, and will be one quarter of that for the same change in C_{ag} showing that the square of the pulse duration is linear in $(C_{ae} + 4C_{ag} + C_{gk})$, as predicted by the theory. The value of the circuit $(C_{ag} + 4C_{ag} + C_{gk})$ may be deduced from the same experiment, and compared with the actual value, as measured on a bridge. A typical experiment gave 37·9pF for $(C_{ae} + 4C_{ag} + C_{gk})$ and the measured value was 43·7pF.

Similarly, a plot of the leading edge of the pulse shows it to be approximately exponential; the exponent will be found to vary inversely as $(C_{ae} + 4C_{ag} + C_{gk})$. By the theory the product of the exponent and $(C_{ae} + 4C_{ag} + C_{gk})$ is equal to the g_m of the valve; this is easily checked since the g_m of the valve is measurable. In an experiment, theory gave a g_m of 16·5mA/V for a valve with a measured pulse g_m of 18·0mA/V.

It has been shown that the output pulse of a millimicrosecond blocking oscillator has the following characteristics:

$$\text{Duration} = T = \pi\sqrt{[L(C_{ae} + 4C_{ag} + C_{gk})]} \quad \ldots\ldots (12)$$

$$\text{Leading edge} = V(t) = V_o e^{at},\ V(t) \leqslant V_{max}$$

$$\text{with } a = \frac{g_m}{C_{ae} + 4C_{ag} + C_{gk}} \quad \ldots\ldots\ldots (13)$$

where V_{max} = peak output voltage.

By equation (13) the 10 to 90 per cent rise-time will be given approximately by:

$$\begin{aligned} \text{10 to 90 per cent rise-time} &= 2{\cdot}2/a = \\ &(2{\cdot}2/g_m)(C_{ae} + 4C_{ag} + C_{gk}) \quad \ldots\ldots (14) \end{aligned}$$

Using the typical values of g_m and $(C_{ae} + 4C_{ag} + C_{gk})$ given above, the rise time for such a circuit is 6·6mμsec, which is well within the range of values shown in Fig. 3.

The three equations (12), (13), 14) enable the designer to predict quickly the effect of a change of valve type or a change in transformer winding details.

Conclusions

It has been shown that the range of the blocking oscillator has been extended to cover the millimicrosecond region. If shorter, faster rising pulses are to be generated than is possible at present, improvements in valve design are necessary. The theory shows that the width depends on the square root of the capacitance $(C_{ae} + 4C_{ag} + C_{gk})$ and on the square root of the primary inductance. The rise-time depends directly on the inductance and inversely on the mutual conductance. The peak output voltage depends directly on g_m. Thus improvements in valve parameters will have more effect on the rise-time and peak voltage than on the pulse duration; in the immediate future, therefore, shorter rise-times are likely to be attained, while a significant reduction in the pulse duration is unlikely.

Acknowledgments

The author would like to express his gratitude to the atomic Energy Authority for permission to publish this article, and also to Mr. S. D. Abercrombie and Mr. G. V. Stupart, of A.W.R.E., for their advice and guidance.

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An Elimination Technique for Certain Impedance Equations

By C. D. Allen*

A set of linear simultaneous equations of a type which frequently arises in the analysis of linear networks is considered. A short method of performing the elimination necessary to obtain the impedance equations of the network is proved.

THE impedance equations of a network may often be most easily derived in a form which includes certain currents in, and p.d.'s across, certain impedances of the network. If these impedances are known, additional equations connecting these currents and p.d.'s may be written down, and the resultant impedance equations of the network obtained by elimination. We shall develop a method of writing down these equations directly.

We assume the equations, before elimination, to be

$$[A]\,[I]_n = [V]_n \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

in matrix notation, where the I and V with suffices from $p+1$ to n are the currents and p.d.'s internal to the network. These are assumed to be related by the equations

$$[B]\,[I]_n = [V]_n \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

where the first p rows and columns of $[B]$ and $[V]$ are zeros. Thus equations (2) do not contain I_1 to I_p, or V_1 to V_p explicitly. Note that the remaining V's of equations (2) are the same quantities as those of equations (1).

We may now substitute the V_{p+1} to V_n from the $n-p$ equations (2) into the last $n-p$ of equations (1), obtaining a set of equations

$$\sum_{s=1}^{n} a_{qs} I_s = \sum_{s=p+1}^{n} b_{qs} I_s \quad p+1 \leqslant q \leqslant n$$

which may be rearranged as

$$\sum_{s=p+1}^{n} (a_{qs} - b_{qs}) I_s = -\sum_{s=1}^{p} a_{qs} I_s \quad \ldots\ldots\ldots\ldots \quad (3)$$

These may now be solved for the $n-p$ variables I_{p+1} to I_n. Writing

$$c_{rs} = a_{rs} - b_{rs}$$

we obtain a solution for, e.g., I_r as follows:

$$I_r = \frac{\begin{vmatrix} c_{p+1,p+1} & c_{p+1,p+2} & \ldots & c_{p+1,r-1} & -\sum\limits_{s=1}^{n} a_{p+1,s} I_s & c_{p+1,r+1} & \ldots & c_{p+1,n} \\ c_{p+2,p+1} & c_{p+2,p+2} & \ldots & c_{p+2,r-1} & -\sum\limits_{s=1}^{p} a_{p+2,s} I_s & c_{p+2,r+1} & \ldots & c_{p+2,n} \\ \cdots & & & & \cdots & & & \cdots \\ c_{n,p+1} & c_{n,p+2} & \ldots & c_{n,r-1} & -\sum\limits_{s=1}^{p} a_{n,s} I_s & c_{n,r+1} & \ldots & c_{n,n} \end{vmatrix}}{\begin{vmatrix} c_{p+1,p+1} & c_{p+1,p+2} & \ldots & c_{p+1,n} \\ c_{p+2,p+1} & c_{p+2,p+2} & \ldots & c_{p+2,n} \\ \cdots & & & \cdots \\ c_{n,p+1} & c_{n,p+2} & \ldots & c_{n,n} \end{vmatrix}} \quad (4)$$

for $p+1 \leqslant r \leqslant n$.

We are now in a position to substitute for I_{p+1} to I_n in the first p equations (1). Performing this substitution and multiplying throughout by D, the determinant in the denominator of equations (4), we obtain the impedance equations of the network in the form

$$D \,.\, \sum_{s=1}^{p} a_{i,s} I_s + \sum_{r=p+1}^{n} a_{i,r} \begin{vmatrix} c_{p+1,p+1} & c_{p+1,p+2} & \ldots & -\sum\limits_{s=1}^{p} a_{p+1,s} I_s & \ldots & c_{p+1,n} \\ c_{p+2,p+1} & c_{p+2,p+2} & \ldots & -\sum\limits_{s=1}^{p} a_{p+2,s} I_s & \ldots & c_{p+2,n} \\ \cdots & & & \cdots & & \cdots \\ c_{n,p+1} & c_{n,p+2} & \ldots & -\sum\limits_{s=1}^{p} a_{n,s} I_s & \ldots & c_{n,n} \end{vmatrix} = D \,.\, V_i \quad \ldots\ldots\ldots\ldots \quad (5)$$

for $1 \leqslant i \leqslant p$.

The determinant in equations (5) may be written as the sum of p determinants whose $r-p^{\text{th}}$ column contains one of the terms in the summation over s. Thus we may rewrite the equations as

$$\sum_{s=1}^{p} [a_{i,s} \,.\, D - \sum_{r=p+1}^{n} (a_{i,r} \begin{vmatrix} c_{p+1,p+1} & c_{p+1,p+2} & \ldots & a_{p+1,s} & \ldots & c_{p+1,n} \\ c_{p+2,p+1} & c_{p+2,p+2} & \ldots & a_{p+2,s} & \ldots & c_{p+2,n} \\ \cdots & & & & & \cdots \\ c_{n,p+1} & c_{n,p+2} & \ldots & a_{n,s} & \ldots & c_{n,n} \end{vmatrix}) I_s] = D \,.\, V_i \quad \ldots\ldots\ldots\ldots \quad (6)$$

It can now be seen that the expression in square brackets in equation (6) is, in fact, the expansion by the top row of

$$\begin{vmatrix} a_{i,s} & a_{i,p+1} & a_{i,p+2} & \ldots & a_{i,n} \\ a_{p+1,s} & c_{p+1,p+1} & c_{p+1,p+2} & \ldots & c_{p+1,n} \\ a_{p+2,s} & c_{p+2,p+1} & c_{p+2,p+2} & \ldots & c_{p+2,n} \\ \cdots & & & & \cdots \\ a_{n,s} & c_{n,p+1} & c_{n,p+2} & \ldots & c_{n,n} \end{vmatrix}$$

and hence the impedance equations of the network may be written

$$\sum_{s=1}^{p} \begin{vmatrix} a_{i,s} & a_{i,p+1} & a_{i,p+2} & \ldots & a_{i,n} \\ a_{p+1,s} & c_{p+1,p+1} & c_{p+1,p+2} & \ldots & c_{p+1,n} \\ a_{p+2,s} & c_{p+2,p+1} & c_{p+2,p+2} & \ldots & c_{p+2,n} \\ \cdots & & & & \cdots \\ a_{n,s} & c_{n,p+1} & c_{n,p+2} & \ldots & c_{n,n} \end{vmatrix} I_s = \begin{vmatrix} c_{p+1,p+1} & c_{p+1,p+2} & \ldots & c_{p+1,n} \\ c_{p+2,p+1} & c_{p+2,p+2} & \ldots & c_{p+2,n} \\ \cdots & & & \cdots \\ c_{n,p+1} & c_{n,p+2} & \ldots & c_{p,n} \end{vmatrix} V_i$$

for $1 \leqslant i \leqslant p$.

Referring to equations (1) and (2), these equations may be written down immediately as follows.

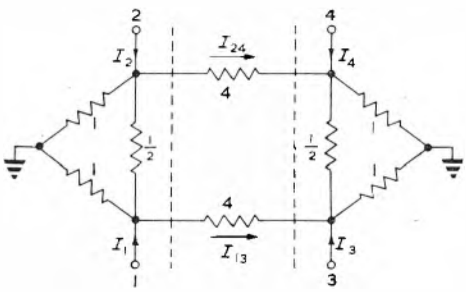
In the i^{th} equation, the coefficient of I_s is the determinant D, bordered at the top and left by the appropriate elements of the i^{th} row and the s^{th} column of the matrix $[A]-[B]$.

* *Air Trainers Ltd.*

The left-hand side of the equation is V_r multiplied by the determinant D. This determinant is itself made up of those rows and columns of $[A]$ which are modified by the subtraction of $[B]$.

Example

As an example of this procedure, consider the network shown in Fig. 1. This consists of two identical networks



connected by two resistors, as indicated by the dotted lines in the figure. Each of these two networks has, as may easily be verified, the following impedance equations:

$$1/5\ (3I_1 + 2I_2) = V_1$$
$$1/5\ (2I_1 + 3I_2) = V_2$$

where the suffices 1 and 2 are replaced by 3 and 4 respectively for the other network. When they are joined in the manner shown, we may immediately write down the following equations:

$$1/5\ \begin{array}{c} \begin{array}{cccccc} I_1 & I_2 & I_3 & I_4 & I_{13} & I_{24} \end{array} \\ \left|\begin{array}{cccccc} 3 & 2 & 0 & 0 & -3 & -2 \\ 2 & 3 & 0 & 0 & -2 & -3 \\ 0 & 0 & 3 & 2 & 3 & 2 \\ 0 & 0 & 2 & 3 & 2 & 3 \\ 3 & 2 & -3 & -2 & -6 & -4 \\ 2 & 3 & -2 & -3 & -4 & -6 \end{array}\right| \end{array} \begin{array}{c} \\ V_1 \\ V_2 \\ V_3 \\ V_4 \\ V_{13} \\ V_{24} \end{array} \qquad \begin{array}{l} V_{13} = V_1 - V_3 \\ V_{24} = V_2 - V_3 \end{array}$$

the above being the matrix $[A]$ in this example.

For the connecting resistors the matrix $[B]$ is as follows:

$$\begin{array}{c} \begin{array}{cccccc} I_1 & I_2 & I_3 & I_4 & I_{13} & I_{24} \end{array} \\ \left|\begin{array}{cccccc} 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 4 & 0 \\ 0 & 0 & 0 & 0 & 0 & 4 \end{array}\right| \end{array} \begin{array}{c} \\ V_1 \\ V_2 \\ V_3 \\ V_4 \\ V_{13} \\ V_{24} \end{array}$$

Subtracting these two we obtain the matrix

$$1/5 \left|\begin{array}{cccccc} 3 & 2 & 0 & 0 & -3 & -2 \\ 2 & 3 & 0 & 0 & -2 & -3 \\ 0 & 0 & 3 & 2 & 3 & 2 \\ 0 & 0 & 2 & 3 & 2 & 3 \\ 3 & 2 & -3 & -2 & -26 & -4 \\ 2 & 3 & -2 & -3 & -4 & -26 \end{array}\right|$$

and from this we may write down by inspection the impedance equations of the network, e.g. that for V_3 is

$$1/5\ \left(\left|\begin{array}{ccc} 0 & 3 & 2 \\ 3 & -26 & -4 \\ 2 & -4 & -26 \end{array}\right| I_1 + \left|\begin{array}{ccc} 0 & 3 & 2 \\ 2 & -26 & -4 \\ 3 & -4 & -26 \end{array}\right| I_2 + \left|\begin{array}{ccc} 3 & 3 & 2 \\ -3 & -26 & -4 \\ -2 & -4 & -26 \end{array}\right| I_3 + \left|\begin{array}{ccc} 2 & 3 & 2 \\ -2 & -26 & -4 \\ -3 & -4 & -26 \end{array}\right| I_4 \right) = \left|\begin{array}{cc} -26 & -4 \\ -4 & -26 \end{array}\right| V_3$$

Thus, as can be seen even from this simple example, much labour is saved by this method. If the matrix $[B]$ is of low order, however large the order of $[A]$, the coefficients in the final equations are low order determinants. The method is particularly valuable if only a few of the resultant equations are required. G. Kron has given[1] a method for solving large linear networks piecemeal which leads to equations of the form considered in this article, and to which the above method may be considered a useful adjunct.

Acknowledgments

Acknowledgments are due to the management of Air Trainers Ltd, by whose permission this article is published.

REFERENCE

1. Kron, G. Detailed Example of Inter-connecting Piece-wise Solutions. *J. Franklin Inst.* 259, No. 4.

Large Single-Crystal Germanium Ingots

One of the largest single-crystal ingots of germanium in the world has been grown recently at the Research Laboratories of The General Electric Co. Ltd. where a research programme on transistors and other crystal valves is in progress.

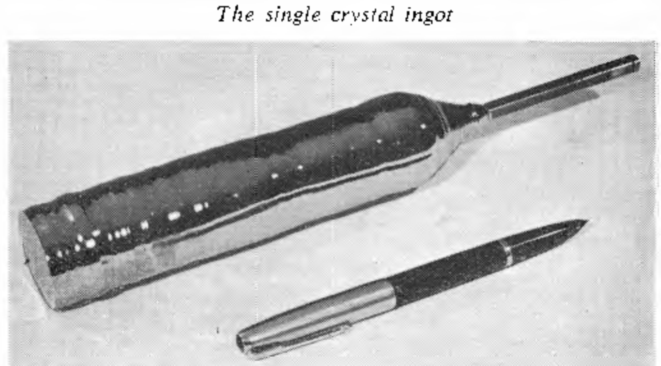
The ingot, which is about 8in long and weighs 1 200g took about six hours to grow. It was produced by a process involving the slow withdrawal of a rotating 'seed' crystal from a pool of molten germanium.

The company has developed this technique to the stage where large crystals such as this can now be grown automatically with great consistency and uniformity.

The value of the ingot is approximately £650 and the impurity content is controlled to a value of less than 1 part in 20 000 000.

In the manufacture of crystal valves, the production of such large diameter crystals results in considerable savings in cost. When the ingot is sawn into wafers, less material is lost as waste from the trimming of the outside and ends, and higher productivity is obtained from each machine producing the ingots.

The single crystal ingot



ERA

(An Electronic Reading Automaton)

The ERA, developed by The Solartron Electronic Group Ltd, is an electronic reading machine which can 'read' normally typed or printed characters and provide an output which can be used directly for the input to a computer, thus obviating the need for preparing punched cards or tape as is normally the case. The ERA must, of course, be programmed for the particular typeface with which it has to deal. The pilot model will 'read' the numerals 0 to 9 at the speed of 120 characters/second; both the range of recognition, and the speed, can be readily increased.

A simplified diagram of the pilot model of the reader is shown in Fig. 1 and the method of operation is briefly as follows.

A raster of vertical lines is produced on the face of the scanner tube by means of the deflexion circuits. A photo-objective is employed to obtain an image of the raster about the character to be 'read'. As the image of the scanner spot scans a character the light reflected at any instant is proportional to the luminance of the reflecting surface, i.e. the white paper will reflect more light than a black character. A photo-multiplier tube converts the reflected light to video pulses which are in turn amplified and 'cleaned up' in the video amplifier and clipper respectively.

Some misalignment can be compensated in the 'AND/OR logic' (to be described later). Where severe misalignment may occur, each character is scanned twice; once to correct misalignment, and once to read it. In the first scan, its top, bottom left and right extremes are observed, divided by two, and in the subsequent scan put on a pair of X and Y shifts to the scan to bring its centre to the centre of the character. In more detail, the machine counts, horizontally, the position of the first and last lines which have any black content on a staircase counter. Half the difference gives the shift required. Vertically, a similar process is used with unit lengths instead of lines.

The clock pulse generator develops a basic pulse time of 2μsec. From this is obtained an 8μsec pulse (feature period) plus 4μsec blank period between features.

10 periods are used for the character. The line feature is extended one feature at the top and bottom to allow for character misalignment. 2 feature times are used for fly-back.

Twice as fine a raster is needed for registering as for reading. To save circuits at not much cost in cycle-time, the raster always runs at fine pitch, and reading is inhibited during every second line. The 'unit feature' and 'tens of features' generators gate each black or white through a 100-way electronic switch into its appropriate position in the 100-feature stores. At the end of a 'read' stroke the store is filled.

The logical matrix is composed of diodes pre-programmed to give 'AND/OR logic'; that is to say, to respond either when say features x or y or z are stored black ('OR-logic') or when say features x and y and z are stored black ('AND-logic'). Black and white criteria can be mixed in

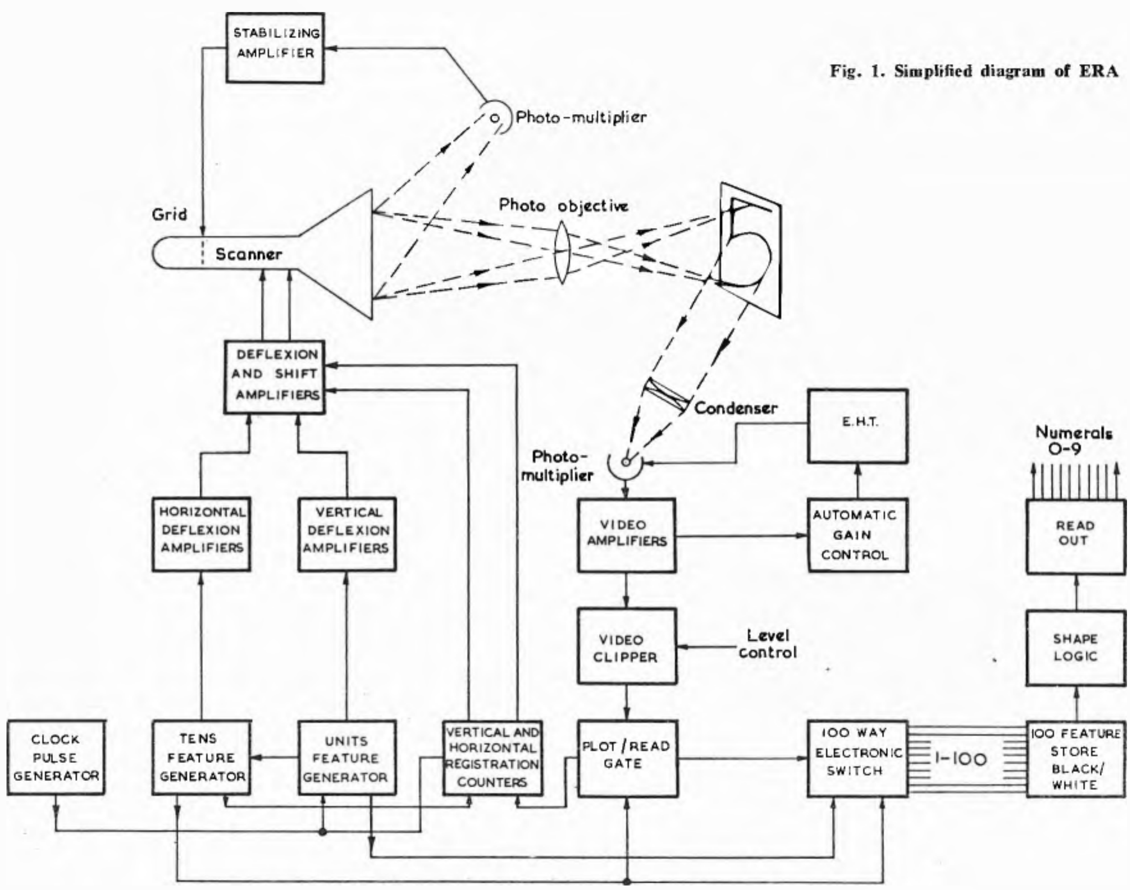


Fig. 1. Simplified diagram of ERA

any stage of the logic. If the potential is arranged to change on an 'out' wire when any diode of a set from various 'in' wires conducts, one has an 'OR' circuit; if it cannot change till every diode stops conducting, one has an 'AND' circuit.

The AND/OR logic consists of a series of groups of this kind:

"If black is (either in 12 and 13 or 32 and 33) *and* is in 22 and 23, but is *not* in 37 or 38, the character is 4"

(In practice the statements are a bit more lengthy).

The primary output consists of pulses corresponding to the numerals, one per wire. These can directly operate a keyboard or sorter. For feeding a computer directly, the numerals can be stored each in binary form (or with other moduli for shillings, pence, etc.) with which contemporary computers can operate.

The time-clock can be synchronized by a computer to make the read-time a sub-multiple of the computer's clock time. With additional units, standard addresses can be added to each set of numerals for appropriate processing.

To correct for progressive 'creep' in reading a long document such as a paper roll, the smoothed component of the correction output is available as a servo signal.

By splitting each character up into a large number of small areas (100) a considerable redundancy of input information is supplied for, with perfectly printed characters four 'bits' are sufficient to distinguish 0 to 9 plus six alphabetical characters.

This redundancy is, however, necessary to overcome the unreliability of each separate bit of information. Due to blurring, paper grain, and shake in the the operating levers, no two prints of figures from the same machine are identical. Still more serious discrepancies occur between figures from different machines. Specks of dirt or grimy folds in paper can be other sources of misleading information. A typical character printed by a cash register is shown in Fig. 2.

Fig. 2. Typical carbon copy from cash register

STEREOSCOPIC TELEVISION FOR HARWELL

A stereoscopic television camera unit which has been designed specifically for use in nuclear research has been supplied by Marconi's Wireless Telegraph Company Ltd. to the Atomic Energy Authority's research station at Harwell.

The equipment will be used with special remote manipulating equipment for the handling at a distance of dangerous radio-active materials. Special equipments are at present under development, some of which will be capable of remote manipulation up to distances of half a mile (or more if desired).

It is obvious that some form of visual aid is necessary for operations of this kind. Ordinary closed-circuit television has already been tried, but has proved to have limitations, insofar as the absence of perspective in the screened image makes it difficult for the operator to judge the distance of the manipulator's 'hands' from the objects to be handled. With the stereoscopic television now developed by Marconi's, perspective has been restored and the operator sees what appears to be a solid (i.e. three dimensional) image.

One of the types of manipulator which will be used with the stereoscopic unit is that manufactured by Messrs. Savage & Parsons Ltd of Watford to the specifications of the Atomic Energy Authority.

This type of manipulator, which is capable of operating through a biological shield up to 6ft thick, is controlled by clips attached to the operator's fingers. The movements of the fingers are transmitted through a system of extension rods terminating in a mechanical hand which reproduces the hand and finger movements of the operator. Sufficient control over the mechanical hand is obtained to enable such operations as removing the stopper from a bottle and pouring the contents into a beaker to be effected without difficulty, provided, of course, that the operator can see the objects to be manipulated.

The Marconi stereoscopic camera channel consists of two industrial Vidicon cameras, two control units and two display monitors. The cameras are mounted side by side, with their lines of sight inclined so that they intercept at the "point of interest."

The left-hand camera of the pair (corresponding to the left eye) is connected to one of the monitors, which thus gives a left-eye view of the scene; similarly, the right-hand camera and monitor give a right-eye view.

The two monitors are positioned in the display cabinet in such a way that the pictures are superimposed by means of a semi-silvered mirror. A vertically polarized polaroid filter covers the face of one screen, while the other is covered by a second polaroid filter which is horizontally polarized. If the composite image is viewed through suitably polarized spectacles a stereoscopic effect is obtained.

A COMPUTER FOR CABLE PROBLEMS

The Addison Electric Co. Ltd, Bosworth Road, London, W.10, have added to their range of quality control and automation equipment for the cable industry, an analogue computer designed for application to heat transfer problems in electrical cables. This instrument is based on the design of J. H. Neher in association with Lynmar Engineers Inc.

The new computer allows the determination of the temperature rise at given times and at various locations in and outside the cable upon the application of a prescribed load cycle. It eliminates thereby calculations which are both very time consuming and of great complexity. Considerable savings can thus be effected by this instrument in the design and the analysis of cable systems.

In use, the thermal constants of the cable and its surroundings are represented by the electrical constants of a resistance-capacitance network. These are set up by means of front panel controls, together with the required load conditions. The latter can be in the form of a complete 24 hour load cycle. The thermal behaviour is then studied at preselected points and times by the aid of a valve voltmeter, whereby 1 hour of actual time normally corresponds to 1 second of computing time. The principal uses of the new instrument can briefly be summarized as follows:

(1) Determination of short time emergency ratings and the percentage of ultimate temperature rise after a given time with constant loads for various cable systems.

(2) Determination of the effect of load and maximum temperature rise which will occur during a given cyclically applied loss cycle in various cable systems.

(3) Determination of oil flow problems and the temperature rise at various points in various cable systems as a function of time.

Portability, relative simplicity and low price have been primary requirements in the design of the new instrument, since it is intended in the main for use in Engineering Offices.

Short News Items

The Annual Dinner of the Institution of Electrical Engineers was held at Grosvenor House, London, on 28 February when the President, Sir Gordon Radley, K.C.B., C.B.E., Ph.D.(Eng.), was in the chair. The principal guest was The Rt. Hon. Sir Oliver Franks, G.C.M.G., K.C.B., C.B.E., M.A., who proposed the toast of "The Institution" to which the President replied. The toast of "Our Guests" was proposed by Sir George Nelson, Bt. (immediate Past President), and the reply was given by Dr. The Rt. Hon. Charles Hill, M.P. (Chancellor of the Duchy of Lancaster).

A Two-Day Symposium on Digital and Control Techniques was held at the Trafford Park Works of Metropolitan-Vickers Electrical Co Ltd recently. The symposium was organized jointly by Metropolitan-Vickers and its subsidiary company, Sunvic Controls Ltd. Twelve papers were presented, covering subjects under the grouping of Servomechanisms, Digital Techniques and Process Control.

The International Congress and Exhibition of Measuring Instrumentation and Automation which will be held in Dusseldorf from 2-10 November will be the first independent event of its kind to be held in Germany. It will be devoted to the technique of the measurement and regulation of electrical and technical process values. Further information may be obtained from Nordwestdeutsche Ausstellungsgesellschaft M.B.H., Enhrenhof 4, Dusseldorf.

20th Century Electronics Ltd have signed a five-year agreement with the French company, Compagnie Generale de Telegraphie Sans Fil. Under the agreement the French organization will use 20th Century's designs and patents. Provision is made in the agreement for the training of French engineers. Over the past seven years 20th Century Electronics have signed similar licence agreements with the Netherlands, Belgium, Germany, Switzerland and France.

Pye Ltd have announced that British Railways are to put into service in April the first train to be permanently equipped with closed-circuit television for the entertainment of passengers. With a coach fitted as a soundproof studio, the pictures will be seen on 17in monitor sets at each end of the passenger coaches. Three loudspeakers in each 64-seater coach will provide the accompanying sound. The train's first run will be an excursion from Glasgow to London for the England v Scotland football match at Wembley.

Leo Computers Ltd, makers of the LEO Automatic Office, have now completed their move to new premises of 30 000ft^2 at Minerva Road, North Acton. This change has been made necessary to meet the demand for their new model, LEO II, the prototype of which is now in operation at Cadby Hall. LEO II, like the earlier model, has been designed especially for clerical work. While it incorporates the fundamental design of LEO I, it includes many improvements evolved as a result of practical experience. The Production Manager is Mr. E. J. Kaye, and Dr. J. M. M. Pinkerton is in charge of electronic development.

The Council of the Royal Society of Arts has decided to found a new award, to be known as the Benjamin Franklin Medal, which is to be made annually "to individuals who have attained early distinction, with promise of future achievement, in the promotion of arts, manufactures and commerce". With the approval of H.R.H. The Duke of Edinburgh, President of the Society, it has been announced that the first recipient is to be Frederic C. Williams, O.B.E., D.Sc., M.I.E.E., F.R.S., to whom the award has been made "for his contributions to electrical engineering".

The Council of the British Institution of Radio Engineers announces that the Institution has been granted armorial bearings and supporters. The shield of the coat of arms makes allusion to the pioneers of radio science, namely, Professor James Clerk Maxwell and Heinrich Hertz, while the supporters are those of the 7th Duke of Devonshire, who endowed the Cavendish Laboratory, Cambridge, and Admiral The Earl Mountbatten of Burma who played an important part in the founding of the Institution and who was President from 1946-48. The shield is surmounted by the head of Mercury, messenger to the gods. In addition, a new motto has been adopted, "Scientia pro Hominibus"—"Science for the good of mankind".

RCA Great Britain Ltd announce that during 1956 dollar orders totalling \$800 000 were obtained for British-made audio equipments. In addition to the line of consumer products, RCA Great Britain Ltd also sold in the past year electronic engineering products to the value of \$350 000.

Mr. F. S. Mockford, commercial manager of Marconi's Wireless Telegraph Co Ltd, has been elected chairman of the Radio Communication and Electronic Engineering Association in succession to Mr. C. H. T. Johnson of Decca Radar Ltd.

Marconi's Wireless Telegraph Co Ltd, as a result of increasing business in the field of aviation electronics, have created two new posts on the aeronautical engineering side. Mr. G. P. Parker has been appointed Deputy Chief Air Radio Engineer (Development) and Mr. J. H. Gill has been appointed Deputy Chief Air Radio Engineer (Projects). Both Mr. Parker and Mr. Gill will be responsible to Dr. B. J. O'Kane, Chief Air Radio Engineer.

Educational Productions Ltd have recently reissued their series of three wall charts, "The Principles of Radio", produced for the E.M.I. Institutes. The cost of these has now been increased to 10s. They are obtainable from Educational Productions Ltd, East Ardsley, Wakefield, Yorkshire.

Atkins, Robertson & Whiteford Ltd of Glasgow and London have moved into a larger new factory in the Thornliebank Industrial Estate, Glasgow. Telephone Giffnock 1031/2.

Cable and Wireless Ltd have announced the opening of a direct radiotelephone service between Amman (Jordan) and Kuwait (Persian Gulf). The cost of a three-minute call is 30s.

Erratum. In the circuit diagram of "A Stable F.M. Receiver with Preset Tuning" by G. S. Robinson, on page 89 of the February issue, the connexion between the lower end of L_4 and earth was omitted. The h.t. voltage for the receiver is 250V.

THE R.E.C.M.F. EXHIBITION

A description, compiled from information supplied by the manufacturers, of selected exhibits to be shown at the Exhibition of the Radio and Electronic Component Manufacturers' Federation, in Grosvenor House and Park Lane House, London, from 8 to 11 April

(Figures and letters in parentheses refer to stand numbers)

A.K. FANS LTD. (93)

20, Upper Park Road, London, N.W.3.

MINIATURE COOLING FANS

(Illustrated below)

Modifications have recently been carried out to the 1in diameter 'Airmax' fan, type 10/H3/27.8/.54/6, which involve both the motor bearings and the rotor which has been reduced still further in weight.

This fan has recently been subjected to tests and has run continuously for 1 000 hours at an ambient temperature of +85°C, and also for 1 000 hours at ambient temperatures ranging between −40°C and −80°C. The performance remains unchanged at 7ft³/min against 0·35in s.w.g. at 10 000rev/min, and it is available for operation on 6, 12 or 24V d.c.

ADVANCE COMPONENTS LTD. (30)

Roebuck Road, Hainault, Ilford, Essex.

F.M.-A.M. SIGNAL GENERATOR

(Illustrated above, right)

This instrument has been primarily designed for servicing radio and television receivers for bands I, II and III, but with its wide frequency range and good specification, the type 63 is a useful addition to any electronics laboratory for use in development work and in the field. This signal generator provides frequency or amplitude modulated signals over a continuous frequency range of 7·5 to 230Mc/s. The r.f. oscillator is a variable capacitance Colpitts circuit with switched inductors for five ranges. The frequency is directly calibrated to an accuracy of ±1 per cent, and a slow-motion drive, with a reduction ratio of 40 : 1, is fitted to the frequency control. An internal 5Mc/s crystal calibrator has been incorporated so that the calibration may be checked at 5Mc/s intervals to an accuracy of ±0·01 per cent. For setting between check points an interpolating scale is provided. The cursor is adjustable for correcting small errors. The output signal may be internally frequency modulated at 1kc/s with a fixed deviation of ±60kc/s, or at the mains supply frequency, with a variable deviation of 0 to ±150kc/s. An external modulating source

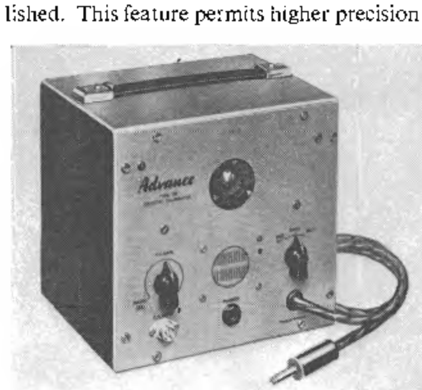
may also be used for deviations up to ±150kc/s and modulating frequencies between 20c/s and 20kc/s. The signal may also be internally anode-modulated to give either 10 per cent or 30 per cent amplitude modulation at 1kc/s. The output level is continuously variable from 1μV to 100mV, and with the oscillator circuits triple screened the leakage is very small.

CRYSTAL CALIBRATOR

(Illustrated below)

This calibrator is designed to facilitate the setting of signal sources to multiples of 5Mc/s or 1Mc/s over the frequency range 1 to 250Mc/s and can be used at higher frequencies with reduced sensitivity.

The instrument comprises a 5Mc/s crystal oscillator which beats with the unknown signal in the grid circuit of a pentode valve. This valve functions as a detector and optional 1Mc/s oscillator. The resulting beat frequency between the unknown signal and the nearest 5Mc/s (or 1Mc/s) multiple is fed via a low-pass filter and gain control to an audio amplifier. The amplifier beat note is then fed to the speaker (or phones) and to a rectifier circuit. The resultant d.c. output is smoothed and applied to the magic-eye tuning indicator. The tuning indicator is of the twin-sensitivity type which permits the use of a wider range of acceptable input voltages without recourse to adjustment of the gain control. At zero beat the audio amplifier response falls to zero and thus the eye opens when exact resonance is established. This feature permits higher precision



than is ordinarily obtainable using aural indicators.

The instrument may also be used for receiver calibration, but as this application is not a primary design objective, it will be greatly dependent on receiver characteristics, e.g., input impedance, sensitivity, signal-to-noise ratio, etc. A small fraction of the 5Mc/s signal appears at the input socket, together with a weak signal at 1Mc/s. Thus, if the r.f. input socket is connected to the input terminals of a sensitive receiver with the b.f.o. switched on, beats will be heard when the receiver is tuned to multiples of 1Mc/s or 5Mc/s. In general, the 1Mc/s responses are appreciably weaker than those at 5Mc/s.

BRAYHEAD (ASCOT) LTD. (U)

Full View Works, Kennel Ride, Ascot, Berkshire.

CERAMIC VALVEHOLDERS

The body of these B9A valveholders, type BHS/W/TV 52, is moulded in high-grade low-loss ceramic material, silicone treated to prevent moisture absorption. They are available with contacts of either spring quality brass, phosphor-bronze, or beryllium-copper with tinned or silver-plated finish.

The valveholder saddle is manufactured in steel, cadmium plated, and combines the functions of chassis fixing and screening can retention. Two types of screening can are available in each of three standard lengths. The first of these is a close fitting can, for maximum heat dissipation, while the second is of larger diameter for use where low capaitances are necessary. Various types of valve retaining clips are available for use when screening cans are not desirable.

BRITISH PHYSICAL LABORATORIES (82)

Houseboat Works, Radlett, Hertfordshire.

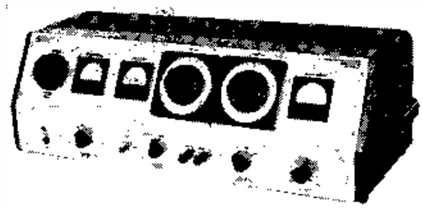
ELECTROLYTIC CAPACITOR BRIDGE

(Illustrated above, right)

This instrument is designed for the measurement of capacitance, power factor and leakage current of electrolytic capacitors. The instrument, which is mains operated, is completely self-contained and provides a continuously variable d.c. source of supply for the polarizing voltage.

The bridge is contained in a steel cabinet having a sloping front panel on which all essential controls and meters are arranged, such as the polarizing voltage meter, the leakage current meter, the direct reading capacitance and power factor dials, and the balance indication meter.

A special feature of the instrument consists in the automatic protection against overload of all meters used in the bridge. The range switch of the polarizing voltage meter is ganged with the selector switch of the polarizing voltage range. The leakage current, at short-circuit, is limited to the



full-scale deflexion of the leakage current meter, and finally, a special circuit is employed for the balance indication by means of which the meter current is limited to full-scale deflexion when no capacitor is connected to the bridge, or when the capacitor has a short-circuit. A switch is provided for discharging the capacitor under test before removing it from the instrument.

Two models are available: the CB154-A which has a range of 0·2μF to 2 200μF and the CB154-C with a range of 0·1μF to 11 000μF.

BRITISH ELECTRIC RESISTANCE CO. LTD. (19)

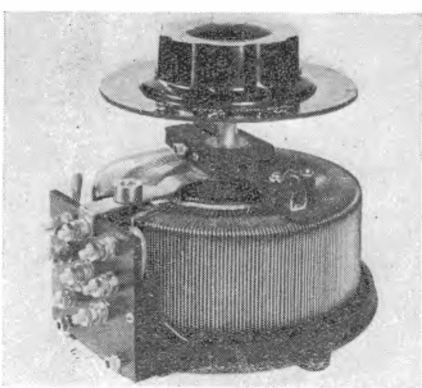
Queensway, Enfield, Middlesex.

ROTARY VARIABLE TRANSFORMERS

(Illustrated below)

Three new additions have been made to the range of rotary 'Regavolt' variable transformers. The models in question (type 70, 71 and 72) have ratings of 1·5 and 2·5kVA. Thus, the range of BERCO rotary 'Regavolts' now extends from 250VA to 2·5kVA. All these models are available as ganged or motorized units and, in addition, there are special models for 400 to 2 500c/s for the requirements of the aircraft industry and other specialized fields.

One of the features of the new models is the self-aligning brush gear giving a constant contact area and sustained contact resistance. By adjusting the brush pressure to the most economical minimum, these units achieve the least possible losses.



FERRANTI LTD. (39)

Hollinwood, Lancashire.

TRANSFORMERS AND TRANSDUCTORS

(Illustrated above, right)

New ranges of transformers and transductors will be shown. These are as follows:

Forth Series

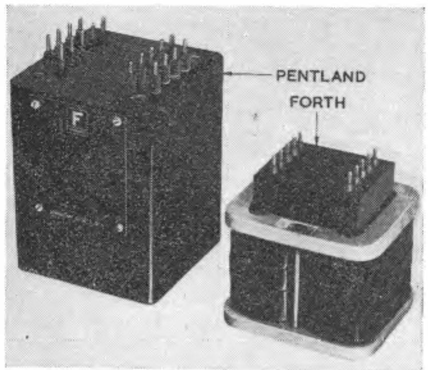
This range of miniature resin cast transformers and chokes offers a considerable reduction in weight and volume over components of equivalent ratings, and is therefore of particular appeal to designers of airborne equipments. The units are designed to meet the relevant clauses of RCS 214.

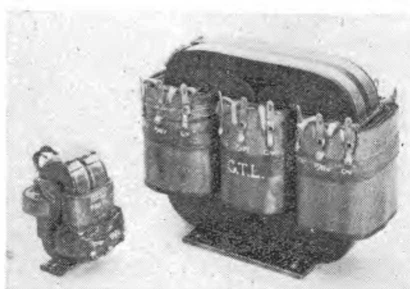
Talisman

These resin cast transductors have been produced for incorporation in servo-amplifying and switching equipments.

Hitemp

Designed for power distribution in aircraft, but equally suitable for the electronics field, these components have a winding temperature of 250°C and offer a considerable reduction in weight over conventional units of equivalent ratings. Both single and three-phase units are available.





GRESHAM TRANSFORMERS LTD. (70)

Hanworth, Middlesex.

TRANSFORMERS

An answer to the problem of operating transformers at high working temperatures in confined space will be displayed on the Gresham Transformers stand. Combining the advantages of a circulating liquid coolant with resin moulded construction this transformer is typical of the special problems with which this company deals.

Among the more standardized types are the Cadet Range of commercial transformers and chokes and an open type of E-core construction for three-phase operation.

The E-core construction on show has been developed to meet the demands of the aircraft industry for a three-phase transformer as light in weight as possible. As will be shown, this type of construction can also be applied to C-cores. *(Illustrated above)*

ALFRED IMHOF LTD. (40)

112-116, New Oxford Street, London, W.C.1.

INSTRUMENT CASES AND RACKS

A number of new models is announced. In addition to their existing range of 3, 4, 6 and 7ft racks they now include a new 5ft rack, thus increasing the standard range to 12 different sizes and 5 different heights. A completely new range of forced ventilation type enclosed racks is now being produced in 4, 5, 6 and 7ft sizes—all of which are based on common plan measurements of 19in panel width and 19in depth. Also, a prototype of a new type heavy duty totally enclosed rack is in course of development and is based on the requirements of the K114 specification.

The range of cases is further expanded with five new types of standard cases, each comprising three different sizes: and a new trolley case, thus providing 16 different new metal cases.

Nearly 30 new parts are now being produced in the IMLOK construction system. New corner connectors and matching extrusions together with big design improvements increase strength and appearance and additional items such as locks, two types of hinges, friction and octupus clips, improve the simplicity of construction and reduce labour costs.

LION ELECTRONIC DEVELOPMENTS LTD. (137)

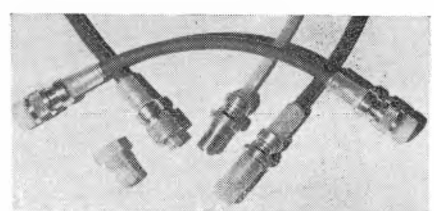
Lion Works, Hanworth Trading Estate, Feltham, Middlesex.

RESIN MOULDING

Leocasting is the name given to this firm's method of resin moulding, and the latest application of this technique is illustrated in a panel-mounting neon indicating bleeder-resistance unit now available for commercial purposes. Physically robust in construction, these units are sealed against humidity changes, and will operate in temperatures from −40°C to +80°C. These Leolite indicators serve two purposes: (*a*) to provide a sealed-in resistance load for a circuit, and (*b*) to indicate when that circuit is functioning. The range available covers voltages from 80V up to 40kV.

TEMPERATURE CONTROLLER

A new temperature controller-monitor will be shown which is designed to provide precise temperature control of a liquid bath, as used in laboratories. The sensing element is a low inertia, high sensitivity thermistor, and the controller has been operated to maintain a liquid bath at within a hundredth part of a degree (Fahrenheit) of the required temperature.



SEALED PLUGS

(Illustrated above)

The new hermetically sealed high-voltage plugs to be shown are moulded in polythene on to the ends of various types of standard coaxial cables. One member is fixed (or panel mounted) and the other free. These plugs and sockets are simple and compact and are particularly useful in electronic or electrical circuits where very high voltages are present, as in pulse circuits and power supplies.

LONDON ELECTRICAL MANUFACTURING CO. LTD. (44)

Beavor Lane, Hammersmith, London, W.6.

This year being the Silver Jubilee of this company, their stand will feature this as a theme.

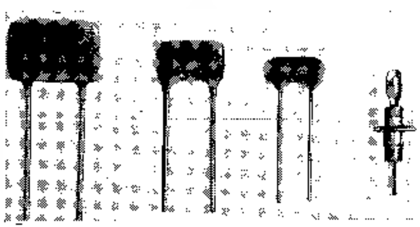
They will be showing their established range of protected silvered mica capacitors, filter capacitors, and the Ministry type 'Catacon' moulded capacitors. The full range of F.E.C. tubular and disk ceramics will also be displayed.

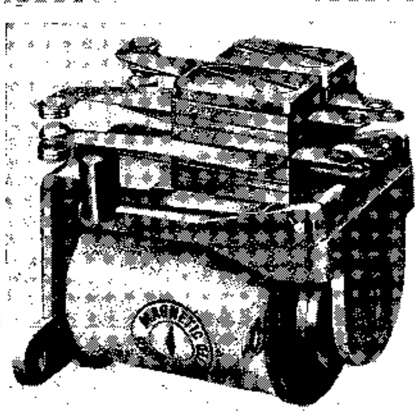
MINIATURE PROTECTED SILVERED MICA CAPACITORS

(Illustrated below)

Several new products will also be shown. These include the type 1106R miniature protected silvered mica capacitors, a range of both mica and ceramic capacitors specially developed for printed circuits, these include pre-formed leads, new types of ceramic lead-thro, and stand-off capacitors.

Also on show will be a high-voltage pulse-type ceramic, and capacitors for suppression and earth isolating to meet the latest B.S. specifications.





MAGNETIC DEVICES LTD. (V)

Exning Road, Newmarket, Suffolk.

MINIATURE A.C. RELAY

(Illustrated above)

The series 590 relay is one of the smallest a.c. relays available and has a very low coil consumption of 2VA or 4VA according to contact assembly.

The general design, including the balanced nature of the armature, gives good operation under acceleration and vibration conditions.

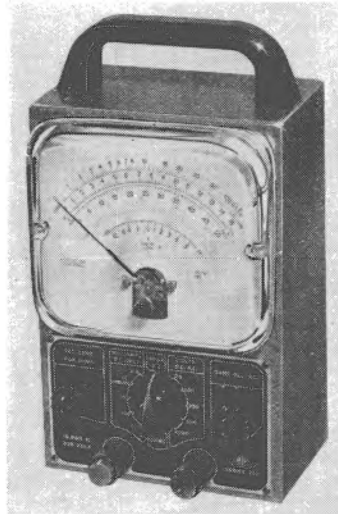
Contacts can be varied to suit individual requirements and are available from single-pole to four-pole.

MEASURING INSTRUMENTS (PULLIN) LTD. (58)

Electrin Works, Winchester Street, Acton, London, W.3.

MULTI-RANGE TEST SET

(Illustrated above, right)



The series 100 multi-range test set is a compact portable instrument of modern design, having a dial completely covered with a raised Perspex cover.

A total of twenty-one basic self-contained ranges are included, which provide adequate facilities for the measurement of a.c. voltage, d.c. voltage and current, and resistance. All voltage measurements, a.c. and d.c., are at 10kΩ/V. The voltage ranges extend from 10V to 1kV and the current ranges from 100μA to 500mA, f.s.d.

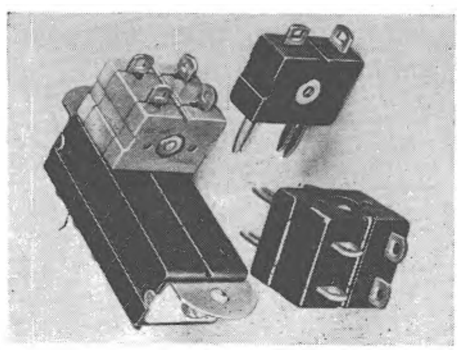
N.S.F. LTD. (62)

31-32, Alfred Place, London, W.C.1.

CONNECTORS

(Illustrated below)

The 'Varicon' connector, announced last year, is now in production and a complete range is now available. This connector is based on a new principle and offers unlimited combinations by the use of only four basic parts. Features of design are minimum insertion and withdrawal pressures, and versatility. A type suitable for printed circuit applications will be available shortly.



THE PLESSEY CO. LTD. (K.L.)

Ilford, Essex.

MINIATURE AND PRINTED CIRCUIT COMPONENTS

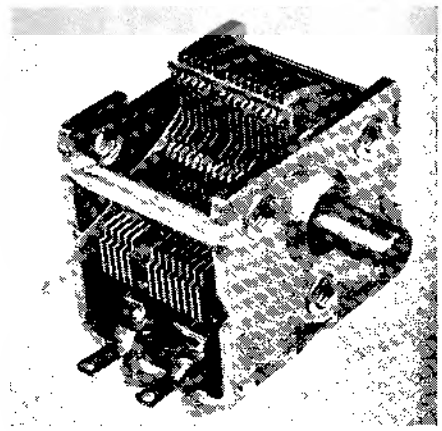
(Illustrated next column)

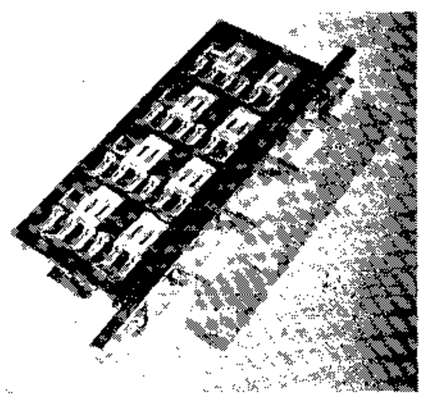
Among a range of new components will be a two-gang miniature tuning capacitor, type 'W', designed for use in transistorized radio receivers.

The special construction of this miniature tuning capacitor, which can also be supplied with alternative fixings and connexions for use in printed circuits, ensures that correct tracking is always maintained between radio frequency and oscillator sections throughout the frequency band. This is achieved by the use of different shaped vanes in each of the two sections, which also eliminates the need for padding capacitors. Weighing less than 3oz the capacitors require less than 2in^2 of panel area and can be supplied in a range of capacitance values.

A complete range of all-aluminium sub-miniature electrolytic capacitors will be displayed ranging from 0·1in diameter and 7/16in in length, including spigots. These sub-miniature capacitors are available in a range of capacitances from 1 to 50μF and for operation at peak working voltages from 1·5 to 70V.

Also on view will be a range of electrolytic capacitors designed for printed circuit





panels. In order that the capacitors can be plugged in accurately by automatic assembly processes, the tags are mounted in a specially designed terminal moulding which locates each one in relation to the cathode. Being wider than the others the cathode tag provides visual indication for alignment before insertion. Moreover, a 'vee' slot on the side of the moulding can be used for identification with automatic or hand-tool insertion.

Capacitors are mainly of fabricated plate construction but some are of etched foil.

A new miniature push-button switch, providing up to four-pole changeover switching, will be exhibited for the first time. The compact design of this new switch makes it suitable for inclusion in very small radio receivers, tape recorders, etc., where push-button switching is necessary.

POWER CONTROLS LTD. (W)
Exning Road, Newmarket, Suffolk.

ROTARY TRANSFORMERS

The 2in rotary transformer reference ZA. 42169 is to M.O.S. specification and has type approval. Continuously rated at 11W it has an intermittent output of 20W.

A further larger machine to a similar specification has a continuous output of 60W and an intermittently rated output of 100W.

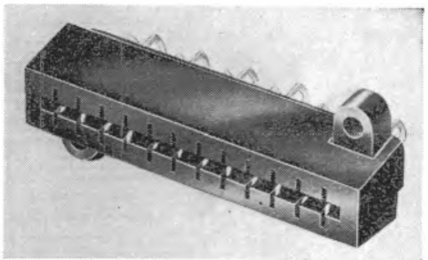
Special emphasis is given to the low percentage ripple output. Standard input voltages are 6, 12 or 24V d.c.

PRINTED CIRCUIT CONNECTORS

(Illustrated below)

Edge connectors produced in high-grade black bakelite and having silver-plated phosphor-bronze contacts as standard, are immediately available in 12-way and 18-way versions. Special contacts to suit customers requirements can be supplied. Provision for polarizing keys to prevent incorrect circuit insertion are provided.

Various other types of connectors are under development for boards using the



0·156in spacing, also special types of connectors with cable clamps and covers, using plug contacts added to the board in conformity with the standardized printed circuit grid.

Particular care has been taken to ensure that the contacts do not damage the printed circuit foil.

GEO. SALTER AND CO. LTD. (4)
West Bromwich

FASTENERS

A working model designed to demonstrate how the company's fasteners contribute to efficiency and speed of assembly will be shown by Geo. Salter and Co. Ltd., the spring makers.

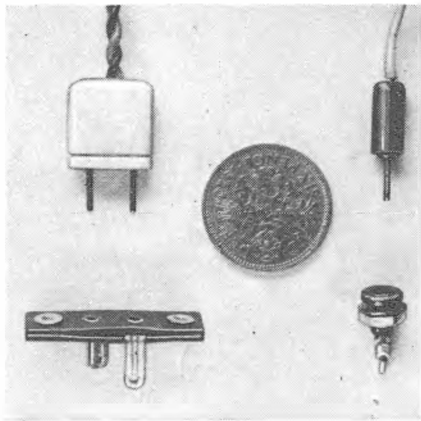
The radio and electronics industries are among the chief users of the products of the rapidly growing Retaining Ring Division of the Salter organization.

The model will show several different sub-assemblies in which fasteners are used, passing on a conveyor belt beneath 'hands' holding application tools. The sub-assemblies stop beneath appropriate hands, which descend to give the impression that fasteners are being fixed in position.

SPEAR ENGINEERING CO. LTD. (91)
Titan Works, Limpsfield Road, Worlingham, Surrey.

THERMAL SHUNT CLAMP

The 'Spearette' thermal shunt clamp has been introduced for the purpose of avoiding damage to transistors and other delicate components whose characteristics may be altered by the application of heat when soldering into circuits. The clamp is of



lightweight construction and is manufactured from material with rapid heat dissipating qualities. In use it is clamped on to the connecting wires of the transistor between the component and the soldered joints.

SUB-MINIATURE PLUGS AND SOCKETS

(Illustrated above)

The 'Spiniature' range of plugs and sockets is in keeping with the trend of modern design and practice. The plugs can be completely dismantled for wiring. Socket strips are available from two to twelve ways. The advantage over multi-pin plugs and sockets is that individual lines may be broken for test purposes. Individual plugs and sockets are at present available in red and black, but it is intended that the colour range will be increased.

TAYLOR ELECTRICAL INSTRUMENTS LTD. (D)
419-424, Montrose Avenue, Slough, Buckinghamshire

MOVING-COIL METERS

On show will be the new patented design of panel meters, known as centre pole magnet types. This is a departure from the conventional moving-coil type of movement. The new design consists of a centre core magnet surrounded by a soft iron ring where the coil rotates around the magnet. The meter shows a number of advantages, of which the most important is that the torque over the power ratio is twice that of conventional movements. The new meter also incorporates dry balancing ensuring permanency of zero setting, thus practically eliminating the necessity of zero adjustment.

PATTERN GENERATOR

Among the new instruments for the radio and television service engineer is the Model 94A T.V. waveform and alignment generator. This is a useful instrument as it is suitable for all television systems and covers all frequencies, including i.f.'s from 4 to 220Mc/s. In addition to a large number of patterns with interlacing and equalizing pulses (where applicable), the instrument incorporates an a.m. signal generator, f.m. signal generator and a sweep oscillator, all from 4 to 220Mc/s.

TELEGRAPH CONDENSER CO. LTD. (26)
North Acton, London, W.3.

CAPACITORS

Several new ranges of capacitors will be shown. Of particular interest is an entirely new range of p.t.f.e. dielectric capacitors in tubular construction, they extend to 0·2μF, and above this capacitance the construction is in metal boxes with ceramic bushings.

These capacitors are suitable for working at 200°C, and have low power factor and are intended for use where high working temperatures preclude the use of other plastic film of paper dielectrics.

As an extension to the existing range of T.C.C. tantalum electrolytic capacitors, a series of miniatures has been developed, primarily for use with aircraft instruments and sub-miniature transistor circuits.

Concurrent with printed circuits in T.C.C. production, new ranges of paper dielectric and electrolytic capacitors have been developed for their specific use. The capacitors are vertically mounted and have pre-tinned and surface preserved terminations making them suitable for dip-soldering.

STANDARD TELEPHONES AND CABLES LTD. (62)
Connaught House, Aldwych, London, W.C.2.

SILICON JUNCTION RECTIFIERS

SenTerCel ½A silicon rectifiers, which have been available in experimental quantities for some months, went into full production last February. Outstanding advantages are high temperature performance and the large output in relation to size and weight. Operation at ambient temperatures up to 100°C is permissible and the rectifiers, each of which weighs only 0·045oz are smaller than a conventional ¼W resistor. Three types are in full production—RS22A for a maximum peak inverse voltage of 150V, RS21A for a maximum (p.i.v.) of 100V and RS20A for 50V maximum (p.i.v.). The devices are hermetically sealed for long life and stable characteristics.

CHASSIS-COOLED RECTIFIERS

These compact selenium rectifiers will be displayed for the first time. They contain the new square format plates in metal cans for contact cooling, having all the advantages of the conventional selenium rectifier stack, but of smaller size and weight. Provision is made for voltage doubler and push-pull connexions. Present range is for 125V or 250V at 60mA or 120mA.

WIRELESS TELEPHONE CO. (J)
Hallamgate Works, Sheffield, 10

MINIATURE COMPONENTS

This firm have now commenced production of a new range of single tuned, sub-miniature, intermediate frequency transformers (⅜in dia. × 11/16in high), oscillator and ferrite aerial coils. These new components, approved by Messrs. Mullard Limited, for use with transistors OC45 and OC44, are equally suitable for conventional sized receivers as well as for midget sets. Moreover, they are also available for use with transistors made by other manufacturers.

Other exhibits will include their latest type ST side trimming i.f. transformers and r.f. coils, f.m. and a.m./f.m. i.f. transformers and ratio detectors, a selection of 'Pevic' cable marker sleeves, and a display of cable assemblies.

Notes from ———

NORTH AMERICA

R.F. Probe

The Narda Corporation of Mineola New York announces the Model 229 tuneable r.f. probe with optional detector for the use with all waveguide coaxial slotted lines provided with the standard $\frac{3}{4}$in diameter mounting hole. Model 229 has a fine wire probe adjustable in depth over a wide range by a fine-pitch threaded knob. The fine wire probe is an extension of the centre conductor of a coaxial line which is provided with shunt and series tuning elements for tuning the probe pick-up over the range 900 to 18 000Mc/s.

Two probe outputs are provided. A detector output has provision for using either a standard microwave crystal or a bolometer. The detector output connector is a BNC series connector. An r.f. output is also provided which enables the probe to be used with microwave receivers or other external detectors.

Nuclear Power Packs

A family of nuclear power packs having a shelf and use life of over 25 years and capable of operating over wide ranges of temperature, acceleration and vibration have been developed by the Universal Winding Company, of Jamaica, New York. These packs are suitable for use in weapon and ordnance systems as power sources for warheads, fuses, destructors, timers and programming devices, and are said to be capable of delivering energy pulses up to 337 000 ergs. Sizes range from less than 1 to 2in^3, and they are supplied encapsulated in a metal case and are provided with standard connectors.

The heart of the power pack is a nuclear battery, which converts nuclear energy directly into electrical energy. It is made with current ratings from 5 to 5 000 $\mu\mu$A and equilibrium voltages in the order of 10 000V. Battery performance is not affected by environmental conditions, and shelf and use life are not changed by short circuiting.

The constant current characteristic of the Nuclear Battery is used to charge a capacitor, making available a pulse source of electrical energy of essentially zero impedance. Pulse energy may be used repeatedly and means are provided to reliably regulate capacitor voltages at specific values between 75 and 750V.

A.C./D.C. Magnetic Amplifier

Designed by the Ahrendt Instrument Company, College Park Maryland for self-contained 400c/s input signals, this magnetic amplifier is adaptable to input signals from d.c. to 1Mc/s with the addition of a reference transformer. Capable of driving suitable servo-motors, the amplifier does not require any vacuum tube or transistor driving stage in a normal servo loop.

Designed for use in instrument and computing servo systems, the circuit is hermetically sealed in a MIL-T-27A size HA can and is of full-wave design. External circuits are reduced to a minimum through built-in servo motor reference and anti-stickoff voltage for double speed data systems.

Telemetering Conference

The 1957 Telemetering Conference will be held at El Paso, Texas from 27 to 29 May, 1957 and will be sponsored by the American Institute of Electrical Engineers, the Institute of Aeronautical Sciences, and the Instrument Society of America.

Conference session subjects will include: The use of transducers in telemetering systems; techniques in aircraft flight testing; industrial telemetering; mechanical and environmental aspects of packaging; and new telemetering systems.

The conference will feature one session on the techniques of data transmission, from the earth satellite to be launched during the year, and another at the White Sands guided missile proving ground.

IRE Annual Awards

The Institute of Radio Engineers has announced the recipients of three of its annual awards for 1957. The presentation of these awards was made during the IRE National Convention, held from 18 to 21 March, 1957.

The Morris Liebmann Memorial Prize Award went to O. G. Villard, Jr. Professor at Stanford University, Stanford, Calif. "for his contributions in the field of meteor astronomy and ionosphere physics which led to the solution of outstanding problems in radio propagation."

Donald Richman, Supervising Engineer at Hazeltine Corp., Little Neck, N.Y. was the recipient of the Vladimir K. Zworykin Prize Award "for contributions to the theory of synchronization particularly that of colour sub-carrier reference oscillator synchronization in colour television."

The Harry Diamond Memorial Prize Award was given to Georg Goubau, Physicist at the Signal Corps Engineering Laboratories, Fort Monmouth, N.J. "for his many contributions in ionospheric research and circuit theory and for his discovery of the surface wave transmission principle."

Nuclear Reactor

Plans are being made to build a nuclear reactor at Bell Telephone Laboratories' location at Whippany, N.J. It will be provided by the Air Force to assist the laboratories in carrying out an expanded programme for research in nuclear physics.

Objectives of this expanded programme are to make available more information about the electric, magnetic, and structural properties of solids, and to study the effects of nuclear radiation on various materials and components used in military electronic systems.

The reactor will be of the same type as one now under construction at Massachusetts Institute of Technology.

Vibration Calibrator

The Vibration Calibrator Model 501, produced by Tel-Instrument, of Broad Street, New York and designed to calibrate vibration pick-ups or to measure vibration of non-magnetic metallic surfaces has a vibration amplitude range of 2×10^{-5}, 2×10^{-4}, ·002 and 0·02in at frequencies from 10c/s to 20kc/s. The accuracy rating is 5 per cent. The same accuracy is obtainable even when measuring vibrations of non-sinusoidal nature. Besides allowing direct meter reading of vibration displacement in thousandths of an inch, voltage terminals are provided to permit observation of vibration waveform with a conventional oscilloscope.

Radar Helicopter

The General Electric Company has supplied the high powered AN/APS-20E airborne search radar for the U.S. Navy's new Sikorsky HR2S-1W radar helicopter, with which it is intended to extend a fleet unit's early-warning coverage.

In most cases, the helicopter radar is said to detect a low-flying enemy plane more than twice as far away as shipboard radar.

The radar, claimed to be the most powerful airborne search radar in production today is used by the Navy in anti-submarine and airborne early warning aeroplanes and blimps, and the U.S. Air Force in its comparable radar picket planes.

The front fuselage has been designed to accommodate the large, mushroom-shaped radome which houses the radar antenna, while the radar indicator unit and associated equipment are carried inside the rear fuselage structure.

Professorship at Chicago

Plans to endow an Enrico Fermi Distinguished Service Professorship at The University of Chicago in memory of the famous nuclear physicist have been announced.

The Professorship, to be established at the University's Institute of Nuclear Studies, is designed to perpetuate and memorialize Dr. Fermi's scientific contributions. He was both teaching and conducting research at the Institute at the time of his death in 1954.

In 1938 he was awarded the Nobel Prize "for his identification of new radioactive elements produced by neutron bombardment and his discovery, made in connexion with this work, of nuclear reactions effected by slow neutrons."

LETTERS TO THE EDITOR

(We do not hold ourselves responsible for the opinions of our correspondents)

A Series-Parallel Transistor Combination

DEAR SIR,—A series-parallel transistor combination similar to the usual valve stabilized circuit is shown in Fig. 1.

The output is 6·3V at 0 to 2A. No change in voltage could be detected for ±10 per cent change in output and the ripple is such that it cannot be detected on a c.r.t. display having sensitivity of 1mV/cm.

The upper limit of stabilization is dictated only by the dissipation in the series transistor (4W).

The OD604 transistor which acts as a common collector stage could be omitted if smaller current consumption only was required, in which case the series transistor would change to a type suitable for handling less power.

The reference battery is very convenient if a fixed ouput of 6·3V is needed—the drain from the battery being of the order of 2μA. If a variable supply were needed the battery could be replaced by a variable resistor (about 300kΩ in the circuit shown), by-passed by, say 32μF—the only disadvantage being a small drift with temperature.

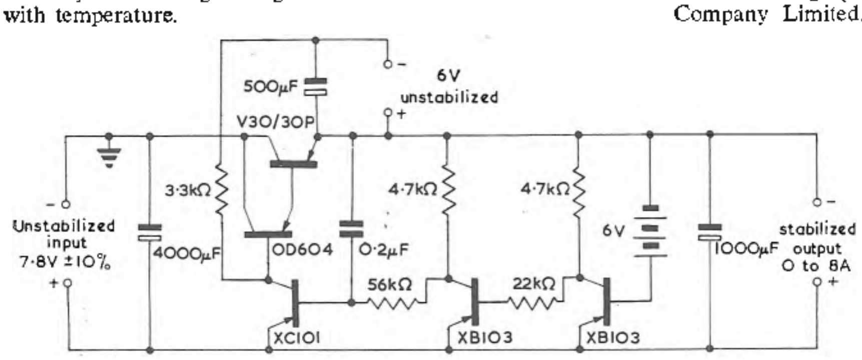


Fig. 1. A series-parallel transistor circuit

The circuit arrangement shown was constructed from available components and transistors, and the author has no doubt that it could be simplified and improved.

Yours faithfully,

M. A. LLOYD,

Senior Development Engineer

Winston Electronics Ltd.,

Shepperton.

Heat Control in Electronic Equipment

DEAR SIR,—I feel it necessary to call attention to what appears to be an important inconsistency in Mr. E. N. Shaw's otherwise very valuable article in your January issue.

In Fig. 1 of this article Mr. Shaw points out that for a given surface emissivity and for constant convection conditions, the skin temperature rise of the container is a linear function of the specific thermal loading. This being so, it must follow that the mean outside temperature of the box for a given number of watts dissipated within it, will be independent of any measures taken inside the box. In particular, therefore, if the interior of the box is blackened in order to increase the heat absorption, the skin temperature will not increase; the results of Mr. Shaw's experiment 3 would therefore appear to be fallacious. What does happen, of course, is that the heat gradient from the heat source to the outside of the box becomes less, so that although the outside temperature remains the same the internal temperatures will all be lower.

These remarks, of course, apply generally to all cases where the outside surface of the box remains untreated, and where the box is not ventilated. If the anomalous results reported in experiment 3 have to be explained in some other way, perhaps by a variation in the supply voltage to the resistor, there may be doubts regarding the validity of some of the other results reported in the article.

Yours faithfully,

C. GILLAM,

Chief Communications Engineer,

Marconi's Wireless Telegraph Company Limited.

The author replies:

DEAR SIR,—While my article was intended to record a practical approach to the reduction of thermal hazards in electronic equipment without becoming too deeply involved in the intricacies of thermodynamics, the inconsistency mentioned by Mr. Gillam did not pass unnoticed and was, in fact, referred to as a 'seeming anomaly,' although no penetrating analysis was attempted during the run of experiments.

It was, however, more closely examined at a later date in a specially arranged experiment comprising two identical resistors dissipating 30W within two polished aluminium containers six inches in diameter and ten inches long, differing only in that one had all internal surfaces blackened. Supply voltage changes were guarded against by connecting the resistors in series and maintaining a constant current through both. It was gratifying to find the 'inconsistency' reproduced in an entirely different set-up in which the blackened container grew hotter by 6° at the bottom without an appreciable change at the top.

Having disproved the suspected fallacy, an explanation could be attempted in terms of the 'swings and roundabouts' principle so closely associated with heat problems. Within internally bright containers most of the heat is transferred by convection to the most effective upward-looking dissipating surface. Blackening the interior reduces both the source temperature and the vigour of this convection stream, subtracting heat from the most effective surface and dispersing it more uniformly by radiation into less effective vertical surfaces and the highly ineffective downward-looking base. Remembering that convection loss from flat bright plates can be increased 100 per cent by changing from the downward-looking to the upward-looking aspect for the same equilibrium temperature, the 3° mean rise recorded in Exp. 3 (and confirmed in the specially devised test piece described above) is completely in keeping with a change in the distribution of the total heat within a container and its dissipation by convection from less effective surfaces.

The empirical relationships pictured in Fig. 1 apply to the more usual configurations and any attempt to include the effect of changes in internal distribution of total heat would be profitless, especially since increasing the emissivity of external surfaces would compensate for varying convection efficiency by introducing a radiation loss unaffected by different surface aspects.

I am obliged to Mr. Gillam for spurring me on to account for an effect which had already engaged my attention and trust that my explanation has restored his faith in the validity of the other results presented in the article.

Yours faithfully,

E. N. SHAW,

Great Malvern,

Worcestershire.

Step Function Pulse Technique for Ultrasonic Measurement

DEAR SIR,—The opening remarks of the above note in your February issue (page 77) completely ignore the ultrasonic resonance method of thickness testing, although this is briefly mentioned further on.

The resonance method using longitudinal waves[1,2,3] is now well established for the measurement of sections down to 0·01in and more recently to 0·005in.

From our experience in manufacturing equipment using this principle over the past ten years, we have found that limitation due to the internal configuration is not, in general, a serious problem as might be inferred from the article.

Yours faithfully,

W. V. RICHINGS,

Chief Development Engineer

Dawe Instruments Ltd.,

Ealing.

REFERENCES

1. ERWIN, W. S. The Sonigage. *Engineering* pp 487 (Dec. 22, 1957).
2. U.S. Patent 2,431,233 (British Patent 628,170).
3. U.S. Patent 2,431,234 (British Patent 628,116).

BOOK REVIEWS

Photoconductivity Conference

Edited by R. G. Breckenbridge, B. R. Russell and E. E. Hahn. 640 pp. 40 figs. Demy 8vo. J. Wiley & Sons. Inc., New York. Chapman & Hall Ltd., London. 1956. Price 108s.

THE volume comprises the text of papers and discussions contributed by various authors at a conference held in Atlantic City in November 1954. The contents do not offer a comprehensive survey of photoconductivity but give valuable and detailed information on theoretical and experimental problems and data of current research. The papers have been grouped by the editors into a few main sections but in some cases the classification appears to be arbitrary, particularly for the papers of the last two sections.

Two papers provide an introductory section. One by Rose repeats with some additions his theoretical approach first published in 1951. In its earlier pages the paper could have been improved by the omission of trivial statements. The other paper by Petritz is mostly concerned with the limits of performance of a photoconductor as a radiation detector and is a most useful contribution.

The second group of papers deals with the initial and final processes in photoconductivity, namely, absorption of radiation and the loss of excitation energy in recombination processes. Herring gives a comprehensive survey of the theoretical treatments of energy states and configurations for recombination sites, while Lax surveys the effects of lattice vibrations on absorption and recombination. Bardeen and his colleagues fasten attention on germanium and silicon with respect to indirect transitions between lattice energy bands. Dexter contributes an elegant theoretical paper on lattice edge absorption in solids while Fan and his colleagues give specific consideration to the absorption edge processes in germanium and silicon. A paper by James on electronic-vibrational state interaction in crystals completes the section.

The next section is more directly concerned with photoconductivity as determined by constituent processes, beginning with an extensive paper due to Rittner having some special reference to infra-red sensitive photoconducting layers, and containing a valuable discussion of the pros and cons of the barrier layer theory. In another paper Stöckmann shows that the "gain" effect in materials, such as cadmium sulphide, can be explained by bulk crystal properties rather than boundary processes. In this section the importance of surface states in photoconductivity becomes apparent from the papers by Miller and by Garrett and Brattain. Finally Pincherle gives a brief but lucid account of the photoelectromagnetic effect.

The last two sections may be considered together and bring into focus practical investigations of the subject. Of particular interest are the papers by Burstein *et coll.* Dunlap, and by Morton *et coll.* on impurity activated silicon and germanium which offer some promise for sensitive detectors in the 5-10 infra-red region. We also find here papers by Frederikse and Blunt, by Moss and by Kurnick and Zitter on the intermetallic compounds, such as indium antimonide, which are of great current interest. The other group of photoconductors, lead sulphide, selenide and telluride are covered in the papers of Chasmar, Mahlman, Levinstein, Scanlon *et coll.* and Woods, in which large amounts of experimental data are presented. A few papers describe work on other photoconductors such as zinc oxide and tellurium.

There is no doubt that the book will be attractive to those in the same or allied fields of the solid state both for reference and as indicating the important and provocative problems still of interest. There are few complaints to make and only one to mention, namely, the prohibitive cost of such texts which rises annually with no signs of abatement.

G. F. J. Garlick

Frequency Modulation

By L. B. Arguimbau and R. D. Stuart. 94 pp. 64 figs. Demy 8vo. Methuen & Co. Ltd. 1956. Price 8s. 6d.

COMMENCING with a historical background this book gives a thorough and clear elucidation of the advantages and problems of f.m. communication for those already possessing some knowledge of communication techniques and having a fair grasp of the necessary mathematics. The commonly used circuits for both transmission and reception which are peculiar to f.m. systems are next discussed in detail. Several of the analytical approaches used are less widely known than they deserve, and lead to easier comprehension of the problem under discussion. The behaviour of an f.m. system in the presence of noise and interference is comprehensively analysed both for the case of very small and larger interference amplitudes compared with the wanted signal. The requirements of a receiver design for best performance under these conditions are considered in detail and in the last chapter the discussion is extended to the possibility of the use of f.m. for picture transmission. One or two printing errors were detected but these are such that the meaning is quite obvious. The authors being eminent workers in the communication field in the U.S.A., American terminology is used, but most students will find this no difficulty having been brought up partly on text books from similar sources.

H. N. Gant

Office Work and Automation

By H. S. Levin 203 pp. 32 figs. Demy 8vo. Chapman & Hall Ltd. 1956. Price 36s.

THIS is a most "readable" book. The author has a flowing and friendly style which is kind to one's power of assimilation and yet provides a punch when it is required.

He states that the book is aimed at business managers and executives, but the reviewer would go further and say that anyone interested in automation and computing machinery, be it from a business, technical or laymen standpoint, will derive enjoyment and information from reading it.

As the title implies, the book covers all aspects of business office machinery and describes how the various interdepartmental means of communication from memo pad to telephone and teleprinter can, and have been, integrated to produce mechanical data processing systems which will give managements sales-important information many tens of times faster than the usual human organizations.

The author quite rightly views office management as 90 per cent information and 10 per cent decision and proceeds to make the reader see business from a new point of view, that of rapid information handling by means of the fast-growing technology of electronic data processing machines. He faces up to the problems of choosing and installing machines and predicts some of the effects computers will have on present office work and workers; he outlines a means of evaluating what sort of computer is best suited for any business, shows how a smooth transition from manual to automatic office work can be achieved and calls attention to the pitfalls and drawbacks of the machines while clearly underlining their advantages.

The reviewer recommends this book to anybody and everybody who has wondered how a radio valve can help run a business.

W. Woods-Hill

Reports on Progress in Physics—Volume XIX

Edited by A. C. Stickland. 367 pp. 80 figs. The Physical Society. 1956. Price 50s.

TOPICS of electronic interest are fewer than usual in the latest of these valuable surveys produced by the Physical Society. Only two papers have a direct bearing on electrical theory—one by H. Y. Fan on Infra-red absorption in Semiconductors, and J. A. Ratcliffe's interesting applications of Diffraction Theory to the Ionosphere.

Infra-red absorption spectra offer important information on the properties of semiconductors. Absorption by electrons accelerated across the energy gap to the conduction band ceases at a critical wavelength which indicates (though not too simply) the width of the gap. Interband excitations of free carriers cause absorption whose distribution depends on the structure of the energy bands. Excitation of electrons from localized states determined by lattice defects and impurity centres provides similar information on their energy levels, while excitation of lattice vibrations enables the degree of ionic binding (in ionic crystals) to be estimated from the strength of the absorption. Dr. Fan's 48 pages of theoretical and experimental details do not make easy reading for the non-specialist, but they make clear the still-growing importance of infra-red work for semiconductor development.

J. A. Ratcliffe's paper will be welcomed by many as a lucid summary of the Fourier-transform theory relevant to the transmission and propagation of radio waves, including as it does the more recent work of Wiener, Klintchine and others on auto-correlation. One might at first be surprised that Wiener's name does not appear among the references listed, and that the aspects of diffraction theory developed by Gabor, Blanc-Lapierre and others from the standpoint of Information Theory are not touched upon; but the author is concerned almost entirely with the problem of a "rough" reflecting surface, and has restricted his references accordingly.

To the electronic engineer J. P. Blewett's comparative study of current Proton Synchrotron designs may be of most interest, revealing as it does the complexity of the electronic and other problems raised by the expansion of atomic scientists' ambitions with suitable financial backing. Energies of 25 000 million electron-volts are soon expected to be reached, in machines with a circumference of half a mile, incorporating electromagnets weighing some thousands of tons and consuming several megawatts of power. Extremely ingenious methods including the submersion of a tapered coil in a mercury bath, and (more commonly) the servo-controlled saturation of a ferrite core, have been used to synchronize the frequency of the exciting oscillator to that of the rotating beam of protons.

The remaining six papers cover a wide range of non-electronic topics, and the volume throughout is of the high quality which we have come to associate with this authoritative series.

D. M. MACKAY

Probleme der Halbleitertechnik (Problems of semiconductor technique)

General Editor: J. Wosnik. 64 pp. 111 figs. Royal 8vo. Verlag Friedr. Vieweg & Sohn, Braunschweig. 1956. Price DM12.

THIS large size slender volume forms the fifth number of a series of publications sponsored by the Nachrichtentechnische Gesellschaft (Communication Society), a subgroup of the VDE. The present number is edited by Dr. J. Dosse whose book on transistors was reviewed in this journal in September 1956. The number contains twelve papers read at a symposium held in April 1956 at the University of Mainz. The contributors are German, Swiss and French specialists in the field of semiconductors at governmental, industrial and university research establishments. A list of the titles of the papers will indicate the scope of the publication:

W. Schultz, Influence of surfaces on the electric properties of rectifiers and transistors; *H. Becherer,* Test results concerning the production of an ideal blocking characteristic in surface diodes; *H.-L. Rath,* What are the possibilities of impedance measurement on barrier layers?; *W. Heywang* and *M. Zerbst,* Determining volume and surface recombination in semiconductors; *W. Guggenbühl* and *M. J. O. Strutt,* Theory of high frequency noise of transistors with low current densities; *W. Guggenbühl, B. Schneider* and *M. J. O. Strutt,* Measurements concerning the high frequency noise of transistors; *W. Heinlein,* Equivalent diagram of germanium diodes of high inertia; *W. Moortgat-Pick,* High frequency amplification with transistors; *J. P. Vasseur,* Measurement of the high frequency parameters of transistors; *H. Weber,* Impulse amplification with transistors; *B. Rall,* The use of the junction transistor in counter circuits; *H. Selow,* A switching transistor and its use in counter circuits.

It may be noted that Professor Strutt of the ETH Zurich, the co-author of the two papers on high frequency noise, is the author of a book on transistors reviewed in this journal in December 1954.

The present volume is well produced and should be of particular interest to research workers in the transistor and related fields.

R. NEUMANN

Television Receiving Equipment

By W. T. Cocking. 454 pp. 279 figs., Demy 8vo. 4th Edition. Iliffe and Sons Ltd. 1957. Price 30s.

THE larger part of this book has now been rewritten. Band 3 reception is thoroughly treated as well as the increasing problems of attaining freedom from interference combined with high definition. Magnetic deflection has been expanded to five chapters and synchronizing methods are discussed, including flywheel sync.

The book assumes that the reader will have a fair knowledge of ordinary sound-radio technique. The treatment is largely non-mathematical, but formulae useful to the designer have been collected in appendices.

Handbook of Industrial Electronic Control Circuits

By J. Markus and Vin Zeluff. 352 pp. 120 figs. Royal 8vo. McGraw Hill Publishing Co. Ltd. 1956. Price 66s.

THIS book gives a list of industrial electronic circuits published during the period 1948-55 and in this respect is a sequel to the Handbook of Industrial Electronic Circuits which contains circuits in use before 1948. All the circuits given have been published in the journal *Electronics.*

Meetings this Month

THE BRITISH INSTITUTION OF RADIO ENGINEERS

Date: 10 April. Time: 6.30 p.m.
Held at: The London School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, London, W.C.1.
Lecture: Uses of Electroplated Coatings in the Electronics Industry.
By: R. W. Stobbs.
Date: 24 April. (Time and places as above).
Lecture: Properties of Semiconductor Circuit Elements.
By: A. A. Shepherd.

North Western Section

Date: 4 April. Time: 6.30 p.m.
Held at: The Reynolds Hall, College of Technology, Sackville Street, Manchester, 1.
Lecture: Electronic Control of Machine Tools.
By: H. Ogden.

North Eastern Section

Date: 10 April. Time 6 p.m.
Held at: The Institution of Mining and Mechanical Engineers, Neville Hall, Westgate Road, Newcastle upon Tyne.
Annual General Meeting.

South Midlands Section

Date: 5 April. Time: 7 p.m.
Held at: The North Gloucestershire Technical College, Cheltenham.
Lecture: Colour Television.
By: G. N. Patchett.

Merseyside Section

Date: 11 April. Time: 6.45 p.m.
Held at: The Council Room, Chamber of Commerce, 1 Old Hall Street, Liverpool, 3.
Annual General Meeting.

Scottish Section

Date: 4 April. Time: 7 p.m.
Held at: The Institution of Engineers and Shipbuilders, 39 Elmbank Crescent, Glasgow.
Lecture: Telemetry.
By: A. Cowie.
Date: 26 April. Time: 6.30 p.m.
Annual General Meeting, followed by lecture: Special Process Instrumentation in Atomic Energy Projects.
By: H. Bisby.

THE INSTITUTION OF ELECTRICAL ENGINEERS

All London meetings, unless otherwise stated, will be held at the Institution, commencing at 5.30 p.m.

Radio and Telecommunication Section

Date: 1 April.
Informal evening on Colour Television.
Talks by L. C. Jesty and E. L. C. White.
Date: 10 April.
Lecture: The Remote and Automatic Control of Semi-Attended Broadcasting Transmitters.
By: R. T. B. Wynn and F. A. Peachey.
Date: 29 April.
Informal evening on Radio in Air-Sea Rescue.
Talks by: G. W. Hosie, D. Kerr and W. Kiryluk.

Ordinary Meeting

Date: 4 April.
The Forty-Eighth Kelvin Lecture: Infra-Red Radiation.
By: G. B. B. M. Sutherland.
Date: 25 April.
Lecture: 138kV Submarine Power Cable Interconnecting the Mainland of British Columbia to Vancouver Island.
By: T. Ingledow, R. M. Fairfield, E. L. Davey, K. S. Brazier and J. N. Gibson.

Measurement and Control Section

Date: 16 April.
Discussion: The Measurement of Currents in High-Voltage Circuits without Orthodox Current Transformers.
Opened by: M. Kaufmann and A. J. King.

East Midland Centre

Date: 2 April. Time: 6.30 p.m.
Held at: Loughborough College.
Lecture: Power Amplifiers used in Automatic Control.
By: J. V. Parry.

Mersey and North Wales Centre

Date: 1 April. Time: 6.30 p.m.
Held at: The Liverpool Royal Institution, Colquitt Street, Liverpool.
Annual General Meeting.
Lecture: The Potentialities of Railway Electrification at the Standard Frequency.
By: E. L. E. Wheatcroft and H. H. C. Barton.

Date: 10 April. Time: 6.30 p.m.
Held at: Philharmonic Hall, Liverpool.
Lecture: Nuclear Energy in the Service of Man.
By: T. E. Allibone.

North-Eastern Centre

Date: 2 April. Time: 7 p.m.
Held at: City Hall, Newcastle upon Tyne.
Lecture: Nuclear Energy in the Service of Man.
By: T. E. Allibone.
Date: 8 April. Time: 6.15 p.m.
Held at: The Royal Station Hotel, Newcastle upon Tyne.
Annual General Meeting and Conversazione.

North-Eastern Radio and Measurements Group

Date: 1 April. Time: 6 p.m.
Held at: King's College, Newcastle upon Tyne.
Annual General Meeting.
Lecture: The BBC Sound Broadcasting Service on Very-High Frequency.
By: E. W. Hayes and H. Page.

North Midland Centre

Date: 2 April. Time: 7 p.m.
Held at: Royal Station Hotel, York.
Lecture: The Potentialities of Railway Electrification at the Standard Frequency.
By: E. L. E. Wheatcroft and H. H. C. Barton.

Sheffield Sub-Centre

Date: 17 April. Time: 6.30 p.m.
Held at: Grand Hotel, Sheffield.
Lecture: The BBC Sound Broadcasting Service on Very-High Frequency.
By: E. W. Hayes and H. Page.

North-Western Centre

Date: 2 April. Time: 6.15 p.m.
Held at: Engineers' Club, 17 Albert Square, Manchester.
Lecture: Earth Electrode Systems for Large Electric Stations.
By: J. D. Humphries.
Date: 9 April. Time: 7 p.m.
Held at: Free Trade Hall, Manchester.
Lecture: Nuclear Energy in the Service of Man.
By: T. E. Allibone.

South-East Scotland Sub-Centre

Date: 2 April. Time: 7 p.m.
Held at: Carlton Hotel, North Bridge, Edinburgh.
Lecture: Choice of Insulation and Surge Protection of Overhead Transmission Lines of 33kV and Above.
By: A. Morris Thomas and D. F. Oakesbott.
Date: 16 April.
(Time and place as above.)
Lecture: An Introduction to Some Technical Factors Affecting Point-to-Point Radio Communication Systems.
By: F. J. M. Laver.
Date: 30 April.
(Time and place as above.)
Annual General Meeting.

South-West Scotland Sub-Centre

Date: 10 April. Time: 7 p.m.
Held at: The Institution of Engineers and Shipbuilders, 39 Elmbank Crescent, Glasgow.
Lecture: Temperature Rises in Electrical Machines on Variable Load and with Variable Speed.
By: A. Tustin and J. J. Bates.

South Midland Centre

Date: 8 April. Time: 6 p.m.
Held at: Malvern Winter Gardens.
Lecture: Stereosonic Sound.
By W. A. M. Clarke.

South Midland Radio and Telecommunication Group

Date: 29 April. Time: 6 p.m.
Held at: The James Watt Memorial Institute, Great Charles Street, Birmingham.
Annual General Meeting.

North Staffordshire Sub-Centre

Date: 15 April. Time: 7 p.m.
Held at: Duncan Hall, Stone.
Lecture: Electronics and Automation, Some Industrial Applications.
By: H. A. Thomas.

Southern Centre

Date: 3 April. Time: 6.30 p.m.
Held at: Portsmouth College of Technology Extension, Anglesea, Portsmouth.
Annual General Meeting.
Lecture: The Human Operator in Closed Loop Control Systems.
By: C. Holt Smith.

South-Western Sub-Centre

Date: 4 April. Time: 3 p.m.
Held at: Electric Hall, Torquay.
Lecture: Television Interference.
By: P. W. Crouch.

PUBLICATIONS RECEIVED

AN AUTOMATIC SYSTEM FOR SYNCHRONIZING SOUND ON QUARTER-INCH MAGNETIC TAPE WITH ACTION ON 35MM CINEMATOGRAPH FILM is the title of number 10 in the series of BBC Engineering Monographs. It is by L. H. Griffiths and N. W. Woodward of the Planning and Installation Department, BBC Engineering Division. Individual copies of these monographs cost 5s., post free; annual subscription 20s., post free. BBC Publications, 35 Marylebone High Street, London, W.1.

THE CENTRAL FILM LIBRARY INDUSTRIAL SECTION have recently issued an up-to-date list of films available on free issue. Further information may be obtained from the Films Division, Central Office of Information, Norgeby House, 83 Baker Street, London, W.1.

THE PRACTICAL ELECTRICIAN'S POCKET BOOK 1957. This is the 59th year of publication of this well-known pocket book published by Electrical and Radio Trading, 189 High Holborn, London, W.C.1. Price 5s. 6d.

A PRIMER TO THE AUTOMATIC OFFICE is a book concerned with the tools available to the office for fulfilling its mission. Published by Automation Management Inc, Westboro, Massachusetts, U.S.A. Price $7·50.

FBI REGISTER 1957, 29th edition. This comprehensive guide to a substantial cross section of British industry lists the products and services of over 7 000 member firms under more than 5 400 alphabetical headings. Published for the Federation of British Industries by Kelly's Directories Ltd, and Iliffe and Sons Ltd, Dorset House, Stamford Street, London, S.E.1. Price 42s.

1957 FINISHING HANDBOOK AND DIRECTORY, seventh edition, is divided into two parts. The first, printed on white paper, discusses some of the finishing procedures, such as spray painting, electroplating, vitreous enamelling, etc., and the second, printed on buff paper and thumb indexed, consists of classified lists both of British suppliers of finishing equipment, plant and materials, and also of jobbing firms. Sawell Publications Ltd, 4 Ludgate Circus, London, E.C.4. Price 37s. 6d.

THE QUEST FOR QUALITY by N. H. Crowhurst (Audio Handbook No. 5) discusses the basic requirements for fidelity in reproduction and gives practical data for experimenting at a minimum expense. Norman Price (Publishers) Ltd, 283 City Road, London, E.C.1. Price 6s.

ELSEVIER'S DICTIONARY OF CINEMA, SOUND AND MUSIC in six languages by W. E. Clason is the second volume in the series. It contains over 3 200 words in its basic list. This list, in which terms are defined in English clearly distinguishes between American and British usages. Each term is set in its proper subject field-cinema, acoustics or music, and defined according to the most precise international standard available. Corresponding terms in the several languages then appear, arranged horizontally across the facing page. Cleaver-Hume Press Ltd, 31 Wright's Lane, London, W.8. Price £6.

R.F. TRANSMISSION LINES is a book which has been arranged to help the student to understand the basic principles with a minimum of mathematical treatment. Specific attention has been given to the various types of line in common use. John F. Rider Publisher, Inc, 116 West 14th Street, New York 11. Price $1·25.

CLOSED-CIRCUIT AND INDUSTRIAL TELEVISION by E. M. Noll presents information about closed-circuit television systems and suggests some of the ways in which systems can serve modern needs. The first chapter describes operations and services that are already being performed by closed-circuit systems and provides many practical examples. The Macmillan Co, New York and London. Price 34s. 6d.