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Commentary

AS originally defined by D. S. Harder, the Vice-President of the Ford Motor Company to imply "the automatic handling of materials and parts in and out of machines", the word automation, if etymologically unacceptable, was at least a simple term and its meaning was understood. Automation was, in fact, an advanced mechanical handling system which, together with the introduction of the conveyor belt, brought about a major revolution in the American motor industry and which has subsequently become the basis of most mass production techniques.

But within recent years automation has been applied —perhaps misapplied—to so many industrial techniques that the term has become almost meaningless and the recent concept of the automatic factory, the "push-button" factory, only adds to the confusion.

Almost any new development, however slight, which brings about an improvement in technique is immediately hailed as automation. The truth is that much of what is labelled as automation is, in fact, automatic, and it seems to us that what is urgently needed is a new definition of the word—perhaps a new word entirely would be better—so that we clearly understand what is meant by automation in the factory, in the office and, even as some suggest, in the home.

Automation in the factory is not in itself something startlingly new, nor indeed is automation in the office. The automatic factory is merely the logical development of the automatic machine. From the simple machine performing a single operation has grown the complex transfer machine which, in itself, is a series of machines—often identical in function—linked together by a mechanical handling system to hand on, or transfer, the product through the various stages. The transfer machine is the integrated whole of the separate processes and is one stage further towards the automatic or "push-button" factory.

But is this automation? The transfer machine as so conceived relies completely on human skills not only to set up and operate but, what is more important, to adjust and correct for departures from standard. There is no in-built mechanism to detect the presence of deviations and to correct for them when they occur. The best that can be done is to bring the machine to a halt. In short, there is no feedback.

The intensive development of the feedback principle to process control has contributed much to the advancement of the automatic factory and there are now many examples, particularly in the chemical and oil industries of fully automatic processes which might be termed automatic factories.

The advent of the computer and, in particular, the data storing device, has necessitated a considerable revision of our understanding of automation and John Diebold, in a recent address at the British Institute of Management's Conference attempted to define automation "as a means of analysing, organizing and controlling our production processes to achieve optimum use of all our productive resources—mechanical and material as well as human".

This, we think, is too broad a definition for almost anything which sets out to achieve optimum use of our productive resources can be classified as automation.

Better factory lighting, improved working conditions, the welfare state, the abolition of restrictive practices on the part of employers and workers alike any one of which could in their respective ways add to our production efficiency, yet they are not automation.

Perhaps one of the most pleasing definitions is that automation is the five day week-end. At first sight it would appear a most highly desirable one but on more mature reflection another problem comes to mind, namely, what to do with our five days. Automation as defined by Diebold is already in the factory and in the office. We are threatened with it in our home and which we are told will add still further to our leisure. All this seems highly desirable but we have the fear that the next step will be the application of automation to our leisure.

Laboratory Equipment for Quantizing Speech

By V. H. Allen*, B.Sc (Eng), A.M.I.E.E.

Trigger and time quantizing circuits are described which enable specified forms of distortion to be applied to speech waveforms. These circuits have been used to examine the fine structure of speech and to assess the effects of distortion. A delta-modulation system, which is a form of pulse code transmission, is also described and the operation analysed.

THE circuits described here were developed for use in investigations into the fine structure of speech waveforms, and they have been designed to apply two different types of distortion to a signal.

The trigger unit quantizes a signal in amplitude and produces a binary output. The quantizing unit is used with the trigger and produces a time-quantized version of the trigger output. It is therefore possible with these two units to distort the amplitude variations of a speech signal and also to distort the distribution in time of the zero crossings. The apparatus has been used to obtain quantitative assessments of the effect of these distortions on the intelligibility of speech. The trigger and quantizer have also been used in the delta-modulation system which is described.

Trigger Unit

Fig. 1 shows the trigger circuit. The input is applied to a Schmidt trigger (V_2 and V_3) via a buffer cathode-follower. The trigger is a two state device in which at any instant one valve is conducting and the other cut off. The condition of the circuit depends on the voltage applied to the first valve control grid and if a varying voltage is applied here, the circuit will switch when the input passes through certain voltage levels.

Fig. 2 illustrates this operation. Fig. 2(a) shows a typical input waveform and Fig. 2(b) the output (as measured on the anode of V_3) to the same time scale. The output voltages V_3 and V_4 correspond to input voltages which are respectively greater than V_1 and less than V_2. If the input is between V_1 and V_2 the state of the circuit depends on the direction of change of the input voltage. The circuit will switch at a time when the input crosses the level V_2, if the input is decreasing, but when the input is increasing it will change state at a time corresponding to the crossing of level V_1. This voltage range V_1 to V_2 is known as the trigger hysteresis or backlash and is

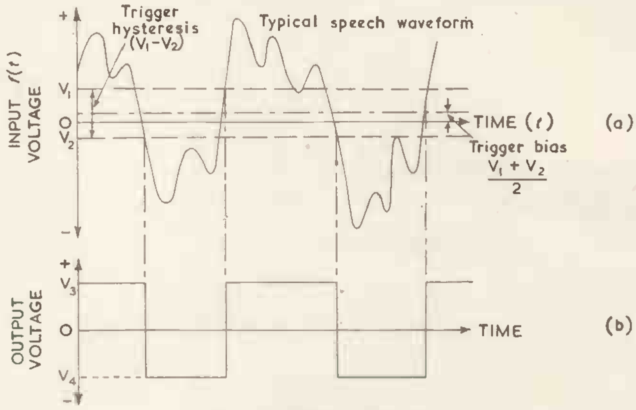

Fig. 2. Trigger operation

characteristic of this type of circuit. Voltages V_1 and V_2 are constant for a particular circuit although they may be changed by adjustment of component values. It is not possible to adjust the absolute levels of V_1 and V_2 independently of their difference V_1-V_2, but to a limited extent R_5 may be adjusted to change the hysteresis while R_7 will control the absolute levels. The ratio; input amplitude/trigger hysteresis, will determine the accuracy in time with which the zeros in the input waveform are preserved in the output. The larger this ratio is made the greater the accuracy becomes. Provision is made for biasing the first trigger so that V_1 and V_2 are not symmetrically spaced about the zero of the input waveform. Potentiometer VR_1

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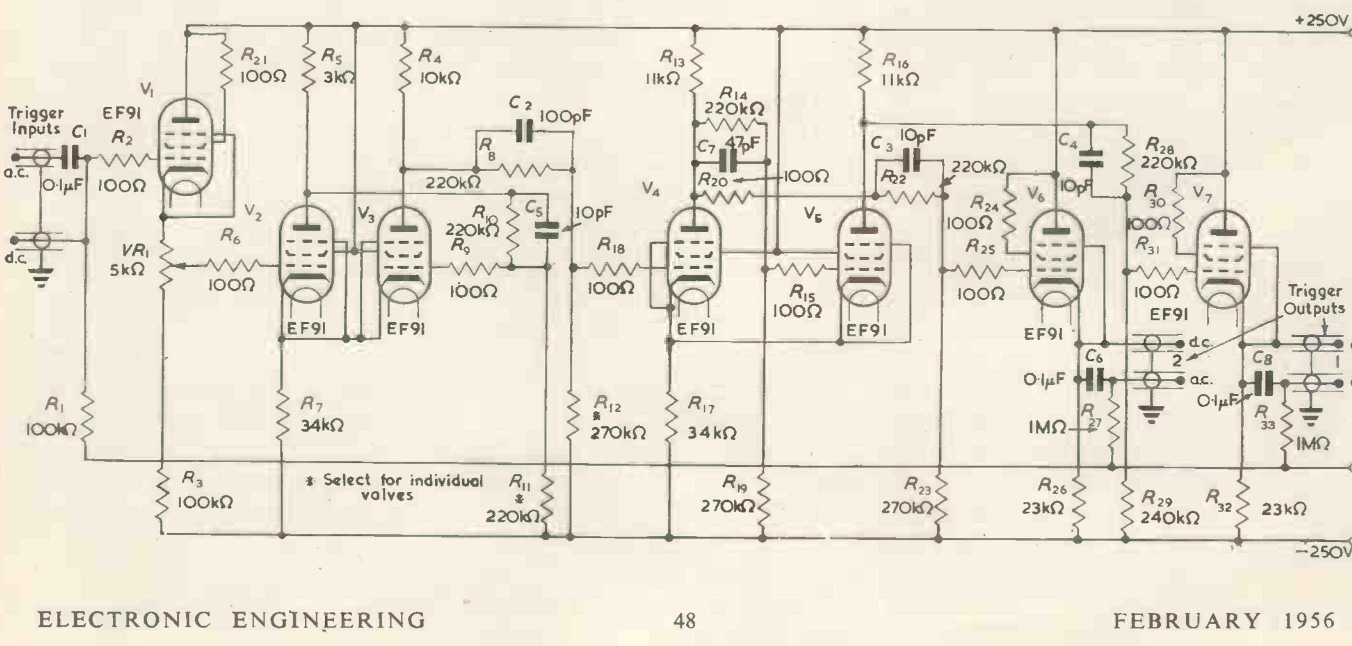
Fig. 1. Trigger unit



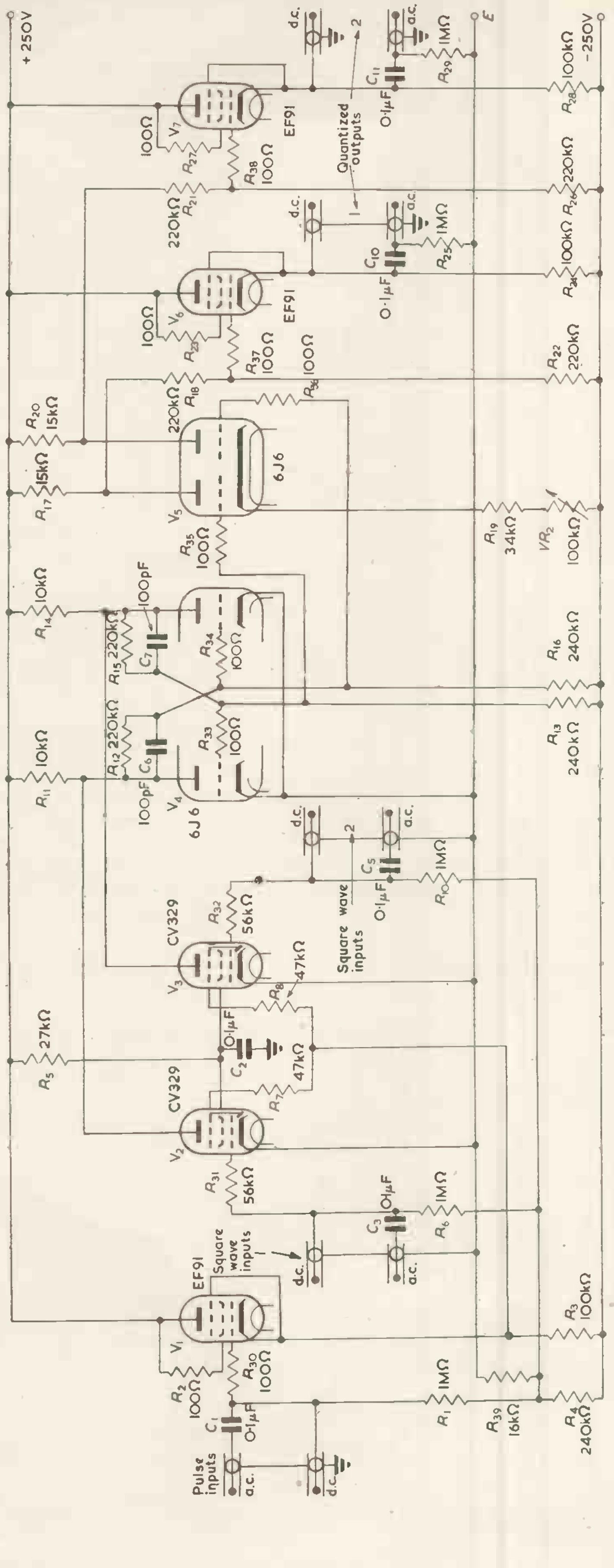


Fig. 3. Quantizing unit

is provided for offsetting the bias. In Fig. 2(a) the bias is $(V_1 + V_2)/2$, where V_1 and V_2 are relative to the zero of the input.

Schmidt triggers with a low hysteresis are sensitive but are prone to partial operation. When the input just approaches, but does not cross a critical level such triggers may produce an output in the form of a short pulse; the amplitude of which is less than the normal change in voltage at the output. The first trigger of Fig. 1 has a low hysteresis and may produce some incorrect outputs. These are eliminated from the output of the unit by a second trigger (V_4 and V_5), which has a large hysteresis and is only switched by the complete and correct operations of the first trigger.

The hysteresis at the input to the unit is 4·5V. Two outputs are available from cathode-followers. The amplitude at each output is 34V peak-to-peak, and the rise and fall times (10 to 90 per cent) are less than 1μsec. Number 1 is in phase with the input and number 2 in antiphase.

Quantizing Unit

The quantizer is used in conjunction with the trigger and a pulse generator. It produces a binary output with a further restriction that the output can only change from one level to the other at instants in time determined by pulses from the generator.

In Fig. 3, V_4 is a double triode connected as a bistable flip-flop, in which the anode loads R_{11} and R_{14} are common with gating valves V_2 and V_3. Both outputs from the trigger are required and each output is fed to the control grid of one gating valve (square wave inputs 1 and 2). The suppressor grids of the gating valves are fed with narrow positive going pulses through cathode-follower V_1. The grids of the gating valves are so biased that the pulses will not appear at the anode of a valve unless the voltage supplied to the control grid of that valve by the trigger is at its high level. For the same reason, variations in voltage at a control grid will not appear at the anode when no pulses are present. Hence, a pulse only appears at an anode when a pulse and a high level of control grid voltage occur simultaneously. Owing to the common anode loads, R_{11} and R_{14}, a pulse occurring at a gate anode will either change the state of the flip-flop or confirm it in its existing state. If a regular series of pulses is fed into the gates together with the outputs from the trigger unit the flip-flop will mark the transitions in the trigger waveform only at times coincident with pulses supplied by the generator. The output from the trigger has therefore been quantized in time. In Fig. 3, V_5 is a limiter which slices off the unwanted superimposed pulses in the flip-flop output.

The output amplitudes are adjustable by means of VR_2. Maximum amplitude is 55V peak-to-peak and the rise and fall times are less than 1μsec. The quantizing pulses are required to be positive going with a minimum amplitude of 20V and a minimum pulse width of 0·5μsec. The unit is suitable for use with quantizing pulse repetition rates up to 250kc/s. Some typical waveforms are shown in Fig. 4.

Delta Modulation System

This is a form of pulse code modulation in which the input signal is sampled from instant to instant and information is transmitted about the changes in amplitude. If the amplitude of the signal at one sampling time is found to be greater than that at the previous sampling time a pulse is transmitted. If the amplitude is less no pulse is transmitted. Pulses will sometimes be produced consecutively and these will run together giving rise to pulses having a width some multiple of the quantizing pulse repetition period. All transmitted pulses will have a constant amplitude and therefore only a simple integrator is needed as a decoder at the receiver.

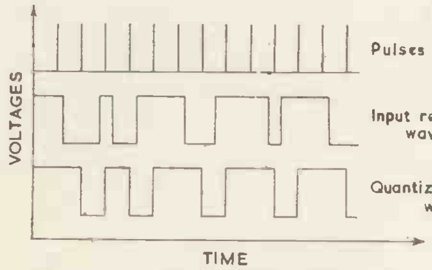


Fig. 4. Quantizer operation

The block diagram of Fig. 5 illustrates the operation of the system. The trigger and quantizing units already described are used, together with an integrator, addition network, and d.c. amplifier. These are shown in detail in Fig. 6. The circuit of the receiver is given in Fig. 7. A pulse generator and driving oscillator are shown in the block diagram but no details are given since any pulse generator having an output of the type described in the quantizer section may be used. The signal to be transmitted is fed into an addition network, the output of which feeds a trigger unit through a d.c. amplifier. The trigger output is time quantized and these pulses are integrated by a simple network. The output of the integrator, which is an approximation to the waveform of the input, is applied to the addition network. The approximated signal is arranged to be in antiphase with the input so that the addition of these voltages gives a voltage whose magnitude represents the difference and whose sign indicates which is the greater of the two. This difference voltage operates the trigger and the system corrects the output from the integrator. The accuracy of the approximation depends on the parameters of the circuits.

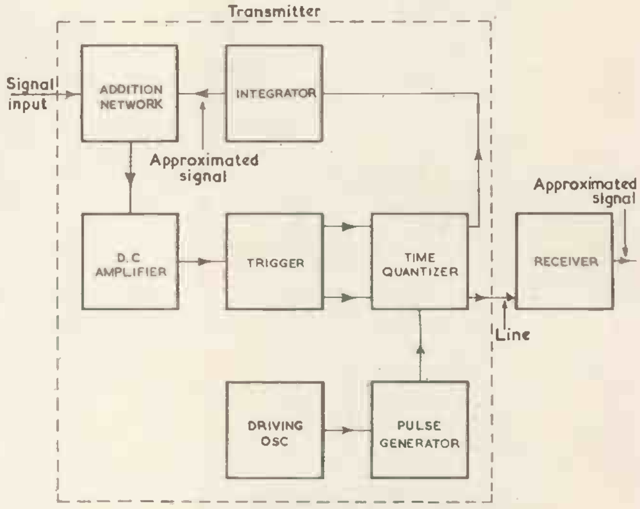
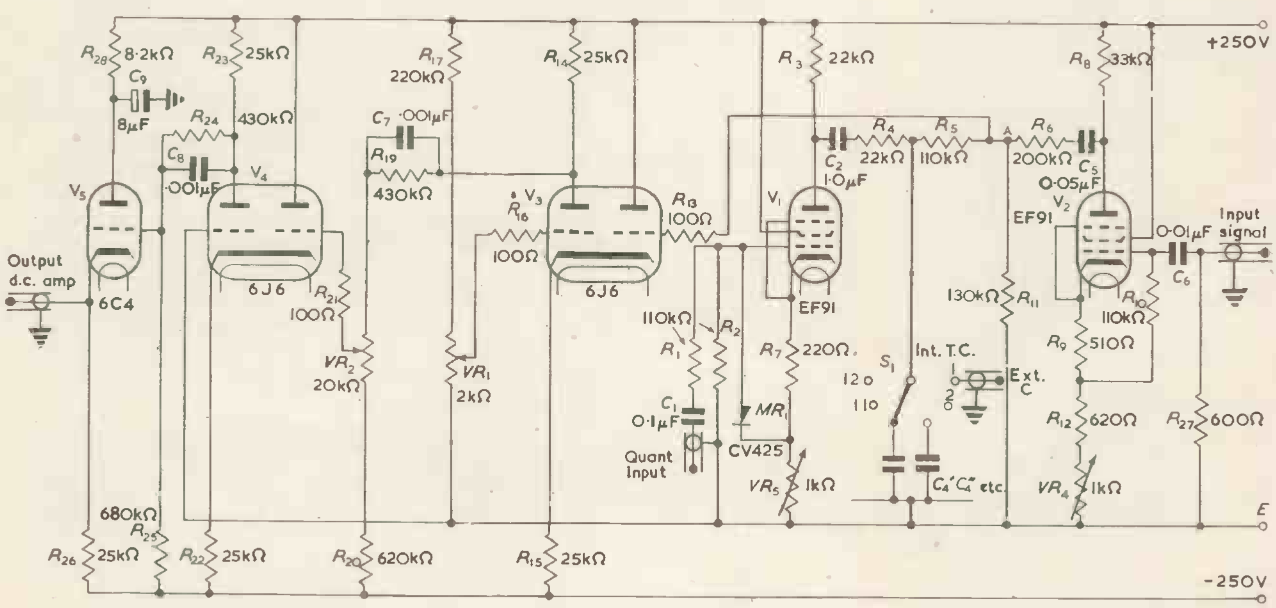


Fig. 5. Operation of system

Referring to Fig. 6, the integrator is the simple network R_4 and C_4. This network is fed by a limiting amplifier V_1 through a blocking capacitor C_2. The time-constant of the integrator may be changed by switching in different capacitors. The addition network is composed of resistors R_5, R_6, and R_{11}, to which the input signal is introduced by amplifier V_2. The output from the network is obtained at point A and is amplified by a d.c. amplifier (V_3, V_4, V_5). Integration of the quantizer output pulses results in a

Fig. 6. Integrator and d.c. amplifier

C4′ C4″ etc. selected for required time-constants



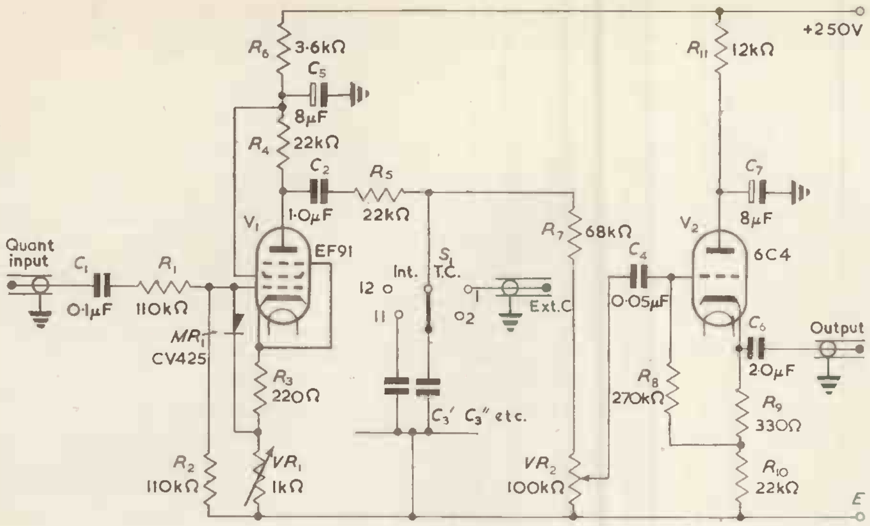


Fig. 7. Receiver

C3′ C3″ etc. selected for required time-constants

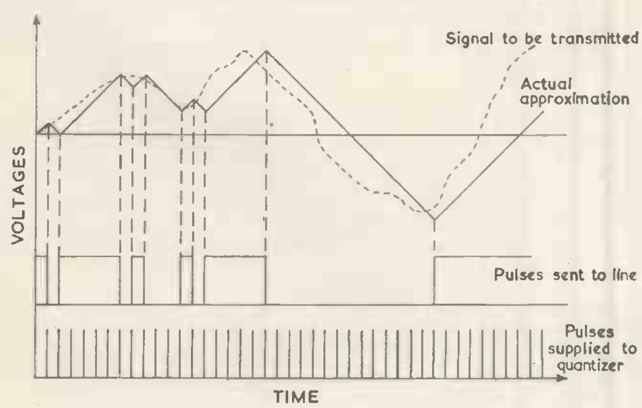
waveform consisting of a series of straight lines of constant slope (positive or negative). This triangular type of waveform is the best approximation that the integrator can make and it is illustrated in Fig. 8.

It will be seen that the whole arrangement consists of a system of quantized feedback in which an error signal is derived and used to correct the output from the integrator. Because a negative error must always result in the emission of a pulse from the quantizer and a positive error in the suppression of a pulse, the feedback chain must be directly coupled. The receiver is basically an integrator and apart from an amplitude factor the output from this circuit will be the same as that from the integrator at the transmitter.

Operation of the System

The output from the system may be discussed by consideration of the behaviour of the integrator at the transmitter. Referring to Fig. 6, the blocking capacitor C_2, under normal running conditions, will become charged to a voltage midway between the high and low levels of the pulse amplifier output. If the difference between these levels is $2V_c$ the integrator will be charged by an e.m.f. $+V_c$ when a pulse is received from the quantizer and discharged by an e.m.f. $-V_c$ when no pulse is received. For the present purpose the ideal integrator would be a linear device and, in order to approximate this, the voltage excursions on the integrating capacitor are limited

Fig. 8. Typical waveforms



to a fraction of the charging e.m.f. by a limitation of the amplitude of the input. The precise effects of non-linearity on transmission efficiency are not known but for experimental purposes the circuits have been designed with $V_I/V_c = 1/6$. Fig. 9 shows the charge-discharge curves; for the parts of the characteristics which are used the rate of rise and fall of voltage is approximately V_c/CR volts/sec. Referring all voltages to point A in Fig. 7 then this rate at point A is:

$$aV_c/CR \text{ volts/sec} \quad .... \quad (1)$$

The change in voltage at point A during one sampling period is:

$$\Delta = aV_c/qCR \text{ volts} \quad .... \quad (2)$$

The trigger is operated by the difference voltage $av_c - v_s$ obtained at point A and pulses or spaces will be emitted from the quantizer at times determined by the quantizing rate in order to make this difference as small as possible. The hysteresis effect was mentioned in the trigger section and the presence of this effect means that the difference voltage must be greater than some minimum before the trigger will detect any error. The hysteresis referred to point A must be kept small with respect to the delta-step (equation (2)) and it is made low by use of the d.c. amplifier. When no input signal is applied to the system the integrator will produce a triangular waveform of amplitude Δ volts and frequency $q/2$. If this frequency is within the audio range it must be suppressed at the output of the receiver by a low-pass filter.

The excursion of the integrator output voltage is limited to $\pm aV_I$ at point A and this is therefore the maximum signal amplitude which can be applied at this point. A signal of this amplitude will be quantized into a number N voltage steps where:

$$N = \frac{aV_I}{\Delta} = \frac{V_I}{V_c} \,.\, qCR \quad .... \quad (3)$$

List of Symbols

V_c	=	charging e.m.f. applied to integrator
V_I	=	maximum voltage excursion allowed on integrator
v_c	=	instantaneous integrator output voltage
v_s	=	instantaneous value of input signal at addition point A
V_s	=	amplitude of input signal at point A
a	=	fraction of v_c which appears at point A
Δ	=	change in av_c at point A during one sampling period
q	=	repetition rate (per second) of quantizing pulses
f_s	=	frequency of input signal
f_{SL}	=	value of f_s at which signal amplitude is just restricted by slope limitation
f_{min}	=	lowest value of f_s required to be transmitted
CR	=	integrator time-constant in seconds
N	=	number of consecutive sampling periods required for a steadily rising v_c to change by V_I volts

V_I/V_c is fixed by considerations of linearity so that the number of voltage steps will be determined by the quantizing rate and integrator time-constant.

At certain values of frequency and amplitude of the input signal the output from the integrator will be limited in slope and amplitude. Consider an input triangular waveform of frequency f_S and amplitude V_S at the addition point. V_S is limited to aV_I so that the slope is $4f_S aV_I$. The maximum rate of rise and fall of integrator voltage is given by equation (1) so that for values of f_S above f_{SL}, where f_{SL} is given by:

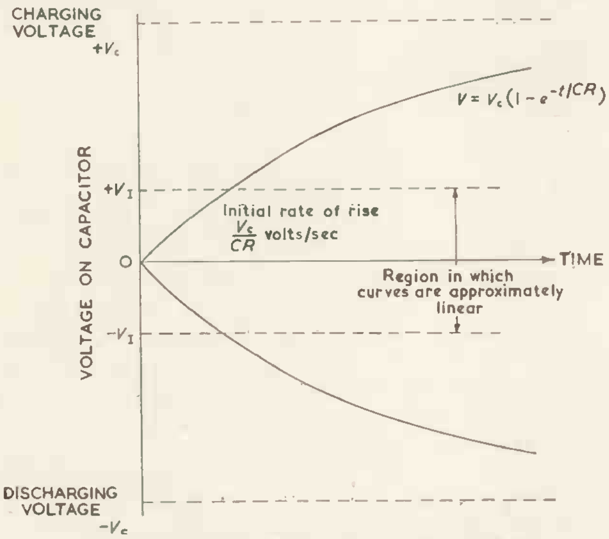


Fig. 9. Charge and discharge of integrating capacitor

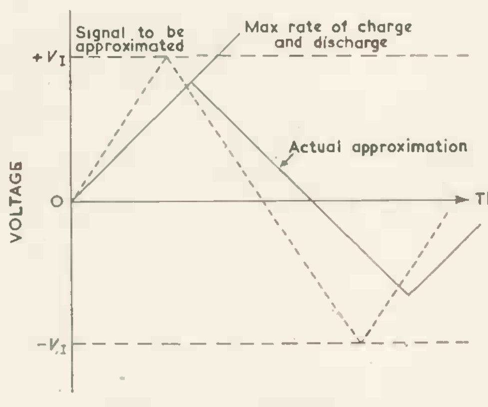


Fig. 10. Limitation of amplitude in delta modulation system

$$4f_{SL}aV_I = \frac{aV_c}{CR}$$

$$f_{SL} = \frac{V_c}{4V_I CR} = \frac{q}{4N} \quad \ldots\ldots\ldots\ldots\ldots (4)$$

the value of V_S must be kept below aV_I if the slope is not to exceed that which the integrator can follow. In this slope limitation region, for any frequency $f_S = nf_{SL}(n>1)$, the maximum value of V_S is given by

$$4nf_{SL}V_S = aV_c/CR$$

$$V_S = \frac{aV_c}{4nf_{SL}CR} = \frac{aV_I}{n} \quad \ldots\ldots\ldots\ldots (5)$$

The restriction of V_S implies a reduction below N of the number of levels available for quantization:

$$V_S/\Delta = \frac{qCRV_I}{nV_c} = (N/n)$$

Since $f_S = nf_{SL}$, and using equation (4)

$$(N/n) = (q/4f_S) \quad \ldots\ldots\ldots\ldots\ldots\ldots (6)$$

in the slope limitation region. The effect of slope limitation is shown in Fig. 10.

The accuracy with which the output approximates to the input will depend on the quantizing rate q and on the number of levels into which the amplitude is quantized. If q is increased the noise and distortion will be reduced, but a limit to q will be set by the characteristics of the transmission channel used. However, more scope is available in the choice of parameters affecting the amplitude quantization. Equation (3) shows that N may be increased by increasing CR and equation (4) shows that increasing N lowers the frequency f_{SL} at which slope limitation begins. From equation (4):

$$CR = V_c/V_I \,.\, 1/4f_{SL} \text{ (independent of } q) \quad \ldots\ldots (7)$$

Experiments have been made in which CR has been chosen to make $f_{SL} = f_{min}$, where f_{min} is the lowest frequency to be transmitted by the system. This ensures that the maximum number of levels are available at f_{min} with no restriction of amplitude below aV_I. The amplitude of frequencies above f_{min} may however be restricted. The output could be equalized to overcome this difficulty but the total number of available quantization levels are not used at these frequencies. Less amplitude limitation would occur if f_{SL} was arranged to fall in the middle of the band but more quantizing noise would be introduced at frequencies between f_{min} and f_{SL} due to "hunting" in the system. If CR is chosen from equation (7) then N and Δ are also fixed:

From equation (4) $N = q/4f_{SL}$

From equation (2) $\Delta = aV_I 4f_{SL}/q$

The important constants of the circuits are as follows:

Trigger hysteresis referred to the addition point, 50mV $V_c = 80$V, $V_I = 13{\cdot}5$V, $a = 0{\cdot}43$.

Effects of Speech Quantization

Speech which has been passed through a trigger unit is very intelligible although the quality is changed[3]. Intelligibility and quality are improved if the trigger hysteresis is small compared with the input amplitude, but the hysteresis must not be made smaller than the level of the noise at the input. If the trigger operates on these noise voltages the noise appears at the output as equal in amplitude to the dichotomized speech.

The delta modulation system preserved good intelligibility down to a quantizing frequency of 5kc/s. At a quantizing frequency of 25kc/s the quality was indistinguishable from that of the input.

Acknowledgments

Acknowledgment is made to the Engineer-in-Chief of the General Post Office for permission to make use of the information contained in this article. The valuable advice and encouragement of Mr. E. W. Ayers is also gratefully acknowledged.

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A Radio Interference Measuring Set Using Point Contact Transistors

By J. N. Barry*, M.Sc., and G. W. Secker*

A portable battery-operated radio interference measuring set having a frequency range of 160kc/s to 285kc/s is described. This equipment is essentially a calibrated superheterodyne receiver having an intermediate frequency of 90kc/s and it incorporates a total of seven point contact transistors. The minimum signal at the input terminals which can be measured reliably is 1μV in 75Ω or 15μV in 15kΩ. The indicated output signal-to-noise ratio at these levels of input is 10dB. The power consumption is only 22mA at 20V h.t., i.e. 440mW total.

The instrument was designed primarily for the purpose of measuring those harmonic radiations from the line time-base of a television receiver which fall within the long wave broadcast band. The set also has provision for monitoring, on headphones, any modulation output from a received signal.

THE successful use of point contact transistors in amplifiers operating at frequencies up to about 1Mc/s[1,2,3] suggested the possibility of constructing an all transistor equipment which could be used to measure received interference signals which fall within the long wave broadcast band. Such signals commonly appear as harmonic radiations from television line time-bases, and may cause considerable interference to broadcast reception if of sufficient magnitude. The equipment described was designed primarily for measuring interference signals from such a source.

To be capable of providing measurements at or below the maximum permissible levels of such interference signals, the equipment should be capable of measuring:

(1) Electric radiation at levels of less than 100μV when received on a 4ft vertical rod aerial terminated in 15kΩ.

(2) Magnetic radiation and any mains borne components at levels of less than 400μV. Measurement of the last two quantities requires the use of an instrument with an input impedance of 75Ω.

In addition to the above sensitivity requirements, the equipment should also incorporate the following features:

(a) A response which is more than 20dB down at 10kc/s off tune. This is to permit identification and measurement of successive television line time-base harmonics.

(b) An image rejection of the order of 40dB.

(c) A variation in sensitivity over the band which is as small as possible (preferably less than 1dB).

(d) Provision of monitoring facilities (i.e., headphones), to distinguish interference signals from broadcast stations.

(e) Long term stability of gain and frequency calibration.

As will be seen, the instrument described conforms to the above specification with the exception of the image rejection at the top end of the band. It is considered that there is no fundamental reason why the image rejection figures could not be improved, though it would probably be at the expense of impairing slightly one or more of the other performance figures.

The instrument itself is contained in a steel case measuring 12in wide by 7in deep by 8in high. The weight (with the battery removed) is approximately 15½lb. Interior and exterior views are shown in Figs. 1 and 2.

Design Considerations

The instrument is, in essence, a superheterodyne receiver having an i.f. of 90kc/s.

Referring to Fig. 3, the circuit comprises an r.f. stage X_1, a mixer X_2, local oscillator X_7, and four i.f. stages X_3, X_4, X_5 and X_6. G.E.C. type GET1 transistors are used in each stage except the oscillator, X_7, which uses a G.E.C. type EW51 high frequency point contact transistor.

This high frequency transistor could also be used in place of the GET1 in the other stages of the equipment, though some re-design of interstage coupling transformers would probably be required to take account of the rather lower output resistance of the EW51.

Carrier voltage from the last i.f. stage is rectified by the

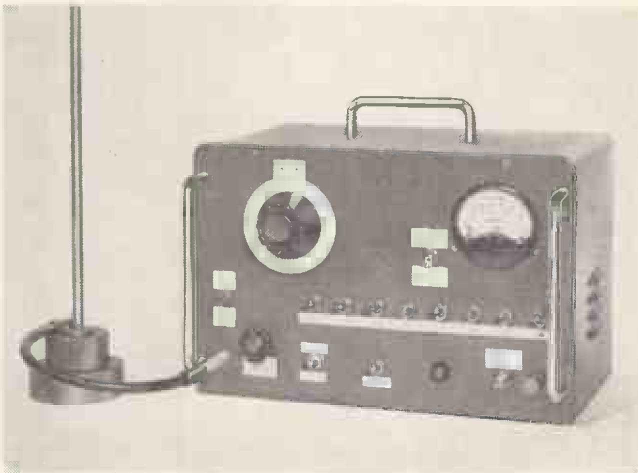
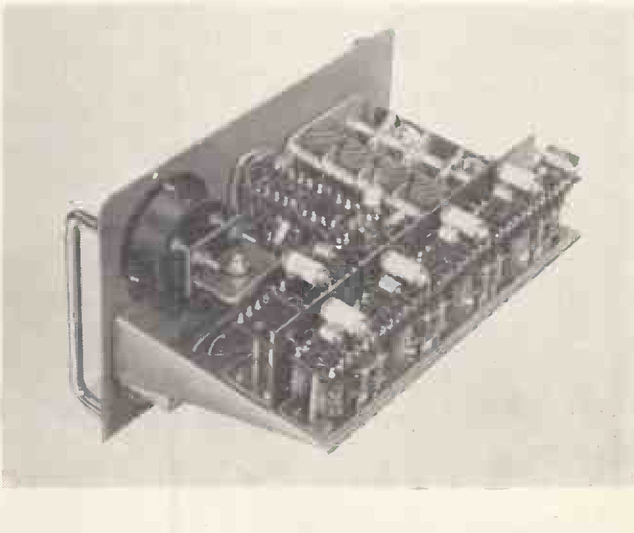


Fig. 1. The complete instrument

Fig. 2. An interior view of the instrument



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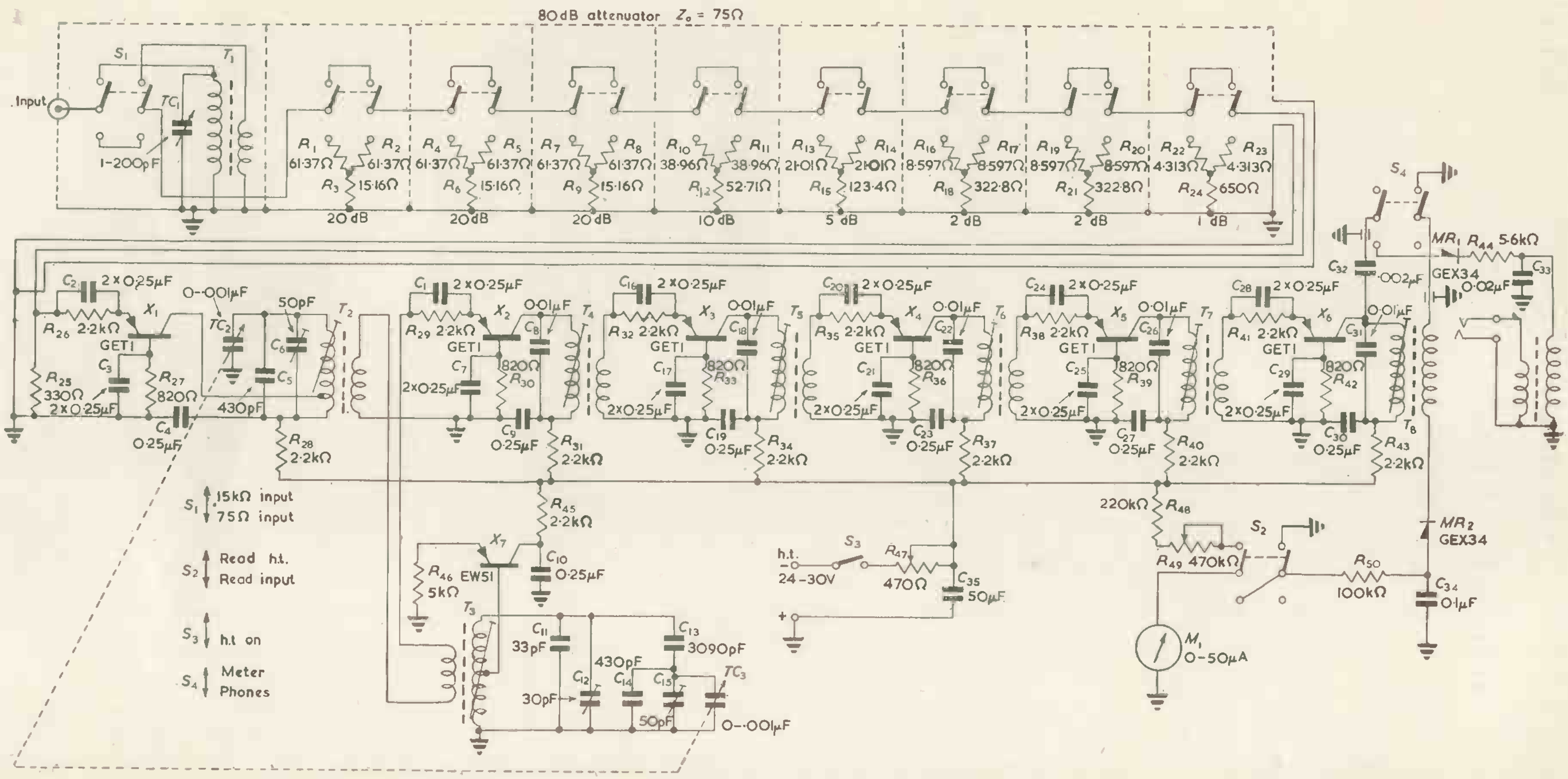


Fig. 3. The circuit of the interference measuring set

Specification of Transformers

T_1 Pri. 364 turns 38 s.w.g. en. and s.s.c. copper wire 4·92mH.
Sec. 26 turns 38 s.w.g. en. and s.s.c. copper wire 28μH.
Sectionalized winding on distrene former in S.E.I. Type 124 pot core.

T_2 Pri. 125 turns 34 s.w.g. en. and s.s.c. copper wire tapped 25 turns from one end.
Sec. 9 turns 34 s.w.g. en. and s.s.c. copper wire.
Sectionalized winding on distrene former in S.E.I. Type 124 pot core.
Slug tuned with ¼in dia. dust iron slug giving a primary inductance of 577 to 716μH.

T_3 Pri. 95 turns 19/46 Litz wire centre tapped.
Sec. 7 turns 19/46 Litz wire.
Sectionalized winding on distrene former in S.E.I. Type 124 pot core.
Slug tuned with ¼in dia. dust iron slug giving a primary inductance of 330 to 400μH.

T_4, T_5, T_6, T_7
Pri. 86 turns 19/46 Litz wire.
Sec. 16 turns 19/46 Litz wire.
Sectionalized winding on distrene former in S.E.I. Type 124 pot core.
Slug tuned with ¼in dia, dust iron slug giving a primary inductance of 270 to 330μH.

T_8 Pri. 86 turns 34 s.w.g. en. and s.s.c. copper wire.
Sec. 350 turns 40 s.w.g. en. and s.s.c. copper wire.
Sectionalized vinding on distrene former in S.E.I. Type 124 pot core.
Slug tuned with ¼in dia. dust iron slug giving a primary inductance of 270 to 330μH.

T_9 Pri. 2 420 turns 44 s.w.g. en. and s.s.c. copper wire.
Sec. 450 turns 42 s.w.g. en. and s.s.c. copper wire.
Windings not interleaved and wound on midget bobbin.
Core. 0·015in radio metal stampings.
Primary inductance approximately 22H.

germanium diode MR_2 (G.E.C. type GEX34 is suitable), and is applied to the meter which is calibrated in terms of the input signal voltage. Another germanium diode of the same type, MR_1, is used for demodulation purposes.

The main considerations affecting the design of the equipment are as follows:—

(1) For measurement of received electric radiations, the input impedance of the instrument must be equal to 15kΩ, and remain sensibly constant over the band. This is achieved by using an input transformer having a tuned primary, and a step-down ratio of 14:1. By making the dynamic resistance of the transformer primary circuit itself high, the input impedance of the instrument will be governed by the impedance loading the secondary. This load was actually made equal to 75Ω, and in this way the input impedance over the band, with the primary of the input transformer tuned to resonance, was within 2 per cent of 15kΩ.

The use of 75Ω as the secondary load enables a standard 75Ω attenuator to be included in the instrument to permit measurement of large input voltages. In addition, by means of S_1 (Fig. 3), the input may also be switched direct to the 75Ω attenuator when making measurements which require an input impedance of 75Ω.

In order that the attenuator be correctly terminated, the input impedance of the r.f. stage must also be 75Ω. This condition may be achieved by shunting the emitter input circuit of the first transistor with a suitable resistor, the value of which is determined by the method outlined in Appendix 1.

(2) To obtain adequate image rejection the dynamic "Q" value of the r.f. stage tuned circuit should be as high and constant as possible. This infers that the damping of the tuned circuit must be small and the C/L ratio large.

The first condition was achieved by connecting the collector of the r.f. stage transistor to a point on the primary of the r.f. transformer 1/5 of the number of turns from the earthy end (see Fig. 3). The resultant dynamic impedance is matched to the input of the mixer by using a step down ratio of 14 to 1 for the r.f. transformer.

This technique is necessary owing to the relatively low value of output impedance presented by the transistor itself, a typical value being about 4kΩ.

The C/L ratio was made large by using the largest practical value of tuning capacitor; actually two 0 to 500pF sections in parallel of a 4-gang capacitor, the other two sections in parallel being used for oscillator tuning. In this way the dynamic impedance over the band varied less than $\pm 7\frac{1}{2}$ per cent.

(3) Since the dynamic "Q" of the r.f. stage is relatively high, and the i.f. bandwidth narrow; in order to maintain sensitivity over the band the tracking error between the r.f. and oscillator circuits should be small, preferably within ±400c/s.

The arrangement used in practice produced a three point tracking curve, and a maximum calculated tracking error of 350c/s[4].

(4) Preliminary experiments showed that the use of a transistor as an oscillating frequency changer with the frequency determining circuit in the base was not very satisfactory. This is due to the necessity of adding resistance in the emitter circuit to avoid damping the base tuned circuit by the relatively low emitter to base impedance. Such added resistance also has the effect of making the working frequency nearer the natural frequency of the tuned circuit, but the arrangement causes considerable loss of input signal voltage.

The arrangement finally chosen, which is shown in Fig. 3, uses a separate oscillator and mixer X_7 and X_2 respectively, the signal and oscillator voltages being applied in series to the emitter of the mixer. Under these conditions a mixer conversion gain of 13dB was obtained, which was considered quite satisfactory.

The a.c. load in the oscillator collector circuit was made practically zero, by returning the collector to earth via a large capacitor. This condition produces the largest amplitude of oscillations, as the input resistance to the oscillator is then most negative. This may be seen from the expression for the input resistance which is:—

$$R_{IN} = r_e + r_b - \frac{r_b\,(r_b + \alpha r_c)}{R_L + r_c + r_b}$$

where r_e = emitter resistance of transistor
r_b = base resistance of transistor
r_c = collector resistance of transistor
R_L = collector a.c. load resistance
α = dynamic small signal current gain factor.

Under these conditions the oscillatory voltage across the primary of transformer T_3 (Fig. 3), was 7V r.m.s., or, as the step-down ratio of T_3 was 14:1, 0·5V r.m.s. at the input to the mixer.

(5) Since the equipment is intended to identify and measure signals separated in frequency by 10·125kc/s, it follows that a high degree of selectivity is required.

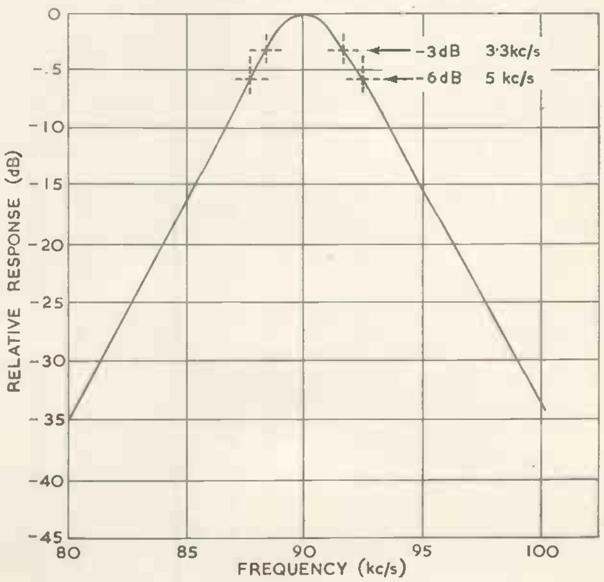
The i.f. amplifier comprises four cascaded stages tuned to 90kc/s. The transistor in each stage is used in the earthed base arrangement, and by-passed resistor is included in the base circuit to provide emitter bias current. The average gain per stage is approximately 16dB.

The particular biasing arrangement shown was chosen to eliminate the necessity of using either a separate battery or a tapped battery to provide emitter bias current. The d.c. resistance in the emitter circuits has been made relatively high (2·2kΩ) to avoid instability troubles at low frequencies, and no adverse effects in practical operation have been encountered.

Should a suitable tapped battery be available, however, its use is to be recommended, as the addition of impedance in the base circuit can then be avoided, but in this case care should be taken to avoid additional damping of the secondary of the interstage coupling transformers due to the biasing circuit.

The frequency response curve of the i.f. amplifier is

Fig. 4. Response curve of i.f. amplifier



shown in Fig. 4, and indicates an attenuation of at least 33dB at frequencies 10kc/s off tune. The bandwidth for the −3dB points is about 3·3kc/s. The latter bandwidth is sufficiently wide to enable wanted signals and broadcast stations to be identified clearly when headphones are used to monitor the output of the equipment.

Approximate matching conditions between stages were obtained by using coupling transformers having a step-down ratio of 5·3 to 1.

(6) Carrier output from the last i.f. amplifier (X_6 of Fig. 3), is taken from the secondary of the step-up transformer T_8. After rectification by MR_2, the voltage across C_{34} is applied to a 0 to 50μA meter M_1 via R_{50}. The time-constant of C_{34}, R_{50} is approximately 10msec. Under these conditions the meter shows a very small erratic movement due to noise; increasing the time-constant of the circuit will reduce this, but at the expense of a sluggish meter indication. In view of the sharpness of the tuning of the instrument the time-constant chosen was considered to be about the best compromise. The meter is calibrated in terms of signal input voltage.

By means of the switch S_2 (Fig. 3), the meter may also be used to measure the h.t. voltage applied to the instrument, and a calibration on the meter enables the h.t. voltage to be set to a predetermined value.

By an alternative arrangement, the output from the last i.f. stage may be demodulated by MR_1 (Fig. 3), and the resulting output monitored on low impedance headphones via jack plug J_1.

Choice of output is effected by operation of the switch S_4.

Calibration

The instrument was calibrated using a standard signal generator, the output of which was maintained at 1V r.m.s. as measured on a standard valve-voltmeter. This reference voltage was fed via a 75Ω attenuator either to the 75Ω input of the instrument, or via a suitable insertion network (shown in Fig. 5) to the 15kΩ input. This network together with the 15kΩ input impedance of the measuring set, forms a 20db pad, and was used to reduce the mismatch to the 75Ω attenuator to insignificant proportions.

The main dial was calibrated by comparing the frequency of the local oscillator against a crystal frequency meter, and engraving the dial in signal frequency, i.e. local oscillator frequency minus 90kc/s.

Specification of Performance

(a) Sensitivity and Signal/Noise Ratio

The following tables give the results obtained from a comparison of meter readings for various input signal levels, i.e., the signal to noise ratio expressed is between indicated peak carrier voltage and indicated noise voltage.

TABLE 1
75Ω Input Impedance

SIGNAL VOLTAGE AT INPUT TERMINALS (μV)	SIGNAL/NOISE RATIO (dB)
1	10
3	18·5
5	23

TABLE 2
15kΩ Input Impedance

SIGNAL VOLTAGE AT INPUT TERMINALS (μV)	SIGNAL/NOISE RATIO (dB)
15	10
45	18·8
75	23·5

The maximum sensitivity of the instrument may be taken as the input level which will provide an indicated signal-to-noise ratio of 10dB, this having proved to be about the minimum ratio for consistently reliable readings.

(b) Variation in Sensitivity Over the Band

The instrument was calibrated at a frequency of 220kc/s. The variation in sensitivity with frequency is given below:

160kc/s	220kc/s	285kc/s
−0·25dB	0dB	+0·25dB

(c) Image Rejection

The response at the image frequency, i.e., at signal frequency plus 180kc/s, is:—

340kc/s	400kc/s	465kc/s
−40db	−35·5dB	−30·5dB

(d) Oscillator Stability

The short term drift of the local oscillator is approximately 50c/s during the first 30 minutes from switch-on. This drift was measured at the highest oscillator frequency (i.e., 375kc/s), by comparison with a crystal frequency meter.

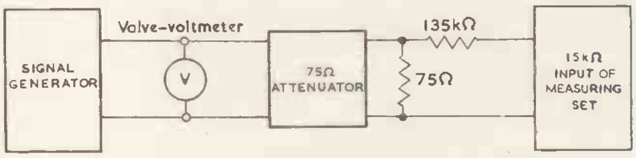


Fig. 5. Calibration set-up

The shift in oscillator frequency with change in h.t. voltage is approximately 50c/s/V. This shift was measured in a similar manner to above.

The long term stability of the oscillator (over a period of some months), is sufficiently good to be within the accuracy of setting the frequency scale on the main dial.

(e) Gain Stability

With a constant h.t. voltage, there is a decrease in gain of approximately 0·5dB during the first 20 minutes from switch-on. No further significant change takes place.

An increase of gain of approximately 3dB takes place when the h.t. voltage is increased from 20V to 26V. This affords a method of compensating any small changes in the gain of the instrument at any time, so as to conform to the calibration of the meter. Adjustment of R_{49} (Fig. 3) will enable the "SET H.T." calibration on the meter to indicate any new value of h.t. voltage required.

(f) Power Supplies

The actual h.t. voltage applied to the instrument is 20V. A dry battery of 24 to 30V may be used as the power source, and the h.t. adjusted to 20V by means of R_{47} (Fig. 3). The total current consumption is about 22mA, giving a total power requirement of 440mW.

Operational Measurements

A comparison has been made between the performance of this instrument and a Post Office Measuring Set, Type R.I. No. 1.

Measurements were made at distances of 6ft and 12ft from the front of a standard television receiver which was operated at normal brightness level and had its line time-base synchronized from a signal generator.

The strengths of the harmonics radiated by the line time-base at frequencies of approximately 185kc/s, 216kc/s and 280kc/s were measured on each instrument, and the results obtained are given in Table 3.

TABLE 3

Comparative Measurements of Interference Signals

	185kc/s (μV)	216kc/s (μV)	280kc/s (μV)	DISTANCE (ft.)
Post Office Set, R.I. No. 1 ..	980	680	510	6
Transistor Set ..	1 000	700	450	6
Post Office Set, R.I. No. 1	105	55	Not measurable	12
Transistor Set ..	95	40	33	12

In the Table, a correction has been applied to the readings relating to the Post Office instrument, in order to take account of a small error of some 1·4dB between the signal generators used to calibrate the respective measuring sets.

The largest discrepancy between the two instruments is seen to be about 2·7dB, and occurs towards maximum sensitivity. For larger input signal levels the error is much less (about 1dB).

Accuracy of Measurements

The various sources of error in the instrument are considered to be as follows:—

(1) A variation of $\pm 0{\cdot}25$dB in sensitivity over the band.

(2) A loss in gain of about 0·5dB during the first 20 minutes from switch-on.

(3) An error of approximately 2 per cent (i.e., $\pm 0{\cdot}2$db) in calibration of the meter due to fluctuations from noise.

Thus if all the errors add, the total is within -1dB.

It has also been found that the long term gain stability is very good. The only variation so far noted (over a period of several months), has been an increase in gain of about 0·5dB.

General Discussion

The equipment described is considered to have several advantages, of which the most noteworthy are as follows.

The pre-set h.t. voltage may be checked easily by reference to the calibration on the meter, allowing measurements to be made quickly and accurately. A simple adjustment is incorporated to enable the h.t. voltage to be re-set when necessary to the value at which the instrument was calibrated.

The equipment is completely portable, and the power requirements are very modest.

In making radio interference measurements with the usual mains driven equipment, special care has to be taken to ensure that the mains connexion in no way impairs the results obtained. The fact that the power supply for the instrument described is contained entirely within its case removes this source of embarrassment to accuracy of measurement.

The sensitivity is entirely adequate for the purposes for which the instrument was designed.

In addition all the transistors are operated well within their maximum ratings, and thus should have a very long life with little change in performance. Already it has been found that similar transistors operating under slightly more rigorous conditions have completed over 10 000 hours life without significant change in performance.

On the other hand, the maximum rated operating temperature (35°C) is not as high as might be wished, but should not be exceeded in normal circumstances. However, recent advances in point contact transistor development have shown that the limit may be raised appreciably with the advent of new types of transistor. For example, the use of the EW51 transistor throughout the equipment should raise the maximum operating temperature to about 55°C.

The noise performance is not as good as should be obtained with thermionic valves, but is considered very satisfactory for equipment using point contact transistors throughout. An actual measurement of the noise factor at the 75Ω input with the instrument tuned to 220kc/s was 19·3dB. (The output noise was measured at the output of the last i.f. stage, i.e. prior to the detector which introduces non-linearity.)

The transistor used in the r.f. stage was actually selected on the score of low noise factor, but contemporary work on the transistor types mentioned in this article has shown that the spread in noise factor values between different samples of a given type under fixed d.c. biasing conditions is only of the order of 6dB.

Appendix I

Calculation of Input Resistance

Referring to Fig. 6:—

If the input circuit L and C is tuned to resonance and

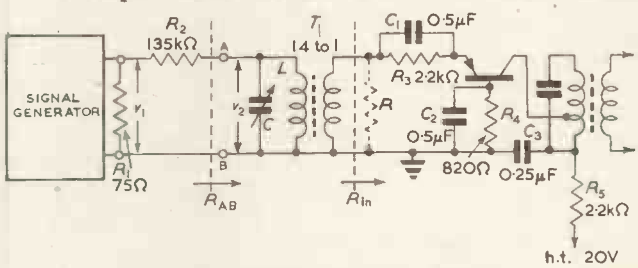


Fig. 6. Calculation of input resistance

its dynamic resistance is much greater than the effective input resistance R_{AB}, then:

$$V_2 = \frac{R_{AB}}{R_{AB} + R_2} . V_1$$

i.e.:

$$R_{AB} = \frac{V_2 R_2}{V_1 - V_2} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Before the addition of the shunt resistance R, measured values were:

$$V_1 = 1\text{V r.m.s.}$$
$$V_2 = 0{\cdot}125\text{V r.m.s.}$$
$$R_2 = 135\text{k}\Omega$$

Thus

$$R_{AB} = 19{\cdot}3\text{k}\Omega$$

Also, Turns ratio of T_1 = 14 to 1.

i.e.:

$$|R_{AB}/R_{in}| = 14^2 \quad \ldots\ldots\ldots\ldots\ldots (2)$$

where R_{in} = effective emitter-base input resistance of 1st transistor

i.e.:

$$R_{in} = 98{\cdot}5\Omega$$

Now R_{in} is required to be 75Ω.

The required value of shunting resistance R is thus given by:

$$1/75 = (1/R) + (1/R_{in}) \quad \ldots\ldots\ldots\ldots (3)$$

i.e.:

$$R = \frac{75 \times R_{in}}{R_{in} - 75}$$

and in this case:

$$R = 315\Omega$$

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Silicone Insulants

Their Properties and Applications

(Part 1)

By J. D. Hayden*, B.Sc., A.M.I.E.E.

Silicone fluids, compounds, resins and elastomers are now becoming established as insulants in the electronic and electrical industries. This article reviews the properties of the various forms of silicone insulants. It will be seen that the unique dielectric behaviour stems principally from that part of the chemical structure common to all silicones, namely the alternate silicone-oxygen linkage. A further article will refer to some of the ways in which silicones are being used in the electronic industry.

SILICONES became commercially available eleven years ago in America. Today their production has grown to very considerable proportions and now their large scale production has commenced in Britain where, incidentally they were discovered and named. This rapid growth can be attributed to the unique combination of properties possessed by silicones resulting in their widespread use in many industries, including polish, textiles, engineering and aircraft. Many new and improved silicone products continue to emerge so that fairly frequent appraisal of their usefulness should be made in the light of these developments.

A large number of different silicone products are made, including fluids, resins, elastomers, greases, water-repellent products and other materials for use in diverse industries. In spite of these variations in composition and form, certain properties are common to all silicones. Chief among them is their stability to heat, cold and oxidation. Many resins, elastomers and fluids can be used at 250°C while for application at the lower extreme, are other fluids with freezing points of −86°C and elastomers with brittle points below −90°C.

Silicones are highly water-repellent and water will condense as discrete drops on surfaces treated with them. Electrical insulation containing silicones exhibits this quality to a high degree. The water-repellency is not appreciably affected by long exposure to high temperatures or to outdoor weathering. Silicone treated insulators therefore, maintain their high surface resistivity under wet conditions.

Silicones are chemically inert and do not affect materials with which they are in contact. This property, combined with low surface tension and the readiness with which silicones wet surfaces, plays an important part in their use as mould release agents in rubber, plastic and metal founding industries.

Silicones are low loss dielectrics over a wide temperature and frequency range. This and the fact that silicones are extremely resistant to heat, has led to the introduction in America of "Class H" insulation which has a temperature advantage over "Class B" insulation of 50°C.

Insulation Classification

Electrical engineers have always found it convenient to classify insulating materials according to their ability to resist heat. Maximum operating temperatures are assigned to each class for a service life of the order of 20 years. Such temperatures cannot be rigidly adhered to and can only offer a comparative guide as insulation life at any temperature is dependent upon the application. Degradation may be due to heat, oxidation, electrical or mechanical reasons. Many new insulants have been introduced in recent years necessitating revision of internationally accepted standards. New insulation classes are now under consideration: their relation to the established "Class A" and "Class B" is as follows:—

Class	*Maximum Temperature °C*
A	105
E	120
B	130
F	155
H	180

Mica, glasscloth, asbestos bonded with silicone compounds satisfy "Class H". These compounds include silicone resins, varnishes and elastomers. Certain modified silicone resins may fall into the "Class B" and "Class F" groupings.

In Fig. 1 is shown the effect of heat on silicone (Class H) and "Class B" and "Class A" insulating materials. Because silicones are expensive it is often thought that their application is confined to high temperature applications. Already it is evident that their combination of properties, such as resistance to oxidation, resistance to acids and alkalis, and water-repellency play a part in extending the life and reliability of insulation at "Class A" temperatures and above.

The superior low loss factor of silicone insulants must also be taken into account. This is typified in silicone resin bonded glass laminates and accounts for their wide use in electronic applications at "Class A" temperatures.

Chemical Structure-Relation of Silicones to Other Insulations

Electrical equipment has depended for its insulation upon two broad classes of dielectrics, organic and inorganic. Organic insulations are used in a variety of physical forms such as resins, moulded plastics, rubber cable coverings, potting compounds and oils. These organic dielectrics are essentially compounds of carbon and under elevated temperature operating conditions their effective life is short. One reason for this is the inherent instability of the carbon-to-carbon linkage. The eventual decomposition product is carbon—an electrical conductor.

The inorganic spacing materials used are principally built upon a framework of silicon and oxygen atoms.

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They include such familiar materials as mica and quartz, whose heat stability is well known. It is due to the inherent stability of the silicon-oxygen bond. However these materials are limited in physical forms to comparatively hard brittle solids and for most applications must be bonded with organic insulants.

Between these two classes of insulation which differ so greatly in heat stability, are the semi-organic silicones. These synthetic materials possess much of the stability and good dielectric properties associated with glass, quartz and

Fig. 1. The effect of heat on silicone ("Class H"), "Class B" and "Class A" insulating materials

the mineral silicates to which they are chemically related. They acquire flexibility, variability, ease of handling and water-repellency from certain organic materials to which they are also related. Silicones are built on a molecular skeleton of alternate silicon and oxygen atoms. Attached to this singularly stable structure are hydrocarbon groups such as methyl and phenyl varied to give silicone compounds with different characteristics.

Fluid

A typical silicone fluid is represented by the formula shown in Fig. 2.

Note the repeatable "Siloxane" unit shown in brackets. These units may vary from 2 to 2 000 or more to form chains of varying lengths. The average length of the chain determines the viscosity of fluid. For instance a fluid with the viscosity of heavy motor oil would have about 300 units.

Elastomers

By cross-linking very long chain molecules, elastic materials can be produced which form the basis of silicone rubber.

Resins

By preparing molecules in which complex three dimensional networks are set up, a variety of resins can be made.

Silicone Fluids

The methyl fluids are well known as dielectrics having any desired viscosity and are remarkable for their resistance to the action of heat and moisture. Their chemical structure is shown in Fig. 2. Except for the very low viscosity members (0·65 centistokes to about 50 centistokes)

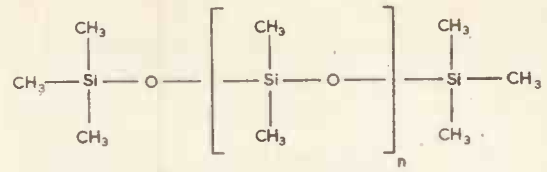


Fig. 2. The chemical structure of MS200 silicone fluids

the dielectric properties vary very little with viscosity. In a detailed study, Hartshorn, Parry and Rushton[1] show that over a very wide range of frequency and temperature, i.e. from 1kc/s to over 10Mc/s and from $-35°C$ to $+150°C$ the power factor of the liquid is less than ·0001. At power frequencies the power factor is approximately that of a good transformer oil, being about ·0003.

At frequencies above 100Mc/s a considerable increase in power factor occurs. This has been shown to be the power loss arising from the relaxation of the electrical structure due to the time constant of the silicon-oxygen linkage. The rise in power factor at low frequency is usually ascribed to ionic conductivity arising from traces of impurity. The same effect is noted in transformer oils. The permittivity of the fluids is sensibly independent of frequency but the diminution of permittivity with rise in temperature is considerable and linear. The temperature co-efficient of permittivity is $-0{\cdot}0016°C$ for the higher viscosity fluids (see Fig. 3).

Volume Resistivity

The volume resistivity is of the order of 10^{14} Ω/cm at 25°C falling to 10^{13} Ω/cm at 200°C.

Electric Strength

The low viscosity fluids meet the requirements of transformer oils and will withstand the standard proof test of one minute at 30kV (4mm sphere gap).

Viscosity/Temperature Relationship

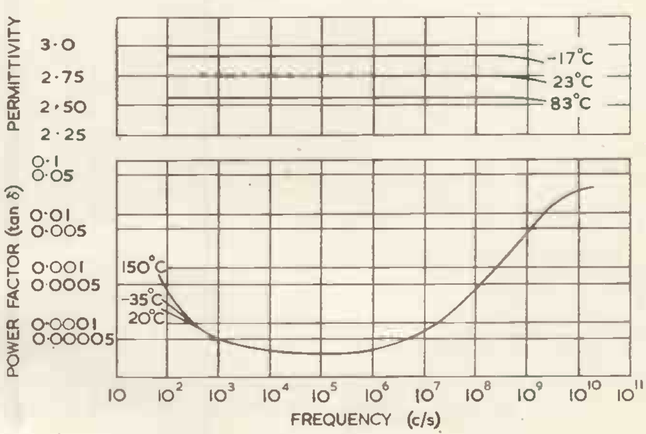
The usefulness of a fluid in general engineering applications is determined largely by its viscosity/temperature behaviour. All fluids show some change in viscosity with changing temperatures, but no series of organic liquids is as nearly constant in viscosity over as wide a temperature range as the MS200 silicone fluids (Fig. 4).

The main physical characteristics of some silicone fluids are shown in Table 1.

Silicone Resins

These may be divided into groups according to

Fig. 3. Effect of frequency on permittivity and power factor of 1 000 centistoke MS200 fluid



application :—

(a) Coating varnishes that form flexible films.

(b) Impregnating varnishes that cure in depth.

(c) Bonding resins that set hard for rigid and structural laminates.

(d) Wire coating resins specially compounded for solvent and abrasion resistance.

These resins are supplied as solutions in suitable solvents and are applied and processed according to usual practice, the main difference being that silicone resins require a baking temperature of about 200°C or more. The curing characteristics for the various resins vary, the flexible varnishes being somewhat slower curing and exhibiting an initial thermoplasticity which disappears as ageing proceeds.

Coating and Impregnating Varnishes

When films of the varnishes are prepared on woven glasscloth, their heat stability is at once apparent. The electric strength at room temperature is not significantly changed after seven days' heat ageing in air at 250°C. The electric strength usually rises during this period as polymerization of the varnish continues long after the dry state is reached. Some embrittlement occurs and it is usual for flexible insulating components to be only partially cured prior to application. The graph, Fig. 5 compares the thermal endurance of a silicone impregnating varnish with an organic varnish used in Class-B work. The "life" is based on the hours necessary to reduce the electric strength to half its initial value.

The cloth coating varnish MS 994 has higher heat stability and produces a more flexible film. The bond strength of a silicone varnish when measured as the force required to break an impregnated winding is lower than that expected of an organic varnish but it improves as curing at 200 to 250°C proceeds through six to twenty-four hours.

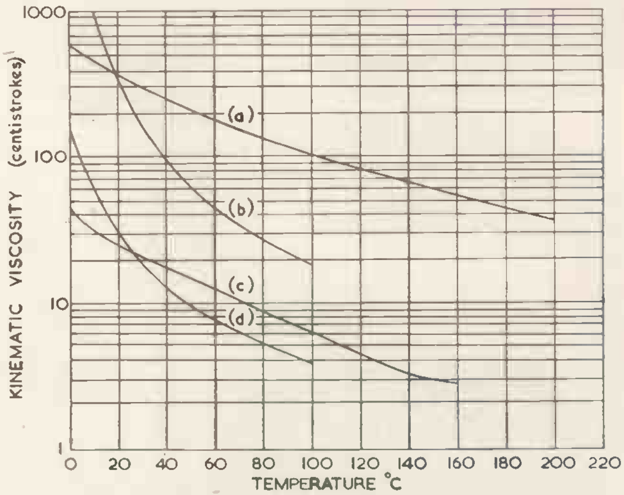


Fig. 4. Viscosity/temperature characteristics of MS200 silicone fluids compared with those of typical transformer and lubricating oils

(a) Silicone fluid (b) Commercial lubricating oil
(c) Silicone fluid (d) Transformer oil

Moisture Resistance

Renwick and Reed[2] state that silicone varnishes are equivalent in moisture resistance to high-quality oil-modified synthetic-resin impregnating varnishes when the criterion taken is either the depreciation in the electric strength of a film of resin on woven glass fabric after immersion in water, or subjection to a high humidity, or the rate at which water vapour permeates a film. How-

TABLE 1.

Physical Properties of Some Silicone Fluids.

FLUID	VISCOSITY AT 25°C (Centistokes)	VISCOSITY TEMPERATURE COEFFICIENT $\left(1-\frac{V210°F}{V100°F}\right)$	PERMITTIVITY AT 25°C 100c/s	FREEZING POINT (°C)	BOILING POINT (°C)		FLASH POINT MIN. (°F)	THERMAL CONDUCTIVITY $\frac{\text{cal cm}}{\text{sec cm}^2\ °\text{C}}$ AT 50°C	SPECIFIC GRAVITY AT 25°C/25°C	REFRACTIVE INDEX AT 25°C
MS200/3	3	0·51	2·52	−65	70–100		215	·00027	0·90	1·39
				Pour Point						
MS200/10	10	0·57	2·65	−65	> 200		325	·00032	0.94	1·40
MS200/20	20	0·59	2·68	−60	> 200		520	·00034	0·96	1·40
					Volatility after 48 hours at °C	per cent				
MS200/500	500	0·62	2·75	−50	200	<2	600	·00038	0·97	1·403
MS200/12,500	12,500	0·58	2·82	Solidification temp. −46	200	<2	600	·00038	0·97	1·403
				Freezing Point						
MS510/50	50	0·62	2·7	<−70	250	10	525	—	0·99	1·42
MS510/550	550	0·66	2·8	<−70	250	6	525	—	0·99	1·43
MS550	100–150	0·75	2·9	−50	250	15*	575	·00035	1·06—1·08	1·49—1·50

** The thermal stability of MS550 is higher than that of the other silicone fluids in spite of this high initial volatility.*

ever, if this property is assessed by clamping films of the varnishes (on 1·6mil glass fabric) between hollow electrodes filled with water and continuously impressing 230V d.c. across the electrodes, the silicone varnishes show a smaller leakage current. For example, after seven days of immersion, films of MS993 of 3·5mil total thickness passed leakage currents of 3·5μA/in^2, while similar films of a high-quality oil-modified phenolic resin varnish passed 31μA/in^2.

The moisture absorption of silicone varnish bonded components is extremely low. In a silicone varnish impregnated system, moisture will first penetrate through fine

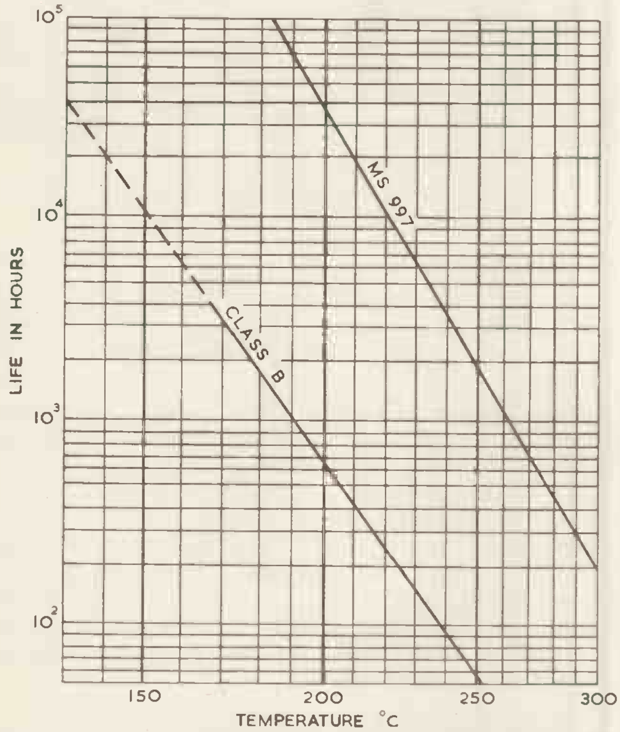


Fig. 5. Comparison of the thermal endurance of silicone ("Class H") and organic ("Class B") varnishes

cracks in the varnish film, if these occur, resulting in a drop in insulation resistance. In practice, the water-repellent nature of silicones has a delaying action and a correctly silicone insulated winding will maintain a higher insulation resistance under humid conditions than a conventionally insulated winding. A unique property, common to insulation incorporating silicones, is that it dries out rapidly from the wet conditions and regains high values of insulation resistance. This is an important feature.

The power factor and permittivity are small (tan δ less than 0·01, K about 3) and in common with other silicone insulants are sensibly independent of temperature over a wide range. Tan δ rises at frequencies above 10^7c/s in the manner indicated for fluids. Power factor is, of course, dependent on the state of cure and improves with cure. Ehlers[3] in a study of silicones for transformer construction compares the power factor of silicone varnish and elastomer films with an oil modified organic varnish on glasscloth.

In Fig. 6 the steep rise in power factor at 100°C of the organic varnish is compared with the negligible change for silicone varnish at 200°C.

The low loss feature of silicone varnishes at temperatures above 100°C may be important for several applications for which "Class A" or "Class B" materials are now used. The more recently compounded Silastomer stocks will probably have loss factor values at high temperature approaching those of the silicone varnish films.

Bonding Resins

These resins have similar dielectric properties to the silicone varnishes but cure to a hard finish. They are used for the preparation of glass, mica and asbestos laminates and may be blended with the varnishes for adjusting flexibility. Laminates are formed under heat and pressure. Flat sheets, tubes and complicated shapes are made (Fig. 7).

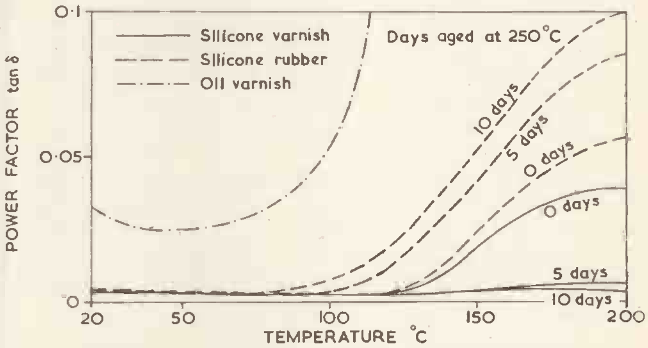


Fig. 6. The power factor/temperature characteristic of silicone varnish, silicone rubber and oil varnish when coated on glass cloth

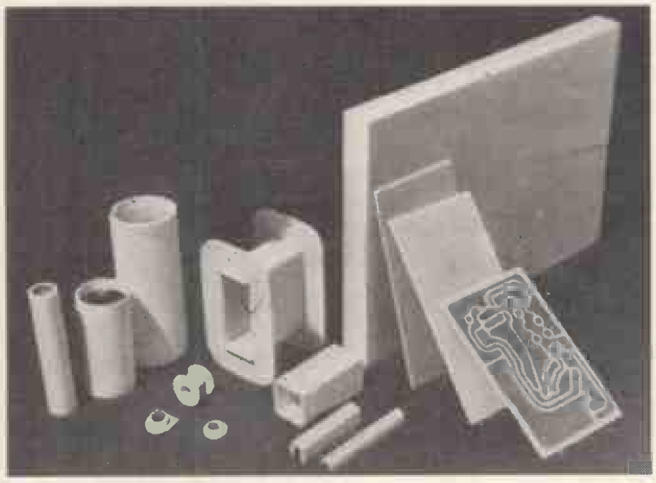


Fig. 7. Silicone bonded glass laminates

Wire Coating Resins

Modified silicone resins are used for bonding glass-covered wire and more recently for enamelling bare wire. They have better solvent and abrasion resistance than the straight silicone varnishes so far available. Extensive life tests on silicone insulated motors indicate that the modified silicone resin bond for glass-covered wire has satisfactory life at Class-H temperatures when a silicone varnish is used for impregnation.

The thermal stability of the new wire enamel is still under investigation. Laboratory tests show that it ages at a slower rate at 180°C than vinyl acetal wire coating does at 130°C. A paper presented at the 1953 winter meeting of the A.I.E.E. describes Class-A motors run to destruction by cycling through heat and moisture. Test temperatures were 150, 175 and 200°C obtained by frequent rotation reversal. In the same way motors wound with modified silicone enamelled wire were operated 200, 225 and 275°C. The conclusion states that the data indicate that silicone insulated motors wound with silicone enamelled wire can be operated at an average copper temperature in the range 160 to 180°C with a life comparable to Class-A motors operated within their temperature limits.

The particular silicone enamel under investigation does not quite meet the elongation and abrasion resistance requirements of B.S. 1844 (wire enamelled with resins of the vinyl acetal type) but in other respects it meets the standard.

Elastomers

Silastomer is a trade name for a range of silicone elastomers varying from stocks for moulding and extruding to thin pastes for coating fabric and filling coils. After application, Silastomer is heated in air for a few minutes at about 150°C to vulcanize the stock. This is followed by an after cure which may last 24 hours at 250°C to develop optimum properties. Earlier Silastomer stocks had somewhat poor mechanical strength, limited elongation and were easily torn. New stocks with much superior mechanical and dielectric properties are now available and as a result Silastomer is an insulant of growing importance. Silastomer consists of three ingredients:—

(a) silicone polymer

(b) heat stable fillers

(c) oxidizing agent—necessary for the vulcanization process.

A typical new stock is Silastomer 80 which can be extruded on to conductors or to form sleeving. It is also suitable for the preparation of mouldings (Fig. 8).

DIELECTRIC PROPERTIES

The volume resistivity of Silastomer 80 is 10^{14} Ω/cm^3 when measured at 200°C. The power factor rises from 0·0006 to 0·002 and permittivity from 2·92 to 3·48 after seven days immersion in water at 70°C.

An outstanding property of Silastomer 80 is the stability of dielectric properties over a wide temperature range. From 0 to 200°C, power factor, permittivity and electric strength remain sensibly constant. The change in power factor with frequency follows the trend reported for silicone fluid. Above 10^6 c/s there is a rise which peaks above 10^{10}c/s (at 10^{10}c/s $\tan \delta = 0{\cdot}0167$).

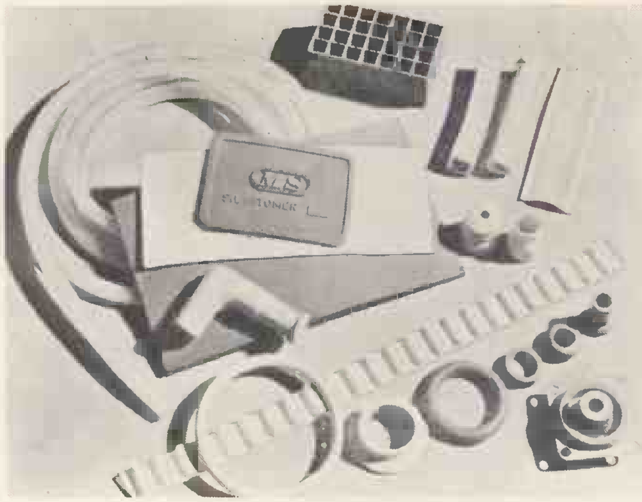


Fig. 8. Extruded and moulded Silastomer components

RESISTANCE TO CORONA

Of the elastic materials known today, Silastomer is the most resistant to the chemical and electrical effects of corona discharge. The following American test has been reported.

Samples of extruded cable were wrapped around an insulated mandrel having a diameter equal to that of the cable. The cable was surrounded by a copper screen electrode. A voltage stress of 200V/mil was applied between conductor and screen resulting in severe corona between the cable surface and screen. The Silastomer cable failed after 12 000 hours continuous stress without any visible signs of deterioration. Failure was attributed to voltage fatigue rather than to any effects of the corona. Organic rubber insulated cable was found to fail under the same conditions within three minutes.

THERMAL STABILITY

Silastomer meets the American "Class H" specification which recommends a top operating temperature of 180°C. The useful life for a given operating temperature depends

TABLE 2.

Typical Properties of Some Silicone Resins.

PROPERTY OF CURED RESIN	COATING RESINS		IMPREGNATING VARNISH	WIRE ENAMEL	BONDING RESINS	
	MS 935	MS 994	MS 997	MS 1360	MS 840	MS 2103
Electric strength, film thickness <10mil (V/mil)	>1 000	>1 500	>1 000	>1 500	>1 000	>1 000
Power factor at 10^2c/s	0·003	0·001	0·006	0·005	0·003	0·002
at 10^6c/s	0·004	0·001	0·007	0·013	—	0·002
Permittivity at 10^2c/s	2·9	2·8	3·1	3·6	2·9	2·9
at 10^6c/s	2·7	2·8	3·0	3·5	—	2·9
Craze life (min, hours at 250°C)	800	3 000	1 000	—	—	—
Flex life (min, hours at 250°C)	100*	1 000	250	—	—	—
PROPERTY OF RESIN SOLUTION						
Solids content (per cent)	50	50	50	50	80	60
Solvent	Xylene	Xylene	Xylene	Cresylic Acid	Acetone	Toluene
Viscosity at 25°C centistokes	80–150	80–125	100–200	4 300–8 600	350–1 750	60–125
Processing	Require curing at 200–250°C			Cures at 50°C above vinyl formal wire enamels	Will rapidly air dry tack-free to form a soft film. Require curing at 250°C to form hard non-thermoplastic bond.	

* *MS935 has superior low temperature flexibility. It remains flexible down to −55°C.*

TABLE 3.

Typical Properties of some Grades of Silastomer.

GRADE NO.	USES	PERMITTIVITY AT 1 Mc/s	POWER FACTOR AT 1 Mc/s	ELECTRIC STRENGTH (V/mil)	TENSION STRENGTH (lb/sq in)	ELONGATION AT BREAK (per cent)	HARDNESS (B.S. degrees)
50	Cable insulation, sleeving mouldings, etc. ..	3·1	0·002	550	900	380	54
80		3·0	0·002	550	750	250	82
152		2·9	0·003	450	700	375	52
122	Caulking and sealing compounds	3·0	0·005	450	775	30	95
123		3·2	0·005	500	650	30	90
132*	Fabric coating ..	3·5	0·003	—	—	—	—
160	High permittivity stock	6·1	0·007	260	560	125	70
6–126	Coil filling thin paste	6·1	0·003	350	470	70	80

* *Results obtained when Silastomer 132 was applied to glasscloth were as follows;—*

1) *Heat cleaned glasscloth (0.004 in. thick) was coated to give an overall thickness of 0.007in. The breaking strength was 156lb/in along the warp and 132lb/in along the weft.*

(2) *Other samples coated to 0.010in thickness were creased four times. The retention of breaking strength was 60 per cent along the warp and 70 per cent along the weft.*

(3) *Similar samples had an original electric strength of over 1000V/mil and this showed no decrease after 9 days at 250°C.*

on the application. If retention of electric strength is accepted as a criterion, it has been demonstrated that for Silastomer 80 this remains unchanged after six months at 250°C. On the other hand as the temperature increases above 150°C, there will be some decrease in flexibility and probably changes in mechanical properties provide the better indication of expected life. Unlike organic insulation, Silastomer when decomposed by burning still retains insulating properties; a fact that may be used to advantage in control circuit cables that may have to operate for a short time through fire.

Low Temperature Flexibility

All grades of Silastomer are flexible down to −60°C and special grades remain flexible down to −90°C. This is not achieved by the use of plasticizers.

Thermal Conductivity

High thermal conductivity is an important feature of Silastomer. Its thermal conductivity is higher than that of resinous dielectrics and mica composite materials and this can be a deciding factor in its favour where heat dissipation is important.

The result of measurements made on one grade of Silastomer using a Cenco-Fitch thermal conductivity apparatus are as follows:—

At 100°C Silastomer cured 24 hours at 250°C

k (metric) = $0{\cdot}513 \times 10^{-3}$ Cal.cm/°C/sec/cm^2

k (English) = 1·49 B.t.u., in/°F/h/ft^2

At 200°C, k (metric) = 1·7.

Thus conductivity rises with temperature.

The properties of several grades of Silastomer are shown in Table 3.

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(*To be continued*)

The Phase Comparator*

By J. C. Anderson, B.Sc., A.M.I.E.E., A.M.Brit.I.R.E.

The property of steel which varies most rapidly with strain is its permeability, and this article describes a method which utilizes this fact for the testing of springs.

RESEARCH in solid-state physics in recent years has yielded much information on the relations between the electrical, magnetic and elastic properties of metals. The phase comparator has been developed to apply the results of this research to the non-destructive testing of metals under different kinds of strain. In particular a method was sought whereby an unambiguous "go and no-go" test might be provided for steel coil springs.

Physical Principles

The property of steel which varies most rapidly with strain is its permeability. Furthermore, the elastic limit is clearly shown by a sharp fall in the permeability/strain curve for materials with a positive magnetostriction, which includes iron and steel at low field-strengths. Other properties such as resistivity and hysteresis loss also vary with strain, and it is difficult experimentally to separate these from each other and from permeability effects.

The solution to this difficulty used in the phase comparator is to measure the ratio $\frac{\text{inductance } (L)}{\text{resistance } (R)}$ for a coil into which the metallic specimen is inserted. The inductance L of the coil varies with permeability, while the resistance R varies with hysteresis and eddy current losses, the latter being determined by the resistivity of the

* *Prov. Pat. 11033.*

material forming the core of the coil. When the material is stressed, say by applying tension, L increases as permeability increases. When tension is first applied, there is a rapid reduction in hysteresis loop area while the resistivity increases slowly; initially, therefore, R decreases. However, after quite small stress has been passed, the hysteresis loop area remains fairly constant with increasing tension, while the resistivity increases slowly and linearly, up to the elastic limit. The ratio L/R therefore increases rapidly at first, and then more slowly, and more-or-less in conformity with the permeability/strain curve up to the elastic limit.

At the elastic limit the permeability shows a sharp drop while the resistivity begins to increase more rapidly. The

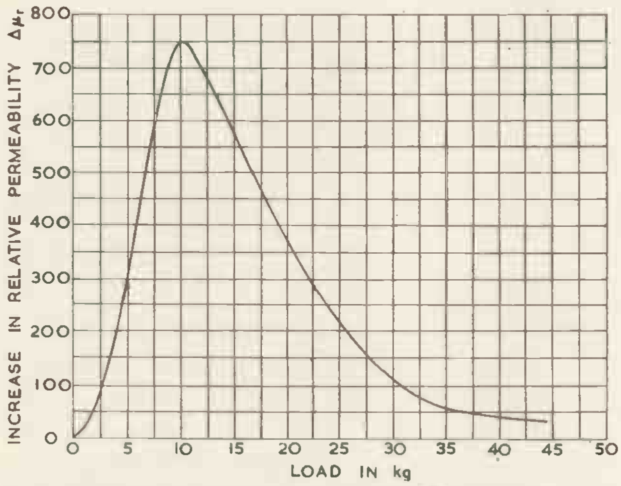

Fig. 1. Permeability against load curve for 2·2mm diameter soft iron wire in a field of 3·2Amps/metre
(After Barratta and Milone)

L/R ratio therefore exhibits a sharp fall at the elastic limit, this being followed by a continued decrease as the specimen is plastically deformed. A typical permeability/strain curve, due to Barratta and Milone[1], is shown in Fig. 1.

Circuit Principles

The basic requirement of the instrument is to measure the L/R ratio of the test coil with the maximum possible sensitivity. To do this, use is made of a parallel resonant circuit, as shown in Fig. 2, to which is applied an alternating voltage at an angular frequency (ω) equal to 0·707 times its resonant angular frequency (ω_0).

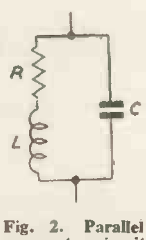

Fig. 2. Parallel resonant circuit

Under this condition, the modulus of the impedance of the circuit is equal to the reactance of the capacitor only, while the phase-angle of the impedance is dependent upon the ratio L/R. If this circuit forms the anode load of an amplifier stage, the gain of the amplifier will be independent of the L/R ratio. The phase-angle of the output voltage will vary, with respect to the input voltage, as L/R varies. This phase-angle, θ, is given by:

$$\tan\theta = (\omega_0 L/2R) - (R/2\omega_0 L)$$
$$= (\omega_0 x/2) - (1/2\omega_0 x)$$

where $x = L/R$.

Letting $A = (\omega_0/2)$:

$$\tan\theta = Ax - (1/4Ax)$$

Considering now a change $\Delta\theta$ in θ we have:

$$\tan(\theta + \Delta\theta) = A(x + \Delta x) - \frac{1}{4A(x + \Delta x)}$$

where Δx is the change in x.

For small values of $\Delta\theta$ and Δx, this may be written as:

$$\frac{\tan\theta + \Delta\theta}{1 - \Delta\theta\tan\theta} = Ax + A\Delta x - \frac{1}{4Ax[1 + (\Delta x/x)]}$$

Assuming $1 \gg (\Delta x/x)$ and $1 \gg \Delta\theta\tan\theta$, this yields:

$$\tan\theta + \Delta\theta \simeq Ax + A\Delta x - (1/4Ax)$$
$$\therefore \Delta\theta \simeq A\Delta x$$
$$\text{i.e. } \Delta\theta \simeq (\omega_0/2)\,\Delta(L/R)$$

Thus the change in phase-angle of the output voltage of the amplifier will be proportional to the change in the ratio L/R for small changes. It remains to arrange to measure this phase-angle.

Use is made of the well-known relation:

$$\sin A - \sin B = 2\sin\left(\frac{A - B}{2}\right)\cos\left(\frac{A + B}{2}\right)$$

If the output of the test-coil amplifier is $E\sin(\omega t + \theta)$ and this is combined in opposition with the signal from another

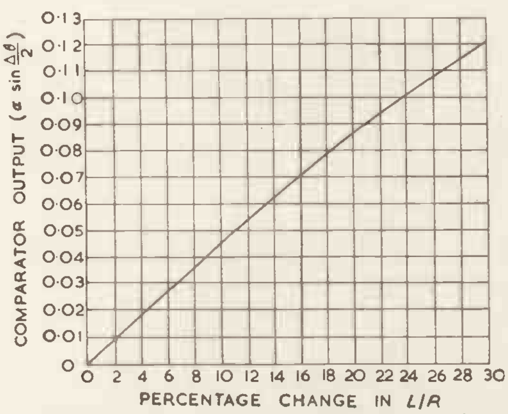

Fig. 3. Comparator reading against tension curve for mild steel bar

amplifier $E\sin(\omega t + \alpha)$, then we have a resultant signal given by:

$$E[\sin(\omega t + \theta) - \sin(\omega t + \alpha)] =$$
$$2E\sin\left(\frac{\theta - \alpha}{2}\right)\cos\left(\omega t + \frac{\theta + \alpha}{2}\right)$$

If, initially, $\theta = \alpha$ the resultant signal will be zero. An increase of $\Delta\theta$ in θ will yield a resultant signal $2E\sin(\Delta\theta/2)\cos[\omega t + \theta + (\Delta\theta/2)]$. Thus the resultant signal has an amplitude proportional to $\Delta\theta$ if $\Delta\theta/2$ is small. The calibration curve for the system in terms of output signal against percentage change in L/R is shown in Fig. 3.

Applications

(1) Tension Tests

The comparator has been used as an indicator of stress in mild steel bars under tension, and a typical graph of comparator output against load in tons is shown in Fig. 4. This curve is much in accordance with theory. The portion OA corresponds to the initial rapid decrease in hysteresis loop area; the portion AB corresponds to a constant hysteresis loss with increasing permeability and resistivity, and may be compared with Fig. 1. The point B is the yield point of the material, while peaks C and D are considered

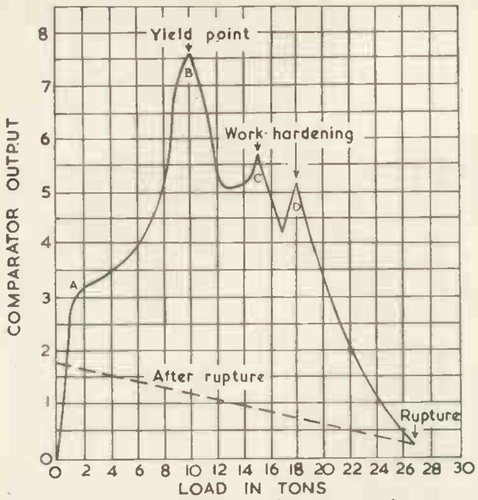

Fig. 4. Typical comparator reading against compression curves for steel springs

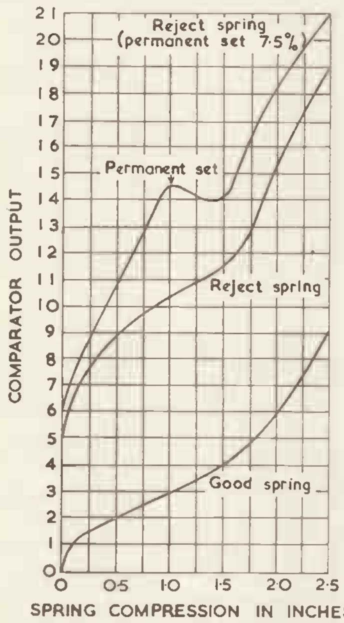

Fig. 5. Carbon steel coiled springs

(*Wire diam.* 0·192*in*. *Spring diam.* 2·134*in*. *Free length* 7 5/16*in*. *Normal steady load* 67*lb*.)

to be due to work-hardening of the material as it stretches.

(2) Spring Tests

In this type of test a coil spring is inserted into the coil and compressed inside it. The actual arrangement used for bench-testing of the softer springs dealt with is shown in the photograph of the apparatus. The spring under test is inserted in the coil carried on the compressing jig and a bridge carrying a locating bush is lowered on to the spring. A foot stirrup applies downward pressure to the bridge, thus compressing the spring into the coil. The jig itself is made in brass and wood to avoid stray magnetic effects interfering with the coil. For heavier types of spring the foot stirrup is replaced by a jig in which the bridge is carried on two lead screws, these being operated from an electric motor through suitable gearing. Typical results are shown in Fig. 5. Curve A refers to a spring known to be good. Curve B refers to a spring rejected on mechanical tests (Brinell hardness and loading), while curve C refers to a very soft spring which took a 7·5 per cent permanent set on compression. This last curve illustrates the expected fall in comparator output as the spring material passes the elastic limit, this being followed by a recovery due to work-hardening while the spring takes a permanent set. The important aspect of these results is that the poorer spring gives a higher output reading on compression due to it travelling higher up the permeability/stress curve, i.e. approaching more nearly the elastic limit. It is easily shown, of course, that the maximum stresses in a coil spring appear at the surface of the material of which it is made. The comparator was therefore operated at a frequency such that the effective skin-depth was of the order of 1 to 2mm, so that the maximum effect was obtained.

It follows from the above that the criterion of goodness for a spring is the amplitude of the output from the comparator. This permits a very simple routine test for springs. The resultant signal is used to operate a relay controlling a "reject" light. This is illuminated when the output passes a certain level, predetermined with the aid of a spring known to be just acceptable. One-hundred per cent testing of springs for quality control purposes can therefore be carried out by an unskilled operator.

Conclusion

The above tests are only two of a wide variety of static and dynamic tests to which the comparator may be applied. It is felt that it should have a wide application in routine quality control testing as well as in development work in laboratories.

The experimental phase comparator arranged for testing of coil springs in a foot-operated compressing jig.

Acknowledgments

My thanks are due to the Head and members of the staff of the Department of Telecommunications Engineering at the Northern Polytechnic, in particular to Messrs. R. A. Greenfield and D. Miller, for their valuable assistance. Also I wish to thank Messrs. A. Reyrolle & Co. Ltd., in particular Mr. W. Anderson for his encouragement.

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A Digital Potentiometer

By S. K. Dean*, B.E.E., A.M.I.Mech.E., A.M.I.E.(Aus.),
and D. F. Nettell*, B.Sc., A.M.I.Mech.E., AM.I.E.E.

This article describes an instrument for measuring voltage in discrete integers on either the binary or decimal scale. It was designed for use with a teleprinter perforator so that instrument readings recorded on teleprinter tape can be fed direct into an electronic computing machine for analysis without the need for manual transcription.

IT is often convenient to record instrument readings as a series of discrete integers rather than by observing the position of a pointer on a line on a chart.

The discrete integer presentation can be very useful where the readings are to be fed into some form of digital computing machine, particularly if the recording instrument can supply the information automatically in the form in which it is required by the computer.

Various methods of achieving this by using conventional self-balancing potentiometers coupled to cam or commutator systems have been tried or suggested. The instrument, described in this report, is of the potentiometer type but the balance is achieved by a sequence of switching operations carried out by relays and uniselectors and the signal voltage represented in discrete integers on the binary or decimal scale.

The instrument was developed primarily for use in conjunction with a teleprinter perforator to record signals on the binary scale. This is convenient because teleprinter tape is used to feed information into high speed electronic computing machines.

Principles of Operation

The instrument operates by comparing the input signal in the form of a voltage with a series of reference voltages within the instrument. The reference voltages (to which the input is connected in turn) are so arranged that the first has a value equal to half the full scale reading of the instrument. The second reference voltage is half the first, the third is half the second and so on.

The difference between the signal and the reference voltage is sensed by a detector. If the signal voltage is greater than a reference voltage the latter is used to back off the signal voltage and the difference of the two is applied to the next reference voltage stage. If the signal voltage is less than the reference voltage the signal is applied to the next reference stage without being backed off.

Two forms of this principle are outlined below and details of a practical circuit are given in Appendix I.

METHOD 1(a)

In Method 1(a) only one detector is used. This is illustrated in Fig. 1(a). Five sets of reference voltages are represented by batteries having voltages of 8, 4, 2 and 1 and 0·5 volts respectively. The signal voltage can be referred to these by means of the contacts *A*, *B*, *C* and *D*.

* Formerly The British Iron and Steel Research Association.

Suppose for example the input signal is 11V. Then the comparison of signal and reference voltages takes place as follows:

(1) Initially all the contacts *A*, *B*, *C* and *D* are in the upper position. The contact *A* is then changed to the lower position and the signal is compared with a 7·5V reference consisting of the 4V, 2V, 1V and 0·5V batteries. Since the signal is greater than the reference the detector, through a switching mechanism not shown, causes the contact *A* to return to the upper position so that the signal is now backed off by the 8V reference for the rest of the sequence.

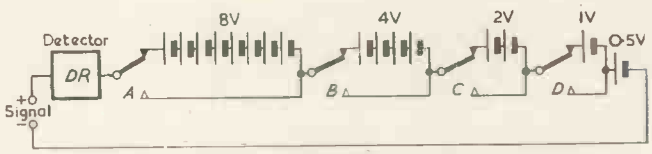


Fig. 1(a). Principle of operation with single detector

(2) The contact *B* is then made in the lower position and the input signal backed off by the value of the first reference (8V) is compared with the next reference voltage (2 + 1 + 0·5 = 3·5V).

Then:

Input signal	11V
Backing off voltage	8V
Voltage applied at 2nd stage	3V
Reference voltage	3·5V

In this case the signal voltage minus the backing off voltage is less than the reference voltage and the contact *B* is held in the lower position. This transfers the input to the third stage.

(3) At the third reference stage:

Input signal	11V
Backing off voltage	8V
Voltage applied at 3rd stage	3V
Reference voltage	1·5V

The signal voltage less the backing off voltage being greater than the third reference stage the detector causes the contacts C to return to the upper position and the backing off voltage is augmented by 2 volts from the third reference stage.

(4). At the fourth stage:

Input signal	11V
Backing off voltage (8 + 2)	10V
Voltage applied at 4th stage	1V
Reference voltage	0·5V

Again the signal voltage less the backing voltage is greater than the reference voltage and the detector causes the contact *D* to return to the upper position.

The signal voltage is equal to the sum of the reference voltages which have been used to back off the signal:

1st reference voltage	8V
3rd reference voltage	2V
4th reference voltage	1V
	11V

The position of the contacts *A, B, C* and *D* indicates the signal voltage on the binary scale.

Note that with four stages 8 + 4 + 2 + 1 = 15V can be measured. With *n* stages, voltages up to $(2^n - 1)$ can be recorded in steps of 1V.

METHOD 1(b)

This method is similar to method 1(a) in using only one detector, but the batteries are replaced by the potentials appearing across resistors. This is a more practical arrangement but precautions have to be taken to ensure that the potentials remain constant.

By correct selection of the reference voltages the instrument readings are corrected to the nearest whole digit.

The circuit is shown in simplified form in Fig. 1(b).

The reference voltages are provided by the potentials across the chain of resistors R_{11} to R_{16} and the supply voltages are adjusted so that the potential drops across the various sections would be as follows:

R_{16}	16V
R_{15}	8V
R_{14}	4V
R_{13}	2V
R_{12}	1V
R_{11}	0·5V

supply voltage 31·5

The signal voltage is applied through a detector relay *DR* to the complete measuring chain R_{11} to R_{16} and the various reference voltages are obtained by short circuiting each section (except R_{11}) in turn by the group of contacts E_1 to A_1. To maintain constant current in the circuit it is arranged that when a section of the resistance R_{11} to R_{16} is short circuited a resistor having the same value is switched into another part of the circuit (R_{21} to R_{26}) so that the total current, and thus the potentials remain constant.

In Fig. 1(b) the relays *A, B, C, D* and *E* when energized in turn, short-circuit sections of the measuring part of the resistance through contacts, A_1, B_1, C_1, D_1 and E_1 respectively, and open-circuit sections of the compensating resistance through contacts A_2, B_2, C_2, D_2 and E_2.

In considering the operation of the instrument it is again convenient to assume a certain input signal, say, 11V and examine the switching sequence.

The battery and its regulating resistance are adjusted so that the potential across the complete measuring resistance is 31·5V.

If the signal of 11V is now applied across the measuring resistors the detector, a moving-coil polarized relay, will move in such a direction as to indicate signal voltage less than reference voltage.

Relay *E* is now energized (by a switching mechanism not shown) closing contacts E_3. This short-circuits, through contacts E_1, a 16V drop section of the measuring resistor and puts a resistor of the same value into circuit by opening contacts E_2 so that the current in the circuit as a whole remains the same.

Now the reference potential = 31·5 − 16 = 15·5V
signal = 11V

Again the detector indicates signal voltage less than reference voltage. Contacts (E_3) are left closed maintaining relay E_1 energized.

Relay *D* is now energized by closing contacts (D_3). This short-circuits the 8V section of the measuring resistor through contacts D_1 and puts the compensating resistor in circuit by opening contacts D_2.

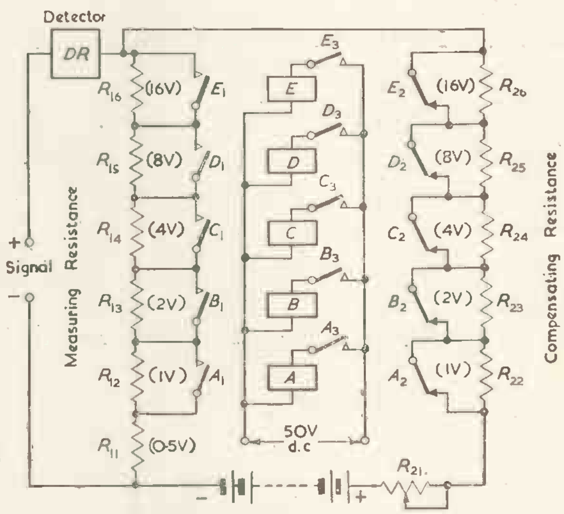


Fig. 1(b). Simplified circuit for single detector instrument

Now the reference potential = 31·5 − 16 − 8 = 7·5V
signal = 11V

The detector will now indicate signal greater than reference voltage and this causes the relay to be released so that the 8V section of the measuring resistor is left in circuit.

On operating relay *C* in the same way the 4V section of the measuring resistor is cut out but since the 8V section is still in circuit we have

Reference potential = 31·5 − 16 − 4 = 11·5V
Signal = 11V

Hence the signal is less than the reference voltage and relay *C* is held energized.

Operating relay *B*:

Reference potential = 31·5 − 16 − 4 − 2 = 9·5V
Signal = 11V

Signal less than reference and the detector releases relay *B*

Finally by operating relay *A*

Reference potential $= 31{\cdot}5 - 16 - 4 - 1 = 10{\cdot}5$V

Signal $= 11$V

and signal greater than reference voltage so the detector releases relay A.

The rule for whether the relays should be left energized or released is therefore

Signal > reference : release relay

Signal < reference : hold relay

If now the relays which were released are examined it is found that the sum of potential drops on the measuring resistor to which they correspond equals the signal.

Section $D = 8$V

„ $B = 2$V

„ $A = 1$V

11V

This is suitably displayed.

A complete description of an instrument working on the principle is given in Appendix I.

METHOD 2.

In method 2 a separate detector is used at each reference step.

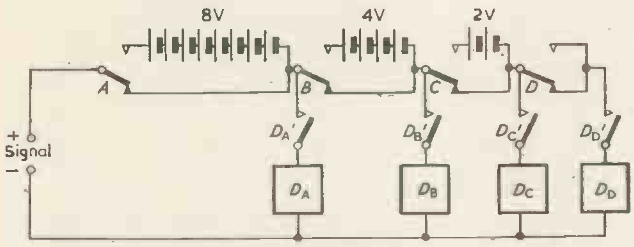


Fig. 2. Principle of operation with one detector per stage

In Fig. 2 the detectors D_A, D_B, D_C and D_D are adjusted to operate at 7·5, 3·5, 1·5 and 0·5V respectively.

Again consider an input signal of 11V. This is first applied to detector D_A through contact D_A'. D_A operates and makes contact A in the upper position. A voltage of $11 - 8 = 3$ is now applied to detector D_B which, being adjusted to operate at 3·5V, does not operate. This allows contact B to remain in the lower position. 3V are now applied to detector D_C (adjusted to operate at 1·5V) which operates and makes contact C in the upper position. A voltage of $3 - 2 = 1$ is now applied to detector D_D (adjusted to operate at 0·5V) which operates.

The signal voltage is equal to the sum of the voltages given by the detectors which have operated, that is, $8 + 2 + 1 = 11$V and the position of the contacts indicates the signal voltage on the binary scale.

Experimental Instruments

A 5 stage pilot model was constructed to test the method and this was later rebuilt as a 10 stage instrument. The 10 stage instrument is described in Appendix I.

The 5 stage instrument proved reliable in operation but preliminary tests with the 10 stage instrument indicate that unless very accurate resistors are used together with a highly sensitive detector the last three digits are subject to error. These results suggest that a reliable 7 stage instrument can be constructed from readily available components.

In the tests the uniselector was stepped at 2·5 steps per second so that a 7 stage reading took just under 3 seconds which compares favourably with the usual self balancing type of instrument.

Application to Teleprinter Recording

As there are 32 combinations of mark and space in a 5 element character, readings from 0 to 31 in units of 1 can be recorded as one character. The instrument lends itself well to this technique because the signal is represented by the combinations of relays which are energized or released at the end of a switching sequence. These combinations are readily transferable to the electrically controlled punches of the teleprinter perforator. Two teleprint characters can be used to record the readings of a suitable 10 stage instrument.

The Use of the Decimal Scale

Although primarily intended as a means of representing voltages on the binary scale the instrument can also be used to indicate on the decimal scale.

Here it is necessary to divide the full range of the instrument into decades and either treat each decade by the dichotomizing process illustrated in Figs. 1(a) and 1(b) or by adopting a distribution such as 4—2—2—1 for the reference voltages. In either case four stages are needed for each decade but the combination of the relays can be connected to give an indication of the appropriate decimal number.

APPENDIX

COMPLETE CIRCUIT FOR SINGLE DETECTOR INSTRUMENT

The complete circuit for a 10 stage teleprinter operating instrument using a single detector is shown in Fig. 3. This circuit is based on that shown in Fig. 1(b) and the principles of operation are the same.

The instrument is designed to measure up to 102·4V in units of 0·1V. This requires that the detector shall operate when 0·1V or more is applied to it and shall not operate for less than 0·1V.

The group of relays A to J is used for short-circuiting the measuring resistors (R_{111} to R_{11}) through contacts A_1 to J_1 and open-circuiting the compensating resistors by means of contacts A_2 to J_2. These relays are energized in turn by level 1 of the uniselector Z.

If, when a relay in the A to J group is energized the signal is less than the reference voltage the detector relay operates and energizes the corresponding relay in the AA to JJ group through level 2 of the uniselector and the detector relay contacts DR_1 and the contacts X_3 and Y_3. This causes the relevant holding contacts in AA_1 to JJ_1 and AA_2 to JJ_2 to close thus retaining the corresponding relays in groups A to J and AA to JJ and ensuring that the section of measuring resistor is short-circuited for the remainder of the sequence.

If the signal voltage is greater than the reference the contacts DR do not close and the relay in the AA to JJ group is not energized, hence, when the uniselector steps on, the relay in the A to J group drops out and the section of measuring resistor is left in circuit.

The uniselector may be pulsed from an external clock or other mechanism or by the self pulsing circuit consisting of relays $X/1$ and $Y/2$.

Contact Y_2 ensures that the detector relay DR has time to operate at each step before the circuits to the holding relays AA to JJ is made through contacts DR_1 The condition could otherwise arise where DR is closed at one stage and should open at the next, but the holding circuit

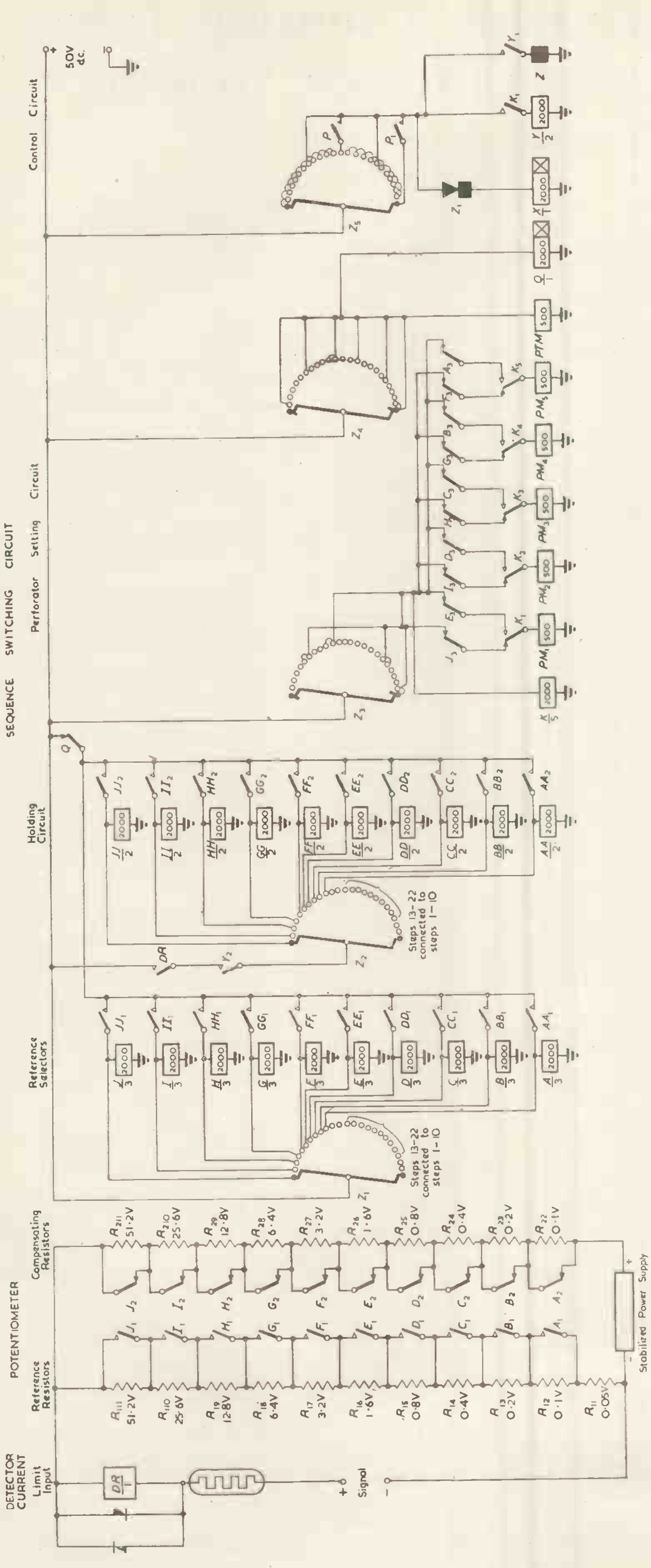


Fig. 3. Complete circuit for single detector ten stage instrument, adapted for teleprinter operation

would make immediately the uniselector stepped on and before DR_1 had time to open. Contact $Y2$ prevents this.

The relay Y ensures that sufficient time elapses between each pulse for relay DR to operate and the duration of each pulse is sufficient to step the uniselector correctly and yet prevent overheating.

The relay Q is used to break the supply to the holding circuit, at the end of a switching sequence and prepare the instrument for a further reading.

A current limiting device has to be placed in the signal circuit, for if the signal is of low value and the source has a small impedance, there would be a tendency for the reference voltage to circulate a large current through the signal source. A barreter as shown in Fig. 3 has proved suitable for this purpose.

The detector consists of a sensitive polarized moving-coil relay and is protected from excess currents when the instrument is unbalanced by non-linear resistors in the form of copper oxide rectifiers shunted across the coil.

Adaptation to Teleprinter Recording

It will be seen that only 10 steps and two levels of the uniselector have been used for the measuring part of the circuit. Level 3 can be used to set up the perforator magnets PM_1, PM_2, PM_3, PM_4 and PM_5 to reproduce the conditions of the A to J group at the end of the sequence.

It is convenient to transfer the conditions of the first five relays J, I, H, G and F, as soon as possible and this is done at step 6 through level 3 and the normally closed contacts J_3, I_3, H_3, G_3 and F_3. These settings are retained at step 7 and at the same time the perforator trip magnet PTM is operated through level 4. This punches the first 5 unit characters into the tape, while the second character is being formed.

In a similar manner the conditions of relays, E, D, C, B and A are set up at step 19 and punched into the tape at step 20.

The use of two steps 6 and 7 and 19 and 20 together with bridging wipers on level 3 for setting up and holding the perforator magnet combinations ensures that the combination bars are correctly positioned before the trip magnet is operated to punch the tape.

It may be desirable to use one of the remaining levels to interrupt the uniselector pulsing circuit at the end of one reading and prevent a further reading being taken until some external stimulus is received which closes contact P. If P remains permanently closed the uniselector will continue to step round and readings will be recorded continuously.

Reference

1. Nettell, D. F. Automatic Recording and Analysis of Data Using Teleprinter Technique. *Instrument Practice 8* (Nov. 1954) and (Dec. 1954).

The Use of Cold Cathode Counting Tubes for the Control of Resistance Welding

By T. W. Brady*, B.Sc.

A digital system for controlling resistance welding employs valves developed in the last few years. By its nature the scheme is most usefully employed for synchronous equipments fitted with heat control. The circuit described needs no calibration, is easily tested after manufacture, and is not voltage sensitive. Moreover, it provides visual indication that it is working correctly.

RESISTANCE welding is now widely used in industry, for as a process it offers many significant advantages over other methods of joining metals.

This article describes the electronic control of resistance welding by a new technique, and it is assumed that readers are to some extent familiar with the basic "seam" and "spot" forms of resistance weld, with the apparatus required to produce them (Fig. 1), and with the principle of the ignitron switch (Fig. 7).

Previous knowledge of past control arrangements is not assumed and these will be discussed in the text.

Cold Cathode Counting Tubes ("Dekatrons")

Very many circuits have been devised in the past for controlling resistance welding, but it was realized when cold cathode counting tubes[1] became available that a welding control using them should offer a substantial number of advantages†. These may be listed as

(1) A digital method controlling the 50c/s pulses rather than what may loosely be described as an analogue method. This distinction will be explained later.

(2) The counting tubes would be indicators that the circuit was working in correct manner.

(3) A simplification of the control circuit.

(4) Reduced cost.

These are fundamental advantages; at least one other advantage was obtained in practice, but this was due to circuit design and it will be described later.

(1) above may need amplification for readers not familiar with the techniques used in the past. While it is not safe to generalize, the most common method of timing prior to the introduction of the cold cathode tube circuit was an adaptation of the simple resistance-capacitance charge or discharge characteristic. The capacitor was allowed to charge (say) to a certain voltage level; this level could be altered by means of a potentiometer, thus giving variation in the timing.

This arrangement is not inherently synchronous, and so 50c/s peaks from a peaker transformer are superimposed on this curve, Fig. 2. Despite this, if the slope of the curve is not very steep, and the supply voltage—from which the calibration voltage is derived—varies, it is possible to gain or lose one cycle, more especially if the potentiometer setting is not accurate.

* *The British Thomson-Houston Co. Ltd.*
† *Patent applied for.*

Therefore a system which depends on the position of a glow in a counting tube—a pure digital system, must possess a considerable advantage.

Digital systems were available before counting tubes

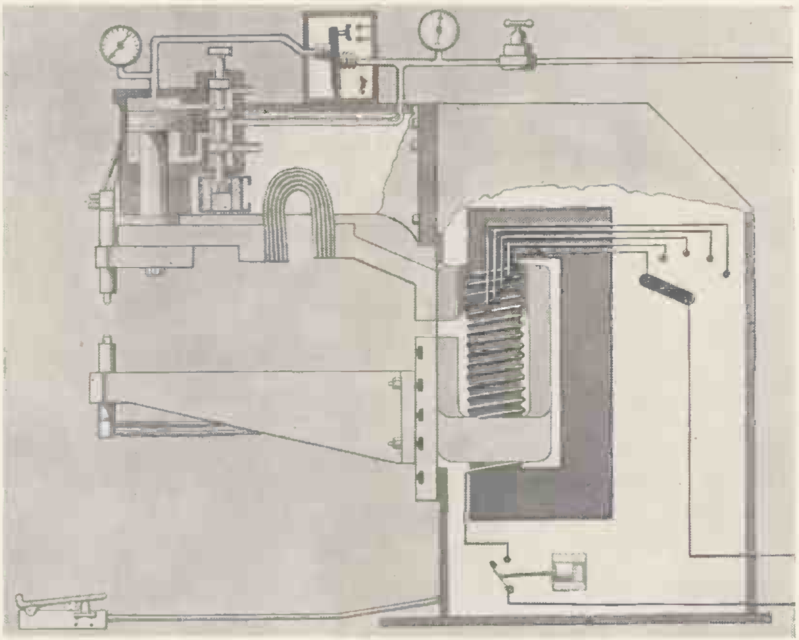


Fig. 1. Diagrammatic view of a welding machine.
The current carrying electrodes first clamp the work, then when the air pressure has reached a suitably high value the welding is allowed to proceed.

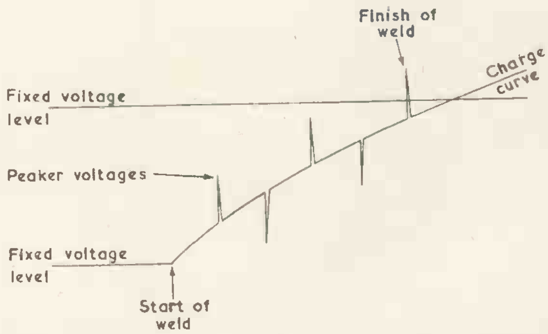


Fig. 2. Charging curve with 50c/s peaks superimposed

were made and indeed they have been used for welding control, but their complexity in the past was such they could not compete in price with the *RC* type of timer.

The Basic Dekatron Circuit

The basic circuit for "seam" and "spot" welding will now be described.

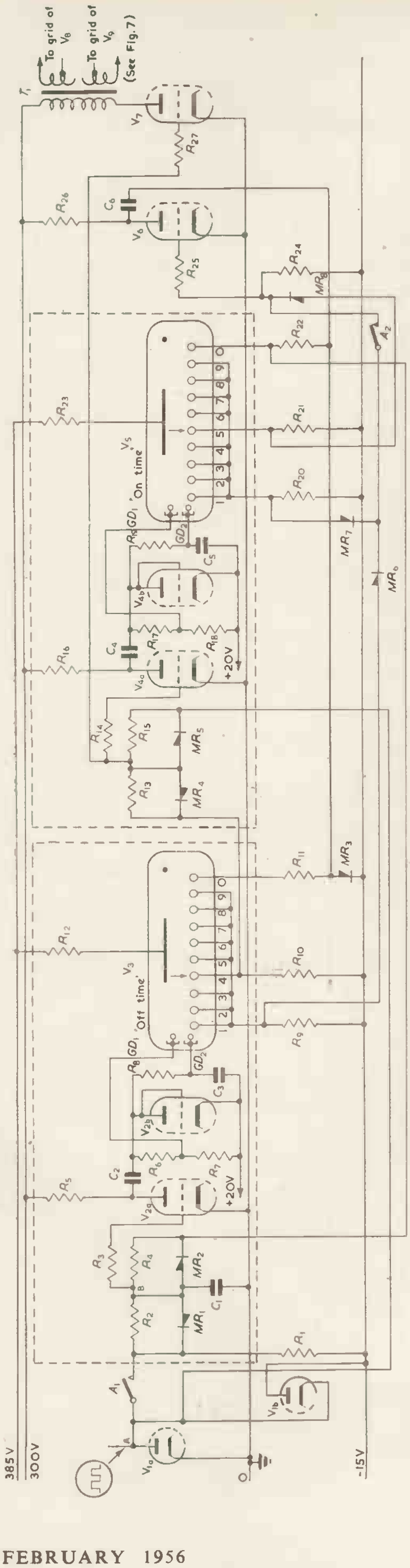


Fig. 3. "Seam" 4 off, 5 on

The logical approach to the counting tube circuit was to use two tubes. One would control the "off" or "cool" cycles and the other the "on" or "heat" cycles. By this means, the functions of the tubes could be dissociated from each other.

Seam Welding

A seam weld of 4 cycles OFF and 5 cycles ON will be described first, and reference should be made to Fig. 3, which shows the circuit in a simplified form, and to Fig. 4 which shows the idealized voltage waveforms at various points.

The basis of all timing in the control circuit is a 50c/s square wave extending in magnitude from -15V to 0V on the main voltage chain. The phase of this square wave

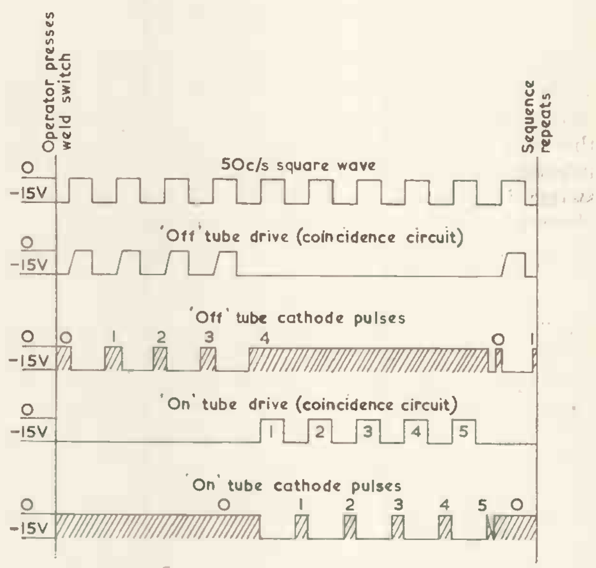


Fig. 4. "Seam" 4 off, 5 on. (Refers to Fig. 3)

may be varied in time since it is derived by clipping a 200V (r.m.s.) sine wave obtained from a phase-shift bridge, amplifying the clipped wave, and then clipping again at the same levels as before.

This produces a square wave with exceedingly steep leading and trailing edges which exists at point A.

When the equipment is switched on to the supply the Dekatrons are quiescent with their glow discharges on the cathodes 0. The circuit arrangement for doing this is not shown, but is quite simple. On the weld being initiated by the operators' switch, contact A_1 closes and contact A_2 opens after the electrode pressure switch has closed. The square wave is therefore applied to one side of the coincidence circuit formed by components $R_2R_3R_4MR_1MR_2$. However, since the other side of the coincidence circuit is returned to cathode 0 of the ON Dekatron, (on which this glow is quiescent), a distorted form of the square wave appears at point B, and hence is applied to the grid of V_{2a} driving this valve and causing the OFF Dekatron to be driven at 50c/s.

The glow discharge therefore steps from cathode 0 round the tube until it reaches cathode 4. This cathode is the selected cathode of the OFF tube and the voltage signal from the cathode is applied to one side of the coincidence circuit formed by $R_{13}R_{14}R_{15}MR_4MR_5$; since the square wave is applied to the other side, the square wave appears at the grid of V_{4a} driving this valve.

The ON Dekatron is therefore driven at 50c/s, but as soon as the discharge leaves cathode 0 the coincidence signal for the OFF tube drive is destroyed, leaving the OFF tube with its glow on cathode 4.

The ON tube continues running until the glow discharge reaches cathode 5 when the voltage signal is applied to the grid of V_6 turning this valve on. The large negative voltage swing at the anode is applied via C_6 to the top of MR_3 which is in the path of both cathodes 0.

This swing causes both counting tubes to reset to their cathodes 0 in a very short interval of time, much less than one cycle.

Conditions now are the same as when the weld was first initiated, and the sequence will repeat indefinitely until it is terminated by contact A_1 opening and A_2 closing.

The principle of starting the sequence with the OFF tube ensures that a synchronous start to the weld is always made, since the operator may close his initiating switch at any time. A ragged or asynchronous start will only affect the OFF cycles.

Again the operator will release his switch when the seam is complete, it may so happen that he releases his switch in the middle of the ON cycles. The 50c/s drive to the right-hand side of the coincidence network cannot be interrupted, and so if the ON tube is running when the switch is released the sequence destroys itself in a synchronous manner. That is to say the last number of heat cycles may be short in number, perhaps two instead of five say, but nevertheless they will be integral.

This termination is achieved by connecting the top of the "common" cathode (i.e. not cathode 0 or the selected cathode) resistor R_{20} through rectifier MR_7 and normally closed contact A_2 to the grid of reset valve V_6. As the common cathode pulses occur in the periods when the 50c/s pulses are absent, the resetting of the Dekatrons is carried out without disturbing these square pulses. (Fig. 4).

If the operator releases his switch when the OFF tube is running the 50c/s drive is interrupted, and a resetting signal is transmitted from the upper end of resistor R_9 via rectifier MR_6 to the grid of the reset valve. Both Dekatrons therefore reset.

"Spot" Welding (Figs. 5 and 6)

When "spot" welding a delay time (OFF cycles) must be selected before the ON cycles commence. This must be so because of the necessity for a synchronous start to the weld. This variable delay time is an asset in some welders, allowing electrode pressure to build up sufficiently.

The sequence for a delay of 3 cycles with a weld of 4 cycles is as follows: When contacts A_1 and A_2 close and open respectively, the OFF tube discharge runs from cathode 0 to cathode 3 when it stops, and the ON tube discharge runs until it reaches its selected cathode. There is now no connexion from this cathode to the grid of V_6, but instead the voltage signal from the selected cathode is transmitted via rectifier MR_9 directly to the grid of V_{2a}.

This signal turns valve V_{2a} on and the glow on the OFF tube is driven on by one position to cathode 4. The coincidence for the ON tube is therefore destroyed and the ON tube is therefore left with the glow on the selected cathode. The OFF tube is left at cathode 4, one in advance of its selected cathode.

As long as contact A_1 is closed and A_2 is open, that is the weld switch has remained pressed, the counting tubes will stay in this condition and form a record of the last weld made. On releasing the weld switch the tubes reset to their cathodes 0 as in the seam weld at the conclusion of welding.

Summarizing the description of the circuits so far. The OFF tube is always arranged to run first ensuring a synchronous start. The drive to the ON tube cannot be

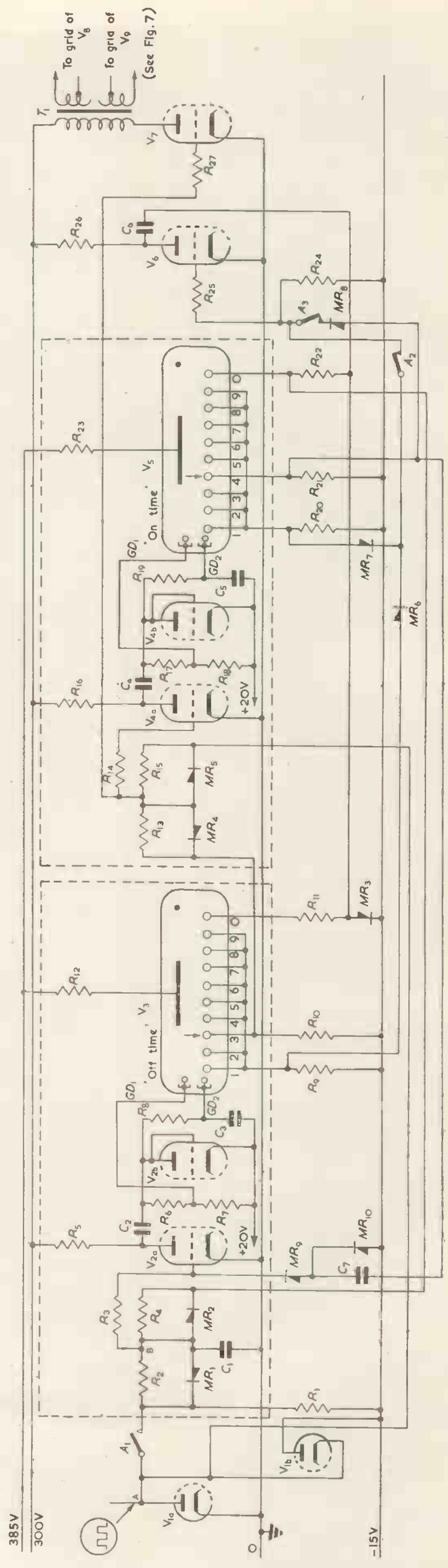


Fig. 5. "Spot" 3 off, 4 on

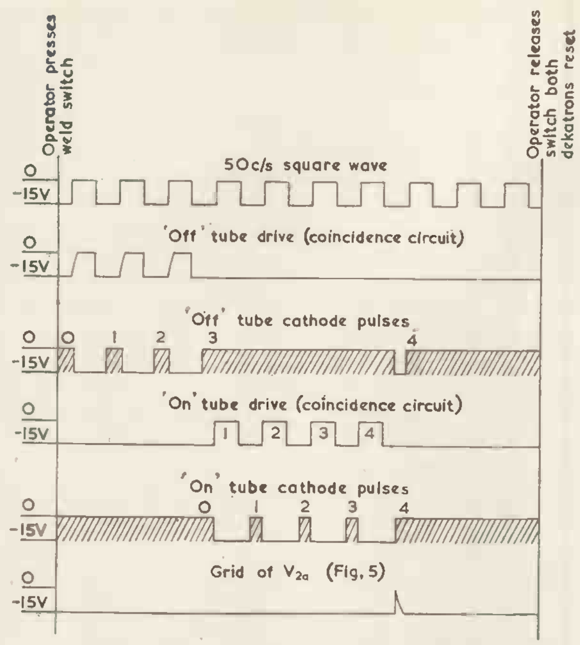


Fig. 6. "Spot" 3 off, 4 on (refers to Fig. 5)

destroyed except by its own action, ensuring a synchronous finish.

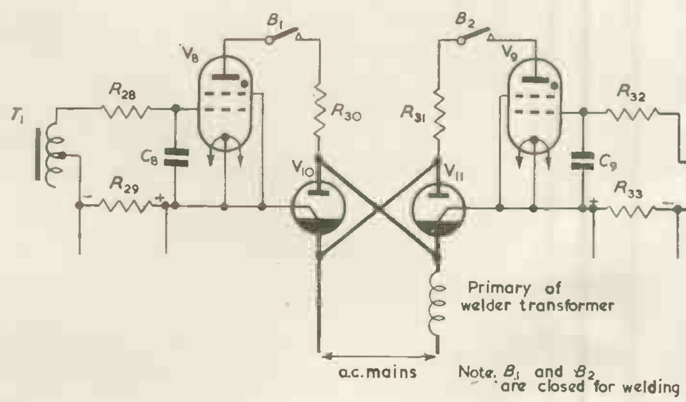
As there is one Dekatron for both OFF and ON tubes, the maximum weld times are 9 cycles OFF and 9 cycles ON for "seam" welding and 9 ON with a delay of 9 cycles before the weld starts for "spot" welding.

The Power Valve Drive

It will be seen from Figs. 4 and 6 that the square pulses at the centre of the coincidence circuit for the ON Dekatron can be used for driving the power tubes since they are correct in number; the leading edge of the pulse may be used to fire the leading trigger thyratron V_8 (Fig. 7) and the trailing edge to fire trigger thyratron V_9, as these edges differ by 180° in phase. Moreover, as the phase of the square wave can be varied the power valves can be fired at any points in their cycles.

The method of using the square pulses is to drive valve V_7 from the centre of the ON tube coincidence circuit. This valve has transformer T_1 in its anode circuit. The secondaries of this transformer drive the trigger thyratrons which in turn drive the Ignitrons. The circuit arrangement is shown in Fig. 7 and the waveforms of the voltages applied to the trigger tube grids in Fig. 8.

Fig. 7. Simplified arrangement of power tubes



Some distortion of the square wave occurs in the transformer, but this is immaterial since the leading and trailing edges are still exceedingly steep. As the positive firing pulses also dwell for 180°, it is impossible to make this welding control "half-wave". This is a condition where pulses of short duration are employed to trigger the trigger thyratrons, and the operator tries to advance the firing points more than the natural power factor of the machine will permit. The result is that the current through one ignitron has not extinguished when the peak voltage tries to fire the other ignitron, and when the current does die away in the first ignitron the voltage peak has collapsed. The tendency is therefore for one ignitron only to fire, hence the term.

The so-called "square wave firing" employed in this circuit eliminates any risk of this and is the advantage mentioned earlier in the text.

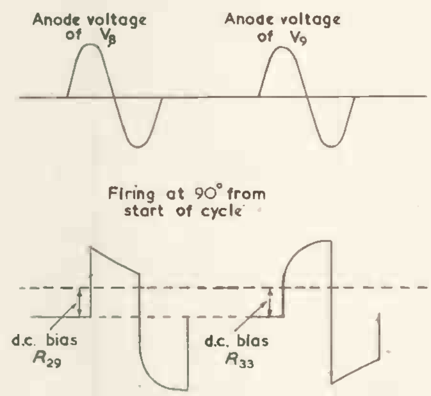


Fig. 8. Grid voltage waveforms of trigger tubes V_8 and V_9. (Refers to Fig. 7)

The FW25C5 Cubicle with FW39C6 Tray

This title designates a manufactured welding control using Dekatron timing. (Figs. 9 and 10). When fitted with the correct Ignitrons this cubicle and tray can control up to 2 400kVA.

The Ignitrons with the trigger tubes and associated equipment are mounted in the cubicle while the control circuit proper is mounted in a tray which is easily removable. The cubicle has a very small cross-sectional area, approximately 18in by 18in, and the controls are at a convenient height.

The Dekatrons are mounted so that when the front cover of the tray is opened they are immediately visible. Fig. 10 illustrates that the tray has an extra feature which has not yet been described. The tray is capable of controlling "long spot" welds, that is welds of a "spot" type, but with a duration of up to 90 cycles. This is accomplished by connecting the OFF tube as a decade of the ON tube. Thus, while the ON tube counts cycles, the OFF tube counts tens of cycles. The essential features of the control still apply, the welds are fully synchronous, but the delay before the weld commences is now no longer variable and is limited to one cycle.

This circuit has not been described because it involves very small changes to the circuits already detailed and it involves no new principles. There is little point in constructing a tray of this nature without the three facilities "seam, spot and long spot", because the change required to alter one circuit to another is very small.

The Dekatron sub-units are each mounted on a separate plug-in chassis, this can be discerned in Fig. 10. These sub-units comprise the components enclosed in the dotted lines on the simplified key diagrams. At first thought there seems little point in constructing these sub-units as they are not interchangeable, but this is not so. The advantage lies in being able to insert one sub-unit at a time. This facility enables tests of the control circuit to be carried out part by part, providing that a simple temporary connexion is made. The Dekatron tubes, of course, act as indicators and it is thus possible to test the control circuit without any instruments.

Fig. 9. The manufactured equipment with front cubicle cover removed.
The main fuses, safety contactor, trigger thyratrons and BK24 ignitrons are clearly visible.

Conclusion

At the moment the use of cold cathode counting tubes for resistance welding appears so attractive that it seems unlikely a return will ever be made to resistance-capacitance methods of timing, at least for synchronous equipments fitted with heat control.

Turning to the practical aspect, a digital device needs no calibration or "trimming". It is sometimes forgotten that *RC* timing circuits must be trimmed to give correct calibration, and this may be a complex matter with multi-range dials. If the preset trimmers are interfered with, re-calibration is difficult on site. In contrast to this the Dekatron welding control has no preset controls whatsoever.

The device is also very insensitive to voltage fluctuations as the counting tubes themselves are not voltage sensitive, and the rest of the circuit may be considered as a pulse-operated device, ample margin being allowed on the magnitudes of the pulses.

There is little doubt that the fact that the welding sequence can be seen to be taking place is a very great asset. Apart from the confidence it gives the user it may even be used to detect faults in the welding machine. An example of this was a spot welder giving too much heat on a setting where previously the amount was correct. From the examination of the sequence on the Dekatrons the fault was obvious. The pressure switch which starts the weld when the electrode pressure has reached its full value was not closing cleanly, but was first closing, then opening and then closing again. The OFF Dekatron could be seen to complete its run, the ON Dekatron could be seen to start its run but not complete it. Both Dekatrons would then reset and then carry out a complete sequence. The second amount of heat was correct, the first additional and unwanted.

From the theoretical aspect, it appears many control circuits can be considerably simplified by the use of counting tubes. As an example the so-called 3-1 phase welding circuit can be made relatively simply. This is a scheme where the welder transformer primary has 3-phase windings, but only one secondary. Each phase of the primary winding has a pair of Ignitrons (in inverse parallel) connected in series with it. If the primary windings are allowed to conduct in a certain sequence the secondary winding produces a low frequency voltage wave. The main advantage of this type of control is that the welding load which may be quite heavy—is distributed equally among the three supply phases.

The resistance welds described in this article are very simple, but some welding work may require different electrode pressures during the process, or it may require gradual rise of heat at the beginning of the weld and gradual fall of heat at the end. In other words several "orders" must be given by the control. This may be easily accomplished by using one Dekatron as an "order" or "control" tube, the glow discharge on various cathodes being used to control the process. One tube may therefore give up to ten orders. This fact has considerable implications for automatic welding processes.

Fig. 10. The front cover of the tray opened to show the controls.
The machine is set at "Seam" 8c/s "Cool" and 8c/s "Heat".

It is now possible to correlate the functions of a welding machine with other mechanical or electrical functions in a process involving a complex fabricated structure. The welding control may even lose its distinctive nature and form part of a larger control mechanism. The input information to this mechanism could be impressed on punched tape, magnetic tape, or conveyed by some other well established means.

It follows, therefore, that the most significant advance in technique may be the control field, and not just the fact that an analogue method of timing has been changed to a digital method.

Acknowledgments

The author wishes to thank the Directors of The British Thomson-Houston Co. Ltd, for permission to publish this article.

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The Recording of High-Speed Single Stroke Electrical Transients

(Part 2)

By D. R. Hardy*, M.Sc.(Eng.) Ph.D., A.M.I.E.E., B. Jackson†, M.Sc., and R. Feinberg**, Dr.Ing., M.Sc., A.M.I.E.E.

Circuit Techniques

Time-base Generators

Time-base Generators with Spark Gaps

Because of the large deflector voltages required, spark-gaps were almost universally employed in the past as the switching unit for the time-base generator of the continuously evacuated oscillograph.

Most time-base generators of this type employ three balls, the centre of which acts as a trigger electrode and causes the two gaps to spark over when a trigger pulse is applied. Spark-gaps, particularly those with small electrodes, are characterized by their variation in time lag to breakdown unless some form of irradiation is provided. This may be applied in the form of radioactive materials or, more economically, by the ultra violet radiations from a self-illuminating gap of the trigatron type[51].

However, the time lag variation may still be of the order of 10^{-7}sec[52], and the development of gas filled and hard valves which operate at high voltages and with large peak currents, together with the advent of the sealed-off tube with its lower operating voltage, has rendered the spark-gap obsolescent and it is rarely to be found in the modern equipment.

Time-base Generators with Gas-filled Valves

Gas-filled valves are used to perform the same function in the time-base generator as the spark-gaps of earlier designs. They possess the advantages of more reliable performance, operate with smaller trigger voltages and shorter time delays, and will handle large peak currents with little deterioration.

Mercury vapour valves are obtainable over a wide range of voltages and currents, but from the point of view of short ionization time (and short recovery times for repetitive work) are inferior to the recently introduced hydrogen filled valves[53]. Such valves when operating under recommended conditions have a firing delay of about 10^{-7}sec with a variation of, perhaps, 10^{-8}sec[54].

Time-bases using hydrogen thyratrons have been described[55] and near-linear sweep speeds of about 10^{9}cm/sec have been obtained[56] with a cathode-ray tube having an accelerating voltage of 10kV. A hydrogen thyratron circuit of similar performance has been reported with which time-base sweeps of about $2{\cdot}5 \times 10^{8}$cm/sec have been obtained with a Du Mont type 5RP-A oscillograph tube.

Time-base Generators with Vacuum Valves

The time delay which can be permitted in the time-base generator may, in the high sweep speed domain, restrict the choice of circuit to be employed for a particular problem. Vacuum valve time-bases used in conjunction with highly stabilized power supplies have been constructed with an inherent time delay of less than 10^{-8}sec with negligible "jitter", and are usually to be preferred where stringent synchronization conditions exist.

High-speed transient oscillographs are necessarily constructed with cathode-ray tubes which have an accelerating voltage of at least 10kV, in order to obtain the trace brightness required to record satisfactorily. The sweep voltage for such a tube without post deflector acceleration is probably of the order of 2 to 3kV so that for a sweep speed of 10^{-8}sec and plate and lead capacitance of 20pF, a peak charging current of about 5A is required. Valves type 715 and 5D21 have peak currents in excess of 15A and will withstand anode voltages of 12kV and upwards. The Mullard type PL81 miniature valve will withstand a peak anode voltage of 7kV, but the cathode current should not exceed 1A or so under short pulse conditions.

Bauer and Nethercot[13] have described an oscillograph in which a cathode-ray tube with straight acceleration (GEC type 908BCC) is used. Time sweeps of 5×10^{-8}sec duration, with a trigger delay time of less than 4×10^{-8}sec, were obtained with valves type EF55. The time-base output valve was operated with equal anode and cathode loads and a pulse transformer used to give the necessary grid-cathode pulse amplitude. Maximum recordable writing speeds of about 2×10^{9}cm/sec were attained with a temporal resolution of about 10^{-9}sec.

Fletcher[58] described a time-base for use with Lee's oscillograph[34], which has a minimum sweep duration of 3×10^{-9}sec with a trigger variation of 10^{-10}sec. A pentode type 3D21 operating at 4kV and drawing saturation currents of up to 10A during the actual scan, was employed as time-base generator and the time of sweep varied by changing the cathode temperature.

The use of post deflector accelerator tubes simplifies the design of time-base in that smaller working voltages are required and many valves are available which have the required characteristics as well as the necessary reserve of cathode emission to give the high peak currents required for this work.

A time-base has been described[59], using valves type CV2127 (6CH6), for use with a GEC post deflector accelerator tube type VCRX357A. The circuit produces a rate of change of time-base voltage of 5kV/μsec, which corresponds to a time sweep duration of 10^{-7}sec, and has a time delay of 10^{-8}sec.

Moody and McLusky[60] describe a time-base circuit, used with a DuMont 5XP11 sealed-off cathode-ray tube with 2kV straight acceleration and 10kV post deflexion acceleration, in which the 250V paraphase time-base waveforms are produced by valves type EL31, and which has a minimum time sweep duration of 10^{-7}sec.

Trigger Circuits

The design of trigger circuits for use with high speed time-bases depends essentially on the nature of the initiating pulse, the output pulse required in order to operate the time-base and on the overall time delay which can be

* *Formerly University of Manchester, now with Brush Electrical Engineering Company Limited.*
† *Formerly University of Manchester, now with Electrical and Musical Industries Limited.*
** *Ferranti Limited.*

tolerated. The initiating pulse may be obtained as a result of some manual operation under the control of the operator or, alternatively, may be produced by an event which occurs at random. In the former case the design of trigger circuit is less stringent if the overall time delay which occurs between the mechanical operation and the appearance of the final pulse is not critical. In the latter, the minimum possible time delay must be ensured, since the signal under investigation must itself be delayed by this interval before arriving at the oscillograph signal deflector system.

Conventional Vacuum Valve Circuits

The vacuum valve has been used for many years as the basis of trigger circuit design in the microsecond domain. Circuits developed during the war years for use in radiolocation employed valves of conventional design, examples of which are the 6SN7 (double triode), 6AG7 and EF55 (pentodes) and 807 (tetrode).

More recently, miniature valves such as types 12AT7 (double triode), 6CH6 and CV2179 (pentodes) and PL81 (tetrode) have been introduced. The interelectrode capacitances have in general been reduced and the smaller physical size of the circuit layout has enabled loop inductance and wiring capacitance to be reduced, with a corresponding improvement in performance. These, however, are now being replaced in many applications by the secondary emission type of valve (see later).

Trigger Circuits with Gas-filled Valves

Thyratron pulse generators may be employed if the available initiating pulse is greater than, say, a few volts.

The ionization time of gas-filled valves varies according to type, but may be taken as a few microseconds for mercury vapour valves operated with a grid pulse which just exceeds the critical value[53], about $1{\cdot}4 \pm 0{\cdot}4\mu$sec for an argon thyratron type GTIC[61] and less than $0{\cdot}1\mu$sec for a xenon filled valve type 2D21 operated with a large positive pulse[62].

Whereas mercury thyratrons have been little used, the argon thyratron (type GTIC) has been employed[21,56] in such trigger circuits, but a variation in the time of operation of greater than $0{\cdot}1\mu$sec may occur even with stabilized power supplies. The xenon or hydrogen thyratrons which are superior in this respect are, therefore, to be recommended.

Results obtained by Dixon and Neher[63] for types 2D21 and 2050 indicate that immediately after triggering the current rises to half final value in 10^{-8}sec and then in a low inductance circuit, increases to full value (which, in the case of the 2D21, is a peak current of 8A) in a further 3×10^{-10}sec. The ionization time for both types was reduced when high anode voltages of 1 to 5kV were used. Fletcher[58] also used the 2D21 as a trigger generator and observed a variation in firing delay of only 10^{-10}sec. Lewis and Wells[44] claim a jitter of less than 10^{-9}sec provided the power supplies are stable, and the rise time of the front edge of the output pulse is given as 10^{-8}sec for a type 2D21 and 5×10^{-9}sec for a type 2050.

Hydrogen thyratrons with equally attractive characteristics are available over a wide range of working voltages. A miniature hydrogen thyratron referred to as type 5C22* is said to have an ionization time of a few millimicroseconds[64].

Hydrogen thyratrons of larger capacities are available which range from the BTH type BT79 with a working voltage of 3kV and peak current 35A to the Mullard type 5C22 which has a maximum anode voltage of 16kV and a peak current of 325A.

* *This valve does not appear to be identical with the Mullard 5C22.*

Trigger Circuits with Secondary Emission Valves

The secondary emission type of valve is probably the most useful element in high speed trigger circuits which operate in the millimicrosecond domain. Since it is a vacuum valve it does not suffer the comparatively long ionization times and associated jitter of gas-filled valves. Because of a higher band figure of merit, the secondary emission valve has in many cases superseded normal type pentodes for high speed pulse production. Additional features which are frequently of value are that amplification may be obtained without phase inversion if a load resistor is placed in the dynode circuit and that the anode current is many times greater than the cathode current. This latter property was used by Wells[62] in the design of his trigger circuit. Moody and McLusky[60] describe a circuit which has an overall time delay of not greater than 10^{-8}sec and will operate with an input signal amplitude as low as 0·2V. The sensitive trigger pulse amplifier described in an earlier publication[65] employs a secondary emission valve type EFP60 and a pentode type 6AK5, and has a trigger time as short as 3×10^{-9}sec. The output impedance is 75Ω, across which is produced a pulse of 16V amplitude.

Mechanical Relay Pulse Generators

Mechanical relays suitable for operation at low switching potentials have been produced[66] which have platinum contacts, wetted with mercury, and enclosed in hydrogen at about 10 atmospheres pressure. Pulses of either polarity may be produced by this device and have rise times of less than 2×10^{-10}sec[67].

Such relays appear to be reliable at potentials of less than 10V if no spark occurs or, at potentials greater than 100V when a gas discharge occurs before the contacts close[44]. At intermediate voltages, operation is found to be unsatisfactory due to the presence of a number of irregular pulses which appear at the output.

Whitby[68] has described relays of a coaxial design which have platinum contacts capable of handling larger powers and which give pulses with rise times of 10^{-9}sec. If the contacts are adjusted so they do not close completely, a gas discharge occurs which leads to a rapid build up of current. The relay may be used at up to 600V and possibly higher if the gas pressure is raised.

Transistors[69]

So far as is known, transistors have not yet been used extensively in high speed trigger circuits. Typical pulse rise times of about 10^{-7}sec have been obtained, which are independent of voltage up to a maximum pulse amplitude of about 50V. Claims have been made of much shorter rise times, but it seems likely that these figures were obtained with selected transistors and may be difficult to reproduce.

Brightening Pulse Generators

In order to prevent damage to the screen, the current in the electron beam of the cathode-ray tube is arranged to have a maximum value only during the actual time sweep. This is achieved in practice by the application of a negative pulse to the cathode or a positive pulse to the modulator of the cathode-ray tube, either of which should have a duration ideally equal to that of the time sweep.

It is sometimes convenient to obtain such a pulse by differentiating the time sweep voltage, but such a procedure may result in the early part of the signal being lost at high sweep speeds because of the inherent time delay of the brightening pulse amplifier. Alternatively, the time sweep may be triggered from the brightening pulse amplifier but, in this case, an undue delay in operation of the time-base may result in background illumination from the stationary or slowly moving spot with a corresponding reduction in overall contrast[56].

For the slower sweeps the trigger circuits of the previous section may be arranged to give sharp fronted, flat topped pulses of sufficient duration. A beam trap tube of the type described by Feinberg et al[15] may be used successfully at faster sweep speeds since brightening pulses which have longer time durations than the actual time sweep can be used with this type of tube without undue background illumination.

Potential Dividers

Potential dividers consisting of resistive or capacitive elements, or both, have for many years been the accepted method of reducing the amplitude of high voltage electrical transients to a voltage level which can be displayed on a conventional type cathode-ray oscillograph[70]. Many papers have since appeared in the literature[43] in which the effect of stray capacitance, inductance and characteristics of various types of delay cables have been considered, one of the more recent being that by Howard[71].

It is claimed[72] that resistive dividers can be used without serious error over the range 0 to 10Mc/s and the compensated resistance-capacitance types up to 1 000Mc/s. A divider of the resistance-capacitance type for use at 30kV was found to have an error of 5 per cent at 30Mc/s, but it was estimated that reasonable accuracy would be maintained up to 100Mc/s[13]. For very high frequencies (greater than, say, 100Mc/s) the type of divider described by Fletcher[58] should prove more suitable. Two concentric coaxial transmission lines are used, one of which has a dielectric of titanium dioxide ceramic with a dielectric constant of 85 and the other, the more conventional polythene, with a dielectric constant of 2·25. The dimensions are such that the divider ratio is 100 : 1.

Wide Band Amplifiers

It has been seen that cathode-ray tubes capable of recording fast transients invariably have a straight accelerating voltage of not less than 2kV with a corresponding maximum deflexion sensitivity of about 0·3mm/V. In many problems the signal under investigation will have an amplitude of very much less than that required to give a reasonable deflexion.

Amplifiers of conventional design with resistance-capacitance coupling have an upper limit to the range of frequencies which can be handled without much loss of gain and in most designs this occurs at a bandwidth of the order of 10Mc/s.

Secondary emission valves type EFP60 have been used in a four-stage design which employs intervalve filter type couplings to give an amplification of 4·7 per stage with a bandwidth of about 50Mc/s[65]. A further design[73] using nine secondary emission valves type VX5038 in cascade, gave an overall gain of 1 000 with a bandwidth of 100Mc/s, whereas with valves type 6AK5 (miniature pentode), the same gain was obtained with a bandwidth of only 70Mc/s.

In recent years much attention has been given to the construction of distributed amplifiers within the frequency range 100 to 200Mc/s[74] with gains of up to 100. Such an amplifier has also been constructed which has a gain of 5 000 and with a bandwidth of 150Mc/s[75]. Larger bandwidths may be obtained at the expense of gain; amplifiers with bandwidths of nearly 400Mc/s, but with gains of only 2·8, have been designed[76]. Detailed design considerations are discussed by the authors referred to above and also by Lewis and Wells[44].

Photographic Techniques

A signal applied to the deflector system of a cathode-ray oscillograph may be translated into a permanent record, either as a result of the beam electrons impinging directly on a sensitive material placed sometimes outside or, more usually, inside the tube itself or through the medium of a luminescent screen, the light output from which reacts on a photographic emulsion.

The former method which has been used for many years with conventional continuously-evacuated oscillographs, and is now being employed in the recently introduced micro-oscillographs, demands high energy electrons in order to penetrate the gelatin layer of the usual type of photographic emulsion. Some reduction in accelerating voltage is possible by the use of special plates in which the density of silver halide particles is increased at the surface of the emulsion.

Exposure Time Considerations[77]

In the photography of repetitive traces the exposure time which may be permitted in order to obtain an image of good resolution is determined by the jitter or random time variations both in the time-base generator of the oscillograph and in the occurrence of the signal under observation, and under favourable conditions may be as long as several minutes. With single sweep traces, however, the exposure time for the slower sweeps is determined by the diameter of the spot and its velocity. Since the various screen phosphors respond differently to a given excitation in that the rates of build up and decay of light output vary considerably, the exposure time may also be affected by the choice of screen material. When the build up and decay times are small compared with the sweep duration this effect can be ignored and the exposure time is then given by the quotient of trace width and writing speed of the beam.

The effective exposure time for high speed transients may be very much less than a microsecond. It is well known that the Bunsen-Roscoe reciprocity law, which states that the density of a photographic image is constant provided the product of exposure time and intensity of illumination is constant, does not apply for such short exposure times. The relative speed of an emulsion falls asymptotically to a finite value as the exposure time is reduced. With short persistence screens, however, the exposure time is constant so long as the writing speed exceeds about one trace width per microsecond, since the exposure is then entirely governed by the decay characteristics of the screen. The fastest obtainable films and lenses must therefore be used in order to record such traces. Ideally the best results would be obtained with a fast emulsion which has a maximum sensitivity at the peak emission wavelength of the screen phosphor, but as yet no such correspondence has been found practicable[78]. The compromise usually adopted is to use a blue screen with a peak emission at about 0·43μ and a fast emulsion such as Ilford 5G91 with a maximum sensitivity at about 0·56μ and about half maximum at 0·43μ.

Choice of Lens

Because of the short exposure times available, the choice of camera lens is restricted to those with the widest apertures. The Wray $f/1$ copying lens, which has a magnification M of 0·25 and, hence, an effective aperture of $f/1{\cdot}25$, is specially corrected for minimum spherical aberration and bloomed for blue-green light with minimum chromatic aberration, and allows a 9cm cathode-ray tube trace length to be conveniently recorded on 35mm film.

Choice of Materials

A small inertia, which may be defined as the exposure indicated for zero density when the linear portion of the gamma curve is extended, is more desirable than a high gamma or contrast for the recording of high speed transients. Fast emulsions which possess this property usually suffer from the practical disadvantage of a large grain size which, in turn, limits resolution if small values of image/object magnification ratio are used.

If large variations in writing speed occur in a particular trace and the lens aperture is set to give the correct density for the faster parts of the trace, the resulting over exposure of the slower parts causes the image to spread and, perhaps, obliterate the faster and less dense portions. Films are available such as the Ilford 5B52 in which this difficulty has been overcome by incorporating a yellow dye in the emulsion and coating it on an orange base. Although ranges in writing speed of 10 000:1 may be satisfactorily recorded with this type of film, the effective emulsion speed is only some 25 per cent of that of the fastest films and is, therefore, unsuitable at the present stage of development for the recording of very high speed traces.

However, the principle may be employed to give improved recording at slower speeds if the recently developed tubes[15] with their increased light output are used in conjunction with such films.

Processing

A density above fog of 0·1 (which corresponds to a difference in light transmission of 12·5 per cent) is generally accepted as standard for the limiting condition at which a trace may be distinguished from its background, although levels of 0·02 above fog have been identified[79].

This density difference is used as a datum at which parameters such as maximum recordable writing speeds may be compared.

It is known (the Kron effect) that a photographic image produced by light of high intensity develops more slowly than a normal image. This has been quantitatively illustrated with different developers and times of development by Berg[80], but no evidence of low intensity reciprocity failure at low light levels was observed with exposure times down to 10^{-4}sec. It was shown, however, that the negative density for a given exposure was increased some three times, and the relative speed at a density of 0·1 above fog was increased by up to 50 per cent by over-development in a vigorous developer.

The processes of hyper-sensitization (treatment before exposure) and latensification (treatment after exposure) may give an increase in relative speed of up to two or three times[81] with normal development, but become less effective as the development time is increased. It has been confirmed[15] that no appreciable increase in relative speed is obtained over a wide range of pre- and post-exposures of different intensity.

Conclusions

The sealed-off cathode-ray tube with its advantages in cost and physical size and its wide variety of operating conditions has received considerable attention over the past twenty years or so, whereas little has been published regarding the conventional form of continuously evacuated oscillograph.

The performance of the sealed-off type of tube has been improved to such an extent that writing speed is no longer the limiting factor in determining maximum temporal resolution, which is now set at a limit of about 5×10^{-11}sec by the design of the signal deflector system. Transients which have a frequency spectrum containing components of up to 1 000Mc/s may now be displayed with a fair degree of confidence. It is possible to extend this bandwidth up to 10 000Mc/s, but attenuation at this frequency may then be as high as 70 per cent.

The introduction of the post deflexion acceleration technique has simplified the problem of small amplitude pulse recording with macro-oscillograph tubes since the voltage output required from the signal amplifier may now be appreciably reduced. Whereas sealed-off tubes have the advantage of greater deflexion sensitivity over conventional continuously evacuated types because of the lower accelerating voltages employed, the micro-oscillograph with its small spot size, may enable deflexion sensitivities in terms of spot widths per volt to be obtained which exceed even those of the sealed-off tubes with post deflexion acceleration*.

Improvements in the performance of time-bases and their associated trigger pulse and brightening pulse circuits have been quite remarkable, and have resulted, in part, from the many types of valve which have become available in recent years.

Wide aperture lenses which have been specially designed for work in the blue-green part of the spectrum may now be obtained at reasonable cost. Photographic emulsions are now produced which, when used in conjunction with recommended developers, are able to satisfy all but the most stringent requirements of high speed recording. An increase in sensitivity has been obtained with experimental emulsions, but usually at the expense of a coarser grain.

Progress has been reported in the design of conventional type potential dividers, but of greater interest is the coaxial divider described by Fletcher, since this lends itself more readily to the type of equipment employed in experimental investigations which involve high voltage transients of very short duration.

The introduction of distributed amplifiers has now enabled recordings to be made of low voltage transients of much shorter durations than hitherto. Further development is necessary before the performance of these amplifiers, in terms of frequency response, becomes equal to that of the cathode-ray tube signal deflector system.

Acknowledgment

The General Electric Company Limited very kindly supplied the photographs reproduced in Fig. 1 and information on the performance of the tubes.

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* *An oscillograph built by Central Research Laboratories, U.S.A., appears to be based on the design of Lee[34] and to incorporate the deflector system of Smith et al[32]. The deflexion sensitivity of this tube is given as 0·2V/spot width.*

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New International Radio Station in Australia

Communication between Australia and the rest of the world was accelerated by the opening of a new international radio receiving station last October by the Overseas Telecommunication Commission (Australia).

The station, in New South Wales, and one of a network operated by the Commission, will play a big part in the relaying and receiving of messages to and from all parts of the world during the Olympic Games in Melbourne in 1956.

It provides new radio telephone and radio telegraph channels between Australia and the British Solomon Islands, Canada, Ceylon, China, Fiji, Hong Kong, India, Indonesia, Lord Howe Island, Malaya, Macquarie Island and Mawson (Antarctica), Nauru, Netherlands, New Caledonia, New Zealand, Papua-New Guinea, the Philippines, Portuguese Timor, ships at sea, South Africa, the United Kingdom (relaying to other countries), and the United States (also relaying to other countries).

The new receiving station at Bringelly is built on 544 acres in a rural area about 30 miles west of Sydney, capital of New South Wales. The system consists of 32 rhombic serials supported on 104 wooden masts ranging in height from 70ft to 120ft.

The receiving hall, in the main building, is designed to accommodate 70 receivers, of which 42 are being installed in the initial stages, including independent sideband receivers for radio-telephone services and special radio-telegraph receivers for use with the most modern techniques in channelling and keying. Any receiver may be monitored through a central control desk, receivers being selected merely by dialling as on a standard automatic telephone.

Bringelly is linked with the Commission's central operating room in Sydney General Post Office by 14 telephone lines. Direct telephones are also provided to each centre for circuit control, and a private automatic branch exchange provides external and internal communication.

The London Audio Fair 1956

The first London Audio Fair is to be held at The Washington Hotel, Curzon Street, W.1, on Friday, Saturday and Sunday, 13-15 April, 1956. The opening hours will be 11 a.m. to 9 p.m. each day.

The Fair is being organized by a Committee of six members representing companies engaged in the manufacture and sale of high quality sound reproduction equipment. The object is to present high grade equipment of this type to the general public as well as to the Trade in a more effective manner than the National Radio Show, with its accent on domestic radio and television, can achieve.

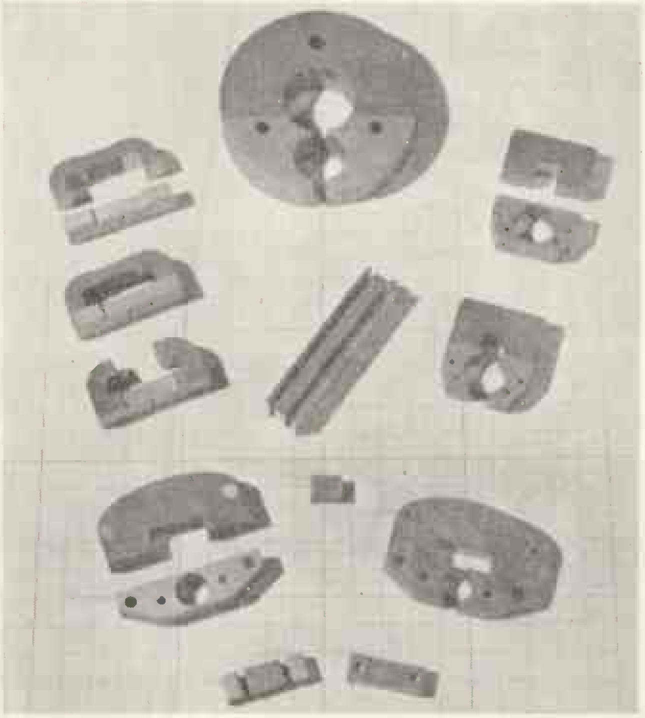
The greater part of the ground floor of the hotel will be taken up by stands upon which each manufacturer may present a static display of his products. The principle accent of the Fair, however, will be on demonstration of the equipment under conditions similar to those encountered in the home. For this purpose the whole of the first and second floor of the Hotel, together with one wing of the third floor, will be taken over by the Fair and the rooms will be used as demonstration rooms.

These dates have been chosen so that the Fair can attract members of the Trade who will be in London for the R.E.C.M.F. Exhibition which closes on Thursday, April 12, 1956.

L. H. Brooks of The M.S.S. Recording Co. Ltd, is Honorary Secretary.

Plastic Bonded Magnets

The illustration below shows a range of plastic-bonded composite magnets now being manufactured in the new factory of James Neill and Co. Ltd, of Sheffield. These composite magnets are being used extensively in measuring instruments; telephone equipment and relays.



The Design of Filters Using only RC sections and Gain Stages

(Part 2)

By A. N. Thiele*, B.E. (Syd.), A.M.I.R.E. (Aust.)

Design Examples

To show how the design formulæ are used, two designs are worked out below.

Accurate 18dB per Octave High-pass Filter With 40c/s Cut-off Frequency

In this case:

$$|(e_{in}/e_o)|^2 = 1 + \alpha^6 = (1 + \alpha^2)(1 - \alpha^2 + \alpha^4)$$

Thus a single *RC* section must be connected in cascade with an active filter.

For the single section $\omega_o = 2\pi \times 40 = 250\text{sec}^{-1}$

$\therefore CR = (1/250) = 4\,000\mu\text{sec}.$

* *E.M.I. (Australia) Pty. Ltd.*

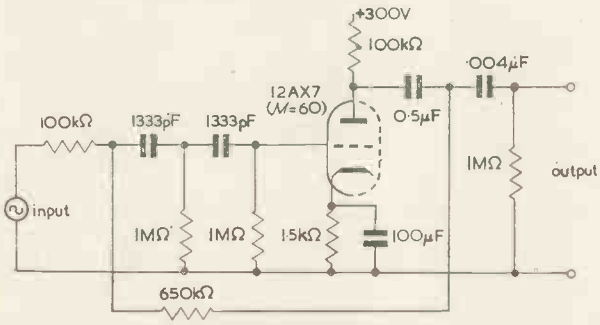


Fig. 15. Typical circuit without buffer stage 18dB/octave high-pass filter with 40c/s cut-off frequency

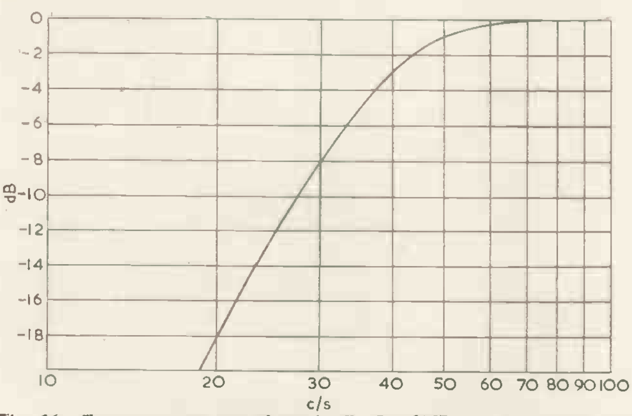


Fig. 16. Frequency response of maximally flat 18dB per octave high pass filter with 40c/s cut-off frequency

(Note that use of the approximation $2\pi = 100/16$ simplifies computation and involves an error of only 0·5 per cent.)

For the active filter, $y = -1$, thus $\dfrac{x_2}{\sqrt{(1 + \beta M)}} = +1$ and $1 + \beta M = x_2^2$.

If in the two-section *RC* network, R_1 is made equal to R_2, $x_2 = 2 + (R_1/R_2) = 3$, and $1 + \beta M = 9$.

For a high-pass filter:

$$1/\alpha_3 = \frac{1}{\alpha_2 \sqrt{(1 + \beta M)}}$$

i.e.:

$$\omega_o/\omega = \frac{1}{\omega CR \sqrt{(1 + \beta M)}}$$

$$\therefore CR = \frac{1}{\omega_o \sqrt{(1 + \beta M)}} = \frac{1}{250 \times 3} = 1\,333\mu\text{sec}$$

If we assume that the stage gain, $M = 60$, then since $\beta M = 8$, $\beta = (8/60)$, so that if the series resistor is 100kΩ, the feedback resistor is $(52/8) \times 100 = 650$kΩ.

From these constants the circuit diagram can be drawn as in Fig. 15. Since the feedback circuit presents to the *RC* sections an input impedance of $\dfrac{100 \times 650}{750} = 87$kΩ, their values will need to be adjusted slightly. Similarly, the presence of the *RC* sections will modify the feedback slightly. These adjustments, however, are best made by experiment, and if they are carried out as described earlier the curve can easily be made to conform to the ideal 18dB per octave curve of Fig. 16, within better than 0·5dB. Results of similar calculations for all types of filter are given in Fig. 17 and Table 2.

Approximate 18dB per Octave Filter With Variable Cut-off Frequency—High-pass 35c/s-100c/s and Low-pass 5kc/s-14kc/s Combined

The ranges chosen are suitable for use with high quality gramophone reproducing equipment. However, they are also limiting values, since the high-pass and low-pass ranges can be brought no closer together, for reasons which will be apparent later. Other features included in the design are:

Overall gain of unity, i.e. zero dB insertion loss.

Use of only one twin-triode as gain stage and cathode-follower.

Provision of negative voltage feedback over the gain stage to stabilize the equipment against changes in valves or supply voltages.

The high-pass and low-pass filters each cover a frequency range of 2·8 times, or 1½ octaves, this being not only a useful range, but one in which good shapes of filter characteristics can be maintained. Thus q_1 for each filter is $2{\cdot}8^2$ or 8. If we separate the two *RC* sections by placing one before and one

Fig. 17. General circuit schematic

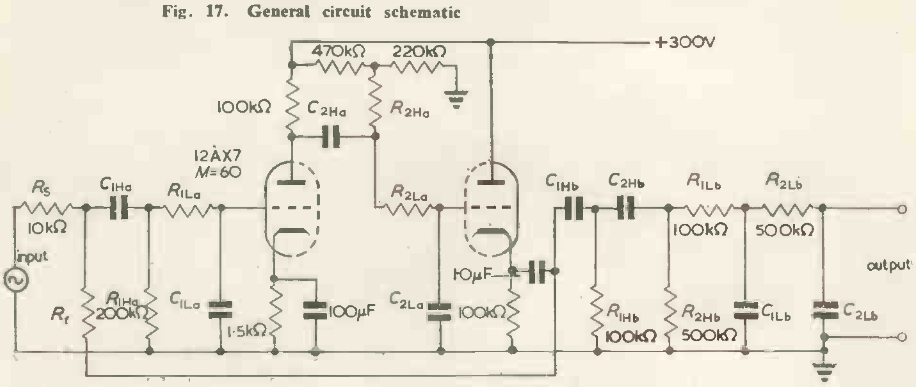


TABLE 2. Component Values

HIGH- OR LOW-PASS (Type of filter)	SLOPE OF CHARACTERISTIC (Type of filter)	CUT-OFF FREQUENCY	βM	R_f (MΩ)	C_1R_1 (μsec)	C_{1Ha} (pF)	C_{1La} calculated (pF)	C_{1La} calculated −130 (pF)	R_{1La} (MΩ)	C_2R_2 (μsec)	C_{2Ha} (pF)	R_{2Ha} calc. (MΩ)	R_{2Ha} calc. −0·15 (MΩ)	C_{2La} calc. (pF)	C_{2La} calc. −20 (pF)	R_{2La} (MΩ)	C_4R_4 (μsec)	C_{1Hb} (pF)	C_{2Hb} (pF	C_{1Lb} (pF)	C_{2Lb} (pF)
H	12dB/oct. Maximally flat	40c/s fixed	1·0	0·59	2 830	14 100	—	—	—	C_1R_1	2 830	1·0	0·85	—	—	—	—	—	—	—	—
L	,, ,, ,,	16kc/s ,,	1·0	0·59	14·1	—	141	11	0·10	,,	—	—	—	28	8	0·5	—	—	—	—	—
H	18dB/oct. Maximally flat	40c/s ,,	3·0	0·19	2 000	10 000	—	—	—	,,	2 000	1·0	0·85	—	—	—	4 000	40 000	—	—	—
L	,, ,, ,,	16kc/s ,,	3·0	0·19	20	—	200	70	0·10	,,	—	—	—	40	20	0·5	10	—	—	100	—
H	24dB/oct. Approx.	40c/s ,,	8·7	0·059	1 280	6 400	—	—	—	,,	1 280	1·0	0·85	—	—	—	4 000	40 000	8 000	—	—
L	,, ,, ,,	16kc/s ,,	8·7	0·059	31·1	—	156	26	0·20	,,	—	—	—	62	42	0·5	10·0	—	—	100	20
H	12dB/oct. Approx.	40–160c/s	2·1	0·27	1 130	5 650	—	—	—	cent. = C_1R_1	1 880	0·15–2·4	0–2·25	—	—	—	—	—	—	—	—
L	,, ,, ,,	4–16kc/s	2·1	0·27	35·4	—	177	47	0·20	,,	—	—	—	59	39	0·15+0–2·25	—	—	—	—	—
H	,, ,, ,,	40–230c/s	3·0	0·19	825	4 100	—	—	—	,,	943	0·15–5·1	0–4·95	—	—	—	—	—	—	—	—
L	,, ,, ,,	2·7–16kc/s	3·0	0·19	48·1	—	240	110	0·20	,,	—	—	—	55	35	0·15+0–4·95	—	—	—	—	—
H	18dB/oct. Approx.	40–113c/s	5·5	0·10	1 570	7 900	—	—	—	max. = C_1R_1	560	0·35–2·8	0·20+0–2·45	—	—	—	2 670	26 700	—	—	—
L	,, ,, ,,	5·7–16kc/s	5·5	0·10	25·5	—	128	0	0·20	min. = C_1R_1	—	—	—	73	53	0·35+0–2·45	15	—	—	150	—
H	,, ,, ,,	40–160c/s	10·8	0·046	1 160	5 800	—	—	—	max. = C_1R_1	484	0·15–2·4	0–2·25	—	—	—	1 800	18 000	—	—	—
L	,, ,, ,,	4–16kc/s	10·8	0·046	34·4	—	172	42	0·20	min. = C_1R_1	—	—	—	230	210	0·15+0–2·25	22·2	—	—	222	—

after the gain stage, then effectively $(R_1/R_2) = 0$.

Then from equation (23):

$$1 + \beta M = 2[1 + (R_1/R_2)]\,\frac{(q_1+1)^2}{3q_1+1} = \frac{2 \times 81}{25} = 6{\cdot}48$$

Using the subscript L for low-pass and H for high-pass filters:

$$1/\omega_{oL} = \frac{1}{2\pi \times 14\,000} = 11{\cdot}25\mu\text{sec}$$

and:

$$1/\omega_{oH} = \frac{1}{2\pi \times 35} = 4\,500\mu\text{sec}$$

Then for the passive sections C_4R_4:

$$C_{4L}R_{4L} = (1/\omega_{oL})\sqrt{\left[\frac{q_1(q_1-1)}{3q_1+1}\right]} = (1/\omega_{oL})\sqrt{\frac{8 \times 7}{25}} = (1{\cdot}50/\omega_{oL}) = 16{\cdot}9\mu\text{sec}$$

Similarly:

$$C_{4H}R_{4H} = (1/1{\cdot}50\omega_{oH}) = 3\,000\mu\text{sec}$$

and in the active filter taking the value of the variable sections C_3R_3 when $q = 1$ (at the outer extremes of range)

$$C_{1L}R_{1L} = C_{3L}R_{3L\min} = \frac{\sqrt{(1+\beta M)}}{\omega_o} = (2{\cdot}55/\omega_{oL}) = 28{\cdot}6\mu\text{sec}$$

and:

$$C_{3L}R_{3L\max} = 28{\cdot}6 \times 8 = 229\mu\text{sec}$$

Similarly:

$$C_{1H}R_{1H} = C_{3H}R_{3H\max} = (1/2{\cdot}55\omega_{oH}) = 1\,760\mu\text{sec}$$

and:

$$C_{3H}R_{3H\min} = (1\,760/8) = 220\mu\text{sec}$$

Note that when the two variable controls are set to inmost frequency, their time-constants are approximately equal, involving an insertion loss at centre frequency of approximately 2 × 3 = 6dB.

In the input circuit of Fig. 18, if R_1 is set at 330kΩ and the gain reduction factor at 3, then first since $C_{1L}R_{1L} = 28{\cdot}6\mu$sec, then $C_1 = (28{\cdot}6/0{\cdot}33) = 86{\cdot}6$pF. Secondly, R_2 must present an equivalent (330kΩ/2) = 165kΩ between control grid and earth in order to reduce gain by 3. If the gain M is 60, the actual value for R_2 is 165kΩ × 61 = 10·1M. Likewise $C_2 = \frac{86{\cdot}6 \times 2}{61} = 2{\cdot}8$pF. Since this capacitance is somewhat greater than the 2·2pF measured for the C_{ga} of a 12AX7 mounted in its socket, an additional 0·6pF must be added to C_2, or C_1 must be made larger.

The variable resistor R_{3H} is given a range slightly greater than 8 to allow for tolerances in components. Its minimum resistance is provided by the two bias setting resistors R_{16}(330kΩ) and R_{17}(150kΩ) which present an impedance to earth of 103kΩ. The variable section is provided by a 1MΩ potentiometer. Similarly, R_{3L} which is made somewhat larger to minimize interaction with R_{3H}, consists of a 220kΩ resistor in series with a 2MΩ potentiometer. Then:

$C_{3H} = (1\,760/1{\cdot}10) = 1\,600$pF and $C_{3L} = (28{\cdot}6/0{\cdot}22) = 130$pF.

If the feedback resistors are made R_{11} (100kΩ) and R_{12} (150kΩ) the impedance seen by the input RC sections due to the feedback method is that of R_{11} in parallel with R_{12}, i.e. 60kΩ. Thus if R_1 is reduced to 270kΩ, the design figure of 330kΩ is still presented to the circuit. Thus:

$$1+\beta M = 1+(100/250)\times(60/3)\times(270/330) = 1+6{\cdot}54 = 7{\cdot}54$$

This is somewhat greater than the calculated figure of 6·48, but in practice it is reduced by the "insertion loss" caused by interaction between the C_3R_3 high-pass and low-pass sections.

Calculated overall gain is thus:

$$(60/3) \times (150/250) \times (270/330) \times (1/7{\cdot}54) = 1{\cdot}30.$$

Considering the input high-pass section, C_{1H} works into an impedance of:

$$60\text{k}\Omega + \frac{(270\text{k}\Omega + 165\text{k}\Omega) \times 1M\Omega}{1{\cdot}435\text{M}\Omega} = 364\text{k}\Omega$$

Thus:

$$C_{1H} = (1\,760/0{\cdot}364) = 4\,840\text{pF}$$

In the output attenuator, assuming an output load of 500kΩ, R_{20} is made 150kΩ to set an attenuation of 1·3, so that the gain of the whole filter is unity. Then since R_{19} provides an additional 560kΩ to earth, the effective:

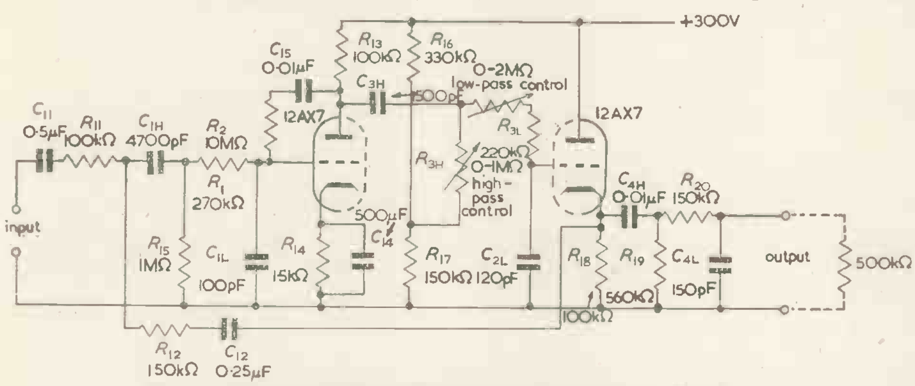


Fig. 18. Combination high- and low-pass filter continuously variable 35 to 100c/s and 5 to 14kc/s respectively

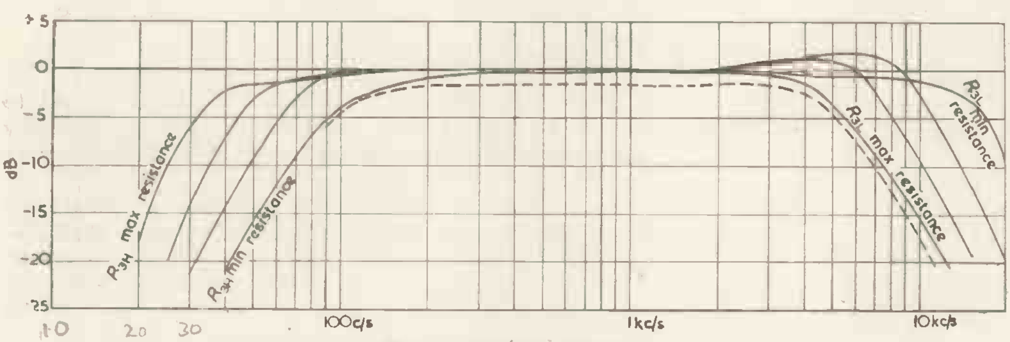


Fig. 19. Frequency response

Solid curves taken for maximum and minimum resistance and intermediate points for each control when the other is set to outermost cut-off frequency. Dotted curves taken on same reference level when both controls are set to innermost cut-off frequency.

$$R_{4H} = \frac{650\text{k}\Omega \times 560\text{k}\Omega}{1\,210\text{k}\Omega} = 304\text{k}\Omega$$

and:

$$C_{4H} = (3\,000/0{\cdot}304) = 9\,900\text{pF}$$

Also the effective:

$$R_{4L} = \frac{150\text{k}\Omega \times 500\text{k}\Omega}{650\text{k}\Omega} = 115\text{k}\Omega$$

and:

$$C_{4L} = (16{\cdot}9/0{\cdot}115) = 147\text{pF}$$

It should be noted that C_4 and R_4 have values chosen to suit the impedance level and attenuation required, but any other arrangement with the same time-constants would be satisfactory. If it is more suitable to connect another stage direct to the cathode-follower output the passive networks C_4R_4 can be placed in cascade with some other part of the amplifier chain so long as no interaction results. If possible, direct coupling is preferable, as for example when the filter is fed from the anode of a previous stage. Coupling capacitors C_{11} and C_{12} would then be omitted. The filter may be fed from any source so long as the total impedance of R_{11}, looking back from its junction with R_{12}, is close to 100kΩ and substantially resistive over working frequency range.

The complete filter calculated above is illustrated in Fig. 18 with components selected at the nearest 10 per cent preferred values.

Experimental Results

A filter was built to the above specification to determine how it would perform under production conditions. No components were specially adjusted or bridged.

Performance was very close to that calculated. Overall gain at centre frequencies was +0·5dB, with both controls set to outermost cut-off frequencies. Frequency response curves plotted in Fig. 19 show that the cut-off frequencies were correct and the curve shapes similar to those of Fig. 9. With no special precautions taken, the noise was −60dB below 2V output. At 0·5 per cent distortion the output voltage was 15V r.m.s. at 1kc/s with both controls set to outermost frequencies and 2V r.m.s. under the worst conditions, at the high-pass cut-off frequency with both controls set to inmost cut-off frequency.

Filters of the accurate 18dB per octave type with cut-off frequencies between the limits of low-pass 1kc/s to 15kc/s and high-pass 35c/s to 2kc/s have been built and they conform to the maximally flat characteristic within the limits of accuracy of the measuring equipment.

Applications

The filters described in this article are most useful in applications where the cut-off frequency must be variable. When a variation in steps suffices, the more accurate type described first is preferable. When the variation is to be made continuously or cheaply, the single element variable type finds its application. In either case, the filters are very useful at the lower frequencies where conventional filters become too costly or too bulky, if not impossible to construct.

Limitations of these filters compared with the conventional type lie in the necessity for providing power supplies, their limited power output, their limited attenuation slope, and the necessity for input and output transformers if connexion into balanced lines is required.

Typical applications include:

Cheap variable "rumble" and "scratch" filters for gramophone reproduction.

Wide range effects filters for broadcasting or recording.

Broad band sub-audio wave analysers, e.g. in wow-meters.

Acknowledgments

The author wishes to record his thanks to his colleagues at E.M.I. (Australia) Pty. Limited; to Mr. J. MacHill for his careful checking of the mathematics, and to Messrs. W. A. Brear and W. Buckland for their encouragement and help in verifying the calculated results.

Notes from NORTH AMERICA

New Computer for M.I.T.

A computer, the first of a new high-speed type for education and basic research, is to be installed at Massachusetts Institute of Technology.

Made available by International Business Machines Corporation, the computer, an IBM Type 704 Electronic Data Processing Machine, will be the principal tool in a new electronic data processing centre.

The computer will be installed in early 1957 in the Karl Taylor Compton Memorial Laboratories, which M.I.T. is now building in Cambridge at a cost of $4 000 000.

M.I.T.'s School of Industrial Management plans to undertake a new programme of studies in "operations research", the new field in which data processing methods are applied to complex manufacturing and distribution problems.

Other fields in which research is expected to be done include aerodynamics, meteorology, atomic research, and solid state physics.

An advisory committee made up of representatives of New England colleges participating in the programme will be formed to advise on such questions as priorities for problems to be submitted to the machine and the suitability of problems.

Research assistants selected from graduate schools of the participating institutions will be trained not only at M.I.T. but also at IBM's educational centre at Poughkeepsie. They will then be in a position to assist in instruction in electronic data processing in their own colleges and to assist other students and professors in preparing problems for the computer.

A New Type of Dry Battery

A new "wafer cell" type dry battery has been announced by the Burgess Battery Company of Freeport, Illinois, and which, it is claimed, makes possible a 30 per cent increase in battery power and life and eliminates traditional hand operations from cell manufacturing.

The new cell consists of a sandwich of artificial manganese dioxide mix between tiny disks of flat zinc and carbon electrodes. The carbon rod of round cell batteries has been supplanted by a small piece of conductive carbon, and the whole sandwich is machine-wrapped in an airtight pliofilm envelope and heat sealed.

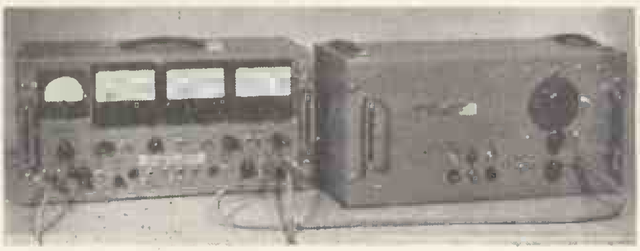
Welded or soldered wire connexions between cells are eliminated by the use of silver wax, a new conductive wax intercell connexion developed by Burgess engineers. A dab of silver wax on the positive and negative sides of the cell permits the cells to be connected in series merely by being stacked in a column, and a multiple cell battery results from the electrical contact established between cells by the wax in pressure contact.

An Envelope Delay Meter

A new apparatus known as the Type 450-A Envelope Delay Meter has been announced by Acton Laboratories of Acton, Mass.

It provides a transmitted output frequency that may be manually set, or automatically swept repetitively through any desired portion of the 200-10,000c/s band. Provision is also made for selection of the speed of the automatic sweep, with speeds of $\frac{1}{2}$, 1, 2 and 4 r.p.m. In addition, the transmitter output may be adjusted from 10dB above to 10dB below one milliwatt on a 600 ohm line (plus 10dbm to −10dbm).

The instrument is appropriate to studies of telephone, carrier, teletype, relay chains, facsimile, telephoto, telemeter and data transmission lines, networks, and systems. Group velocity, actual transit times, and amplitude-frequency characteristics can be determined over the range of 200-10 000c/s. Especially applicable where straight-away measurements are required as on a long line, two instruments are used and no additional cue or pilot channel is required between them. Single instrument operation provides the transmitting and receiving-measuring apparatus required where both input and output of the transmission path are available in one place, as on a loop connexion. Measurements are in absolute terms. Built-in synchronization is also provided via the single channel. Measurements give relative delay times over the 200-10 000c/s band. The instrument is direct reading up to 20 milliseconds delay time. Higher values are read on the meter as delays in excess of 20, 40, 60, etc. millisecond periods. An amplified delay meter provides full scales of 1 millisecond or 5 milliseconds permitting an accuracy of better than ±50 microseconds.



The Envelope Delay Meter

The receiver includes a frequency reading meter to identify the frequency being transmitted and a level meter for amplitude response measurements. Receiver operating range is from 20dB above to 30dB below 1 milliwatt.

Connexions are provided for monitoring the receiver by oscilloscope, or oscillographic recorder, and for external meters for delay, frequency, and amplitude data.

Radio-controlled Traffic Lights

A radio-controlled traffic light system has recently been installed at Evansville, Ind., by the Electronics Division of the General Electric Company.

A master controller is arranged to store a week's information on the most desirable traffic patterns for the town, and automatically every hour the controller codes into tones information on the best traffic light pattern for that particular time. The tones are then transmitted by radio to f.m. radio receivers connected to each of 54 traffic lights in Evansville.

When a decoder receives tones intended for it, appropriate relays are operated which change the length of time the traffic light is green, yellow or red.

In addition, the controller periodically transmits a radio signal co-ordinating all the radio-equipped traffic lights for the fastest movement of traffic.

LETTERS TO THE EDITOR

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

Saturated Diodes

DEAR SIR,—The writer would like to make some comments on the above article which was published in the August issue of ELECTRONIC ENGINEERING.

Referring to the upper curves in Fig. 12 for the A.2087 where the anode current rises at the end of life, similar curves have been obtained for some of the 29C1 valves that have been run in our Valve Life Test Department at Ediswan, Brimsdown.

Some comments on the 29C1 were published by the writer in the March, 1954, issue of ELECTRONIC ENGINEERING (with a typographical correction in the May, 1954, issue). These comments were made very general because the curves and figures available appeared to be so controversial.

The reason for the variability was assumed to be due to the filament voltage accuracy not being so good as that obtained by Dr. Benson and his colleagues. In view, however, of the further curves they have obtained it would appear to the writer that the results published by Dr. Benson are tenuous because insufficient valves have been tested or life tested, to enable accurate conclusions to be drawn except in very general terms.

The information the writer has, goes back to the conception of the valve in 1945 when he had the initial samples made up. In total the numbers life tested run into three figures, and on the basis of this work it would appear that life curves generally follow those of the earlier paper published by Dr. Benson and his associate in November, 1953; but curves of anode current of particular batches of valves can be obtained that after 1 000 hours at normal voltage conditions then go up and/or down for periods of up to 10 000 hours or so.

As an indication of quality we tend to use the life test conditions with overrun filament volts at $E_f = 4{\cdot}5$ volts because that gives a life of 1 000-1 500 hours depending on the particular batch of wire used for the filament.

From theory this would mean a life of 7 000 to 10 000 hours at 4·0 volts and of 70 000 hours at 3·5 volts. Very little work has been carried out with filaments run at 3·5 volts because 70 000 hours is about 8 years, but the lives obtained at 4·0 volts have tended to confirm the figure although with a greater range.

As regards the "spread" of characteristics this must always be a function of economics, because when valves are made they will not be absolutely uniform in characteristics, and a tolerance has got to be allowed, depending on the price that the customer is willing to pay. In that connexion it has often meant scrapping an appreciable percentage of production because the filament wire length between welds has been a fraction of a millimetre out, due to a change of operator or on re-starting up production.

Since a saturated diode depends on the behaviour of a hot tungsten cathode in all the types mentioned in the article, it would seem reasonable to expect that if sufficiently large samples were taken then the behaviour of all types would be similar. They would follow the equations that have been worked out for tungsten wire by various authorities, but bearing in mind the correction due to so called "end effects" caused by the short filament length used. Excluding of course the occasional freak results such as that shown in the Fig. 12 mentioned.

Yours faithfully,
D. L. HALL,
The Edison Swan
Electric Co. Ltd.
Brimsdown, Middlesex.

DEAR SIR,—In their article on "Saturated Diodes" in your August issue, Dr. Benson and Mr. Seaman, in their concluding paragraphs, express certain opinions on a number of commercial tungsten filament diodes they have studied. Unfortunately by their use of the phrase "poor long term characteristics" they leave the reader with the impression that some at least of these diodes would give unsatisfactory life.

Writing on behalf of the makers of the AV33 diode, may I point out that its long term characteristics as a control diode (as it was designed) are thoroughly adequate and that many thousands of these valves are giving satisfactory service in a.c. voltage regulators? In the practical applications we have seen, the diode is required to maintain adequate change of saturated emission per change of filament voltage, the slow changes in emission during life being compensated by adjustment of a filament rheostat (which is usually provided anyway for changing the regulated output voltage). It is not necessary for the diode to maintain constant saturated emission for a constant filament voltage over an extremely long time; indeed this requires unduly expensive design and processing.

Attree (Ref. 3 above) has shown that the rate of fall of emission with time depends to a large extent on the way the valve is loaded. In this connexion we can quote a recent AV33 life test, a batch of 10 being run at approximately 2mA anode current. The average anode current shows a drop of 10 per cent in twenty days.

Yours faithfully,
D. M. SUTHERLAND,
Amalgamated Wireless Valve
Co. Pty. Ltd,
Ashfield, N.S.W.,
Australia.

The authors' reply:

DEAR SIR,—We wish to thank Mr. Hall and Mr. Sutherland for their interesting comments.

The results we have obtained can, of course, only be taken as typical owing to the small number of valves tested, but nevertheless they do give some very useful information. Unfortunately, we could not test as many valves as we should have liked to do because of the expense which would have been involved and we feel it is a great pity that Mr. Hall has not published the results of the large number of tests carried out in his laboratories.

The phrase "poor long term characteristics" used concerned mainly the early part of life characteristics. Since submitting the manuscripts for the article under consideration and for the earlier article[1] dealing with 29C1 valves only, the various life tests reported have been continued giving the results shown in Figs. A, B and C. It is seen from Fig. A for AV33 valves that the later part of the life characteristic of one of the valves is quite good.

In some cases, e.g. 29C1 valve No. 6, the emission current has shown a continuous decrease with time. With others, however, such as 29C1 valve No. 3 and AV33 valve No. 1, there eventually comes a time when the emission current increases or decreases at random with time. The two valves just mentioned were operated at filament voltages of 0·3V above the makers' recommended values and the period referred to appears after about 140 days for the AV33 and 200 days for the 29C1 valves concerned when the anode currents had dropped to about half their initial values.

The problem of avoiding variations in filament voltage during a life test is difficult to solve. We tried to keep the variations small by using a relatively large secondary battery, this being charged from the d.c. mains as the tests proceeded. After some experience with such an arrangement it was very rarely that the filament voltages during our life tests were more than 0·05V from the nominal values. Such consistency of filament voltage is thought to be comparable with what would be obtained across the filament of a diode used in say a voltage stabilizer. Our test conditions thus approximate to expected typical operating ones.

We agree with Mr. Sutherland that the manner in which a valve is loaded determines the rate of fall in emission, but the results of our life tests on 29C1 diodes do not always conform to expectations. It is debatable, however, whether any two valves can be expected to behave alike. 29C1 valves No. 7 and 9 were purchased at the same time, presumably from the same production

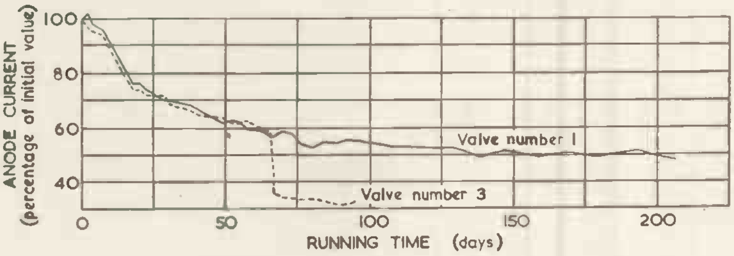


Fig. A. AV33 life test.
Anode voltage for both valves:— 90V.

Filament voltages:—	Initial anode currents:—
Valve No. 1. 4·00V.	Valve No. 1. 4·70mA
Valve No. 2. 3·75V.	Valve No. 3. 3·08mA.

batch, and were life-tested simultantaneously. The voltages on the two filaments were the same, but the anode voltages were different. The anode current of the valve running at the higher anode voltage decreased by a greater amount than that of the other valve. This test would, therefore, lead one to suspect that the anode voltage has an effect on life. The characteristics of 29C1 valves No. 2 and 9, however, operated under the same conditions, although at different times, show just as great a divergence as that between No. 7 and 9. Also, the emission of 29C1 valve No. 3 running at a filament voltage of 4·3V decreased more slowly than that of 29C1 valve No. 6 which was operated at a filament voltage of 4V and the same anode voltage.

The rate of fall of emission current of 10 per cent in twenty days quoted by Mr. Sutherland is rather good for new valves although we have found that relatively old valves usually exhibit a smaller rate of fall.

We agree with Mr. Hall that the life characteristic of A.2087 valve No. 2 shown in Fig. 12 might be a freak result. An examination of Fig. 11, however, shows that this valve would be operating at a higher temperature, than a 29C1 valve running at a filament voltage of 4·5V so that the result agrees to some extent with those obtained by Mr. Hall, since life decreases, in general as filament temperature increases.

Although the life characteristics depend on the behaviour of hot tungsten, it is unlikely that every filament will be free from impurities and the variations between valves could be attributable to the different amounts of slight impurities present. A similar argument could be applied to valves of different types, although in this case there is the additional factor of the different "end effects" due to different forms of construction.

When one of the filament wires of AV33 valve No. 3 failed the other was found to be emitting more than half the current noted the previous day. It does not follow that the two wires were not sharing the emission equally since each wire tends to blanket some of the anode area from the other wire when it is hot while the remains of the burnt-out filament wire would tend to act as a grid.

In any apparatus using a saturated diode, it will, as Mr. Sutherland says, be necessary to have a variable resistor in the filament circuit. This is necessary to allow for the variation in characteristics between valves as well as to allow for the variation of characteristics with age. In order that this resistor may have a sufficient range of variation to cope with these expected changes, it is, of course, necessary to know what the order of these changes is likely to be. It follows that the "spread" of the characteristics in these valves is not such a serious matter as it might be in other types. The spreads quoted in our article are considerably less than those allowed in the relevant CV specifications, namely CV430 for the 29C1 and CV2171 for the A.2087.

As the valve ages, the emission for a given filament voltage decreases, this decrease being fairly uniform over the whole range of filament voltage. Thus, the overall performance of a unit using these valves is not likely to deteriorate as the valve ages. Also, as Mr. Attree pointed out in correspondence concerning our earlier article dealing with the 29C1 diodes only, in most applications the valve will in fact operate under conditions of constant emission rather than at constant filament voltage, but knowing the relation between emission and filament voltage, the two can be interrelated. As we pointed out at the same time, it is impracticable to test valves at constant emission unless very frequent observations are made.

Yours faithfully,

F. A. BENSON
M. S. SEAMAN,
Department of Electrical Engineering,
University of Sheffield.

REFERENCE

[1] BENSON, F. A., SEAMAN, M. S. Characteristics of the Temperature-Limited Diode Type 29C1. *Electronic Engng.* 25, 462 (1953).

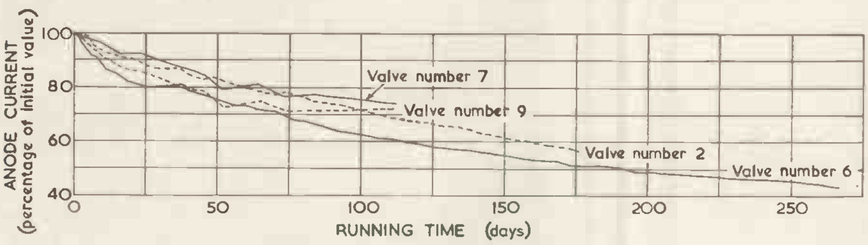
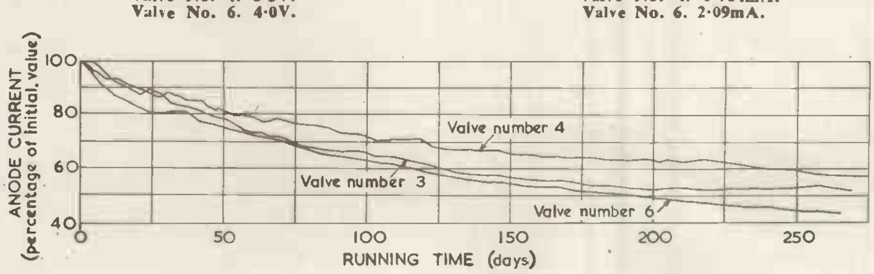


Fig. B (above). 29C1 life test.
Results for valves run at a filament voltage of 4·0V.

Anode voltages:—		Initial anode currents:—
Valve No. 7.	50V.	Valve No. 7. 2·10mA
Valve No. 6.	90V.	Valve No. 6. 2·09mA
Valve No. 2.	200V.	Valve No. 2. 2·30mA
Valve No. 9.	200V.	Valve No. 9. 2·30mA

Fig. C (below). 29C1 life test.
Results for valves run at an anode voltage of 90V

Filament voltages:—	Initial anode currents:—
Valve No. 3. 4·3V.	Valve No. 3. 3·91mA.
Valve No. 4. 3·5V.	Valve No. 4. 0·704mA.
Valve No. 6. 4·0V.	Valve No. 6. 2·09mA.



BOOK REVIEWS

Ultrasonic Engineering

By A. E. Crawford. 344 pp., 222 figs. Demy 8vo. Academic Press Inc., New York. Butterworths Scientific Publications, London. 1955. Price 45s.

THIS book will appeal to a wide range of readers, and will well repay study by all who are concerned with industrial processing.

The subject of ultrasonics has aroused widespread interest over the past decade. During that period work was done on a laboratory scale on many applications which showed promise of success, but which failed to develop on an industrial scale. In some cases the disappointment was due to the inherent unsuitability of the application, in others it was due to initial experiments having been carried out with inadequate apparatus.

It is obvious that the author of the book under review has himself been closely concerned with the engineering problems which have arisen in the development of adequate equipment. The applications which he has selected for description are those which have become established as being of real industrial value.

The variety of subjects discussed is sufficiently comprehensive to enable most potential users of ultrasonics to find something akin to their own requirements, and to form an assessment of the value of making initial experiments in their own field.

The first section of the book is devoted to basic principles. The phenomenon of cavitation is very carefully treated, and the proper emphasis is given to the important part it plays in causing physical changes in liquids.

The summary of possible transducer systems is realistic, the practical experience of the author again being indicated by his recognition of the fact that no existing transducer system is free from limitations. The rate of development of ultrasonic processing has been largely influenced by the difficulties of making transducers capable of giving adequate cavitation effects.

The second section of the book is given to the description of existing transducers and ancillary apparatus.

It is becoming evident that the use of quartz in power ultrasonics will soon be limited to experiments on a laboratory scale.

The principles of the operation of polycrystalline materials such as barium titanate are discussed, and the applications of these new materials are described. The sections of the book dealing with magneto-strictive and electromagnetic transducers are thorough and very clear.

In the applications section of the book the description of smoke treatment will be of topical interest. The increasing use of ultrasonic cleaning plants for small mechanical parts is given considerable attention.

The author indicates a somewhat reserved attitude towards the claims which appear at intervals in the press for the artificial ageing of wines and spirits.

An up to date review of ultrasonic drilling, machining and soldering techniques should lead to the wider adoption of methods which are now well proved.

Applications in the medical field are briefly described as being still of an experimental character.

Altogether, the result is a very well balanced introduction to the subject which will give valuable guidance to those wishing to be informed of modern techniques.

C. CROPPER.

Nuclear Radiation Detectors

By J. Sharpe. 179 pp., 51 figs. Foolscap 8vo. Methuen & Co. Ltd. 1955. Price 11s. 6d.

THE great amount of work performed during and since the war on nuclear energy has resulted in the discovery of new radiation detectors and the improvement of existing types. Although much has been published in the recognized journals, there still remain the numerous official reports which are not so accessible. This monograph which appears in the series "Methuen Monographs on Physical Subjects", collects a great deal of this information in tabular and graphical form. The author draws on his experience at the Atomic Energy Research Establishment, Harwell, in assessing and commenting on various methods and devices at present in use. In the course of 179 pages he considers as deeply as space will allow "the physical foundations of detector elements and some of the related technology".

Comparison will inevitably be made with the monograph by Dr. D. Taylor in the same series entitled "The Measurement of Radio Isotopes" (persistently referred to in this volume as "Measurement of Radioactivity"). The two books are complementary; Sharpe dealing with the physical basis of detection and Taylor discussing the applications to measurement.

A very brief introductory chapter considers the basic process of detection and leads to the second chapter on the interaction of radiation with matter. Detectors which are considered next are phosphors and ionization media, detection efficiency being dealt with in a further chapter. The complete scintillation counter is discussed in Chapter V, the first part of which is devoted to secondary emission and the photomultiplier. Ionization chambers, proportional counters and Geiger counters are covered in the final chapter comprising 50 pages. In the copy of the monograph under review an index was listed in the table of contents but was not present at the end of the book.

The author refers to a large amount of published literature and has abstracted many tables and results together with unpublished work from A.E.R.E. Workers in the field of nuclear radiation physics will find this monograph a useful source of information.

D. H. LE CROISSETTE.

Television Receiver Servicing Volume 2

By E. A. W. Spreadbury. 308 pp., 172 figs. Demy 8vo. Trader Publishing Co. Ltd. 1955. Price 21s.

THIS book, like Volume 1, is a welcome addition to the literature dealing with television servicing.

Much of the material is based on articles which have appeared in the *Wireless and Electrical Trader* and the sequence of chapters is therefore quite haphazard, no logical order being followed. The first chapter, No. XIII, deals with video stages and, like all the other chapters, is well illustrated with clear circuit diagrams. Photographs of test card "C" appearing on receivers with various faults are also shown. Most types of video stages are discussed.

Interference suppressors are next described and a chapter on vision detectors follows.

Chapter XVI deals with tuning circuits and includes sound rejector circuits. Instability of r.f. and i.f. amplifiers is discussed at some length and the effect of tuning circuit drift. Methods of overcoming change of valve impedance and capacitance with change of gain are shown.

A chapter on multi-channel tuners follows. This is very interesting and is probably the best collection of circuits yet available. Tuners up to the present time are included and adequately described.

A chapter on A.G.C. systems, the sound channel including noise limiters and power supplies follows.

Chapter XXI deals with aerials and feeders and includes a discussion on dbs and is followed by a chapter on reflections and ghosting.

The book concludes with a useful description of test equipment for alignment.

The disappointment of the book is its recurring weakness of description. This is likely to prove confusing to the very readers who should benefit most from such a book. Some statements are loose, such as "cathode shoots up negatively" (page 81), "A.G.C. line goes positive by 5 volts" (page 159); "the reading should be between 90 volts and 110 volts, or rather 110 volts and 90 volts" (page 21), but some are quite incorrect, such as "it is indeed a feature of pulse suppression that all the circuits up to the limiter must be able to handle high intensity impulses without attenuating them, which means that they must have a sufficiently wide bandwidth" (page 181); "peak inverse voltage 1·4 times the a.c. mains voltage" (page 190). There are also rather rambling explanations such as the one about the reasons for different impedance input circuits. The author thinks that the variety of values is due to each designer having "a figure in his head for the centre impedance of a dipole" . . . "he tells the sales manager, the publicity manager, and the service department . . . and thereafter that is an established figure".

Briefly then, a good value for money book which could so easily have been so much better.

C. H. BANTHORPE

Molecular Beams

By K. F. Smith. 133 pp., 25 figs. Pott. 8vo. Methuen & Co. Ltd. 1955. Price 8s. 6d.

THIS book is one in the Methuen's series of monographs on physical subjects intended to supply science students at university level with a compact statement of the modern position in each subject.

An earlier book on the same subject by Dr. R. Fraser was first published in the Methuen series in 1937 and the new volume replaces this.

The length of this new volume has been increased considerably in order to include an account of the resonance apparatus and the technique of obtaining radio frequency spectra. The effects of magnetic and electric fields on atoms and molecules are also discussed.

The Mobile Manual For Radio Amateurs

352 pp., 80 figs. Demy 8vo. American Radio Relay League. Price $3·00.

THIS manual has been prepared by the headquarters' staff of the American Radio Relay League. It includes articles on tried and tested equipment which have appeared in the monthly publication of the League. There is a section on receiving with information on automotive noise suppression; a group of articles describing over thirty different mobile transmitters; sections on mobile antennas and power supplies and excerpts from the Federal Communications Commission's regulations governing mobile operation.

High Vacuum Technique

By J. Yarwood. 208 pp., 110 figs. Demy 8vo. 3rd Edition. Chapman & Hall Ltd. 1955. Price 25s.

THIS third edition has been completely revised and new material has been added to bring the book up to date in view of developments during and since the war. While giving a systematic and logically developed course in vacuum practice, the book includes many details of modern commercial equipment and practice, tables of relevant physical constants, and details of the properties and manipulation of the many specialized materials encountered in this type of work. There is also a comprehensive bibliography.

Short News Items

The Scientific Instrument Manufacturers' Association announce that a permanent exhibition by member firms is to be opened at their headquarters at 20 Queen Ann Street, London, W.1, on 9 February. This exhibition will cover an entire floor of SIMA House, which has been completely redecorated in modern style. Since sufficient space is not available to enable all member firms to show their products at the same time, space is allocated by ballot for limited periods, so that the exhibits will constantly change. Arrangements have been made to ensure that a representative cross-section of instruments is always on view.

"Silicones for Industry" Exhibition in London. An exhibition giving full details of the history, production and rapidly expanding applications of silicones is to be held at the Tea Centre, Lower Regent Street, London, W.1, from 7-18 February. The exhibition is to be staged by Midland Silicones Ltd, the first British producers of silicones. It will be open each day from 10 a.m.—6 p.m. Film shows will be given at intervals throughout each day. Invitations to the exhibition can be obtained from Midland Silicones Ltd, 19 Upper Brook Street, London, W.1. The exhibition will also be open to the general public.

An International Exhibition on Instrumentation-Automation will be held in Oslo from 9-22 April. It is being organized by the Norwegian Industries Development Association and the Royal Norwegian Council for Scientific and Industrial Research. Further information and details may be obtained from the Secretariat, Studieselskapet for Norsk Industri, Munkedamsveien 53B, Oslo.

The 9th International Congress of Applied Mechanics will be held in Brussels in the buildings of the Universite Libre de Bruxelles from 5-13 September. All information and brochures concerning the conference are available from The General Secretariat, Universite Libre de Bruxelles, 50 Avenue F. D. Roosevelt, Brussels, Belgium. Brochures are also obtainable through all American Express agencies.

An International Congress on Microwave Tubes, organized by the Société des Radioélectriciens and by the Société Française des Ingénieurs Techniciens du Vide, will be held in Paris from 29 May to 2 June in the lecture rooms of the Conservàtoire National des Arts et Métiers, 292 rue Saint-Martin, Paris. Further information may be obtained from Le Comite d'Organisation du Congrès Tubes Hyperfréquences, 44 rue de Rennes, Paris VIe.

Northampton Engineering College, London, announce a "Sandwich" course for a diploma in Electrical Engineering, covering eight terms' study. This diploma course has been designed to provide complete exemption from the examination requirements of The Institution of Electrical Engineers for Associate Membership. The student spends approximately six months in full-time study at the College, followed by six months in industry in each of the four years. Further details may be obtained from the head of the Electrical Engineering Department, Northampton Engineering College, St. John Street, London, E.C.2.

A Conference on Courses for Electrical Technicians, at which the chair was taken by the President of The Institution of Electrical Engineers, Sir George H. Nelson, was held recently in the Institution Building. Nearly two hundred and fifty persons were present, including a large number of principals of technical colleges and education and training officers in industry. The Ministry of Education, Regional Advisory Councils for Further Education, associations concerned with technicians and the Services were also represented. The City and Guilds of London Institute have now drawn up regulations and syllabuses for the conduct of examinations for electrical technicians and the main object of the recent conference was to help publicize the scheme and to provide an opportunity for discussing its implementation. The new scheme will offer Technicians' Certificates for technicians engaged in the design, manufacture, testing, erection, operation and maintenance of electrical plant and equipment in a number of branches of electrical engineering. At the outset the courses will cover plant and machinery, power generation and supply, and industrial electronics. The Report on Courses for Electrical Technicians is available, price 1s., from The Institution of Electrical Engineers, Savoy Place, London, W.C.2.

Automation Consultants and Associates Ltd are a recently established company at 18 Berkeley Street, London, W.1. Their purpose will be to interpret the highly complex possibilities of automation to the policy forming and executive groups who control important activities. The Chairman is Sir Walter Puckey and among the Directors is Mr. J. A. Sargrove, founder of Sargrove Electronics Ltd.

The South of Scotland Electricity Board, as part of its service to Scottish industry, is organizing an Electronics and Productivity Exhibition and Conference to be held in Glasgow's Kelvin Hall from 6-9 February. This Exhibition will present, for the first time in Scotland, a comprehensive review of electronic devices. Admission is by invitation card only which is available from the Board's offices at 351 Sauchiehall Street, Glasgow, or other service centres.

Standard Telephones and Cables Ltd have designed and manufactured for the BBC the first of six 10kW frequency-modulated transmitters. The first will shortly undergo operational trials at Wenvoe. In order to ensure uninterrupted service these transmitters will work in parallel, one pair for each programme. In addition, a special combining network has been designed by Standard Telephones and Cables engineers in co-operation with the BBC to permit the operation of three transmitters carrying different programmes into a single antenna.

New Research Laboratory in Switzerland. The Radio Corporation of America has recently established Laboratories RCA Ltd, at Zurich in order to provide facilities for fundamental research by RCA in Europe and to furnish a new service for the European licencees of RCA. The research programme will be directed by Dr. Albert Rose of the RCA Laboratories at Princeton, New Jersey, and will consist of experimental studies in the field of solid-state physics, with special reference to the electronic and optical properties of semi-conductors. An Industry Service Laboratory has also been set up to distribute to all licencees technical information, primarily through technical bulletins, on new development originating within the RCA.

C. G. Mayer has been appointed Managing Director of the new Laboratories RCA Ltd.

The United Kingdom Atomic Energy Authority and the Indian Department of Atomic Energy have reached an agreement which ensures that there shall be close co-operation and mutual assistance in the promotion and development of the peaceful uses of atomic energy. The agreement provides for the Authority and the Department to arrange for members of their staffs to consult and work together on mutually agreed topics.

Land Speight & Co Ltd, sole Scottish distributors and service agents for Ericsson Telephones Ltd, have changed their address to 2 Fitzroy Place, Sauchiehall Street, Glasgow, C.3. The telephone number remains as before, Central 1082.

Tufnol Ltd. of Perry Bar, Birmingham, announce the opening of a new branch office at Ellison House, Woodlands Terrace, Glasgow, C.3. From this office will be conducted the sales and technical service for Tufnol in the whole of Scotland. Mr. J. D. Bruen has been appointed Manager of the new office.

The Association of Special Libraries & Information Bureaux announce the publication of Volume II of the Index to theses accepted for higher degrees in the universities of Great Britain and Ireland, covering the academic year 1951-52. Arranged under subject headings, this volume lists over 3 000 thesis titles, and gives the authors' names and universities and the degree for which it was presented. The price per volume is 25s.

Automatic Telephone & Electric Co Ltd have received an order to supply a number of their recently introduced battery operated v.h.f. radio telephone units to the New Zealand Posts and Telegraphs Department. Known as the Country Set, this equipment has been designed to operate for long periods off a 12V battery supply. It provides all the normal telephone facilities, and can be operated into an automatic, C.B. or magneto type exchange.

Marconi's Wireless Telegraph Co Ltd have received an order from the Norwegian Telegraph Administration for eleven 5kW f.m./v.h.f. broadcasting transmitters and a quantity of phasing equipment. The transmitters to be supplied are of a new design, their simplicity in operation will make them particularly suitable for unattended working. The contract was obtained by Marconi's through their Norwegian agents, Norsk Marconikompani.

Fielden Electronics Ltd, industrial instrumentation specialists of Wythenshawe, Manchester, recently opened a Midlands office at 18 Wolverhampton Street, Dudley, Worcs. The engineer in charge is Mr. F. Bernard Price.

The Radio Trades Examination Board granted incorporation. The Board of Trade has now granted incorporation under the 1948 Companies Act to the Radio Trades Examination Board. The Board was formed in 1942 by the co-operation of industry, the retailers and the appropriate professional body. Secretarial facilities for the Board continue to be afforded by the British Institution of Radio Engineers, who together with the Radio Industry Council, the Radio Television Retailers' Association and the Scottish Radio Retailers' Association, financially support its activities. Further details of the work of the board may be obtained from the Secretary, 9 Bedford Square, W.C.1.

The Mond Nickel Fellowships Committee now invites applications for the award of Mond Nickel Fellowships for the year 1956. Awards will be made to selected applicants of British nationality educated to university degree or similar standard, though not necessarily qualified in metallurgy, who wish to undergo a programme of training in industrial establishments. Each Fellowship will occupy one full working year. Full particulars and forms of application can be obtained from the Secretary, Mond Nickel Fellowships Committee, 4 Grosvenor Gardens, London, S.W.1.

Microwave Instruments Ltd of North Shields have opened a London office at 12 Palace Chambers, Bridge Street, S.W.1. The telephone number is TRAfalgar 6575.

West Instrument Ltd, a subsidiary of West Instrument Corporation of Chicago, have commenced operations in England from 1 Newman Street, London, W.1. Their new factory at Horsham, Sussex, is being completed. This British company will manufacture a full range of precision industrial temperature control equipment. Mr. James A. Harnett has been appointed Managing Director of the new company.

The National Aeronautical Establishment at Bedford will in future be known as the Royal Aircraft Establishment, Bedford. The National Aeronautical Establishment was set up in 1946 to supplement the work of the R.A.E., Farnborough.

Electrical and Musical Industries Ltd and Collaro Ltd have both concluded licence agreements with the A.R.F. Development Corporation, a subsidiary of the Armour Research Foundation of Illinois Institute of Technology, Chicago, which will enable them to use the many patents held by Armour in the field of magnetic recording. Mr. J. P. Skinner, Manager of the A.R.F. Development Corporation, has released this information on his return to Chicago after visiting this country.

The Israel air line, El Al, is to fit the Kelvin Hughes periscopic sextant to its three Britannias scheduled for delivery during mid-1957. The sextant, specially designed for use in pressurized aircraft and at great altitudes, will be particularly useful on routes with inadequate radio aids.

Permanoid Ltd, of New Islington, Manchester 4, announce the opening of a new branch at 14 Gibson Street, Glasgow, W.2. This branch will carry a comprehensive range of stocks of all Permanoid plastic cables, together with television aerials manufactured by their subsidiary company, Arrell Electrical Accessories Ltd.

Redifon Ltd announce that passengers travelling across the Atlantic in the new 6 500 ton liner "Bergensfiord" will be able to make private telephone calls to almost any part of the globe. The transmitter employed will be one of the most powerful ever fitted for this purpose in an ocean-going liner. The "Bergensfiord", due to make her maiden voyage next summer, is under construction for the Norwegian American Line by Swan Hunter and Wigham Richardson Ltd, Wallsend-on-Tyne.

Electrical Engineers (ASEE) Exhibition Ltd have changed their address to 6 Museum House, 25 Museum Street, London, W.C.1.

Mr. R. H. Hammans is now President of the Radio Society of Great Britain.

Mr. D. Geddes has been appointed Press Officer to the E.M.I. Record Division, whose offices are at 8-11 Great Castle Street, London, W.1. Mr. J. Dyer, Press Relations Officer of the E.M.I. Group, Hayes, will deal with all information on policy and technical matters in connexion with records as hitherto.

Mr. Terence O'Neill has joined The Solartron Electronic Group Ltd as Personal Assistant to Mr. E. E. Jones, the Group's Commercial Director.

Mr. S. Black has been appointed head of the Publicity Department of the British Electrical and Allied Manufacturers' Association in place of the late Mr. J. J. Conlan.

Sir Ivor Cox has become Deputy Chairman of Associated Electrical Industries Overseas Ltd and will be succeeded as Group Managing Director by Mr. F. J. E. Tearle, who has also become a Director of A.E.I. Ltd.

Mr. A. G. Peacock has been elected Chairman of the Electrical and Electronics Section of the Scientific Instrument Manufacturers' Association in succession to Mr. P. Goudime, Managing Director of Electronic Instruments Ltd. Mr. Peacock is a Director of Mervyn Instruments and Honorary Exhibition Secretary of the Physical Society.

Errata. In the last sentence of Mr. Hyde's letter to the Editor on page 40 of the January issue, for ". . . $R = s$ and $a = 1$ . . . " read " . . . $R < s$ and $a > 1$ . . . ."

It is also regretted that an error occurred in the Philips Electrical Ltd half-page advertisement on page 69 of the January issue. In the description of output voltage for "5-22Mc/s for f.m." read "5-225Mc/s for f.m."

ELECTRONIC EQUIPMENT

A description, compiled from information supplied by the manufacturers, of new components, accessories and test instruments.

White Noise Generator

(Illustrated below)

THE Dawe type 419 white noise generator has been designed to produce electrical noise uniform in intensity over the entire audio and video frequency bands. Three bandwidth ranges are provided, covering 30c/s to 20kc/s, 30c/s to 500kc/s, and 30c/s to 5Mc/s respectively.

The energy levels on the three bandwidth ranges for 1V r.m.s. output are 6mV, 1mV and 0·5mV respectively, when referred to an ideal one-cycle band.

The noise source in the instrument is a thyratron valve placed in a transverse magnetic field. The magnetic field damps the oscillations which are usually produced by a gas discharge and largely equalizes the energy level of the noise spectrum.

The spectrum is further modified by the two-stage wideband amplifier which has three different filter networks between the first and the second stages. In the 20kc/s and 500kc/s ranges low-pass filters are switched in and these give a gradual cut-off for frequencies above the nominal band. In the 5Mc/s range the network compensates for the peak in the noise output of the thyratron at 700kc/s, the fall in level at the higher frequencies thus providing a uniform noise spectrum up to 5Mc/s.

Dawe Instruments Ltd,
99, Uxbridge Road,
London, W.5.

One-third Octave Filter Set

(Illustrated above right)

THE Brüel and Kjaer type 1609 filter set is specially made for acoustical measurements and is designed to meet the requirements of the "Working Committee" for the standardization of the measurements of sound transmission according to the code of July 1949.

The apparatus has 27 fixed third-octave filters between 40c/s and 16kc/s for the standardized main frequencies, but the frequency range is considered larger than required, so that it is also a useful instrument for other investigations in electrical laboratories. The apparatus can be connected to suitable amplifiers. The micro-

phone amplifier type 2602 is designed to serve as an input and output amplifier for the filter.

The audio frequency filter is furthermore provided with weighting networks for noise level measurements. The apparatus is designed for mechanical connexion to level recorder type 2304, so that recordir g of reverberation curves and automatic recording of noise spectograms can be carried out.

Distributed by

B & K Laboratories Ltd,
59/61, Union Street,
London, S.E.1.

High Frequency Power Transformers and Chokes

(Illustrated below)

THE Components Division of Mullard Ltd are now manufacturing high frequency power transformers to customers' requirements

The use of Ferroxcube as the core material enables efficient operation to be achieved over the frequency range 2kc/s to 20Mc/s. Powers up to 1kW can be handled. In addition to their excellent electrical performance, the weight of these transformers is often less than that of iron cored components.

Inductances for smoothing and interference suppression are also made. These range from low-current high inductance (up to 200H) types to high-current low inductance types used for suppressing power supply circuits.

The larger transformers and chokes use

Ferroxcube "U" cores. Where only moderate amounts of power are involved, however, it is possible to use Ferroxcube pot cores, which have the advantages of a low external field and lower winding capacitances.

The larger transformer illustrated measures $4\frac{3}{4}$in by $2\frac{1}{4}$in by $2\frac{1}{4}$in and has a power rating of 1kW at 20kc/s.

Mullard Ltd,
Century House,
Shaftesbury Avenue,
London, W.C.2.

Square and Sine Wave Decade Oscillator

(Illustrated below)

THE Winston decade oscillator is designed to supply square and sine wave signals of good waveform over the

frequency range of 10c/s to 100kc/s. The frequency is selected by a dial scaled 10 to 100 and a mulitiplier switch can be set at X1, X10, X100 and X1000. The frequency calibration is within $\pm 1\frac{1}{2}$ per cent. On sine wave output the harmonic distortion is less than 1 per cent and the hum content is less than 0·1 per cent at full output. On square wave output the rise time at 100kc/s is approximately 0·3μsec.

Winston Electronics Ltd,
Shepperton,
Middlesex.

Alternating Voltage Stabilizer

(Illustrated above right)

THE A.C.2 Mk IIA is a development from the old A.C.2 Mk I and the previous A.C.1 stabilizer. This latest model uses the same circuit as the type A.C.7, in which all capacitors and resistors have been derated strictly in accordance with current Inter-Service requirements, and the whole instrument is very much stronger both electrically and mechanically than its predecessors. The A.C.2 Mk IIA is a model that has been designed specially for applications where no controls are required to appear on the front panel. This model was introduced at the request of a Government department, and is the preferred model where the instrument is to be used at a

fixed voltage and where meters are not required.

The A.C.2 Mk IIB is a laboratory instrument, fitted with two meters, and with mains on/off switch and voltage setting control available on the front panel.

The instrument is primarily intended to provide a stable output voltage at the nominal value of the supply, which may be anywhere between 200 and 250V. For any given output voltage, the input voltage can vary between minus 17·5 per cent and plus 8·75 per cent from the output voltage.

It is also possible to use the stabilizer as a variable voltage supply between certain limits.

The current rating is 0 to 9A at 25°C and 0 to 7A at 40°C.

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

Heavy Duty Soldering Iron

THE Acru "Pyrobit" extra heavy duty soldering iron has been produced for the soldering of heavy gauges of sheet metal, wire, etc., where an electric iron could not normally be used. The power consumption is 450W and the weight of the iron is approximately 8lb. The large area of the element ($11\frac{1}{4}in^2$) plus the method of clamping ensures a long life with continuous usage.

The Acru Electric Tool Manufacturing Co Ltd,
Chapel Street, Stockport Road,
Levenshulme,
Manchester, 19.

Coaxial Switch
(Illustrated below)

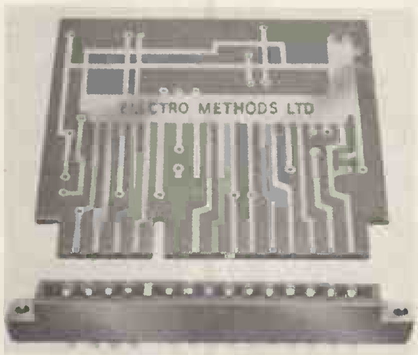
THE type CS.11 coaxial switch is a development of the same firm's attenuator switch and casting type A37. On the back plate six Belling & Lee coaxial sockets are mounted with their

centre terminals connected to the switch contacts. The wiper of the switch is brought to the centre terminal of a similar socket mounted on the side of the casting. The unit comprises, therefore, a six-position coaxial switch of small dimensions, the overall diameter being $2\frac{1}{2}$in. The crosstalk between channels is better than −70dB at 45Mc/s and the external leakage is better than −80dB.

Advance Components Ltd,
Marlowe Road,
Walthamstow,
London, E.17.

Printed Circuit Connectors
(Illustrated below)

ELECTRO METHODS announce that they have completed a licensing arrangement with Winchester Electronics Incorporated, U.S.A., to manufacture a complete range of high-grade electrical components. Included among these are printed circuit receptacle connectors which function as a connecting link between printed circuits and conventional wiring.



They allow instant removal and replacement of the "plug-in" card, provide positive identification of individual circuts and simplify attachment of cable lead-off wires.

These connectors have 5/32in centre-to-centre contact spacing and 5A contacts. They will be available in 6, 10, 12, 15, 18 and 22 contact position receptacles.

The contacts are spring temper phosphor bronze gold plated over silver, and the bodies are mineral filled Melamine.

Electro Methods Ltd,
Caxton Way,
Stevenage,
Hertfordshire.

Quench/Amplifier Unit
(Illustrated above right)

THIS dual purpose instrument enables the resolving time of counters to be accurately defined by applying to them a negative quenching pulse of known duration.

Designed for use with self-quenching Geiger-Müller counters, the unit is built on novel lines, which includes the provision of a switch to cut off the quench pulse. It then acts as a pre-amplifier or pulse former. This is of importance when using counters where external quenching is not required.

The construction and design of the box makes the unit suitable for counting

above or below lead castles or shields.

The quench/amplifier unit, type 660, together with the "I.D.L." e.h.t. supply unit, type 532 and the scaler, type 500, with suitable counters and leadware, form the basic units for precision Geiger-Müller counting requirements. With this basic equipment and additional I.D.L. instruments, it is possible to build up more elaborate counting systems for scintillation and proportional counting, and ultimately to the automatic scanning of beta- and gamma-ray spectra.

Isotope Developments Ltd,
Beenham Grange,
Aldermaston Wharf,
Nr. Reading,
Berkshire.

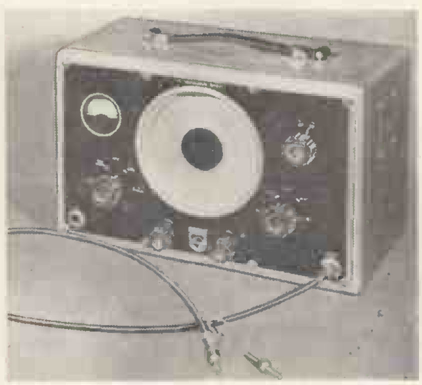
Wideband RC Signal Generator
(Illustrated below)

PHILIPS type GM.2317 is a low frequency generator with a wide range of frequencies from sub-audible to supersonic. It is designed to supply a stable l.f. voltage for measuring bridges or for modulating any type of h.f. oscillator.

Using the Wien bridge principle, the apparatus supplies frequencies from 20c/s to 250kc/s in six ranges and with an absolute accuracy of better than 2 per cent.

Output voltage (maximum 10V) is adjustable by a 4-step attenuator and is also continuously variable. This voltage is monitored on a built-in voltmeter. Output impedance depends on the attenuator settings and varies between 3kΩ and 7Ω. Total distortion does not exceed 0·3 per cent.

Philips Electrical Ltd,
Century House,
Shaftesbury Avenue,
London, W.C.2.



Meetings this Month

THE BRITISH INSTITUTION OF RADIO ENGINEERS

Date: 29 February. Time: 6.30 p.m.
Held at: The London School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, London, W.C.1.
Discussion: Technique of Microwave Measurements.
Opened by: E. M. Wareham.

Merseyside Section

Date: 1 February. Time: 7 p.m.
Held at: The Council Room, Chamber of Commerce, 1 Old Hall Street, Liverpool 3.
Lecture: Development of a Design for an Angle Modulation Radio Link.
By: H. C. Spencer.

North-Western Section

Date: 2 February. Time: 6.30 p.m.
Held at: Reynolds Hall, College of Technology, Sackville Street, Manchester.
Lecture: Design of Battery Operated Frequency Modulation Receivers.
By: R. A. Lampitt.

West Midlands Section

Date: 8 February. Time: 7.15 p.m.
Held at: Wolverhampton and Staffordshire Technical College, Wulfruna Street, Wolverhampton.
Lecture: The Ionophone Loudspeaker.
By: A. E. Falkus.

Scottish Section

Date: 22 February. Time: 7 p.m.
Held at: The Institution of Engineers and Shipbuilders, 39 Elmbank Crescent, Glasgow.
Lecture: Colour Television.
By: B. V. Somes-Charlton.

South Wales Section

Date: 22 February. Time: 6.30 p.m.
Held at: Glamorgan Technical College, Treforest.
Lecture: Colour Television.
By: G. N. Patchett.

THE INSTITUTION OF ELECTRICAL ENGINEERS

All London meetings, unless otherwise stated, will be held at the Institution, commencing at 5.30 p.m.
Date: 2 February.
Lecture: The Potentialities of Railway Electrification at the Standard Frequency.
By: E. L. E. Wheatcroft and H. H. C. Barton.
Date: 6 February.
Discussion: What should be our National Fuel Policy?
Opened by: E. F. Schemacher.

Radio and Telecommunication Section

Date: 8 February.
Lecture: Pulse Techniques, with particular reference to Line and Radio Communication.
By: E. M. Deloraine.
Date: 20 February.
Informal evening on Ultrasonics in Industry.
Talk by: C. F. Brocklesby.

Measurement and Control Section

Date: 14 February.
Lecture: An On-Off Servomechanism with Predicted Change-over.
By: J. F. Coales and A. R. M. Noton.

Supply Section

Date: 22 February.
Lectures: The Penetration of Surge Voltages through a Transformer coupled to an Alternator and The Propagation of Surge Voltages through Turbo-Alternators with Concentric Conductor Type Windings.
By: B. C. Robinson.

Faraday Lecture

Date: 15 February. Time: 6 p.m.
Held at: Central Hall, Westminster, London, S.W.1.
Lecture: Coal Mining Electrically.
By: B. L. Metcalf.
(Admission by ticket obtainable from The Institution.)

East Midland Centre

Date: 7 February. Time: 6.30 p.m.
Held at: Loughborough College.
Lecture: The Generation and Synthesis of Music by Electrical Means.
By: A. Douglas.

Cambridge Radio and Telecommunication Group

Date: 14 February. Time: 6 p.m.
Lecture: Quartz Crystals for v.h.f. Communication.
By: N. C. Rolfe.

East Anglian Sub-Centre

Date: 28 February. Time: 8 p.m.
Held at: The Cavendish Laboratory, Cambridge.
Lecture: The United Kingdom Atomic Energy Project.
By: J. V. Dunworth.

Mersey and North Wales Centre

Date: 20 February. Time: 6.30 p.m.
Held at: Liverpool Royal Institution, Colquitt Street.
Lecture: Transatlantic Telephone Cable.
By: M. J. Kelly, Sir Gordon Radley, G. W. Gilman and R. J. Halsey.

North-Eastern Centre

Date: 14 February. Time: 7 p.m.
Held at: The Cumberland Technical College, Workington.
Lecture: The Future of Electronics in Industry.
By: E. R. Davies.

North-Eastern Radio and Measurement Group

Date: 20 February. Time: 6.15 p.m.
Held at: King's College, Newcastle upon Tyne.
Lecture: High Speed Photography.
By: W. D. Chesterman.

North-Western Centre

Date: 7 February. Time: 6.15 p.m.
Held at: The Engineers' Club, Albert Square, Manchester.
Lecture: Germanium and Silicon Power Rectifiers.
By: T. H. Kinman, G. A. Carrick, R. G. Hibberd and A. J. Blundell.

North-Western Radio and Telecommunication Group

Date: 15 February. Time: 6.45 p.m.
Held at: The Engineers' Club, Albert Square, Manchester.
Lecture: Pulse-Time-Modulation Terminals for Music Transmission over Radio Links.
By: R. F. Rous.

Northern Ireland Centre

Date: 14 February. Time: 6.30 p.m.
Held at: Lecture Room A, Engineering Department, Queens University, Belfast.
Lecture: TRIDAC—A Large Analogue Computing Machine.
By: F. R. J. Spearman, J. J. Gait, A. V. Hemingway and R. W. Hynes.

South-West Scotland Sub-Centre

Date: 1 February. Time: 7 p.m.
Held at: The Institution of Engineers and Shipbuilders, 39 Elmbank Crescent, Glasgow.
Lecture: Equipment of Instrumental Accuracy for Recording and Reproduction of Electrical Signals using Cinematographic Film.
By: H. McGregor Ross.
Date: 29 February. (Time and place as above.)
Lecture: Germanium and Silicon Power Rectifiers.
By: T. H. Kinman, G. A. Carrick, R. G. Hibberd and A. J. Blundell.

South Midland Radio and Telecommunication Group

Date: 27 February. Time: 6 p.m.
Held at: The James Watt Memorial Institute, Great Charles Street, Birmingham.
Lecture: The Theory, Applications and Manufacture of Transistors.
By: A. F. Gibson, S. W. Noble and B. B. Frusztajer.

North Staffordshire Sub-Centre

Date: 10 February. Time: 7 p.m.
Held at: Dunoan Hall, Stone.
Lecture: Colour Television.
By: L. C. Jesty.

Rugby Sub-Centre

Date: 1 February. Time: 6.30 p.m.
Held at: The Rugby College of Technology and Arts.
Lecture: Germanium and Silicon Power Rectifiers.
By: T. H. Kinman, G. A. Carrick, R. G. Hibberd and A. J. Blundell.
Date: 14 February. Time: 6.30 p.m.
Held at: Rugby Radio Station.
Lecture: New High-Frequency Transmitting Station at Rugby.
By: C. F. Booth, and B. N. MacLarty.

Southern Centre

Date: 8 February. Time: 7.30 p.m.
Held at: The R.A.E. Technical College, Farnborough.
Lecture: V.H.F. Propagation by Ionospheric Scattering and its Application to Long-Distance Communication.
By: W. J. Bray, J. A. Saxton, R. W. White and G. W. Luscombe.

THE SOCIETY OF INSTRUMENT TECHNOLOGY

Date: 9 February. Time: 7 p.m.
Held at: Manson House, Portland Place, London, W.1. Annual General Meeting of Control Section.
Lecture: The Scope for Feedback Control and Automatic Calculation in Industrial Mechanization.
By: A. Tustin.

THE TELEVISION SOCIETY

Date: 21 February. Time: 7 p.m.
Held at: The Institute of Education, Mallet Street, London, W.C.1.
Lecture: Some Problems in a Band-sharing Colour Television System.
By: A. V. Lord.
Date: 28 February. (Time and place as above).
Lecture: Development of a 21-in. Colour Television Receiver.
By: H. A. Fairhurst.
(Admission to the above lectures by ticket only.)

PUBLICATIONS RECEIVED

TRUTH WRESTED FROM NATURE BY SCIENCE is a well produced and illustrated book recently published by the Dunlop Rubber Co. Ltd. It deals not only with research itself but with the application of that work in the pilot plants, laboratories and test-houses of the various production groups and factories. The Dunlop Rubber Co. Ltd., St. James's House, St. James's Street, London, S.W.1.

YEAR BOOK OF THE PHYSICAL SOCIETY 1955 contains special lectures before the Society, proceedings of meetings of the Society, report of the Council for 1954 and Accounts and balance sheet for 1954. The Physical Society, 1 Lowther Gardens, Prince Consort Road, London, S.W.7. Price to non-members 10s.

FERRANTI COMPUTERS is the title of a brochure issued on the occasion of the establishment of the Ferranti Manchester Electronic digital computer at the Instituto Nazionale per le Applicazioni del Calcolo in Rome. Ferranti Ltd., Publicity Department, Hollinwood, Lancashire.

THE BRITISH COUNCIL TWENTY-FIRST ANNIVERSARY REPORT includes a message from the Prime Minister and an article by Sir Harold Nicolson. Since the end of the war the Council has arranged programmes for 35 726 overseas visitors, mainly professional people and technicians, including many who have come under United Nations or Colombo Plan schemes. A general survey for the year 1954-55 is given and a summary of the work undertaken by the Council since its inception. The British Council, 65 Davies Street, London, W.1.

THE DESIGN OF A RIBBON TYPE PRESSURE-GRADIENT MICROPHONE FOR BROADCAST TRANSMISSION is the subject of the fourth monograph in the BBC Engineering Division series. BBC Publications, 35 Marylebone High Street, London, W.1. Price 5s.

COUNTING INSTRUMENTS is a catalogue covering the range of mechanical electromagnetic counters manufactured by Counting Instruments Ltd., 5 Elstree Way, Boreham Wood, Herts.

THE CANADIAN STANDARDS ASSOCIATION INFORMATION FOR UK MANUFACTURERS EXPORTING ELECTRICALLY-OPERATED EQUIPMENT TO CANADA is the revised edition of a booklet which first appeared in 1952. Virtually all the British electrical equipment sold to Canada each year, with the exception of some heavy plant for power stations, now receives a seal of approval before it leaves this country. Approval is given by the British Standards Institution, acting as agent for the Canadian Standards Association. This system of approval-in-advance is now successfully used by some 400 British firms. The British Standards Institution, 2 Park Street, London, W.1. Price 5s.