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LOOKING FORWARD

Seasonal greetings, which are traditionally circulated at this time, invariably contain a message of hope for the future. Whilst argument exists as to whether the true purpose and spirit of Christmas are really understood, few will deny that there is a general desire for peace and goodwill.

Foreign affairs again cast a shadow over the lives of everyone but the eternal hope for peace finds expression in looking forward to the profitable enjoyment of man's labours. In this spirit, the British Government continues to plan and build the 1951 Festival. The terms of reference of this Festival are "British contributions to civilization," in which engineering will occupy a proud position, for no single field of endeavour has outnumbered the contributions made by science.

The Government has also stated that apart from the main Festival Exhibitions, 1951 is expected to be an occasion for other organized activities from ". . . our independent and vigorous scientific Institutions." Thus, although the new defence programme cannot be forgotten, the Institution continues to plan and look forward to the 1951 Convention.

Facilities have now been granted for the Institution to hold the Television Session of the 1951 Convention in Kings College, Cambridge. This session will be held during August, 1951.

The Radio Communication and Navigational Aids Session will be held at the University College, Southampton, during July, 1951, and as with Kings College, Cambridge, the Institution especially appreciates the arrangements which have been made by the College authorities for residential accommodation during the period of each session.

The Valve Technology and Nuclear Instrumentation Session will be held at University College in London at the end of June, 1951.

The Audio Frequency Engineering Session will be held in London during the 1951 Radio Show.

Further details including titles and authors of individual contributions in each session will shortly be circulated to the membership. There is already indication that the main problem of the Convention Committee will be accommodation and that the success of these Sessions is already ensured, subject to international circumstances.

Apart from the Convention, members may look forward also to an increase in other Institution activities. It is known that we shall conclude this, our Silver Jubilee Year, with the most favourable Annual Report that has yet been given in the history of the Institution. Such progress can only be achieved by increasing membership and a wide appreciation of the Institution's work and status.

Goodwill plays a great part in the development of the Institution's activities. It is unfortunate that expressions of goodwill at this time of year are seldom maintained throughout the ensuing twelve months. Perhaps it is a 20th-century failing to regard difficulties as inevitable and, if absent, then it is necessary to create them. We take pride in recalling the difficulties which have been overcome in furthering the objects of the Institution. Much co-operation had been hoped for, some has been achieved, and the unbroken progress of the Institution has earned increasing goodwill.

General goodwill can only lead to peace and that in turn is the first essential towards progress and the great happiness of man. It is in that spirit that we look forward to 1951.

PROGRAMME AND PAPERS COMMITTEE

James Robinson Hughes was born in London in 1912 and was educated at Colfe's Grammar School, Lewisham.

In 1930 he joined Siemens Brothers & Co., of Woolwich, as a Senior Student, and obtained City and Guilds qualifications in communications subjects. After completing his training, he joined the Development Laboratory and for the next seven years he was engaged on development work for the factory production of various items of telephone equipment. Soon after the outbreak of war, Mr. Hughes took charge of the Audio Frequency Laboratory at Dewsbury.

In 1942, Mr. Hughes was appointed Technical Secretary to the British Radio Valve Manufacturers' Association, a position he held for six years until he joined his present firm, Hivac, Ltd.

Elected a Member in 1946, Mr. Hughes served on the Membership Committee until 1948. Since 1948 he has been a member of the Programme and Papers Committee and he is responsible for arranging the Hearing Aids Symposium which is to be held on January 10th, 1951.

He is examiner in Audio Frequency Engineering for Part IV of the Graduateship Examination.

Edwin Arthur William Spreadbury was born in London in 1904. His technical education was gained at Willesden Polytechnic where, between 1923 and 1926, he obtained various City and Guilds Certificates.

Entering the radio industry in 1923, Mr. Spreadbury had a wide experience before joining the laboratory staff of *The Wireless and Electrical Trader* in 1937, where he was subsequently made responsible for the production of the well-known Service Sheets. He was appointed Technical Editor of *The Wireless and Electrical Trader* in 1941.

First elected an Associate of the Institution in 1934, Mr. Spreadbury was transferred to Associate Membership in 1937. He was appointed a member of the Programme and Papers Committee in 1941 and his intimate knowledge of technical journalism has proved of great assistance in the examination of papers and the arrangement of programmes.

Mr. Spreadbury has also served on the Library Committee since 1947 and represents the Institution on the Radio Trades Examination Board. He is an examiner for the Radio and Television Servicing Certificate Examinations conducted by the Board. Mr. Spreadbury was elected a Member of the Institution in 1947.

Arthur William Keen was born at Woodstock in 1919 and was educated at Southfield School, Oxford. After a short period with E. K. Cole, Ltd., he joined the television department of A. C. Cossor, Ltd. He was commissioned in the R.A.F. in 1939 and his final appointment was Chief Instructor of No. 8 Radio School, Cranwell. On leaving the R.A.F. in 1946 he was engaged as a television research engineer by R.F. Equipment, Ltd. Since 1947 he has been with E.M.I. Research Laboratories, Ltd., and has been concerned with large-scale radar and television projects.

Mr. Keen was elected an Associate Member of the Institution in 1945 and transferred to Member in 1950. He became a member of the Papers Committee in 1948.

The author of a number of papers in the *Journal*, Mr. Keen was recently awarded the Louis Sterling Premium for his paper on "The Integration Method of Linearizing Exponential Waveforms." He is also the author of "Principles of Television Reception."

SIGNAL SOURCES FOR TELEVISION TESTING*

by

D. W. Thomasson† (*Associate Member*)

A paper read before the London Section on 18th November, 1950.

SUMMARY

The paper reviews the performance requirements for signal sources used in television testing, and examines methods whereby these requirements can be satisfied for a minimum cost. Suitable circuits are considered, and some complete equipments are outlined.

1.0. Introduction

Television testing involves the use of several types of test gear which are not normally needed for work on radio sound receivers. The R.F. and I.F. stages of a television receiver cannot be aligned with sufficient accuracy without the aid of a suitable signal generator, the accuracy obtainable with the average " test oscillator " used for radio receiver alignment being totally inadequate. The scanning circuits of the television receiver can only be tested and adjusted with the aid of a signal which at least simulates the waveform of the standard television signal, and an oscilloscope is almost essential for this and other sections of television test and maintenance work.

It is generally agreed that specialized signal sources are needed for television test work, but there is a wide divergence of opinion regarding the exact equipment necessary. The term " Pattern Generator " may be applied to a simple generator producing a few crude pulses, or a complex instrument which provides an output which is a close approximation to the standard television signal. Some authorities state that a response curve tracer is essential for alignment work, while others maintain that better results are obtained by aligning for optimum picture quality.

The present study seeks to relieve this confusion by proposing a minimum performance specification for such apparatus, the specification being based on the fundamental working principles of television. Such a specification would be of little value if it could not be satisfied within the cost limits imposed by the economic conditions of the trade and industry, and it is therefore augmented by a review of the available circuits which can be used, comparison of alternative circuits being based on their relative efficiency and economy. Examples of the combination of these circuits to form complete instruments are outlined.

2.0. Performance Requirements

2.1. *General Requirements*

2.1.1. Television picture or pattern signal sources contain two separable parts : the video-frequency generator and the radio-frequency generator. The requirements for the video generator are mainly concerned with the output waveform, whereas the performance of the radio-frequency generator is critical mainly in respect of frequency. The most general specification for the video generator is that its output should bear sufficient resemblance to the standard waveform to ensure that a receiver adjusted on a basis of the video generator output will function correctly with the normal transmitted signals. The accuracy of the R.F. generator should be high enough to ensure that no deterioration in picture quality can result from the disparity between the frequency of the test apparatus carrier and the normal transmitted carrier frequency.

2.1.2. The video signal requirement could be satisfied by producing an exact replica of the standard signal, but this would presumably require the use of an exact replica of the generating equipment used, and some degree of simplification must be accepted. It is important to guard against over-simplification, however. Several attempts have been made to introduce test routines based on very simple modulation waveforms. In one case, a 1 kc/s sine wave signal is suggested, it being stated that

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"approximately 20 horizontal bars" should appear on the receiver screen. This may well be true, but the presence of the bars does not indicate that the receiver is functioning correctly. The frame time base may be running at 47·6, 50, or 52·6 c/s, the frame fly-back may be incorrect, and many other important faults may be present.

2.1.3. The most serious failing of this type of test is the absence of any check on interlacing and time-base interaction. Almost as serious is the absence of information regarding the horizontal resolution, sync-separator action, and internally generated "ghost images." It is clear that an adequate test can only be made if the test signal is at least an approximation to the standard signal (Fig. 1). The only debatable point concerns the allowable tolerances of the approximation.

2.1.4 Correct alignment of the R.F. and I.F. stages of a television receiver can only be carried out with the aid of a test signal having a frequency within 0·1 per cent. of the correct value. As this statement does not accord with some examples of current practice, the matter must be examined more closely. With "vestigial sideband" tuning, now in general use, the response curve in the region of the carrier frequency is very critical. A relative shift of as little as 100 kc/s between the carrier frequency for which the set is tuned, and the actual carrier frequency, can raise or lower the extreme frequency response by as much as 20 per cent. The frequency error is only 0·15—0·22 per cent., but the effect is clearly visible.

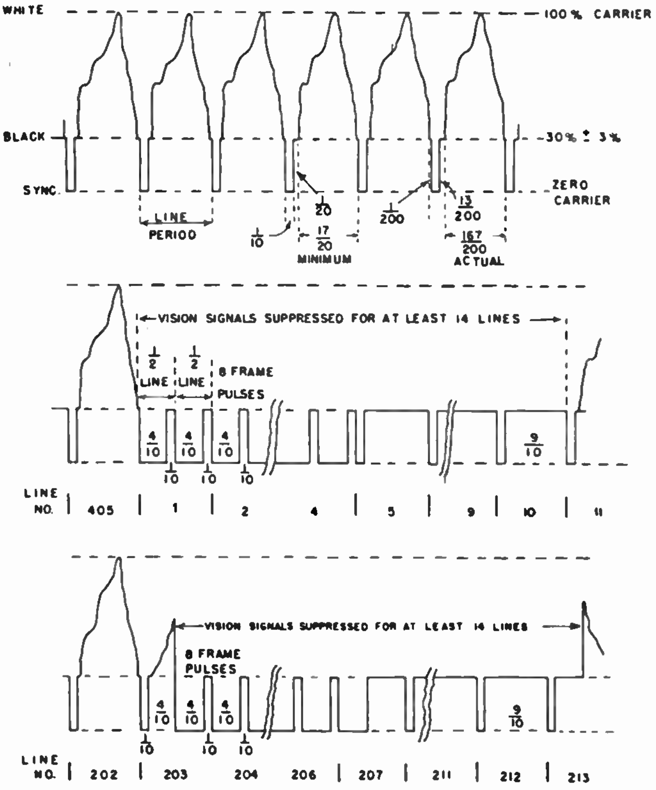


Fig. 1.—The B.B.C. television waveform.

2.1.5. It is almost impossible to obtain sufficient accuracy with a continuously tunable generator. An attempt has been made to cover the whole 41-68 Mc/s band with a single continuous 180° scale. With a vernier cursor and slow-motion drive, a setting error of the order of 50 kc/s may be expected, corresponding to an angular error of 20 minutes of arc. A further 50 kc/s may be added for drift and calibration error, and it is clear that the accuracy is insufficient. In at least one known case, the vernier and slow-motion drive are omitted. The use of such a generator is likely to do more harm than good.

2.1.6. The necessity for frequency accuracy does not apply to the carrier alone. It has been suggested that the alignment of a television receiver could be carried out by following a set routine in which given adjustments are made with given input frequencies applied. Such routines are, in fact, used in factory alignment, but only for rough preliminary adjustments, the proper alignment being carried out with a video test signal. The limitations of the method will be obvious from the figures quoted above. Even with a frequency accuracy of ±0·1 per cent., the process could be compared with the measurement of the video response curve using a generator whose accuracy is ±50 kc/s.

2.1.7. The most satisfactory solution is to establish the carrier frequency by crystal control, or by a highly stable fixed-tuned oscillator. For many purposes, a single carrier frequency will suffice, if provision is made for altering the frequency as and when necessary. Video modulation should be applied to the carrier in a separate modulator circuit, the modulation being either a complete video signal or, for response checking, a single variable frequency signal of reasonable accuracy. It is also possible to base curve tracing equipment on the same principle, the modulating frequency being varied in synchronism with the scan on a cathode ray oscilloscope.[8]

2.1.8. One matter which has not been mentioned concerns the measurement of sound channel rejection. For this purpose, a second carrier frequency can be provided, with optional 1 kc/s sinusoidal modulation. This can be used for alignment of the sound channel, and for checking sound break-through.

2.1.9. Summarizing the requirements stated—

(*a*) The video signal must approximate to the standard signal, allowable tolerances to be specified.

(*b*) The carrier frequency must be within 0·1 per cent. of the nominal value.

(*c*) Radio-frequency signals for use in accurate alignment must be very precisely controlled, a tolerance of 5 per cent. on the difference between the signal and the relative carrier being suitable.

2.2. *Video Signal Tolerances*

2.2.1. A method of expressing time intervals as a percentage of the line scan interval will assist in the specification of video signal tolerances. With a line scan interval of approximately 100 μsec., 1 per cent. of the line scan interval will approximate to 1 μsec. The time intervals will be written in the form "x% L," signifying x per cent. of the line interval. In general, the time relationships between the elements of the composite video signal should be maintained correct within 0·5% L for pattern signals, a smaller tolerance being desirable for realistic presentations. It should be noted that 0·5% L corresponds to a horizontal distance of about 1/170th of the picture width (0·05 in. on picture 8½ in. wide).

2.2.2. With sync-separator circuits of the integration-differentiation type, the leading edge of the line sync-pulse must be sharp, and the mean D.C. levels of the line and frame pulses must be sufficiently different. Sync-separators working on the delay principle demand accuracy of pulse lengths. In either case, little simplification of the synchronizing signal waveform is possible without disturbance of the synchronizing action.

2.2.3. When one repetition frequency has been selected, all the other frequencies and pulse intervals are automatically fixed. It is therefore important to consider whether the frame repetition frequency should be fixed at the nominal value of 50 c/s, or made equal to the frequency of the mains supply. The latter course entails the use of additional circuitry, but has been regarded as an essential feature of all true pattern generator equipment, as a disparity between the frame scan and mains supply frequencies may have an appreciable effect on the operation of some receivers. A further advantage of relating the frame scan and mains supply frequencies is that a semi-automatic check on the operating frequency of the video generator is provided. The mains supply may be subject to considerable frequency variation, but the variations of the frequency of a free-running oscillator might be even greater, though very high stability can be obtained with care.

2.2.4. Another aspect of this matter is the constancy of the mark-space ratio of the various pulses concerned. If the line sync-pulse duration is fixed at, say, 10 μsec, and the line frequency is initially 10 kc/s, then the line sync-pulse duration will be exactly 10% L, the correct value. If the line frequency is now increased by 10 per cent., the line sync-pulse duration remaining 10 μsec, the duration will become 11% L. The mean D.C. level of the line sync-pulses will fall, while the mean D.C. level of the frame sync-pulses will rise. It may upset the sync-separator action.

2.2.5. No definite ruling will be given here on the necessity for relating frame scan and mains frequencies. It can be stated that for ordinary test purposes it has been found possible to work quite satisfactorily without mains locking. It is relevant to note that the recent C.C.I.R. television study group meetings showed a unanimous preference for non-synchronous operation. There is no point in providing mains frequency locking in a test source if it is not provided in the transmitted signal. The fact that some existing receivers will not function reliably with a non-synchronous signal must be regarded as irrelevant.

2.2.6. The complete specification for the synchronizing signal may be summarized as follows :—

Frame scan frequency : 50 c/s±3% OR mains supply frequency.

Line scan frequency : Exactly 202½ times the frame scan frequency.

Line sync-pulses : Frequency : line scan frequency
Length : (10±1)%L (—ve going)

Frame sync-pulses : Frequency : Twice line scan frequency
Length : (10±1)%L (+ve going)

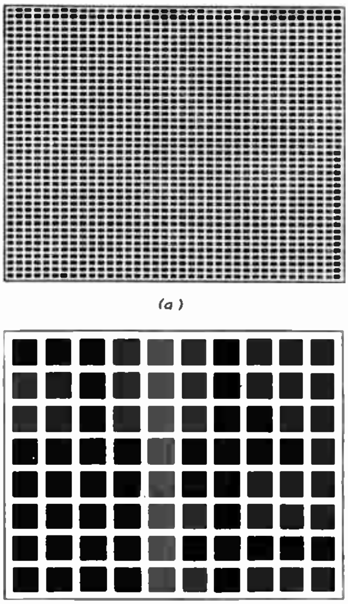
(*Note.*—The tolerances on pulse lengths may be doubled for many receivers, and (10±2)%L is acceptable in such cases, but a few are especially critical in this respect.)

Frame sync-cycle : 8 frame sync-pulses must be substituted for line sync-pulses, starting at the beginning of the 1st line, and in the centre of the 203rd line.

The time intervals between different elements of the signal should, in general, be maintained to within 0·5% L or less.

2.2.7. Blanking signals are not strictly synchronizing signals, but it will be convenient to consider them at this point. Their main function is to avoid a sudden transition between the 100 per cent. " peak white " level and the zero modulation " blacker-than-black " level, and to suppress the trace during the flyback periods. It may seem strange to mention the trace suppression last, but this is a less important function from the point of view of test work. It is sometimes convenient to be able to see the trace during the flyback when making tests, but the sync-pulses must always have a clearly defined leading edge.

2.2.8. The blanking pulses may be specified as follows :—


(a)

(b)

Fig. 2.—Typical synthesized patterns.

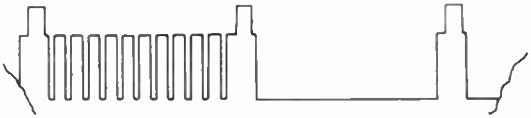


Fig. 3.—Section of video signal for pattern of Fig. 2b.

Frame blanking : Picture signal removed for a period of not less than 1200% L, beginning at or before the start of each frame pulse group. (At one period, it appeared that the B.B.C. were starting this blanking period about 50% L before the first frame pulse.)

Line blanking : Picture signal removed for a period of not less than 13% L, beginning at least 0·25% L before the start of each line sync-pulse.

2.2.9. The picture signal will be examined in detail in the next section, but it may be noted here that it should occupy the correct amplitude range, between the 30 per cent. (±3 per cent.) and 100 per cent. levels. The synchronizing signal should occupy the 0—30 per cent. level, but it may be noted that the B.B.C. fix the minimum level at approximately 1 per cent. It should not be allowed to rise above 2 per cent. in a test source. A few receivers do not employ D.C. restoration to maintain the black level of the picture at a constant intensity, and for such receivers it is desirable to set the mean picture level at about 65 per cent. modulation. The value of this procedure, which was suggested by the manufacturers of such a receiver, may be debatable, but it has been found to have some importance in practice.

2.3. *The Picture Signal*

2.3.1. There are four general types of picture signal which may be used, each type having a particular utility :—

(*a*) Dot patterns

(*b*) Line patterns

(*c*) Shape patterns

(*d*) Still pictures, or realistic patterns.

The choice of pattern type must be based on the balance between utility and complexity.

2.3.2. The dot pattern is built up from a number of dot elements arranged in a suitable pattern on the screen. It is mainly useful for checking scan linearity and constancy of focus. The simplest form of dot pattern is produced with a train of equally spaced pulses and involves only one picture frequency. Pulses at 101,250 c/s, for example, would give eight dots per line, two being removed in the line blanking interval. The dots would appear on the screen as eight continuous vertical lines. A more representative dot pattern would be produced by switching the dots in for the duration of, say, every 45th line. This, however, would necessitate the use of a second picture control frequency and equal resources would suffice for the production of the more useful line pattern, examples of which are illustrated in Figs. 2(*a*) and 2(*b*). The vertical lines are formed by dot pulses as before and the horizontal lines are formed by sets of longer pulses. For pattern (*a*), the necessary signals are pulses ¼% L in length at 40 times the line scan frequency, and pulses 85% L in length at 45 times the frame scan frequency. Pattern (*b*) requires pulses 2½% L long at 12 times line frequency and pulses 600% L long at 9 times frame frequency. Either pattern can be reversed in polarity so that the black and white areas are exchanged.

2.3.3. The shape pattern is considerably more complex in appearance, and demands correspondingly complex generating resources. A shape element which was used in one factory test generator is shown in Fig. 4, this shape being repeated several times to form a complete pattern. The object of the pattern was the simultaneous determination of scan linearity, horizontal resolution, and general performance, the horizontal resolution required for clear reproduction of the " prongs " increasing towards the lower part of the shape. The signals used in synthesis of the shape are a triangular wave, which is clipped at a variable level to give the change in the width of the " prongs," and a square wave which switches this signal in and out several times during each line. With a 1,012,500 c/s triangular wave, a 101,250 c/s square wave and a 450 c/s sawtooth wave controlling the clipping level, the shape shown would be repeated 81 times, in 9 rows of 9 shapes each. This remarkable example of video-signal synthesis will probably remain unique, as more versatile shape patterns can be produced by using scanner devices.

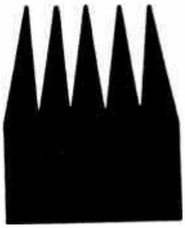


Fig. 4.—Typical shape pattern.

2.3.4. All the above patterns are obtained by synthesis from pulse waveforms, and have the common advantage that the time dimensions in all parts of the picture can be inter-related with accuracy, the only possible source of non-linearity being the scanning generator in the television receiver. For more complex patterns and actual pictures, it is better to employ an electronic scanning device, which scans a master pattern with an electron beam. The scanning action can be obtained in two ways. In the completely electronic type of scanner, the electron beam is projected on to a target plate on which the required pattern has been printed.[1]

In the "flying-spot" scanner, the electron beam is made to produce a spot of light on a very short persistence screen and the light from the spot is passed through a transparency of the required pattern on to a photo-cell.[2,7] Owing to the greater ease with which purely electronic scanning devices can be obtained, the "flying-spot" method has not received the attention it deserves, but it offers an important advantage in that any transparency of suitable size can be reproduced.

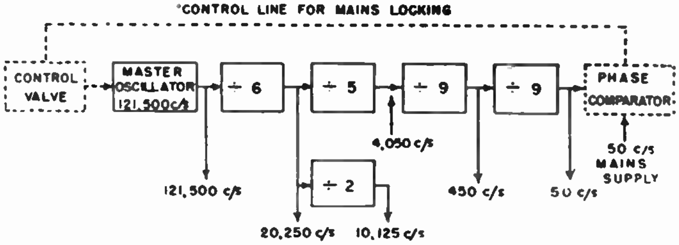


Fig. 5.—Timing signal generator.

2.3.5. Most existing pattern generators worthy of the name provide a formal synthesized pattern. A few provide a shape pattern or actual picture by means of an electronic scanner, and one or two provide both a formal pattern and a picture. For most purposes, a formal pattern of the line type is quite adequate. It provides relatively little information regarding horizontal resolution, but if the pulses forming the vertical bars have sharp trailing edges, the more serious receiver faults will be apparent. While a shape or picture generator is necessary for highly critical testing, it must be regarded as a luxury for routine work.

2.3.6. If a highly detailed test pattern or picture is needed, the electronic scanner must be used. If, however, suitable tubes for "flying-spot" scanning become available, there is no doubt that the increased versatility of this method will make it the obvious choice. The complexity of the apparatus is not increased to an appreciable degree, but the utility is much greater.

2.4. *Summary*

Summarizing the requirements, it is seen that the allowable tolerances throughout are not great. This implies that the operational stability must be high, and that provision must be made for routine checking of performance. It is very difficult to check the operation of circuits of this kind without the aid of an oscilloscope,[4] and the cost of the apparatus would be increased to a considerable degree if a suitable monitor was incorporated. It has been noted, however, that an oscilloscope is necessary for checking the operation of the receiver, and this can be used for checking the generator as well. A very simple oscilloscope circuit will suffice if the time base signals can be derived from the signal generator, and this presents no serious difficulty. This technique can be extended by adding a suitable sweep generator for use in conjunction with the carrier signal generator and the oscilloscope for response curve checking.

Though the tolerances are narrow, they present no insuperable difficulties. The problem is not how to obtain the required performance, but how to obtain the performance for a minimum of complexity and cost. A complex circuit is costly in the original manufacture and in the subsequent maintenance. An over-simplified circuit costs little to make, but may cost a lot to maintain, either because it requires frequent adjustment, or because its components are liable to failure. The ideal circuit is cheap to make and cheap to maintain. It should make the minimum possible demands on the skill of the maintenance engineer and the safety margins should be generous.

3.0. Video Generator Circuitry

3.1. *General Principles*

3.1.1. The process of generating a video signal may be divided into three main parts : the generation of timing signals for use in establishing and relating the time intervals of the signal ; the derivation and combination of the elementary pulses forming the synchronizing signal ; and the formation of the picture or

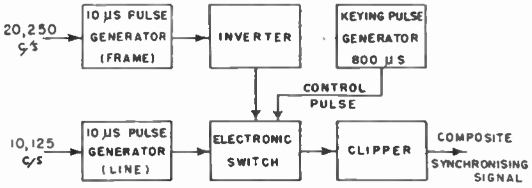


Fig. 6.—Synchronizing-signal generator.

pattern signal, complete with blanking intervals, and with the synchronizing signal added.

3.1.2. The timing signals may be regarded as being equivalent to the ruler with which the draughtsman sets out a drawing of the complete waveform. The accuracy of the final result will depend on the accuracy of the timing signals. This does not necessarily mean that an interval which has a nominal duration of, say, 10 μsec. must be maintained correct to that duration within very narrow limits. It is more important that a nominal 100 μsec. interval should be exactly equal to ten 10 μsec. intervals, and that the 10 μsec. intervals should be identical. This is achieved by establishing, first, a convenient time standard by means of an oscillator, the oscillator frequency being an integral multiple of the frequencies of all the timing signals required. The longer intervals are then established by a division process, which is continued until the lowest required frequency is obtained. A typical example is shown in Fig. 5, where the master oscillator runs at a nominal frequency of 121,500 c/s. This is divided by six to give 20,250 c/s (double line frequency) and again by two to give 10,125 c/s (line frequency). The remaining frequencies are obtained by dividing down from 20,250 c/s, a ratio of 45-1, giving 450 c/s, and a further 9-1 division providing the final 50 c/s output. This timing unit is used in the production of the pattern illustrated in Fig. 2 (*b*).

3.1.3. The synchronizing-signal generator, or shaper, requires three main timing signals, 20,250 c/s for the frame sync-pulses, 10,125 c/s for the line sync-pulses, and 50 c/s for controlling the frame synchronizing action. The timing signals trigger flip-flop circuits. These may be arranged to re-set themselves automatically after a suitable lapse of time, or a further set of timing signals may be provided for re-setting purposes. The 50 c/s pulse obtained from the keying flip-flop is used to select either frame sync-pulses or line sync-pulses in an electronic switching circuit. Alternatively, the switching pulse can be superimposed on the trigger signals, the flip-flops being arranged to fire only when both trigger and pulse signals are present. A typical block schematic for the first method is shown in Fig. 6.

3.1.4. With a pattern signal, the picture generator works on much the same principles as the synchronizing-signal generator (Fig. 7*a*). In the case of the pattern of Fig. 2 (*b*), for example, the elements forming the actual pattern signal are derived from the 121,500 c/s and 450 c/s pulses. Blanking signals are derived from the 10,125 c/s and 50 c/s marker signals, and these are used to operate switching stages. The combined and blanked signal is then combined with the output of the synchronizing-signal generator, with the correct modulation ranges.

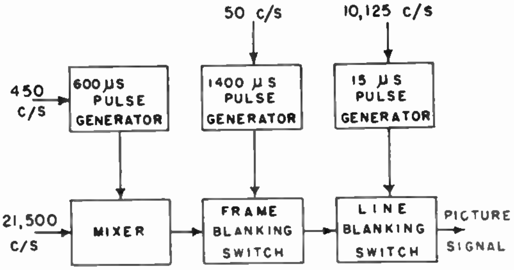


Fig. 7a.—Picture generator—line pattern.

3.1.5. When an electronic or flying-spot scanner is used, only two timing signals are required for the picture generator, the 10,125 c/s and 50 c/s signals for line and frame frequency respectively. These signals trigger sawtooth generators which are used to establish the deflection pattern in the scanning device (Fig. 7*b*). The timing signals are also used to generate blanking pulses. These are used to switch out the signal from the scanning device, the blanked output being combined with the synchronizing signal as before. It is interesting to note that the additional complexity of the scanner type of picture generator is substantially offset by the simpler timing generator which can be used.

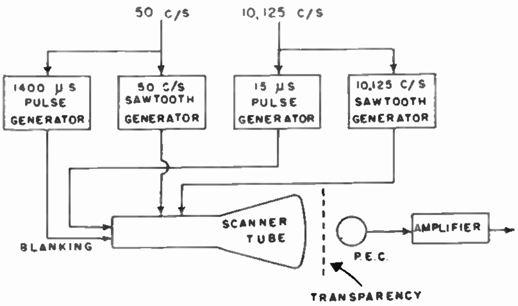


Fig. 7b.—Picture generator—flying spot scanner

3.1.6. In each of the above cases, a typical circuit arrangement has been described, but there are many possible alternatives. The object of the present survey is the selection of the methods which will give a satisfactory result for minimum cost. The various types of circuit will be considered in turn, together with any more general techniques implied by their use.

3.1.7. The operations involved in the generation of a video signal require the following types of circuit :—

(*a*) Oscillators (Free-running or frequency-controlled.)

(*b*) Frequency dividers.

(*c*) Flip-flops. (With one and two stable states.)

(*d*) Electronic switches.

(*e*) Clippers.

(*f*) Sawtooth generators.

(*g*) Amplifiers (single input channel, and for combining two input channels).

The available forms of each type of circuit will be reviewed.

3.2. *Oscillators*

3.2.1. There is a wide choice of different oscillator circuits, many of which can be used with success. For the free-running oscillator, the main requirement is high stability. This is obtainable with oscillators of the resistance-capacitance tuned type which incorporate automatic amplitude control. If the components of the frequency selective network are chosen with care and the amplitude control is effective, it is possible to obtain an overall stability of the order of 0·1 per cent. with this type of oscillator, while the available output is ample for the present purpose.

3.2.2. When the oscillator frequency must be controlled, the choice is more difficult. The control voltage is derived from a circuit which compares the phases of the mains supply and the 50 c/s timing signal, the circuit being arranged to control the oscillator frequency so that the 50 c/s timing signal is maintained at the mains supply frequency.

3.2.3. A suitable phase comparator circuit is shown in Fig. 8. The mains supply waveform is applied between the cathodes of a double diode valve. The output of the timing unit is applied to both anodes with respect to the cathodes. The mean D.C. level of the signal between the anodes is dependent on the relative phase of the two input signals. The circuit can be considered as a modulator, with the output representing the difference beat between the two input frequencies. When the frequencies coincide, the beat frequency is zero, and the mean D.C. level of the output signal remains constant. The remaining components of the output signal must be filtered out to avoid frequency modulation of the timing signals, but the filter must not attenuate the beat frequency component too severely, or the control voltage swing may be inadequate when the difference between the input frequencies is relatively large. This would lead to difficulty in obtaining the initial "lock," since the oscillator frequency would not swing over a sufficient range to reach the stable condition.

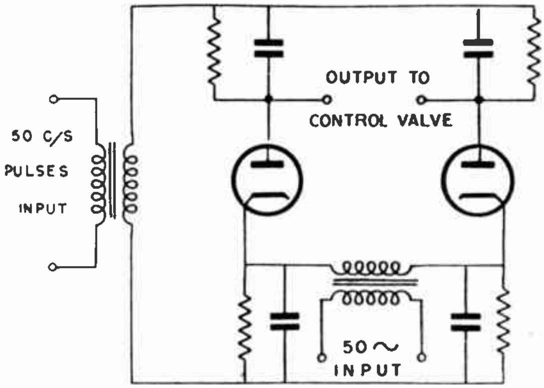


Fig. 8.—Phase comparator.

3.2.4. From a quantitative point of view, it is as well to allow for variations in mains supply frequency of ± 5 per cent. Allowing a similar variation in the free-running frequency of the controlled oscillator, the beat frequency component at the comparator output can range between D.C. and 5 c/s. (To be strictly accurate, between +5 c/s and −5 c/s.) The control signal must be passed through a filter which will attenuate signals lying between 47 c/s and 53 c/s very heavily, but which will introduce the minimum possible attenuation in signals up to 5 c/s. The use of a resonant circuit in the filter is discouraged by the low frequency involved, but a multi-section resistance-capacitance filter can be made to meet the requirement satisfactorily.

3.2.5. The control voltage can be made to adjust the oscillator frequency in a number of ways. The classic method involves the use of a reactance modulator to vary the resonant frequency of a tuned circuit, but this raises certain practical difficulties at the relatively low frequencies required in the present application. The reactance modulator can be made to vary the capacitance or inductance of the tuned circuit by a limited amount. If the corresponding fixed capacitance or inductance in the tuned circuit is comparable with the variation, a large frequency swing can be obtained, If, however, the variation is only a small percentage of the total, the frequency swing is small.

3.2.6. For a generator using an electronic or flying-spot scanner, the master oscillator frequency is 20,250 c/s, and this must be varied by ± 5 per cent. to cover the mains frequency variation. The value of LC for the resonant circuit will be roughly 5×10^{-11}. An adequate frequency swing could be obtained by using values of the order of 1 H and 50μμF, or 50μH and 1μF, but neither case is very practical. It should be noted, moreover, that the full available frequency swing should be as large as possible, to allow for oscillator drift and to obtain the maximum control "stiffness."

3.2.7. An alternative technique is illustrated by Fig. 9. The control voltage is applied between the grid and cathode of V1, which is arranged to control the bias applied to a blocking oscillator, V2. The anode current of V1 is metered to provide an indication of the locking action. If the lock fails for any reason, the meter shows the variation in anode current as the circuit seeks a stable state. While adjustments are being carried out, the meter shows whether the stable state is in the middle of the control range or near one of the limits beyond which the control fails.

3.2.8. A third possible method of obtaining the required frequency control involves the use of a variable resistance circuit to control the quasi-resonant frequency of a resistance-capacitance tuned oscillator. The variable resistance can be the output impedance of a cathode follower, which is included as the parallel resistance element in a frequency selective network of the "Wien" type.

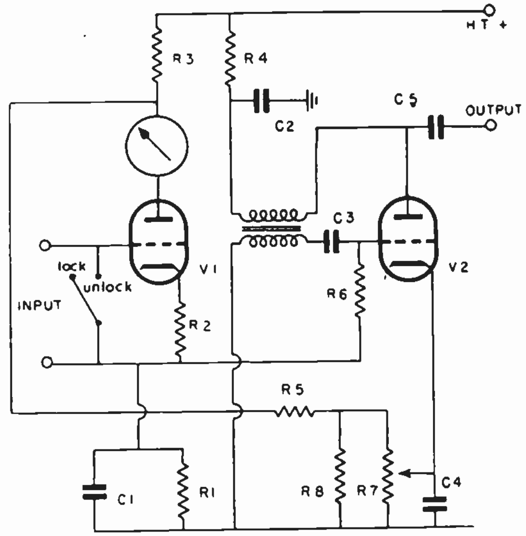


Fig. 9.—Masked oscillator with control valve.

3.2.9. The considerations affecting the choice between free running and controlled master oscillators have been indicated in para. 2.2.5, and it need only be said here that the simplification made possible by the use of a free-running oscillator is an important consideration. Apart from the simplification of the actual oscillator circuit, it will be seen that the subsequent divider circuits can also be simplified if the master oscillator frequency is constant. The choice between the available methods of frequency control can be summarized : up to about 200 kc/s, the blocking oscillator circuit is more convenient, and the reactance modulator is preferred for higher frequencies, where the time constants used in the blocking oscillator circuit become too small. If, however, the oscillator is to be used at any time with the mains locking device disconnected, the resistance-capacitance oscillator with a cathode follower modulator is preferable, as the free-running stability is higher than that of the blocking oscillator or the LC tuned oscillator.

3.3. *Frequency Dividers*

3.3.1. A frequency divider may operate by "counting" the individual pulses of the input signal, and triggering after a predetermined number of pulses, or the circuit may be arranged to trigger on the first pulse after a given period of time. Ideally, the first type should be independent of frequency variations at the input, but the second type will only operate for a limited input frequency range.

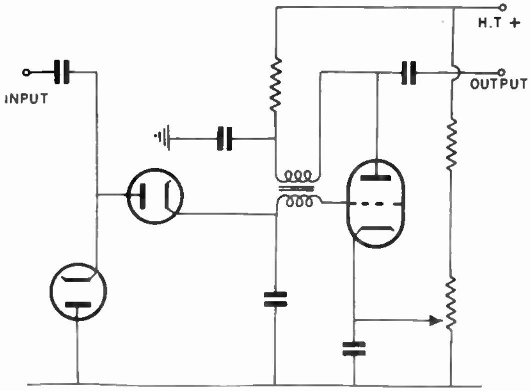


Fig. 10.—Step counter with trigger.

3.3.2. A form of counter circuit is shown in Fig. 10. With a pulse signal applied to the input, the grid voltage of the triode rises in a series of steps until it is positive enough for anode current to pass. The valve then functions as a blocking oscillator, discharging the reservoir capacitance and returning the circuit to the original condition, the process being repeated. The dividing ratio can be adjusted over a wide range by the potentiometer, which sets the cathode potential of the triode with anode current cut off. The circuit will work over a fairly wide range of input frequency if the amplitude of the input signal is constant, though care must be taken to ensure that the de-coupling time constants are adequate. If the cathode by-pass capacitor is too small, for example, the cathode voltage can rise appreciably during the blocking cycle, and may not return to its correct value before the next blocking cycle. With varying input frequency, the degree of recovery of the cathode circuit tends to vary, and this may alter the counting ratio. The circuit will operate satisfactorily with the highest counting ratio required for the B.B.C. signal (9-1) but special precautions are necessary to ensure satisfactory operation at the 13-1 ratio necessitated by the French 819-line system[11] ($819 = 7 \times 9 \times 13$).

3.3.3. Any synchronized relaxation oscillator can be used as a divider working on the time measuring basis. With a fixed input, frequency-dividing ratios of the order of 20-1 can be obtained without special precautions, but the maximum ratio is reduced considerably when the input frequency is variable. If, for example, the divider is to work at a ratio of 5-1 on a 2,500 c/s input, the oscillator would be set to trigger on the first input pulse arriving more than 1·8 msec. after the previous trigger point. If the input frequency is exactly 2,500 c/s, the fifth pulse, at 2 msec, will trigger the circuit. If, however, the frequency rises by more than about 10 per cent, the fifth pulse will arrive less than 1·8 msec. after the preceding trigger point, and the oscillator will trigger on the sixth or subsequent pulse. If, on the other hand, the frequency falls by more than 10 per cent, the fourth pulse will be delayed enough to fire the circuit. Consequently, the maximum permissible input frequency range is ± 10 per cent, though it would be necessary to reduce this range in practice to allow for drift in the oscillator setting, variations in input amplitude, etc. With higher ratios the input frequency variation must be kept within even narrower limits. As an approximate rule, the input frequency can vary by $\pm 35/n$ per cent., where n is the dividing ratio.

3.3.4. A third type of counter may be mentioned for the sake of completeness, though it is not widely used for the present purpose. It is the "multi-state" counter, using a circuit having several stable states, each input pulse selecting a fresh stable state. The most familiar example of this type of circuit is the "Eccles-Jordan" flip-flop (Fig. 11) which is widely used as a binary counter. This circuit can be used with advantage for the 2-1 division from 20,250 c/s to 10,125 c/s, but has not been widely used elsewhere. One generator using binary counters throughout has been rated, however, and it is claimed that the additional complexity is made worth while by the freedom from adjustment.[6] Comparing the resources needed for binary counters and step counters with different ratios :—

Ratio	Binary Counter	Step Counter
3-1	4 triodes	2 diodes 1 triode
5-1 to 7-1	6 triodes	2 diodes 1 triode
9-1 to 11-1	8 triodes	2 diodes 1 triode
13-1 to 15-1	8 triodes	4 diodes 2 triodes
17-1 to 32-1	10 triodes	4 diodes 2 triodes
33-1 to 64-1	12 triodes	4 diodes 2 triodes
65-1 to 81-1	14 triodes	4 diodes 2 triodes
82-1 to 128-1	16 triodes	6 diodes 3 triodes

The extra valves needed for the binary method are an important argument in favour of the step counter method, but the freedom from adjustment may justify the extra cost in some instances.

3.3.5. With a fixed-frequency master oscillator of high stability the synchronized relaxation oscillator is the best available divider circuit, and the most satisfactory form of relaxation oscillator for the purpose is the blocking oscillator. The advantages of this particular circuit are the form of the output pulse, the simple resources needed, and the low maintenance cost. The output pulse is relatively short and of sufficient amplitude to allow proper shaping before use for triggering purposes. Whereas the multi-vibrator requires two triodes, four resistors, and two capacitors, the blocking oscillator requires one triode, one resistor, one capacitor, and one transformer, and is thus less expensive in components, assembly, and maintenance.

3.3.6. With a frequency-controlled master oscillator, two alternatives are usually available. More synchronized oscillators with lower dividing ratios may be used, or step counters can be employed. For a total division ratio of 405-1, it is necessary to use three step counters (5×9×9) or five synchronized oscillators (3×3×3×3×5). The step counters require three triodes and at least six diodes, and the synchronized oscillators require five triodes. For the sake of comparison, it may be added that the binary counter technique would involve the use of nine binary stages (18 triodes) with automatic re-setting to reduce the count from 512 to 405.

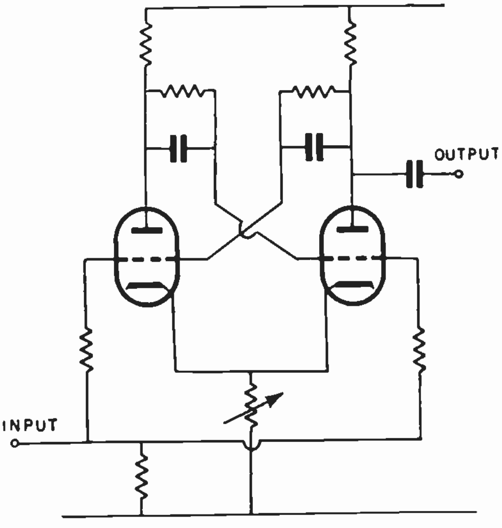


Fig. 11.—Eccles-Jordan flip-flop.

3.3.7. It is common practice to insert buffer stages between successive divider stages, but this is not always necessary. The object of the buffer stage is to prevent reverse synchronizing action whereby the driven stage can trigger the driving stage. This can be avoided by other means, and the problem should not arise at all when step counters are used. Reverse triggering can only occur when the driven stage is running free, and a step counter can only trigger when an input pulse arrives. The driven stage cannot trigger the driving stage, which is still completing its blocking cycle, and reverse action is impossible. The relaxation oscillator can run freely with no input, however, and can thus trigger the stage which drives it if a sufficiently large pulse can be fed back through the coupling. In practice, it is possible to arrange for the coupling to introduce severe attenuation so that the pulse fed back is well below the danger level. In cases of particular difficulty, a small metal or crystal rectifier can be used to limit the reverse pulse.

3.3.8. It is advisable, on the other hand, to provide buffer stages where timing signals are extracted from the divider chain. With the chain properly adjusted, interference with the timing accuracy can only originate in the remainder of the apparatus. The 10 µsec. pulse generator used to obtain the line sync-pulse elements may produce a pulse in its input circuit 10 µsec. after it is triggered. If this pulse is allowed to pass back into the timer unit, the timing may be upset. It is possible to use an attenuation method similar to that used for inter-connections between dividers, but this reduces the available trigger voltage and may lead to unreliable operation.

3.3.9. Finally, where the dividers are adjustable, monitoring points must be arranged. With step counters, the step waveform at the grid provides the most satisfactory monitor display, but connection to this point may affect the division ratio, and it is generally better to monitor the anode current variations. A small resistor can be inserted in each H.T. feed to develop the monitoring voltage, and connection at this point should not affect the operation of the dividers.

3.4. *Flip-Flops*

3.4.1. The term "flip-flop" was originally applied to circuits having two alternative stable states, the changeover from one state to another being initiated by an input pulse. The term has been used more recently for circuits with one stable state and one semi-stable state, the latter persisting for a period determined by the circuit constants. The original kind of flip-flop is sometimes distinguished by the description "double-trigger," the second kind being called the "single-trigger" flip-flop.

3.4.2. Both varieties of flip-flop are used in video generator work. The use of the Eccles-Jordan double-trigger circuit as a binary counter has already been noted. It can also be used for the generation of sync-pulse elements, but two sets of trigger pulses are required, one to mark the start of the pulse elements, and one to mark the ends of the elements. The second set of pulses can be obtained by feeding the original "start" pulses into a suitable delay line. The delay line can also be used to provide terminating trigger pulses for the blanking generator, and the formation of very accurate line sync-pulse waveforms can be facilitated by this technique. An important advantage is that the pulse lengths are determined solely by the delay line, and no adjustments of pulse length are necessary.

3.4.3. The single-trigger flip-flop, of which the cathode-coupled circuit (Fig. 12) is an excellent example, allows a valuable simplification of the timing generator. Only one trigger is needed for each set of pulses, the pulse lengths being determined by the time constant of the inter-valve coupling. The pulse length is not as stable as that obtainable with the delay line method, but the stability is adequate for the present purpose. With careful selection of circuit constants, the variation in pulse length can be kept below ±0·1 per cent. with ±20 per cent. variations in H.T. supply voltage. It should be noted that there is no point in obtaining high pulse length accuracy if the pulse interval varies, as it will in generators using mains frequency locking.

3.4.4. In order to obtain the best possible results from the cathode-coupled flip-flop, it is important to use a very short input pulse, and the input circuit should be arranged so that the input grid is held at cathode potential during a large part of the input pulse duration. This ensures freedom from output variations due to changes in the amplitude of the input pulse. The trigger signal can also be applied as a negative going pulse, connection being made to the grid of the valve which is normally passing current. The output is normally taken from the anode of this valve as a positive going square pulse, but the output may also be taken from the cathode, where the amplitude and output impedance are both smaller, or as a negative-going pulse at the anode of the input valve, where the waveform may show imperfections.

3.4.5. The circuit may also be used in other ways. It can be used to obtain time delays ranging from a few microseconds upwards, the normal square pulse output being differentiated to provide positive and negative trigger pulses. The circuit can also be used to produce controlled bursts of oscillation, a square wave output signal being generated when the input grid potential is above a certain critical level. This has been used for the generation of the vertical bar pulses in a formal pattern, but the absence of any frequency relationship between the line scan and the bar pulses is an important disadvantage. The circuit may be of value in very simple generators.

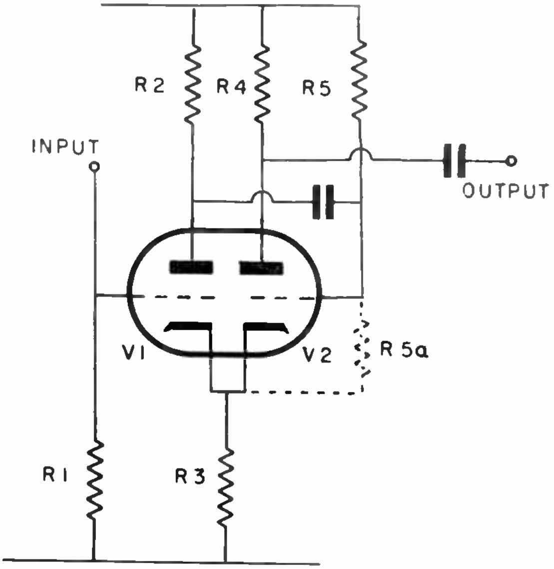


Fig. 12.—Cathode-coupled flip-flop.

3.5. *Electronic Switches*

3.5.1. Little comment is needed on the normal type of switch circuit where the control action is obtained by applying a cut-off voltage to the control or suppressor grid of an amplifier valve. This type of circuit can be used for the sync-pulse changeover action, one switch controlling the line sync-pulses and one controlling the frame sync-pulses. It is important that the D.C. (peak) levels should not alter appreciably during the changeover, and a balanced circuit is therefore necessary. The necessity for a phase reversing device providing out-of-phase control voltages can often be avoided by deriving the control voltage for one valve from an electrode potential in the other. This is complicated by the necessity for a very good low frequency response in the control signal couplings, however. The frame sync-pulses must be switched out for periods of 18·5 m sec., and the control voltage must not change appreciably during this time. The switching action must be rapid, on the other hand, and the most satisfactory solution is to D.C.-couple the control signals.

3.5.2. An example of a fully D.C.-coupled switching system is included in the circuit of Fig. 14 (V5-7), cathode-coupled switches being used. The keying generator V5 produces a positive-going pulse 1·5 msec. long, which is applied through R36 to the second grid of V7. This grid is normally at about 70 volts positive to earth, the cathode of V7 being then at about 80 volts positive. (R33=50,000 ohms.) Under these conditions, the bias applied to the first grid of V7 is such that this section of the valve works as a normal amplifier. When the positive switching pulse is applied, however, the cathode potential rises by about 50 volts, and the amplifier section is cut off. The increased current in the control section lowers the potential of the second grid of V6 from about 170 V to 120 V positive to earth, and this brings the first section of V6 into operation as an amplifier. With proper adjustment of the potentiometers R13, R31, the alteration of the peak direct voltages in the output during the changeover can be made negligible.

3.5.3. In the picture blanking operation, a different action is required. The output voltage must be brought to the "black" level during the blanking action, and the most effective method of switching is to superimpose the switching voltage on the signal voltage and feed the combined signal to a clipper circuit. The switching voltage is arranged to drive the input voltage beyond the clip range.

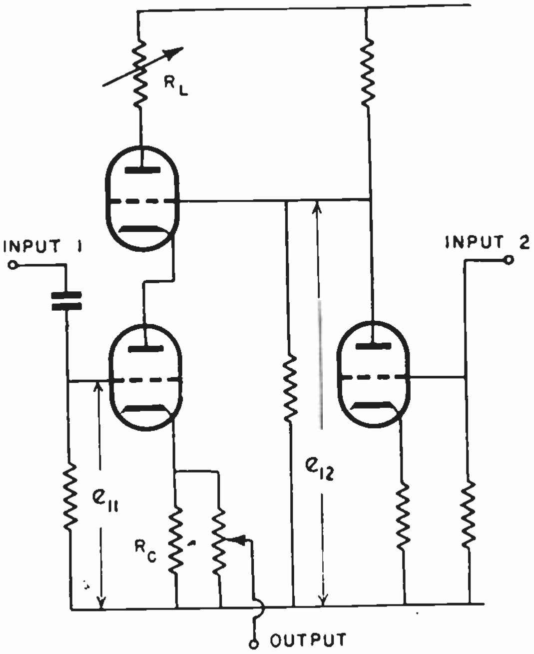


Fig. 13.—*Cascode mixer.*

3.5.4. Another important switching operation is involved in the final combination of the synchronizing and picture signals. This involves the accurate maintenance of waveforms and voltage levels, and an exceedingly important point is that the output must be free from spurious impulses generated in the switching action. A circuit which has been found of value in this connection is given in Fig. 13. The lower valve functions as a cathode follower, the output amplitude being limited to a degree depending on the grid voltage of the upper valve, which increases the low frequency performance of the cathode follower by providing a low impedance anode feed. The synchronizing signal is applied to the lower valve. When the input voltage is negative, the valve should be near cut-off, and no other circuit voltages can affect this appreciably. When the input is positive, the output voltage is dependent on both the upper and lower inputs. With flat-topped sync-pulses applied to the lower grid, the picture signal can be applied via the upper grid.

3.5.5. Quantitatively, the output voltage is :—

$$e_o. = \frac{\{\mu_2 e_{i2} + \mu_1(\mu_2+1)\, e_{i1}\}\, R_c}{R_L + r_{a2} + (\mu_2+1) r_{a1} + (\mu_2+1)(\mu_1+1)\, R_c}$$

Where $e_i =$ input voltage, $\mu =$ amplification factor, $r_a =$ anode impedance, $R_L =$ H.T. feed resistance, $R_c =$ cathode resistance, with subscript 1 for the lower valve and subscript 2 for the upper valve.

If R_c is large compared with R_{a1} and the amplification factors are large compared with unity, the output approximates to $e_{i1} \pm e_{i2}/\mu_1$ The attenuation of the signal applied to the upper grid is undesirable, but if R_L is not large the input impedance at this grid is high, and a single amplifier stage directly coupled to the grid can provide an adequate signal. If the peak-to-peak output required is 10 V, a picture signal of $7\mu_1$ V peak-to-peak is required at the upper grid.

3.5.6. The practical advantages of the circuit more than outweigh this disadvantage. The synchronizing signal feeds into a high impedance and effective clipping is possible, the stabilizing action of the upper valve ensuring that the clip levels do not change during the frame cycle. The low impedance output with the negative tips of the sync-pulses at earth potential can be connected directly to the modulator or the circuit under test in many cases, thus avoiding the necessity for an A.C. coupling with a long time constant. Finally, the circuit provides an effective means of establishing the required signal voltage levels in the combined video signal.

3.5.7. Whatever type of electronic switch is used, all traces of the switching signal must be removed from the output. It is, in fact, desirable to avoid such circuits wherever possible. One alternative has been mentioned (para. 3.1.3.) in connection with sync-pulse control, the triggering input to the flip-flops being superimposed on a switching pulse. The method has one disadvantage, however. The flip-flop circuit must be designed with care to eliminate variations in pulse length with variations of trigger pulse amplitude, or the pulse lengths may tend to vary at different parts of the switching cycle.

3.6. *Other Circuits*

3.6.1. The remaining circuits listed in para. 3.1.7. need little detailed comment, as they are widely used in other types of apparatus. Here again, however, some of the specialized requirements of the video generator may be noted. Most of the points arise from the wide frequency range involved.

3.6.2. Many forms of clipper circuit involve the application of the signal to the grid or anode of a valve through a resistance. When the electrode is positive with respect to the cathode, the current flowing through the resistance restricts the rise in voltage, tending to keep the electrode at or below cathode potential. For ideal operation, an infinite series resistance would be necessary, when the electrode voltage would never exceed the cathode potential. When a grid-cathode path is used, however, the input capacitance of the valve places a definite limitation on the maximum resistance which can be used without loss of high frequencies. While the difficulty is greater with triodes, it is appreciable with pentode valves as well. Typical values for pentodes are : input capacitance 10μμF, series resistance not less than 20,000 ohms, response drops by 3db at approximately 800 kc/s. The use of a separate diode relieves the difficulty to some extent by reducing the grid-cathode resistance, but the capacitance is also increased. The most satisfactory clipper circuit for operation over a wide frequency band is the cathode follower with reduced anode voltage. The mixer circuit described in para. 3.5.4. *et seq.* is an example of this circuit.

3.6.3. Instead of using the output of a pulse generator to trigger a separate sawtooth generator, it is sometimes possible to obtain a satisfactory sawtooth output from the decoupling circuit which supplies H.T. to the pulse stage. If low frequency signals are required it is important to ensure that the H.T. smoothing is very effective, but with higher frequencies this is not so important, as a low time constant coupling can be used to eliminate any ripple. The method is favoured more for economy than as good practice.

3.6.4. The amplifiers required in a video generator are not usually required to provide very large gains, and satisfactory results can often be obtained with triodes. A typical triode working at a gain of five times can be used for video frequency work without difficulty, the response with simple uncompensated coupling being 3db down at 4 Mc/s. With a gain of 25 times, the response is 3db down at about 250 kc/s. These performances could be improved to some extent by the use of feedback, but this is

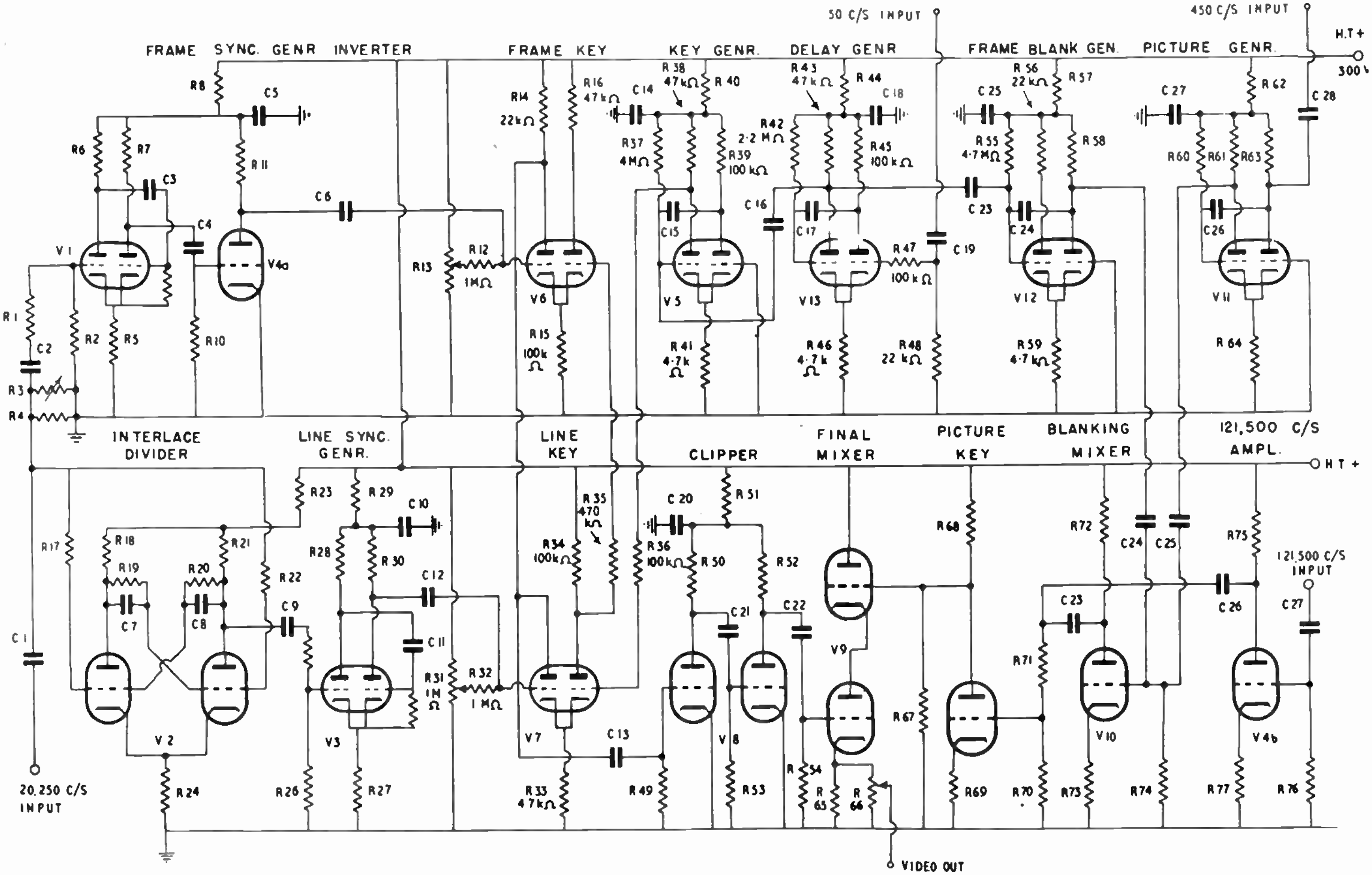


Fig. 14.—Shaper unit.

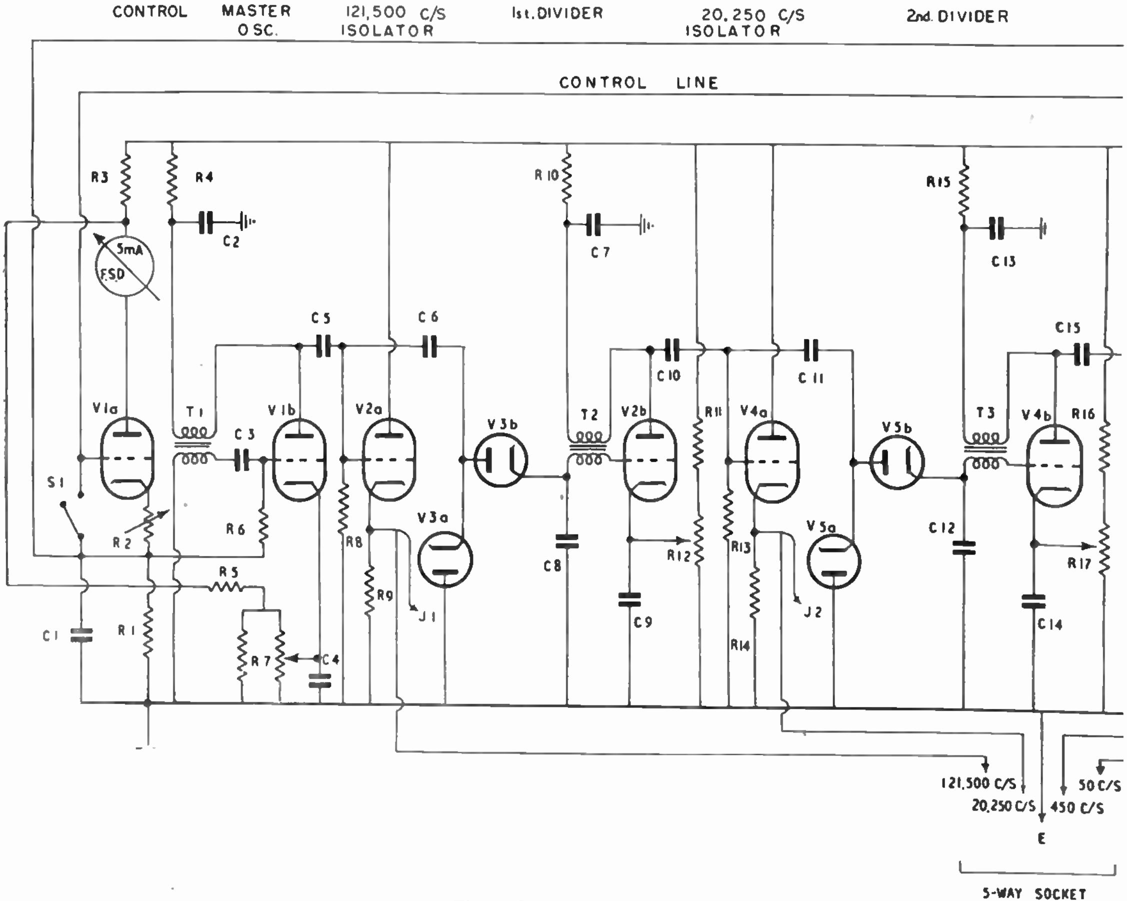


Fig. 15.—Timer unit.

rarely practicable in video generator circuits, which are mainly non-linear in character. It should be noted that the pulse generator stages include amplifiers, and that these amplifiers must be designed for adequate frequency response.

3.7. *The Complete Generator*

3.7.1. These are the circuit elements which are to be assembled to form a complete generator. In selecting the circuits for which alternatives are suggested, the aim should be to keep the whole as simple as possible. It is an advantage to keep the number of different valve types as low as possible, and it is also useful to standardize the layout of similar circuits to facilitate maintenance work. The circuits of Fig. 14 and Fig. 15 show a complete generator, and this may be used to illustrate these and other points.

3.7.2. The generator was required to produce the pattern of Fig. 2*b*, with the line blanking removed on some lines to facilitate observation of the line scanning action. The master oscillator was to be controlled for mains locking, and controls were to be kept to a minimum. It was decided that the timer unit (Fig. 15) should use a controlled blocking oscillator followed by four divider stages of the "step-counter" type. Valves selected for this unit were the 6H6 double diode and the 6SN7 double triode. (The latter were replaced by G.E.C. B65s in the final version.) The operation of the main timing circuits should need no comment, being quite straightforward. Four output isolators were

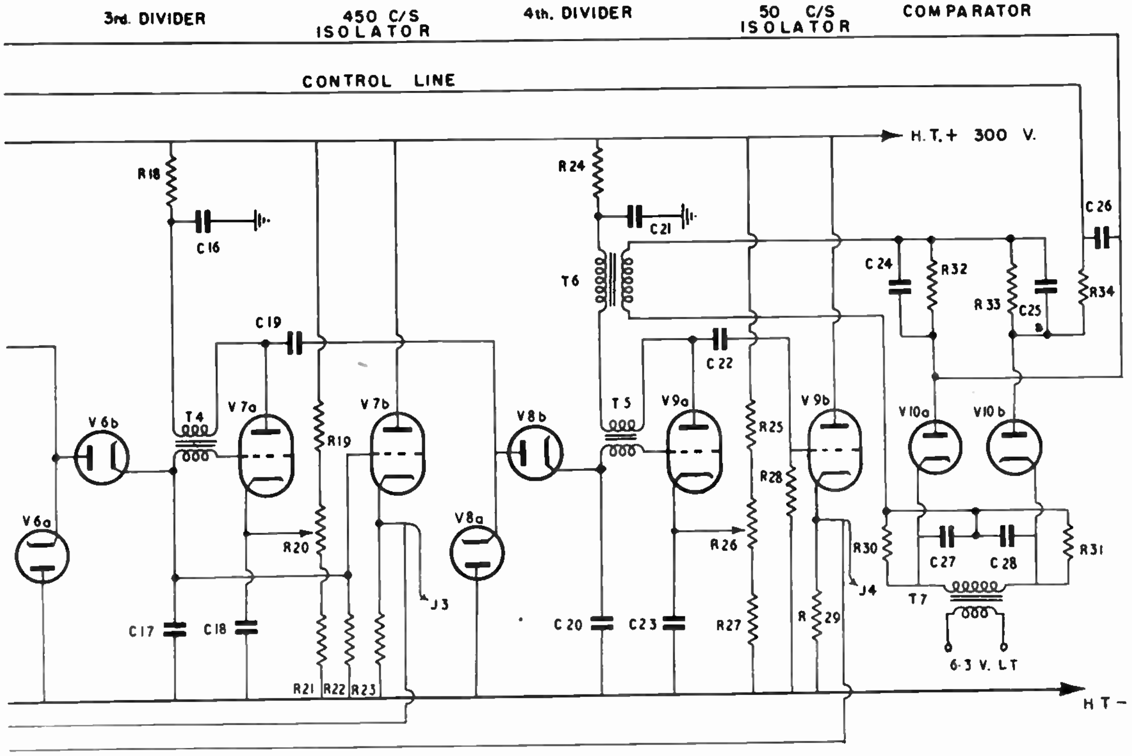


Fig. 15.—*Contd.*

used, the first two also serving as clippers to assist in maintaining a stable count in the early dividers. The timer unit does not provide a 10,125 c/s signal, this being derived in the shaper unit. The outputs are therefore 121,500 c/s from the output of the master oscillator, 20,250 c/s from the output of the first divider, the 450 c/s signal with 4,050 c/s steps superimposed from the grid of the third divider, and 50 c/s from the output of the fourth divider. The monitoring outputs are connected to the main outputs, all the necessary frequencies being available, and the setting-up procedure being quite simple. Adjustments are facilitated if the master oscillator can be set to approximately 120 kc/s against a standard test oscillator, the remaining frequencies being checked by use of standard display patterns. The unit holds in lock over a wide range of mains supply frequencies, and the adjustments only require checking about once a week. No H.T. stabilization is used, but a constant voltage supply transformer may be of value in areas where mains voltage fluctuations are especially heavy. Such a transformer provides a moderate degree of stability for both L.T. and H.T., and is far more effective than the use of perfectly stabilized H.T. supply with an unstabilized L.T. supply.

3.7.3. The shaper unit (Fig. 14) employs 13 double triodes, six of the valves being used in cathode coupled flip-flop circuits. The minor variations in these circuits are worthy of note, as they indicate the versatility of the basic arrangement. The synchronizing-signal generator is straightforward, flip-flops being used to generate 10μ sec pulses at 20,250 c/s and 10,125 c/s. Attempts were made to simplify the circuit by making the 10,125 c/s flip-flop trigger on alternate 20,250 c/s pulses, the recovery time of the circuit being increased so that it was not ready to fire until more than 50μsec after the previous trigger point, but the pulse length variations were found to be excessive. The circuit will only work satisfactorily if the pulse length is smaller than the pulse interval, and the frame sync-pulses are therefore generated as 10 μsec pulses and inverted later to form 40 μsec pulses. The separate sync-pulse elements are combined in the switching circuit described in para. 3.5.2, the combined output signal being passed through an amplifier/clipper to the final mixer. The flip-flops used for generating the sync-pulses are arranged in the normal way with the triggering input on grid 1, and the output is taken as a positive pulse from anode 2. Grid 2 is returned to cathode, as the short time constant required makes the return to H.T. positive unsuitable. The final synchronizing signal output is of the order of 6 V peak-to-peak.

3.7.4. The picture generator section of the shaper unit is triggered by the 450 c/s and 121,500 c/s signals from the timer unit. The 121,500 c/s signal is amplified and clipped in V4b, and the 450 c/s signal is used to trigger 600μ sec pulses (V11). The flip-flop used to generate the 600 μsec pulses employs negative triggering, the trigger signal being applied to grid 2 via C26, the anode impedance of the first valve forming part of a differentiation circuit. Positive pulses are taken from anode 2 and are combined with the frame blanking signal at the grid of V10a. The output from this valve is combined with the 121,500 c/s signal, and the combined waveform is fed to V10b, which acts as a clipper/amplifier. When the positive blanking pulse is present, this valve is held at maximum anode current, with zero grid potential, and no picture signal is present at the output. When the negative 600 μsec pulses are present, the valve is cut off. At other times, the valve is controlled by the 121,500 c/s signal. The output of V10b is applied to the upper grid of the final mixer. Returning to the frame blanking signal, this is generated in V12, which is triggered by V13. Direct triggering from the 50 c/s marker pulse cannot be used, as this coincides with the start of one of the 600 μsec pulses forming the horizontal bars of the pattern, and the frame scan action must be initiated at the end of this bar. V13 is, therefore, used to introduce a 600 μsec delay. Positive triggering on grid 1 is used, and a positive output pulse is taken from anode 2. This is fed through a differentiating capacitor to grid 2 of the blanking generator, where the trailing edge of the pulse acts as a negative trigger pulse. The same arrangement is used for the sync-pulse keying generator V5, and these two generators trigger at the trailing edge of the 600 μsec pulse which starts at the moment of the 50 c/s timing pulse.

3.7.5. The whole apparatus uses 18 double triodes (6SN7 or B65) and five double diodes (6H6, etc.), and the total power drain is 300 V 80 mA H.T. and 6·3 V 12½ A L.T. The relatively heavy L.T. drain in this type of apparatus can be reduced to a useful extent by using valve types in which the heater consumption is based on a unit of 0·2A instead of 0·3 A (double triodes consume 0·4 A in this case), but these valves have a less generous emission reserve, and greater care is necessary to ensure that the operating limits are not exceeded under pulse conditions.

3.7.6. For the sake of comparison, the essential features of a circuit using an electronic or flying-spot scanner may be reviewed. The timer unit may be simplified by the omission of the first counter and two of the output isolator stages. The master oscillator frequency is reduced to 20,250 c/s. The synchronizing-signal generator is not altered, but the picture generator is entirely different. The circuits required are : two deflection generators, the scanning device, photocell and amplifier, and blanking generators. The blanking generators may be fed to the modulating grid of the scanner tube, avoiding any necessity for blanking switches. Of the valves used in generating the formal pattern, one double diode and seven triodes can be omitted. These may be set against the deflection generators and the signal amplifier, showing that the bulk of the extra cost and complexity arises from the actual scanner and, in the case of the flying-spot generator, the photocell.

3.7.7. A suggestion for further simplification of apparatus using the flying-spot technique may be mentioned, but the technique is not recommended. The simplification is in the timing generator.[7] The 50 c/s signal is obtained from an oscillator or pulse generator locked to the mains supply frequency, an alternative being the derivation of a suitable signal directly by clipping and differentiating the mains waveform. A 50 c/s pulse from this circuit is applied to a 20,250 c/s ringing circuit, and alternate pulses from this are used to trigger the 10,125 c/s sawtooth generator. The sawtooth signal is differentiated to obtain the line sync-pulses, the frame sync-pulses being derived from the 20,250 c/s signal in the usual way. It is claimed that this circuit will give perfect interlace when properly adjusted. The last three words may be examined more closely. Interlace will be lost if the line scan frequency is not exactly 202½ times the frame scan frequency. Assuming that the 20,250 c/s ringing circuit has a high effective Q, a small degree of mistuning will alter the relative phase of the output. If the circuit is mistuned by 50 c/s, however, the frequency of the output signal will be an even multiple of 50 c/s, and the interlace will be lost. The tuning must, therefore, be stable enough to ensure that the drift is small compared with 50 c/s, but this does not guarantee that the mains frequency will remain constant. If a free running 50 c/s generator is used, and the resonant frequency of the ringing circuit never departs by more than 0·1 per cent. from 405 times the output frequency of the 50 c/s generator, the technique may be of some value. In the original form, with mains locking, the value is limited.

3.7.8. A more effective simplification can be obtained by using a fixed frequency master oscillator with synchronized relaxation oscillators as dividers. For a formal pattern signal, the timing generator then requires only three double triodes. By using the double trigger technique the synchronizing signal can be generated with three double triodes. The whole generator can be simplified on these lines without serious loss of performance, but the warning against over-simplification may be repeated here. For example, it is possible to use a flip-flop to obtain 10,125 c/s output pulses with a 20,250 c/s signal applied, but the unreliability of the action more than offsets the simpler circuit arrangement.

3.7.9. Summing the matter up, any pattern generator worthy of the name must incorporate a proper timing-signal generator which relates the various timing signals by a process of frequency division. This timing generator must supply all the signals needed for production of the synchronizing and picture signals. The shaper unit, on the other hand, must be completely inert, containing no free running oscillator circuits. Only by following these principles will satisfactory generators be made.

3.8. *Associated Apparatus*

3.8.1. The apparatus used in association with the video generator is as important as the video generator itself, but the techniques involved are more widely known, and relatively little comment is necessary here. The general approach favoured by the present writer has been adumbrated in earlier sections of the paper. Briefly, the following units are considered necessary :—

(1) The video generator.

(2) A carrier signal generator and separate modulation stage.

(3) An oscilloscope.

(4) A video frequency sweep generator.

These units are combined in various ways to provide different types of test facilities. The oscilloscope is used as a monitor for the video generator and for checking the receiver waveforms, suitable synchronizing pulses being available from the generator for use in the latter process. The carrier generator may be modulated by the picture waveform from the video generator or by the video sweep signal, the oscilloscope being used as a panoramic display in the latter case.

3.8.2. The main requirement for the carrier generator is high frequency accuracy. As crystals operating on the third overtone can be used for the direct production of frequencies up to 40 Mc/s, the inclusion of crystal control is not unduly difficult. The main difficulty concerns the modulator stage, which must operate satisfactorily with a wide range of modulating frequencies. Several methods have been tried at various times without complete satisfaction, but grid modulation seems to offer the most satisfactory solution available, a particular advantage being the low modulating signal amplitude required. Another problem arises from the standardization of single-sideband transmission. There has been some doubt regarding the possibility of aligning a vestigial sideband receiver correctly with the aid of a double sideband test signal. The main danger is that the receiver may be adjusted to the wrong sideband, but this should not arise with intelligent users. The provision of true single-sideband working may be ruled out as excessively complex, but there is no reason why the unwanted sideband should not be partially attenuated, so that there is a clearly visible difference in performance when the wrong sideband is chosen.

3.8.3. The oscilloscope may be of the normal type with internal time base for horizontal deflection and vertical amplifiers, or a simplified form can be used. In the latter case, the horizontal deflection signal can be derived from the video generator, the method outlined in para. 3.6.3. being suitable. A 3 in. diameter screen is adequate if the tube focus is good.

3.8.4. The video sweep generator may be regarded as an extension of the now familiar sweep-generator adaptor provided by many oscilloscope manufacturers. The main problem is the generation of an adequate sweep, but this can usually be solved by the use of a beat frequency technique. A sweep of about 3 Mc/s (maximum sweep range) is required. It is possible to arrange for a 30 kc/s sweep at 100 kc/s minimum frequency, and this can be passed through frequency multiplier stages to obtain 3 Mc/s sweep at 10 Mc/s. Beating this with a 10 Mc/s fixed frequency signal provides the required output. The technique may be compared with that used for obtaining adequate deviation in F.M. transmitters for V.H.F. use, and similar methods of frequency stabilization can be employed.

3.8.5. The facilities provided by these units will suffice for most sections of television test work. The minimum performance requirements have been given, and many refinements are possible. The addition of a manual tuning control to the video sweep generator would be useful, and this could be used in the generation of accurate R.F. alignment signals. To obtain a signal at a frequency 10 kc/s above the carrier frequency, the video sweep generator would be set for a fixed output frequency of 10 kc/s, and arranged to modulate the carrier generator. An output filter would then be set to favour the upper sideband. The versatility of the apparatus can be extended in other ways by use of similar refinements.

4.0. Conclusion

4.1. *The Past*

In the past, television pattern generators and other television signal sources have been made by many manufacturers for their own use, each project being developed individually and independently. In many cases, the apparatus resulting from the development has been far from ideal. The whole assembly tends to be inconveniently large, and the circuit is often undesirably complex. Maintenance and adjustment require the continuous availability of an engineer who has made a special study of the equipment. Even with this provision, the time required for the correction of a fault may be appreciable, leading to a serious delay in production when the single generator is used to supply all test signals throughout the factory.

The patent impossibility of using similar apparatus for test work in smaller concerns, such as repair workshops, led to the development of the ultra-simple generator. These generators have been sold for less than one hundredth of the cost of a typical factory installation, but it has been shown that their utility is very limited. This may not be serious if the user understands the limitations properly, and does not attempt to obtain too much information from the results.

Meanwhile, the manufacture of factory generators for sale had expanded, the prices quoted ranging from about £300 to £2,500. The simplified generators were being sold at prices between about £9 and £20. No effective attempt to introduce intermediate apparatus was made until late in 1949, though some television manufacturers had previously made apparatus of this type for use by their retail agents. These manufacturers recognized the necessity for adequate generating apparatus, and were prepared to make and sell suitable instruments at a very low price, any loss being offset by improved servicing facilities.

At the time this paper was first written, there were no generators available which gave a complete signal and cost less than about £300. This figure has since fallen by more than 50 per cent, but is still too high to suit the financial resources of the average television repair agency. A large amount of alignment work is still carried out on a basis of the actual B.B.C. signals, and this leads to inconvenience and delay.

4.2. *The Present*

The performance requirements stated in the second part of the present paper (Sect. 2.1 *et seq.*) are not shaded by limited validity or other restrictions, and are applicable for all television test purposes. A generator which will satisfy these requirements is suitable for all kinds of television test work. Using the circuits and techniques outlined in the third part of the paper (Sect. 3.1 *et seq.*) such a generator can be manufactured and sold for less than £100.

The importance of this conclusion may not be immediately apparent. The full force of the point may be realized when it is noted that a generator of this kind can be used to replace the older type of generator for most purposes. If the generator satisfies the basic requirement given in para. 2.1.1., which states that a receiver adjusted on a basis of the generator output should function correctly with the B.B.C. signal applied, there is no point in obtaining greater perfection of signal waveform. A generator for factory use requires certain refinements which are not needed in a servicing generator, but these can be provided without any enormous increase in cost. The most important refinement is the provision of an internal monitor oscilloscope, so that an immediate check on operation can be obtained at any time.

This opens up new possibilities for factory testing. Where one large generator is now used, it would be possible to employ a number of smaller generators. Failure of one of these would not cause a serious production delay, and the low cost would permit the use of a "repair by replacement" technique, one or more spare generators being available which can be substituted rapidly in the event of any failure. Under existing conditions, the central generator may be out of action for considerable periods, and the total working delay amounts to a startling total.

It is suggested that carrier signals and frequency sweep signals for curve tracer work could be generated at a central point, duplicate generators being provided, with automatic changeover in the event of failure. The equipment at the actual test position would then comprise : video signal generator, the type of picture signal being chosen to suit the particular work being carried out ; built-in monitor oscilloscope with facilities for observing receiver waveforms ; and modulator unit in which the carrier signal from the central generator can be modulated by the video signal or the frequency sweep signal, the oscilloscope being used for response curve checking in the latter case.

Summarizing the present position, it is apparent that the use of simplified techniques, many of which were developed during the war years, can bring true pattern generator equipment within the reach of the average service and repair agency. It can also help in factory test work, by reducing overall cost and increasing reliability.

4. 3. *The Future*

The fact that most television signal generators were developed individually for the manufacturer's own use has led to a scarcity of relevant literature. Most existing notes on the design of such apparatus are of American origin, and concentrate more on the circuits of complete equipments. The reader is allowed to see the end-result, but not the reasoning which led up to it. There has been no serious attempt to define the performance requirements, most articles on the subject preserving a discreet silence on the subject. All these factors have influenced the present paper. The author makes no apologies for using American terminology where the British equivalent is less expressive or possibly ambiguous. The appended Bibliography is also a comment on the greater American activity in this field. Because the reader may not require a given set of performance characteristics, the emphasis has been placed on principle, the practice being represented by a few examples chosen to illustrate the method of combining the individual circuits. Lastly, an attempt has been made to lay down adequate performance requirements. These may not meet with universal approval, but they are based on careful observation, and should provide a useful basis for discussion.

The circuits and techniques noted in the foregoing pages may suffice for the time being, but only the most optimistic observers will accept them as the ultimate solution to the problem. However carefully the synthesizing apparatus is designed, there remains an element of uncertainty regarding the accuracy of the operation. While this remains, there is always a temptation to suspect that the signal source is at fault when the apparatus under test does not function correctly. Two solutions are available : the provision of continuous monitoring, or the use of a completely different generating technique. As the provision of continuous monitoring is unduly expensive, and still leaves a residual doubt regarding the operation of the generator, mention of a possible alternative technique may not be out of place here.

The technique is based on the recording and reproduction of a complete interlaced television signal. For the 405-line standard, the least exacting of all existing standards, the recording would have to last at least 1/25th of a second, being repeated continuously for the period of the test, and the shortest signal element would have to be of the order of 1/200,000th of the complete recording. With disc recording, this would require some 500 inches of track, and a track speed of about 700 m.p.h. Photographic recording with non-mechanical light-control devices is more practicable. With a grain size of 0·0005 cm (5 microns), the complete recording could be made on a piece of film 1 metre long, which would have to move at about 50 m.p.h. While continuous recording is scarcely possible with a film consumption of $1\frac{1}{2}$ km/min, a recording lasting 1/25th second could be made on the periphery of a drum 1 ft in diameter, and there would be no excessive difficulty in arranging for rotation of the drum at 1,500 r.p.m.

Apparatus using this technique would have one outstanding advantage : if the output is present, the waveform must be correct. This removes all doubt regarding the source of failures. Apart from this, the apparatus can be arranged to provide a number of alternative patterns at will by fitting suitable recordings, and the apparatus is much simpler than equivalent synthesizing units. This suggests that the technique may supersede the present methods in due course.

4.4. *Closing Notes*

Attempts to predict the future are fraught with danger, and this is especially true of television engineering. Generators using the recording technique may well become universal in due course but the synthetic video signal generator will be needed for some time to come. It is to be hoped that the present paper will be of some assistance to those engaged in the design of such apparatus, and that the study of performance requirements will establish a much needed minimum standard of performance for all types of television signal source.

The work described was carried out for EARL Services, of Exeter.

5.0. Bibliography

The books and papers listed are those which contain relevant material, and which have been read in the course of the work leading up to the present paper.

Pattern Generators

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DISCUSSION

Mr. Livingston Hogg (Member) said that he would be even more categorical than Mr. Thomasson and say that a pattern generator which did not give the correct pattern was worse than useless on many types of receiver. What was needed was a schedule showing just how each receiver on the market reacted to each known type of pattern generator.

He had seen a number of demonstrations of cleverly designed generators with a minimum number of valves, but so far not one had been satisfactory in service. He was therefore disappointed that the generator described in the paper was not available because of an accident, and he hoped that perhaps this would have been an exception. Therefore he still had to hold to his view that the hard way, i.e. with a sizeable number of valves, was the only way to make a good commercial generator.

He would join issue with Mr. Thomasson on the subject of tuning, as he considered that an ordinary instrument could not hold to an accuracy of 0·1 per cent. on a commercial basis. This difficulty could be overcome by means of a movable cursor which would easily be reset. A simultaneous sound channel was not required because for real satisfaction almost crystal accuracy was needed. It was unfortunate that the B.B.C. frequencies were not convenient for simple crystal circuits to be used.

Mr. R. Pollock (Member) pointed out that the $\frac{1}{2}$ μsec. blanking periods before each line sync-pulse were of considerable importance. If this blanking was omitted, and the right-hand edge of the picture became full white, the excessive rise time required might lead to faulty synchronizing action. Such small differences between the B.B.C. signal and a synthesized signal could affect various receivers differently, and the only way of overcoming the difficulty would be to make a complete survey of the effects obtained with different receivers.

Mr. I. J. Shelley (Associate) suggested that a linear sawtooth signal should be made available for additional tests. Only one extra valve would be needed, but the increase in amount of information which would be obtained when using an oscilloscope would be considerable. The refinement might be of more value in the laboratory than in the service department.

He suggested that the last 40 μsec. of each frame should be suppressed to detect long and short term streaking.

Mr. P. T. H. Dannahy (Associate Member) pointed out that the $\frac{1}{2}$ μsec. blanking period mentioned by Mr. Pollock was provided by the apparatus demonstrated. The broad black bands provided would enable the presence of streaking to be detected without the expedient proposed by Mr. Shelley. The main fault of some patterns was lack of high frequency content.

Mr. F. R. G. Webb said that Mr. Thomasson had proposed the omission of the mains locking facility because the B.B.C. did not employ mains locking. The B.B.C., however, had not dispensed with mains locking, and it therefore appeared that mains locking should be used. He also suggested that the sound channel test signal should be generated internally, and not by a separate source, as the necessary accuracy was not otherwise obtainable.

The most serious failing of all synthetic patterns was the absence of the serrated edge familiar on test cards. This card could only be reproduced with a monoscope or flying-spot generator.

AUTHOR'S REPLY TO DISCUSSION

The "minimum performance specification" for test sources which is given in the paper is based on an analysis of the kind suggested by Mr. Livingston Hogg. Instead of accepting an inadequate generator and noting the conditions under which it failed, the procedure entailed checking the maximum departure from the ideal which most receivers would accept. Unfortunately, it was impossible to check all makes and types of receivers, so the most representative possible selection was made.

In emphasizing the need for using a "sizeable number of valves," Mr. Livingston Hogg suggested that the use of too few valves might lead to unreliability. Too many valves can have the same effect. The important point is that valves should be saved by the omission of relatively non-essential functions, while all essential functions should be retained.

An excellent example arose from Mr. Hogg's next point. He doubted whether 0·1 per cent. accuracy of the vision carrier signal is a commercial proposition, but accepts the unnecessary refinement of a tuning scale covering all television channels. Replacement of the tunable generator by a fixed generator controlled by a suitable 3rd overtone crystal would increase the cost little if at all, but would solve the carrier accuracy problem. For a given area only one crystal and one oscillator setting is needed.

Mr. Shelley's suggestion of a linear saw-tooth signal for use in conjunction with an oscilloscope is covered in the body of the paper, but an alternative may be suggested. A step waveform can be substituted for the dot pulse signals forming the vertical lines of the pattern, and this provides a very useful means of checking picture gradation. A linear sawtooth signal used for the same purpose could only be utilized in full by engineers having a proper knowledge of the implications of "gamma" in the video amplifier section.

This question and that raised by Mr. Dannahy in relation to high frequency content of patterns must be considered in the light of "viewer's reaction." It is well known that the public taste often differs from the theoretical ideal in respect of frequency response of sound receiving apparatus. A similar discrepancy has been noted where television pictures are concerned. High frequency content is not appreciated as much as good low frequency response, which gives a smooth and regular background level.

From another point of view, however, high frequency response is important, since many forms of interference suppressor will only function properly when the preceding circuits have an adequate H.F. response. Perhaps the most satisfactory check for this is an "interference simulator" in the generator.

Mr. Webb misunderstood the point regarding mains locking. The B.B.C. lock to the mains on most transmissions, though not on all. The C.C.I.R. however, have shown a definite opposition to mains locking, and receivers which will only work when locking is used must therefore be considered out of date. Hence there is no point in using mains locking in the generator, and the simplification is welcome. Another aspect of this matter is that as the B.B.C. service area spreads, more and more areas will be covered in which the mains frequency is not always identical with that supplied to the B.B.C. in London.

The question of synthesizing serrated edges has been given some thought. A pattern as shown in Fig. 2*b* may be taken as a starting point. This pattern has a full-white trailing edge for the line signals throughout, the trailing edge being fixed about ½ μsec. before the start of the line sync-pulse. (Fig. 3). If the "dot pulse" elements forming the vertical lines are now delayed relative to the rest of the signal by about 4 μsec., the vertical edges of the pattern will be serrated. The depth of serration can be varied by adjusting the width of the dot pulses.

Similarly, the horizontal edges can be serrated by altering the relative phase of the pulses forming the horizontal lines, though this leads to difficulties regarding the frame blanking.

ANNUAL DINNER OF COUNCIL

The retiring President, Mr. L. H. Bedford, and Mrs. Bedford, were the principal guests at a dinner given by members of the General Council and Standing Committees at the Savoy Hotel on October 31st last.

A message from H.M. the King to mark the Silver Jubilee of the Institution was read before the Loyal Toast.

A presentation to Mr. and Mrs. Bedford was made on behalf of the Council by Mr. J. L. Thompson, who referred to Mr. Bedford's long association with the Institution and the work accomplished during the two years of Mr. Bedford's Presidency.

In his acknowledgment Mr. Bedford referred to the plans made for the 1951 Convention, and his Chairmanship of the Television Session. In particular, he dealt with the present American controversy in colour television.

Until quite recently it had been assumed that a colour picture required three times the bandwidth needed for a monochrome picture of the same resolution. This was because it seemed necessary to transmit this same resolution in each of the three primary colours.

The outstanding result of all recent work on colour television appeared to be the negation of that assumption. Instead two other propositions have been formulated :—

(*a*) That the resolution in respect of colour need not be as high as that in respect of brightness.

(*b*) That, given colour, the resolution can be lowered without loss of picture acceptability.

Both these proposals lead to the conclusion that the bandwidth ratio as between colour and monochrome pictures is markedly less than 3 : 1 ; it can conceivably approach unity. The two proposals are, however, fundamentally distinct and are separate bases of approach by R.C.A. and C.B.S. respectively.

The R.C.A. realizes proposition (*a*) in its principle of "mixed highs," and claims a bandwidth factor of 1·5 on this basis. A further factor of 2 is still required to bring the colour bandwidth down to the monochrome value. R.C.A. obtain this result by reducing the picture repetition frequency by a factor of 2, viz. from 30 to 15 c/s. Flicker is avoided by the introduction of horizontal or dot interlace.

No one can possibly read this work of R.C.A. without being impressed by the considerable brilliance of the thinking and realization, particularly having regard to their achievement of complete compatibility. (*By compatibility is meant that an existing monochrome receiver can without adaptation extract a monochrome picture from the new colour transmission.*)

On the other hand, C.B.S. taking a much easier road have also shown no shortage of brilliance. The C.B.S. approach does not allow any advantages to be taken under proposition (*a*) and is based only on proposition (*b*). While the field sequential system is the obvious and easy method and is basically quite old, the brilliance of C.B.S. resides in three factors :—

1. Their demonstration contrary to all accepted beliefs that an acceptable full sequential colour picture can be transmitted in 4 Mc/s video bandwidth.
2. Their good choice of primary colours.
3. The good engineering of the whole project, particularly the disguising of the colour disc at the receiver.

This mechanical colour disc has been much criticized as a weakness of the C.B.S. system. On the contrary, Mr. Bedford suggested that it was a strength, for the field sequential system can work without a colour disc just as soon as a commercial tri-colour tube is available while every other system is really conditional on the existence of a tri-colour tube. On the other hand, as soon as the tri-colour tube is available, one is forced to recognize the attractiveness of the alternative methods.

Summarizing the issue :—

1. The field sequential system is simple and immediately available. It is non-compatible except as to bandwidth, and its resolution is down compared to monochrome by a factor of 3 × 24/30 or 2·4, i.e., the system has a resolution of 0·42.
2. The compatible class of systems are basically more complicated and, in the opinion of F.C.C., not immediately available. They are, however, compatible in the fullest sense and their resolution factor (relative to monochrome) may be assessed as not less than 0·7 or nearly twice that of the field sequential system.

NOTICES

Obituary

Council regrets to record the death of Emanuel M. Wender, who was elected a Member of the Institution in 1940.

Originally trained for a medical career in Hungary, Emanuel Wender became a naturalized British subject and was a full-time student at the Birkbeck College, London.

Before forming his own company, The Electro Physical Laboratories (Renny & Wender), Ltd., he was engaged on acoustic work with British Acoustic Films, Ltd., and later with British Ozaphone, Ltd.

He was also concerned with his brother, Eugene Wender, with the early development and manufacture of the photographic sound discs for "TIM" the speaking clock.

During the last world war his company did considerable research and development work, whilst he himself was responsible for the adaptation of the automatic photo-electric shell selector for war production. Later he joined the R.A.F.V.R.

He was known to many members through his manufacture of selenium barrier layer photo-cells. In 1949 he went to Australia to start a branch of his company there.

Emanuel Wender died in London of heart failure at the age of 51 years.

National Radio Show

The 18th (British) National Radio Show is to be held at Earls Court, London, from August 28th to September 8th, 1951, the first day being reserved for distinguished visitors and overseas buyers.

The show will include British radio, television and electronic equipment of all kinds, as well as valves and components. The B.B.C. will co-operate in demonstrations and performances of television from a large and fully equipped studio in the exhibition hall.

Over 3,000 applications for invitations have already been received from 44 countries abroad, and an unusually large overseas attendance is expected, especially as other events in the late summer and early autumn of the Festival of Britain year include the Institution's 3rd Convention, the Engineering and Marine Exhibition, and the Motor Show.

Fourth Congress of the International Scientific Film Association

The International Scientific Film Association's Fourth Congress and Festival of Scientific Films was held in Florence from the 14th to the 22nd of October.

Great Britain was represented by a delegation of ten members, and contributed about 30 per cent. of the total of some 120 films shown.

Among the most important decisions reached during the Congress were those dealing with : the setting-up in Brussels of the first International Reference Film Library of scientific films ; the adoption of a standard system of recording, and interchanging internationally, information about scientific films.

The Association wishes to emphasize the advantages that a wider and more organized use of cinematography can bring to scientific research, and also recommends to film makers the production of films illustrating how much recent advances in science can contribute to the well-being of Man.

As a means of internationally co-ordinating such projects, the Association requests all those ready to respond to the above appeal to furnish by March 1st, 1951, a report on the practical steps they have taken or are taking. Such reports will be discussed at the Fifth Annual Congress of the Association in 1951.

Engineers in the B.B.C.

Under the above title the B.B.C. has produced a useful booklet for issue to Universities and Training Colleges as a guide to graduates and undergraduates contemplating careers as engineers.

Several major industrial undertakings have issued similar guides to careers and this booklet meets a demand for information on the opportunities in the Engineering Division of the B.B.C.

"The Velocity of Light"—Correction

In the short contribution on page 362 of the November *Journal*, it was stated that Michelson's experiment was performed in 1935. This should read 1931. The results, however, were not published until 1935.

Mr. D. W. Heightman

D. W. Heightman (Member), formerly managing director of Denco (Clacton), Ltd., has recently joined The English Electric Co., Ltd., as Chief Television Engineer at their Liverpool factory.

Mr. Heightman will be well known to members for his paper on " Propagation of Metric Waves beyond Optical Ranges," which was read before the London and Merseyside Sections and published in the October Journal.

Overseas Research Reports

Under the above title, the Technical Information and Documents Unit of the Board of Trade prepares and issues summaries of reports of research undertaken in the United States and other countries on many aspects of pure and applied science. The summaries, a number of which are issued each month, are available to any interested firm or other body free of charge.

The reports themselves are held in microfilm form by the Unit. and copies may be obtained as either negative or positive film, or in enlarged prints or photostat copies. The charges made cover the cost of reproduction, and are as follows :—

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A photostat copy of a report can usually be borrowed for a period of seven days, and facilities are available for viewing the microfilm copy by means of a film projector at the headquarters of the Unit at Lacon House.

As it is considered that this service to British Industry is not sufficiently well known, it is proposed to publish abridged details of the summaries in the Journal and the first appear on page (vi).

Further details may be obtained from the Technical Information and Documents Unit, Board of Trade, Lacon House, Theobalds Road, London, W.C.1.

Papers by Members

The following are some of the papers and articles published by members of the Institution in contemporary journals during the past few months.

1. T. B. Tomlinson, B.Sc.(Hons.) (Associate). "A New Method of Synchronization for Long-Range TV Reception." *Electronic Engineering*, Vol. 22, April 1950, pages 149-151.
2. J. H. Battison (Member). "VOR Signal Generator." *Tele-Tech*, Vol. 9, May 1950, pages 37-39, 57.
3. A. W. Keen (Member). "Negative-Resistance Characteristics." *Wireless Engineer*, Vol. 27, June 1950, pages 175-179.
4. H. Moss, Ph.D. (Member), L. Woodridge, B.Sc., and Miss M. Webb. "Dimensional Tolerances in Cathode-Ray Tube Guns." *Proc.I.E.E.*, Vol. 97, Part III, July 1950, pages 277-284.
5. J. R. Brinkley (Associate Member). "Multi-Station V.H.F. Systems." *Electronic Engineering*, Vol. 22, August 1950, pages 323-325.
6. G. N. Patchett, Ph.D., B.Sc. (Associate). "Precision A.C. Voltage Stabilizers." *Electronic Engineering*, Vol. 22, September-December 1950, pages 371-377, 424-428, 470-473 and 499-503.
7. R. L. West, B.Sc. (Associate Member). "Gramophone Speed Control." *Wireless World*, Vol. 56, September 1950, pages 325-326.
8. D. W. Thomasson (Associate Member). "Silicones and other Silicon Compounds." *Electronic Engineering*, Vol. 22, October 1950, pages 422-423.
9. C. S. Fowler (Associate Member). "Narrow Pulse Generator." *Wireless Engineer*, Vol. 27, October-November 1950, pages 265-269.
10. R. L. West, B.Sc. (Associate Member) and S. Kelly. "Pick-up Input Circuits." *Wireless World*, Vol. 56, November 1950, pages 386-391.
11. E. G. Hamer, B.Sc.(Eng.), (Associate Member). "Communications on 460 Mc/s." *Wireless World*, Vol. 56, November 1950, pages 412-414.

A NOTE ON INDUCED GRID NOISE AND NOISE FACTOR*

by

I. A. Harris (*Associate Member*)

SUMMARY

Comparison between theory and experiment on induced grid noise is discussed in relation to other published work. Calculation of the noise factor of a common-cathode triode circuit is carried out by a novel system of valve circuit analysis which ensures that transit time effects are inherent in the results. The results confirm the possibility of reducing the noise factor by "de-tuning" the input circuit with or without neutralization.

1.0. Induced Grid Noise

1.1. In a recent paper,[1] experimental results were quoted which suggested that an approximate relation exists between the induced grid noise in a triode with common cathode connections and the electronic part of the valve input capacitance. Also, by assuming that the valve acts, both for signals and for valve noise, as an ordinary complex circuit element, the relation

$$\overline{di_g^2} = \left|\frac{j\omega c_t}{g_m}\right|^2 . \overline{di^2} \quad \ldots\ldots\ldots\ldots(1)$$

was deduced by pure circuit analysis. (In this, $\overline{di_k^2}$ is the mean square induced grid noise current and $\overline{di^2}$ is the space-charge smoothed shot current, for the frequency response range f to $f + df$. c_t is the electronic part of the input capacitance).

In the same work, theoretical results derived elsewhere[2] were also quoted and, as was stated, bore little resemblance to the observed results.

1.2. The primary aim of the present note is to show that other existing theory, properly applied, bears a much closer resemblance to the same experimental results than the comparison quoted above would lead one to believe. In a paper recently published[3] the writer gave an expression (eqn. 24) connecting the correlated fluctuation currents in the cathode-grid and the grid-anode meshes of a basic triode circuit. To an accuracy including the first power in $\omega\tau$, this expression also follows from a combination of results of earlier works by others.[4,5] The induced grid noise current is given by the difference between the two mesh currents, and may be written

$$\delta i_k = \left(\frac{1}{3} j\omega\tau_1 + \frac{2}{3} j\omega\tau_2\right) . \delta i_1$$

or

$$\overline{di_g^2} = \left|\frac{1}{3} j\omega\tau_1 + \frac{2}{3} j\omega\tau_2\right|^2 . \overline{di^2} \quad \ldots\ldots\ldots(2)$$

(In this, τ_1 is the transit time in the cathode-grid space, and τ_2 is the transit time in the grid-anode space.)

This is more conveniently expressed :

$$\overline{di_g^2} = \left(\frac{1}{3}\omega\tau_1\right)^2 . \left(1 + 2\frac{\tau_2}{\tau_1}\right)^2 . \overline{di^2} \ldots.(3)$$

from which, with the usual expressions for τ_1 and τ_2, the value of $\overline{di_g^2}$ can readily be calculated.

Thus, from the well-known expressions for τ_1 and τ_2 :

$$\frac{\tau_2}{\tau_1} = \frac{2 d_2 V_c^{1/2}}{3 d_1 (V_c^{1/2} + V_a^{1/2})}$$

where V_c is the effective control voltage in the grid plane, calculated from the anode current I_a using the 3/2 power law. d_1 and d_2 are the cathode-grid and the grid-anode spacings. For $\overline{di^2}$ it is most expedient to use Rack's expression $4k\,(0{\cdot}644\ \theta_c)\ g_m . df$. By these means relative values of $\overline{i_g^2}$ have been calculated as a function of I_a and have been plotted as curves in Fig. 1, together with the curve obtained from the relation[2]

$$\overline{di_g^2} = \left(\frac{1}{5}\omega\tau_1\right)^2 . \overline{di^2} \ldots\ldots\ldots\ldots\ldots\ldots(4)$$

The curves are based on a theoretical triode with $d_1 = 0{\cdot}1$ mm, $d_2 = 0{\cdot}3$ mm, and a cathode area of $0{\cdot}25$ cm^2, obeying the 3/2 power law for which $g_m \propto I_a^{1/3}$.

1.3. On comparison with the experimental curves,[1] using the curve derived from eqn. (4) as a comparison standard, it is seen that values of $\overline{i_g^2}$ given by eqn. (3) are not inconsistent with experimental values in the region 6 to 10 mA

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U.D.C. No. 621.396.822:621.396.6.

anode current. The marked discrepancy between the slopes of the theoretical and experimental curves is probably a result of the true values of τ_1 and g_m as a function of I_a differing from the "3/2 power law" values at lower currents on account of *Inselbildung*, undoubtedly present in the experimental valves considered.

1.4. The expression for the electronic part of the input capacitance derived from the Benham-Llewellyn theory, assuming zero initial emission velocity, is

$$\omega c_t = g_m\left(\frac{1}{6}\omega\tau_1 + \frac{2}{3}\omega\tau_2\right) \quad \ldots\ldots\ldots\ldots(5)$$

to an accuracy including the first power in $\omega\tau$. The use of this in formula (1) results in the curves drawn as broken lines in Fig. 1. It is evident that the values are low compared with values obtained[1] from the measured values of c_t.

1.5. Values of induced grid noise deduced from formula (1) by using formula (5) for c_t differ from values deduced directly from formula (3), whereas according to the method[1] of deriving formula (1), they should be alike. The reason is evident from a comparison of (2) and (5), from which it is seen that the valve acts as a circuit element for internally generated noise different from that for applied signals. Therefore, according to the school of thought followed here,[4,5] formula (1) is at best only approximately valid. It is not surprising, then, that the experimental curves, and the curves calculated from (1) by using measured values of c_t, do not agree. The appeal to experimental error to explain the difference between the two sets of results would then be unnecessary.

1.6. Formula (4) is widely at variance with formula (2) or (3) adopted here. Firstly, this results from the neglect of the grid-anode transit time τ_2 in the derivation[2] of (4). It is worthy of note that τ_2 was also neglected in other earlier work,[4] but experimental verification was made through a formula in terms of the electronic damping, which also depends on τ_2 in a similar manner. Secondly, the numerical coefficient of $\omega\tau_1$ in (4) is 1/5, whereas in equation (3) it is 1/3. In the writer's opinion the coefficient 1/3 is correct.

2.0. The Noise Factor of the Common Cathode Circuit

2.1. In a recent note[6] the result of applying formula (1) to the noise factor estimation of a

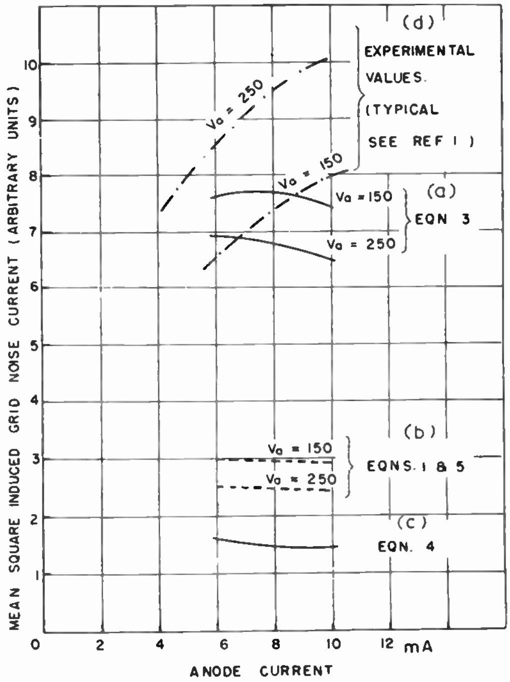

Fig. 1.—Values of induced grid noise : (a) Calculated on the theory of references 3, 4 and 5 ; (b) Calculated on the theory of reference 1 with theoretical values of c_t ; (c) Calculated on the theory of reference 2 ; (d) Typical experimental values. (Reference 1.)

Note.—The values of Va on the experimental curves are in error and should be interchanged.

common-cathode triode circuit has been stated to be that, among other things, the noise factor is a minimum when the input circuit is "detuned" approximately by c_t. The idea of improving the noise factor by detuning the input circuit was also described some time ago by others.[7]

It will be shown here that this effect also follows from a treatment of the problem based on the theory[3] leading to formula (3), using a novel form of "operational model" of the valve as a circuit element. This model is illustrated in Fig. 2, in which the valve *per se* is regarded as a passive circuit element described by a set of simultaneous linear equations between the *mesh* current associated with each adjacent pair of electrodes and a small-signal voltage applied between each electrode and a common external point. This model is a development by the writer from one in which the valve was regarded as a multi-terminal network.[8] The chief advantage of the proposed model is that transit time effects come naturally into the calculations, and neither have to be grafted on to the system nor complicate it out of all proportion to its utility.

The relations defining the "circuit element" of Fig. 2 are :

$$\left.\begin{aligned} i_1 &= \left[y_1\left(1+\frac{1}{\mu}\right)+b_1\right]e_1+(y_1+b_1)e_2 \\ &\qquad +\frac{y_1}{\mu}e_3+\delta i_1 \\ i_2 &= y_2\left(1+\frac{1}{\mu}\right)e_1+(y_2-b_2)\,e_2 \\ &\qquad +\left(\frac{y_2}{\mu}+b_2\right)e_3+\delta i_2 \\ i_3 &= b_3e_1+b_3e_3. \end{aligned}\right\}(6)$$

(i_3 is subsidiary, and often negligible).

(Here, y_1 is the electronic admittance of space I, y_2 is the electronic transadmittance of the current in space II relative to the voltage across space I, b_1 and b_2 are the "cold" susceptances across spaces I and II, respectively, and b_3 is the direct susceptance across both spaces. The b's are essentially $j\omega c$'s where c is the cold capacitance between two electrodes, but the b's may also include the effect of external reactance used for neutralizing. The current components δi and δi_2 are the correlated noise current components induced in spaces I and II respectively.)

2.2. While it is hoped to give a fuller description of this circuit model of the valve and its application at a later date, an illustration of the method provided by application to part of the circuit for the measurement of induced grid noise is of interest here.

Referring to Fig. 2, the anode and cathode are effectively grounded (i.e. $e_1 = e_3 = 0$) and there is an external admittance Y connected between grid and earth (i.e. $e_2 = -(i_1-i_2)/Y$). Solving the first two equations of (6) for i_1-i_2 results in :

$$i_1 - i_2 = \frac{Y(\delta i_1 - \delta i_2)}{Y+(y_1-y_2)+(b_1+b_2)}$$

or $$\overline{di^2} = \frac{|Y|^2 . |\delta i_1 - \delta i_2|^2}{|Y+(y_1-y_2)+(b_1+b_2)|^2} \quad ..(7)$$

in which $b_1+b_2 = j\omega\,(c_1+c_2)$, is the mean square noise current in Y.

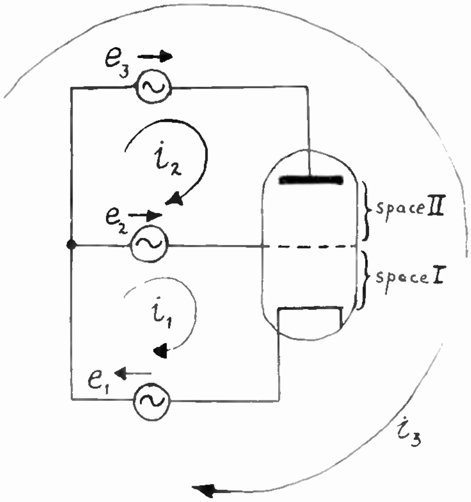

Fig. 2.—Basic triode circuit treating the valve as a passive circuit element. i_1, i_2 and i_3 are mesh currents, and e_1, e_2 and e_3 are ideal zero impedance small-signal generators.

The input damping and the electronic increase in capacitance are naturally included in the real and imaginary parts, respectively, of $y_1 - y_2$. This is better appreciated when it is noted that the values of y_1 and y_2, to the first power in $\omega\tau$, each has the magnitude, g_m, while y_1 has the lagging angle $1/5\,\omega\tau_1$ and y_2 has the lagging angle $11/30\ \omega\tau_1 + 2/3\ \omega\tau_2$.

Apart from this, the solution is the trivial one of division of current between two parallel admittances. The value of $|\delta i_1 - \delta i_2|^2$ is given by eqn. (2).

2.3. For the calculation of the noise factor N of a common-cathode triode circuit, the arrangement shown in Fig. 3 is considered. For present purposes, the noise of the input coupling circuit between the source and the valve electrodes is disregarded, thus making N the noise factor of the valve electrodes alone. There is an input load admittance $Y = 1/R_s + jB$ where the resistive part R_s is regarded as the source resistance at room temperature θ_0, and there is an anode load impedance $Z = R_L + jX_L$. The noise of R_L is, by convention, associated with the next stage. The noise factor is given by

$$N = 1 + \frac{\overline{i_{2v}^{\,2}}}{\overline{i_{20}^{\,2}}}$$

where $\overline{i_{2v}^2} \cdot R_L$ is the noise power in Z due to the valve alone, and $\overline{i_{2o}^2} \cdot R_L$ is the noise power in Z due to the source noise across Y when the valve is ideally "silent." It is important to note that noise currents which are not correlated have to be dealt with separately, the results being combined by adding the mean square values. Therefore there are two problems here, one to evaluate $\overline{i_{2v}^2}$ and the other to evaluate $\overline{i_{2o}^2}$.

In equations (6) we have

$e_1 = 0,\ e_2 = -(i_1 - i_2)/Y$ and $e_3 = -Zi_2$.

To evaluate i_{2v}, put these values in (6), neglect i_3 (which in effect shunts Z and is thus trivial) and solve for i_2.

The result is :

$$i_{2v} = \delta i_2 \left\{ Y + \left(y_1 - y_2 \frac{\delta i_1}{\delta i_2} \right) + \left(b_1 + b_2 \frac{\delta i_1}{\delta i_2} \right) \right\} \Delta^{-1} \quad \ldots\ldots(8)$$

where

$\Delta = Y + (y_1 - y_2) + (b_1 + b_2) +$ terms in Z.

To evaluate i_{2o}, we have to set $\delta i_1 = \delta i_2 = 0$ to represent an ideally silent valve, and put $e_2 = \delta i_o/Y - (i_1 - i_2)/Y$ where δi_o is the noise current in Y due to the source resistance R_s. Such a state is effected without re-solving (6) by putting $\delta i_1 = \delta i_o (y_1 + b_1)/Y$ and $\delta i_2 = \delta i_o (y_2 - b_2)/Y$ in eqn. (8). It follows that :

$$i_{2o} = \delta i_o (y_2 - b_2) \cdot \Delta^{-1} \quad \ldots\ldots\ldots\ldots\ldots\ldots(9)$$

and from this and eqn. (8) follows :

$$N = 1 + \frac{|\delta i_2|^2}{|\delta i_o|^2} \cdot \frac{\left| Y + \left(y_1 - y_2 \frac{\delta i_1}{\delta i_2} \right) + \left(b_1 + b_2 \frac{\delta i_1}{\delta i_2} \right) \right|^2}{|y_2 - b_2|^2} \quad \ldots\ldots\ldots\ldots\ldots(10)$$

The first factor may be resolved further by noting that $|\delta i_o|^2 = 4k\theta_o \cdot df/R_s$, and by defining[9] the equivalent noise resistance R_n of the valve by $|\delta i_2|^2 = 4k\theta_o R_n |y_2|^2 \cdot df$ (imperceptibly different from the value usually measured) which makes the first factor in (10) :

$$|\delta i_2|^2 / |\delta i_o|^2 = R_n R_s \cdot |y_2|^2.$$

2,4. Let us suppose that b_2 (normally $j\omega c_2$) is neutralized by parallel tuning, giving $b_2 = 0$ with a possible residual conductance which will be neglected. Setting $b_1 = j\omega c_1$ and $Y = 1/R_s + jB$, we have

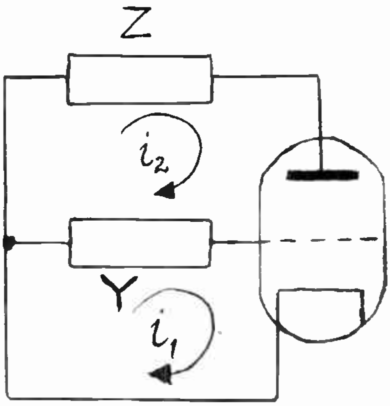

Fig. 3.—Common-cathode triode circuit with input circuit admittance Y and output circuit impedance Z.

$$N = 1 + R_n R_s \left| \frac{1}{R_s} + jB + \left(y_1 - y_2 \frac{\delta i_1}{\delta i_2} \right) + j\omega c_1 \right|^2 \quad \ldots\ldots\ldots\ldots\ldots(11)$$

The term $(y_1 - y_2 \cdot \delta i_1/\delta i_2)$ has been discussed elsewhere,[9, 3] and by taking the first order values of y and δi (see ref. 3, para. 4.4.), is equal to $-1/6\ j\omega\tau_1\ g_m$. The first and second order values give also the real part $1/R_o$, believed to be equal to $11/90 \cdot g_m \omega^2 \tau_1^2$. Therefore, if the input circuit is tuned to make

$$-B = \omega c_1 - \frac{1}{6} \omega\tau_1 g_m \quad \ldots\ldots\ldots\ldots\ldots\ldots(12)$$

then (11) becomes simply

$$N = 1 + R_n R_s \left(\frac{1}{R_s} + \frac{1}{R_o} \right)^2 \quad \ldots\ldots\ldots(13)$$

and this represents the minimum value of N.

With signal tuning to obtain a maximum gain in a neutralized state ($b_2 = 0$), we have :

$$-B = \omega c_1 + \frac{1}{6} \omega\tau_1 g_m + \frac{2}{3} \omega\tau_2 g_m \quad \ldots\ldots(14)$$

and (11) becomes, on evaluating the modulus squared,

$$N = 1 + R_n R_s \left\{ \left(\frac{1}{R_s} + \frac{1}{R_o} \right)^2 + \left(\frac{1}{3} \omega\tau_1 + \frac{2}{3} \omega\tau_2 \right)^2 g_m^2 \right\} \quad \ldots\ldots(15)$$

2.5. Comparison of eqns. (12) and (14) shows that the susceptance difference between noise-tuning and gain-tuning of the input circuit is $(1/3\,\omega\tau_1 + 2/3\,\omega\tau_2) g_m$, which is precisely the value of the " ωc_t " which would have to be put in formula (1) to obtain the value of induced grid noise given by eqn. (2). It is not, however, the theoretical value of ωc_t, the electronic part of the input capacitance, as given by eqn. (5). Therefore, the " detuning " required to obtain a minimum noise factor is only approximately the electronic part of the input capacitance.

2.6. If the noise generated by the input coupling circuit, including the cathode coating losses, is accounted for by the noise of a shunt resistor R at a noise temperature $\lambda\theta_o$, then with noise-tuning (13) becomes :

$$N = 1 + \frac{\lambda R_s}{R} + R_n R_s \left(\frac{1}{R_s} + \frac{1}{R_o} + \frac{1}{R} \right)^2 \qquad \ldots\ldots\ldots\ldots(16)$$

if the noise due to the neutralizing circuit is disregarded. This relation is exactly the same as that for the grounded grid triode with noise-tuning.[9]

It is interesting to note that in (13) or (16) there is no contribution of noise from a " noisy " input damping as was suggested by earlier work under the name of " induced grid noise," but only the passive damping of an equivalent shunt resistor R_o. Even with gain-tuning, there is only additional passive damping, as shown by eqn. (15). Any " noisy " damping would involve a term outside the term in $R_n R_s$, although admittedly the term in $\omega\tau$ under $R_n R_s$ in (15) may be placed outside the large brackets and shown to be *approximately* equal to 5 R_s/R_t, where $1/R_t$ is the transit-time input damping (i.e. the real part of $y_1 - y_2$). The older theory therefore gives approximately correct results when gain-tuning adjustment is made to the input circuit.

Although induced grid noise can be measured artificially, it does not appear as such in an amplifier circuit, in so far as it is correlated to the shot noise. Only a non-correlated part, usually very small, would be an active noise source. These considerations show that *ad hoc* assumptions, such as ascribing a noise temperature to an input damping resistor grafted on to the system, can be misleading.

2.7. Returning to eqn. (10), it is evident that the noise factor is quite independent of the anode load Z. (Although the gain is, of course, dependent on Z.) Secondly, the denominator $|y_2 - b_2|^2$ is approximately equal to $|g_m - j\omega c_2|^2 = (g_m^2 + \omega^2 c_2^2)$. Also, when b_2 is capacitative, the term $b_2 \delta i_1/\delta i_2$ in the numerator contributes a negative conductance which reduces the total conductance in the numerator. Then, provided the tuning of the input is adjusted to cancel the susceptive part due to the valve, it follows that adjustment of b_2 to partial or no neutralization will reduce the noise factor.

This reduction of noise by feedback between anode and grid has been noted experimentally and recorded elsewhere.[10] Questions of satisfactory gain and stability, however, remain.

2.8. The considerations in section 2 of this note are limited to the case in which the pass-band of subsequent stages of amplification is narrow compared with the bandwidth of the input circuit. With a wide pass-band of subsequent amplification, a modified noise factor analysis would be necessary.

3.0. References

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THE FUTURE DEVELOPMENT OF HIGHER TECHNOLOGICAL EDUCATION

The first report of the National Advisory Council on Education for Industry and Commerce was published by His Majesty's Stationery Office on November 14th. The Council was set up by the Minister of Labour in 1948 under the chairmanship of Lieut.-General Sir Ronald M. Weeks and consists of 72 members appointed on a regional basis.

The first draft of the report was circulated in December 1949 to 145 bodies, including the Institution, and the views of these bodies were considered before the publication of the report. The Institution was also represented at the recent conference.

For the purpose of the report Higher Technological Education refers to technological education in technical colleges of a standard at least equivalent to that of a university first degree, or satisfying the educational requirements for corporate membership of a major professional Institution. To develop this type of education the Council's main recommendations are :

(i) The establishment or development of courses of a high standard in technology.

(ii) The creation of new awards of degree standard.

(iii) The establishment of a Royal College of Technologists to approve such courses and confer the awards of degree standard.

These higher technological courses would be held in suitable technical colleges and made possible by improvements in finance, staffing, equipment and accommodation. These colleges could then provide more high-level courses of a degree standard and courses for post-graduate work.

It is suggested that courses should be developed mainly, but not exclusively on a full-time or " sandwich " basis, which combine a practical industrial approach with a greater element of broad fundamental science than is normally found in many existing courses. The standard of entry should be comparable to that of a faculty of science or technology in a university, and should make special provision for students recruited from industry. The length of the course should also be comparable, and there should be adequate provision for suitable works experience.

The Council agree that the universities have a specific function to perform in the development of technological education, but their work should be more closely related to fundamental science than that of the technical colleges.

The Council recommends the creation of three new awards : Associateship for the first award (first degree level) ; Membership for the second award (post graduate level) and Fellowship for those who distinguish themselves in research. These awards would not be a substitute for professional qualifications or, for that matter, any existing awards. It is intended that the first award should be an educational qualification fully comparable to a university degree of equal intellectual content, but of differing type.

To approve suitable courses of advanced technology, appropriate to the first and higher awards, and to appoint suitable external examiners for assessment of the examination, the Council recommends the formation of a Royal College of Technologists.

The Royal College will be an entirely independent body consisting of a Court, assisted by a Council and an Academic Board. The Court would consist of 16 persons of eminence in the field of technology nominated by the Crown, four representatives of the Council and four of the Academic Board. The Council would include persons nominated by universities, technical colleges, employers, employees in industry, professional institutions and local education authorities, while the Academic Board would include persons from the teaching staffs of technical colleges and universities and persons experienced in educational matters chosen from among professional institutions and industry.

The Minister of Education hopes that the report will be widely studied and, before taking any decision on the Council's recommendation, will welcome and consider any comments made to him.

TRANSFERS AND ELECTIONS TO MEMBERSHIP

At a meeting of the Membership Committee held on November 28th, 1950, twenty-one proposals for direct election to Graduateship or higher grade of membership, and fifteen proposals for transfer to Graduate or higher grade of membership were considered

The following elections were approved by the General Council : eighteen for direct election to Graduate or higher grade of membership, and eleven for transfer to Graduate or higher grade of membership.

Direct Election to Associate Member

Collingwood, John Douglas	Ruislip, Middx.
Gliddon, Charles William Emmanuel, Flt./Lt.	Henlow, Beds.
Smith, George	Lusaka, N. Rhodesia
Street, Charles Keith, Sqd./Ldr.	Washington, U.S.A.

Direct Election to Associate

Burtle, Norman Charles	Prittlewell, Essex
Harding, Arthur Edmund B.	Southend-on-Sea
Oliver, Albert George	Croydon, Surrey
Palmer, John Frederick, F./O.	Ramsey, Hunts.
Sabine, Percy Thomas W.	Southend-on-Sea
Whatling, Vernon Frank	London, S.W.16

Direct Election to Graduate

Amancio, Barata Luis Ricardo, Lt.	Sintra, Portugal
Berg, Reidar Ashborn, Lt.	Oslo, Norway
Fjeldstad, Frithjoe, Lt.	Oslo, Norway
Hogg, Douglas	Tunbridge Wells
Mafra, Abel de Azevedo, Lt.	Lisbon, Portugal
Osselton, John Walkinshaw, B.Sc.	Newcastle-on-Tyne
Toscano, Fernando Jose Guerra Limpo, Lt.	Lisbon, Portugal
Turner, Lewis Edgar	London, N.18

Transfer from Associate Member to Full Member

Lenihan, John Mark Anthony, Ph.D., M.Sc.	Glasgow

Transfer from Associate to Associate Member

Dehn, Rudolf, B.Sc.	London, N.W.5
Hamer, Edward George, B.Sc.(Eng.)	Greenford, Middx.
Lott, Alan Edwin	Enfield, Middx.

Transfer from Student to Associate

Boyce, Alfred Michael	Manchester
Foulds, William Henry H.	Portsmouth
Hazelden, Frederick George	Crewkerne, Som.
Sabhaney, Idandas Werhomal, Flt./Lt.	London, W.1
Walker, Ian Claude	Kingston, Surrey

Transfer from Student to Graduate

Harris, John Edward	London, N.5
Snowsill, Alan Harold	London, S.E.21

STUDENTSHIP REGISTRATIONS (*contd.*)

Lalitha, Miss N. S., B.Sc.	Bangalore, India
Madan Lal, B.Sc.	Delhi, India
Mahajan, Keshau Bapurao, B.Sc.	Poona, India
Manian, T. S., B.Sc.	Madras, India
Manohar, Nath Tiku, B.A.	New Delhi, India
Mathure, Sudhakar B.	Bombay, India
Mitra, Nimal, B.Sc.	Calcutta, India
Muthukrishnan, V., B.Sc.	Tanjore, India
Nkele, Aluma	London, S.E.27
Patankar, Aruind Vishnu	Bombay, India
Patel, Jayantilal Ramubhai	Bombay, India
Pillay, P. K. Krishna	Bombay, India
Pimpalkhare, Madhukar Sidheshwar, M.Sc.	Poona, India
Ponkshe, Madhav R.	Bombay, India
Premchandani, Pamo Sadhuram, M.Sc.	Bombay, India
Ranade, Maheshwar Trivikram, B.Sc.	Poona, India
Rao, Murlidhar Ram, B.Sc.	Bombay, India
Sajip, Mohan Shankar	Bombay, India
Sardesai, Damodar Balkrishana	Poona, India
Smith, Paul Procter Hare	Portsmouth
Srivastava, Gopal Narayan, M.Sc.	Lucknow, India
Srinivasulu, Neelum	Madras, India
Stuff, Alan Charles	Washington, U.S.A.
Sud, Romesh Chandra, B.Sc.	Tarn-Taran,India
Tan Khay Boh	Penang, Malaya
Timms, Peter Anthony	Scarborough
Tyler, Ronald Arthur	Clacton-on-Sea
Udyaver, Manohar Shripad	Bombay, India
Varma, Harich Chandra, B.Sc.	Delhi, India
Varma, Sukumara, K. R.	Bombay, India
Virmani, Khem Chand, B.A.	New Delhi, India

STUDENTSHIP REGISTRATIONS

The following forty-two Studentship proposals were accepted by the Membership Committee at their meeting on October 16th, 1950. This completes the list of proposals considered at that meeting.

Fazalur, Rahman Khan, Usufzai	Old Sukkur (Sind), Pakistan
Kishore, Ram Kishore	Meerut, India
Lakshminarayana, N.	Madras, India
Lowry, Peter	London, S.E.27
Maan, Naranjan Singh	Delhi, India
Madon, Kaikhushru Rustomji	Bombay, India
Mahon, Vincent	Dublin, Eire
Mansi, Liugi Anthony Sahatore	London, N.W.6
Marwha, Jitender Nath, B.Sc.	Bombay, India
Mathur, Mahendra Nath	Aligarh, India
Meldrum, Mervyn Thomas	London, W.12
Munroe, Bernard Bistoford	Carshalton Beeches, Surrey
Nicholson, Charles Henry	Chelmsford
Padmanabhan, Nambiar K. P., B.Sc.	Bombay, India
Painter, Arthur Robert	Ludlow, Shrops.
Pollard, Cyril John	Selby, Yorks
Prabhu, Manjeshwar Achyutha, B.A.	Bombay, India
Rajwade, Gajanan Vinayak	Akola, India
Raman, Raghurama Balaraman, B.Sc.	Madras, India
Ramasastri, Vissavajhala, B.Sc.	Kistan Dt., India

Ramaswami, V., B.Sc.	Secunderabad, India
Ramchandani, Nanik Zowkiram, B.A.	Bombay, India
Satyanarayana Rao, Kolanu	Mysore, India
Rao, Ravi, M.Sc.	Calcutta, India
Rogers, Vincent P. F.	Dublin, Eire
Sandeman, William Neville	London, W.4
Sawant, Vasant Narayan	London, W.4
Sharma, Gulzari Lal	Amritsar, India
Sharma, Korpal Bamarsi Dass	Amritsar, India
Singh, Jogindar	Hyderabad, India
Sinha, M. K.	Gaya, India
Singh, Sadhu, B.Sc.	Jubbulpore, India
Songhurst, Morris Hugh	Dartford, Kent
D'Souza, Raymond	Bombay, India
Stanbrook, Donald	Windsor, Berks
Stedman, Maurice Henry	Lingfield, Surrey
Subramanyam, Aiyar Srinivasa	Madras, India
Talwar, Pearey Lal	Amritsar, India
Toynbee-Holmes, Alan, Flt/Lt.	Sleaford, Lincs.
Venter, Jan Andries	Johannesburg
Yadava, Krishna Pal Singh	Aligarh, India
Yunas, Shiekh Mohd	London, W.2

At a meeting on November 28th, 1950, the Membership Committee accepted sixty-one Studentship proposals. All these proposals have been approved by the General Council.

Adhav, Ratnakar Shankar, B.Sc.	Poona, India
Amladi, Radhakrishna Pandurang, M.Sc.	Chelmsford, Essex
Atkins, Arthur Reginald	Aberfeldy, S. Africa
Bengali, Madhusudan Ramchandra	Bombay, India
Bharadwaj, Vidyadhar Laxmam, M.Sc.	Bombay, India
Bhasin, Bimal Kumar	Bombay, India
Bhasin, Charan Jeet, M.Sc.	Delhi, India
Cannon, Ralph Iver	Colombo, Ceylon
Desai, Priyavadan Ratilal	Bombay, India
Deswal, Suraj Bhan	Delhi, India
Dewan, Lakhpat Raj	Bombay, India
Dhiman, D. R., B.A.	Dharmsala, India
Divecha, Gautamraj Amritlal	Bombay, India
Engledew, John Edward, B.Sc.	Edgware, Middx.
Eradi, K. Unni	Singapore
Fear, Peter William	Gravesend, Kent
Gandhi, Jag Mohan, B.A.	Simla, India

George, Kurudamannil Abraham, B.Sc.	Bombay, India
Gopalakrishnan, E. S., B.Sc.	Madras, India
Gopalakrishnamurthy, P.	Madras, India
Gurbachan Singh Salhdev	Simla, India
Hume, Cyril Robert	Blyth, Northumberland
Hussey, John Robert	New Malden, Surrey
Jayaseetha, Miss N. S., B.Sc.	Bangalore, India
Joshi, Prabhakar Shanker	Jabalpur. India
Keon, Ralph Edmund Gaston	Ilminster, Som.
Kesavarao, Karipineni	Gudlavallernu, India
Khandakar, Syed Amzad Ali	Bogra, Pakistan
Kotchah, Ramnath Anantakrishna S., B.Sc.	Bombay, India
Kulkarni, Vithal Pralhadrao, B.Sc.	Bombay, India

continued on previous page

COLD PRESSURE WELDING

by

A. B. Sowter*

The recently developed method for welding metals at room temperature, known as Cold Pressure Welding, has found a vast number of applications owing to its simplicity, reliability and economy. Before describing any of these applications, it is necessary to outline the basic principles of the technique and to indicate its scope.

The process consists simply in pressing together the two pieces of material to be welded, without the application of heat or electricity. The two most critical factors that ensure successful welding by this means are: the preparation of the two surfaces to be brought in contact, and the shape, depth and position of the indentation made, which in turn controls the actual pressure applied.

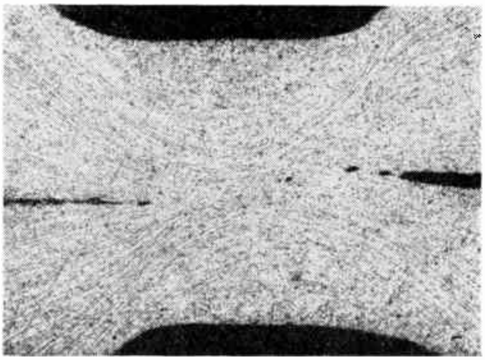

Fig. 1.—Microphotograph of a Cold Pressure Weld (Magnification : X 75).

A microphotograph of a successful cold pressure weld (Fig. 1) shows that it is effected by the flow of the metal from both work-pieces in the zone where pressure is applied. To enable this flow to take place, there must be intimate molecular contact between the actual metal of the two pieces, which means that any impurities on their surfaces must first be removed. It has been found that chemical cleaning processes are unsatisfactory for removing films of oxide or grease, since they inevitably leave a film of solvent on the metal surface. A purely mechanical scratch-brushing technique has finally been adopted, and a surface prepared in this way (Fig. 2) is clean and free from burrs and therefore satisfactory for Cold Pressure Welding.

Fig. 2.—Microphotograph of surface prepared by scratch-brushing (Magnification : X 50).

For each material, there is a critical flow of metal necessary at the cleaned mating surfaces to obtain a weld. Less than the critical flow will not produce a weld, while a greater flow than the critical value will always give a weld, but may weaken the mechanical strength of the final product unnecessarily. By a proper layout of the welding indentations in relation to the stress, it is generally possible to arrange the joint without sacrificing any tensile strength.

It is perhaps surprising that the rate of application of the pressure does not affect the strength or the quality of the weld. In fact, good welds can be made with tools giving either a slow squeeze or an impact.

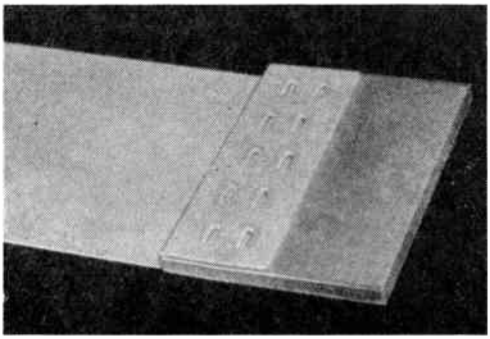

Fig. 3.—Cold Pressure Weld between two pieces of aluminium of differing thickness.

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* Research Laboratories of The General Electric Co., Ltd., Wembley, England.

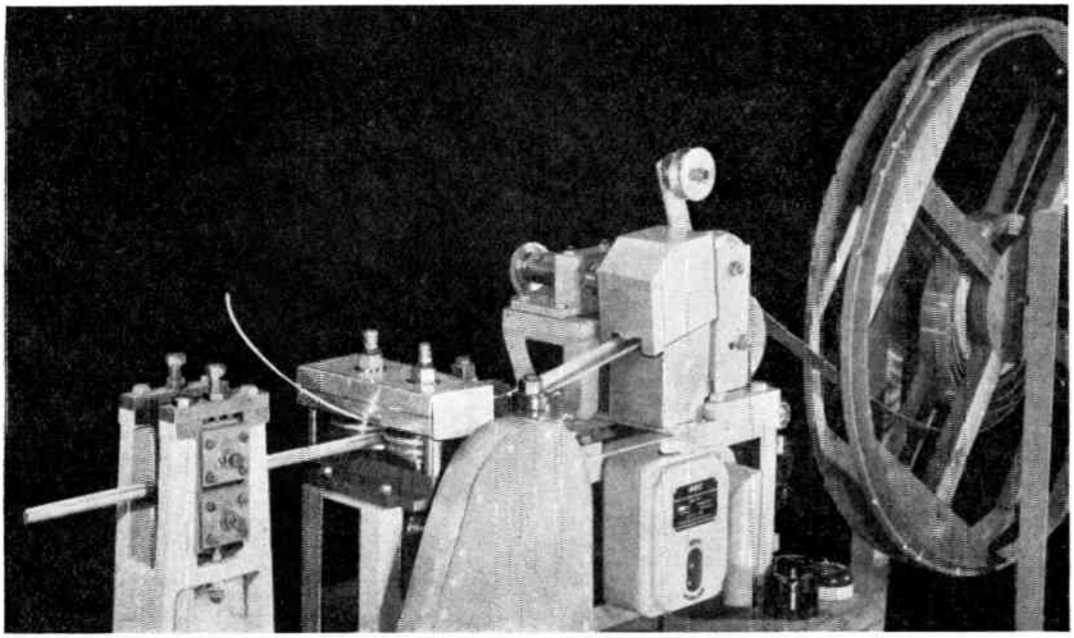

Fig. 4.—Experimental machine for making aluminium-sheathed cable by Cold Pressure Welding.

Cold pressure welding is remarkably versatile in that it can be achieved using specially designed hand tools for impact welding, centre-punches, a hammer and anvil, or the more conventional mechanical and hydraulic presses.

The materials that have so far been most successfully cold pressure welded are the non-ferrous metals, particularly aluminium and its alloys. There are indications, however, that the technique may also be useful for welding ferrous metals. Two different metals may be joined by the process, which may also be used to weld pieces of different thicknesses. This latter point is illustrated in Fig. 3, which shows two pieces of aluminium, whose thicknesses are in the ratio of 6·25 to 1, welded together. Satisfactory welds can also be obtained using certain dissimilar metals, e.g. aluminium and copper, differing in thickness up to a ratio of 20 to 1.

The optimum geometrical design of the dies used for applying the pressure to the work-pieces must be developed specifically for each application. All those devised can, however, be regarded as variations of four basic die shapes : the small rectangular spot weld, the straight weld, the ring weld, and the continuous seam weld. The last-named type of cold pressure weld is ideal for making tubes or for the manufacture of aluminium-sheathed cable. As seen in Fig. 4, aluminium strip is used as the starting material and the forming, welding and trimming operations can all be carried out on the one machine.

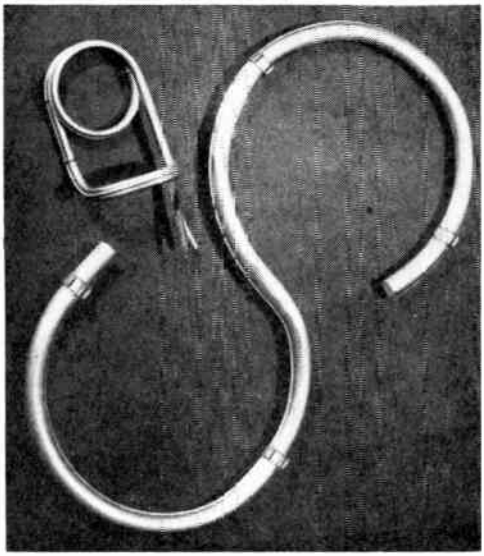

Fig. 5.—Aluminium-sheathed cable.

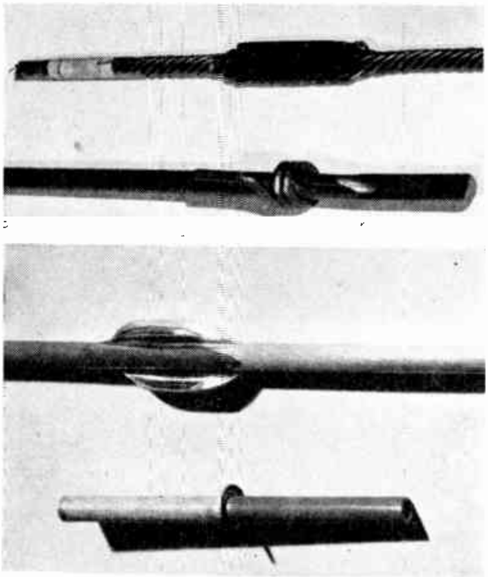

Fig. 6.—Wire joints made by Cold Pressure Welding.

Two varieties of the cable made in this way are shown in Fig. 5, and it can be seen that the sheathing is well able to withstand vigorous bending tests.

Cold Pressure Welding is particularly suitable for joining electrical conductors, whether wires or bus-bars. Experiments have shown that a well-proportioned joint in aluminium has a lower electrical resistance than an equivalent section of the unjointed material. Even when dissimilar metals are cold pressure welded, the resultant joints will have a low and consistent electrical resistance (Fig. 6).

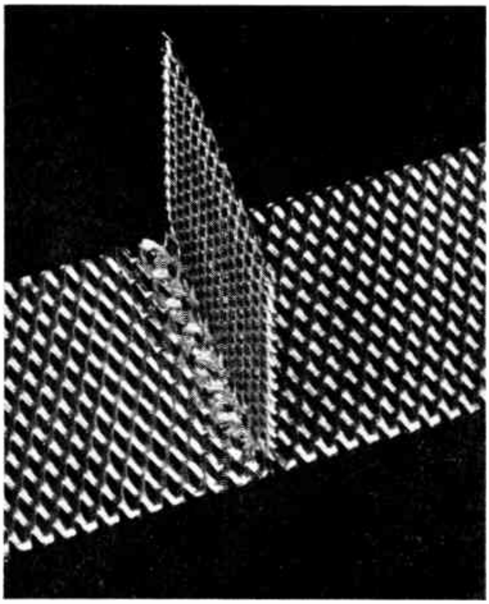

Fig. 7.—Example of joint made in expanded aluminium.

Since "expanded" metal may be cold pressure welded, this technique enables all types of screening devices to be fabricated quickly and easily. Fig. 7 shows two examples of joints made in expanded aluminium.

The fact that metal is displaced while the cold pressure weld is made enables this technique to be used in some instances for welding and forming in one operation. A good example is given by the silver contact shown in Fig. 8, which has been made by welding the silver blank on to a copper strip. As the silver is displaced by the welding face, it flows radially inwards until a cavity in the centre of the tool used is filled at the completion of the stamping stroke.

Fig. 8.—Contact point of silver welded on a copper strip.

Structures can be built up piece by piece and this is particularly useful for fabricating experimental structures.

It is thought that Cold Pressure Welding will, to a large extent, replace spot welding, brazing and riveting for attaching spouts, handles, knobs, etc., to aluminium utensils. The process should also play an increasingly important part in the hermetic sealing of containers for food, drugs and other substances or objects that need to be protected from damp during storage or transportation.

Cold Pressure Welding has already been used to make pressure capsules for maintaining oil pressure in electric cables and ionization chambers for use in X-ray equipment.

These applications of the Cold Pressure Welding process show that the technique can be used extensively in all branches of engineering. Further applications are constantly being developed, while research into the fundamentals of the process is also proceeding.