BBC

ENGINEERING DIVISION

MONOGRAPH

NUMBER 55: **DECEMBER 1964**

A Review of Television Standards Conversion

by

A. V. LORD, B.Sc.(Tech.), A.M.I.E.E.
and
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(Research Department, BBC Engineering Division)

BRITISH BROADCASTING CORPORATION

PRICE FIVE SHILLINGS

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FOREWORD

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CONTENTS

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No.	Title	Date
1.	*The Suppressed Frame System of Telerecording*	JUNE 1955
2.	*Absolute Measurements in Magnetic Recording*	SEPTEMBER 1955
3.	*The Visibility of Noise in Television*	OCTOBER 1955
4.	*The Design of a Ribbon Type Pressure-gradient Microphone for Broadcast Transmission*	DECEMBER 1955
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14.	*The BBC Riverside Television Studios: Some Aspects of Technical Planning and Equipment*	OCTOBER 1957
15.	*New Equipment and Methods for the Evaluation of the Performance of Lenses for Television*	DECEMBER 1957
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18.	*The BBC Colour Television Tests: An Appraisal of Results*	MAY 1958
19.	*A U.H.F. Television Link for Outside Broadcasts*	JUNE 1958
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22.	*The Engineering Facilities of the BBC Monitoring Service*	JANUARY 1959
23.	*The Crystal Palace Band I Television Transmitting Aerial*	FEBRUARY 1959
24.	*The Measurement of Random Noise in the presence of a Television Signal*	MARCH 1959
25.	*A Quality-checking Receiver for V.H.F. F.M. Sound Broadcasting*	JUNE 1959
26.	*Transistor Amplifiers for Sound Broadcasting*	AUGUST 1959
27.	*The Equipment of the BBC Television Film Studios at Ealing*	JANUARY 1960
28.	*Programme Switching, Control, and Monitoring in Sound Broadcasting*	FEBRUARY 1960
29.	*A Summary of the Present Position of Stereophonic Broadcasting*	APRIL 1960
30.	*Film Processing and After-processing Treatment of 16-mm Films*	MAY 1960
31.	*The Power Gain of Multi-tiered V.H.F. Transmitting Aerials*	JULY 1960
32.	*A New Survey of the BBC Experimental Colour Transmissions*	OCTOBER 1960
33.	*Sensitometric Control in Film Making*	DECEMBER 1960
34.	*A Mobile Laboratory for UHF and VHF Television Surveys*	FEBRUARY 1961
35.	*Tables of Horizontal Radiation Patterns of Dipoles Mounted on Cylinders*	FEBRUARY 1961
36.	*Some Aspects of Optical Lens Performance*	APRIL 1961
37.	*An Instrument for Measuring Television Signal-to-noise Ratio*	JUNE 1961
38.	*Operational Research on Microphone and Studio Techniques in Stereophony*	SEPTEMBER 1961
39.	*Twenty-five Years of BBC Television*	OCTOBER 1961
40.	*The Broadcasting of Music in Television*	FEBRUARY 1962
41.	*The Design of a Group of Plug-in Television Studio Amplifiers*	APRIL 1962
42.	*Apparatus for Television and Sound Relay Stations*	JULY 1962
43.	*Propagational Factors in Short-wave Broadcasting*	AUGUST 1962
44.	*A Band V Signal-frequency and a Correlation Detector for a VHF/UHF Field-strength Recording Receiver*	OCTOBER 1962
45.	*Vertical Resolution and Line Broadening*	DECEMBER 1962
46.	*The Application of Transistors to Sound Broadcasting*	FEBRUARY 1963
47.	*Vertical Aperture Correction using Continuously Variable Ultrasonic Delay Lines*	MAY 1963
48.	*The Development of BBC Internal Telecommunications*	MAY 1963
49.	*Apparatus for Measurement of Non-linear Distortion as a Continuous Function of Frequency*	JULY 1963
50.	*New Methods of Lens Testing and Measurement*	SEPTEMBER 1963
51.	*Radiophonics in the BBC*	NOVEMBER 1963
52.	*Stereophony: the effect of cross-talk between left and right channels*	MARCH 1964
53.	*Aerial distribution systems for receiving stations in the l.f., m.f., and h.f. bands*	JUNE 1964
54.	*An Analysis of Film Granularity in Television Reproduction*	AUGUST 1964

A REVIEW OF TELEVISION STANDARDS CONVERSION

SUMMARY

In this monograph the basic functions of a standards converter are considered and the essential processes are discussed in some detail. It is shown that those problems encountered when conversion involves a change in the number of lines per field are essentially similar to those posed by a change in the number of fields per second.

The established methods of standards conversion are surveyed in the light of these arguments. Almost all present-day converters rely on the 'image-transfer' method; the fundamentals of this process are described, and various techniques used for conversion involving a change of field frequency are discussed. Some limitations of present-day image-transfer converters are outlined, and possible improvements are considered.

Recently, other approaches to the problem of standards conversion have been investigated. An outline of these mentions the application of magnetic recording and the use of lumped networks as storage devices.

The design of future standards converters will naturally be dependent upon requirements. Mention is made of their present-day use in the Eurovision network and, in conjunction with video-tape recording and communication satellites, to facilitate programme exchanges between Europe and North America. The concluding discussion deals with the role of standards conversion in the future development of television networks; consideration is given to problems posed by dual-standard operation and the exchange of colour programmes with North America.

1. Introduction

Television standards conversion has been posed as an engineering problem ever since different television standards were adopted in various parts of the world and, to date, research and development have led to practical forms of converter which, in turn, have been used for programme exchanges between many countries. Most of the converters have employed the 'image-transfer' process in which the input signal is used to create, in the form of the original picture, a pattern of electrical charges upon a suitable storage surface, the charge pattern then being rescanned to form the converted output signal. In some possible future applications of standards conversion it may not be permissible to tolerate the degree of picture impairment often suffered at present and in this review it is intended to examine the fundamental requirements of the conversion process, to illustrate how these requirements have been met in some of the current and proposed forms of converter, and to indicate some directions in which improvements in performance may be obtained.

2. Fundamental Considerations

2.1 *The Basic Processes*

The basic problem of standards conversion consists of taking electrical signals representing the scanning of a scene according to one pattern (or raster) and converting them to other signals representing the same scene scanned according to a different pattern.

The problem may be described in terms of changing the form of the spectrum of the signal. Classical scanning theory[1] has shown that the spectrum of the signal corresponding to a certain still picture consists of the sum of a very large number of similar elementary spectra each describing the sampling, at line-scanning frequency, of brightness variations along a narrow vertical strip of the picture. The form of one elementary spectrum, for line- and field-scanning frequencies f_H and f_V respectively, is shown in Fig. 1(a); for the sake of simplicity, it has been assumed that the scanning corresponds to a sequential rather than to an interlaced raster.

In terms of any one narrow strip taken in the field direction of the still picture, changing the number of lines per field involves two fundamental processes. In the first, all traces of the input line frequency are removed from the elementary spectrum by filtering out the higher-frequency components having frequencies exceeding $f_H/2$ and, in the

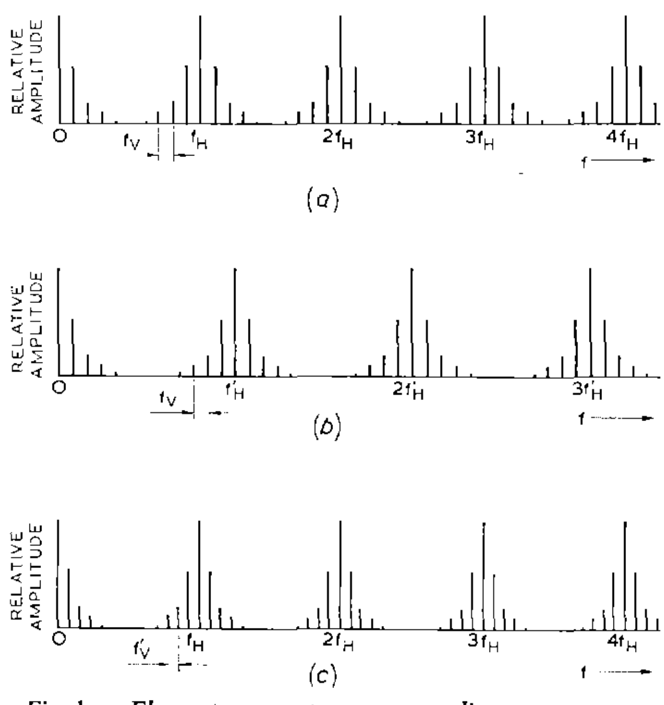


Fig. 1 — Elementary spectra corresponding to one narrow vertical strip of a still picture scanned:

(a) At a line frequency f_H and a field frequency f_V
(b) At a line frequency f'_H and a field frequency f_V
(c) At a line frequency f_H and a field frequency f'_V

second, the resulting low-frequency or baseband components (representing vertical detail) are applied to an elementary spectrum representing sampling at the output line frequency; they form sideband groups around each component of the sampling spectrum. Fig. 1(b) shows the spectrum corresponding to the same narrow vertical strip of picture when the field frequency is maintained at f_V but the line frequency is raised to f'_H. Changing the field frequency, without changing the line frequency, consists of multiplying the frequencies of the low-frequency components remaining after the removal of input line frequency, its harmonics, and their sidebands (i.e. the baseband frequencies) by the ratio of the output field frequency to the input field frequency and then re-applying these modified baseband components to an elementary spectrum representing sampling at line frequency. Fig. 1(c) shows the spectrum resulting from changing the field frequency to f'_V whilst maintaining the line frequency at f_H.

It will be appreciated that the processes of changing the line and field frequencies show essential similarities. In the first process the array of line-frequency harmonics is 're-scaled' in terms of the new line frequency. In the second, the set of sidebands associated with each of the harmonics of line frequency (including those of zero and first order) is re-scaled in terms of the required field frequency.

The spectrum of the complete output signal representing the whole picture consists of the resultant of a large number of similar elementary spectra, each derived by the above-mentioned processes.

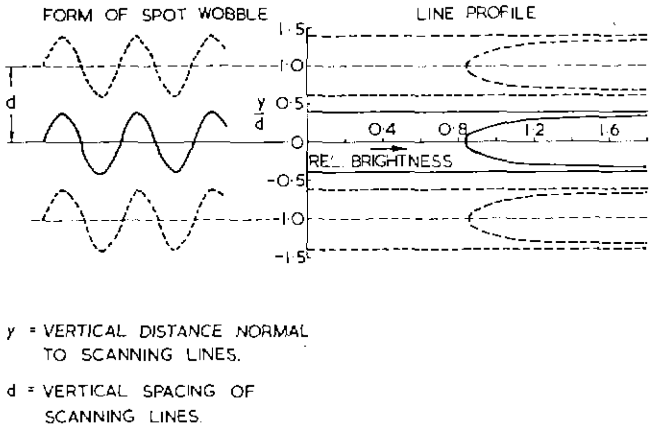
The fundamental processes must, in general, be carried out in any form of standards converter. However, in order to outline their operation in more detail, each will be discussed in terms of its contribution to the operation of the well-known image-transfer converter consisting of a suitable combination of a cathode-ray tube (c.r.t.) and a camera tube. Most of the arguments used would also apply to an image-transfer converter employing a picture-storage tube.

2.2 *Changing the Number of Lines per Field*

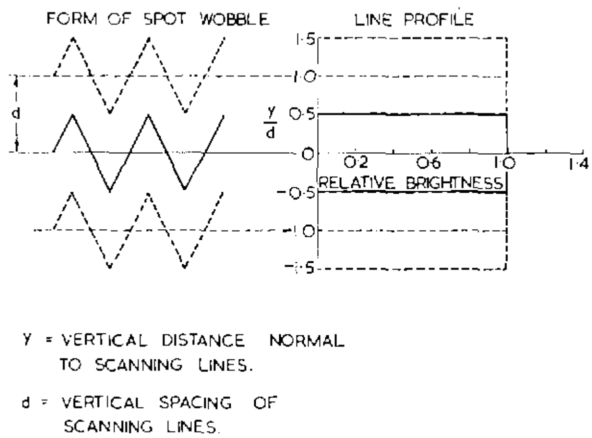
The form of the input spectrum shown in Fig. 1(a) indicates that in order to achieve the required result, the signal must, in effect, be passed through a filter having a suitable response as a function of vertical spatial frequency.[2] In the image-transfer converter the required filtering action is obtained by line broadening; this consists of applying spot wobble to the display, thus suppressing the input line structure. Fig. 2 shows various normalized line profiles, and Fig. 3 shows the corresponding normalized responses as functions of vertical spatial frequency. The c.r.t. scanning spot has, in all cases, been assumed to be infinitely small and horizontal motion has been neglected. For a spot of finite vertical aperture the effective apertures obtained would be the result of convolving those shown in Fig. 2 with the aperture of the spot, and the responses shown in Fig. 3 would be modified by multiplying them by the transforms of the spot apertures.

From Fig. 3 it will be seen that the commonly used sinusoidal form of spot wobble, indicated as (a), provides a response as a function of vertical spatial frequency which, while eliminating the input line-scan frequency, is not entirely free from its harmonics. Further, the shape of the response below half the frequency of the input line scan indicates that the relative amplitudes of the wanted zero-order or baseband sidebands are modified.

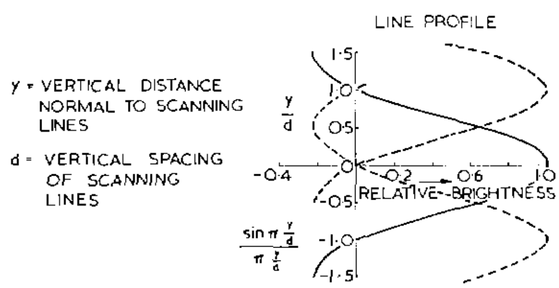
In the case of triangular spot wobble, indicated as (b), the input line-scan frequency and all its harmonics are



(a) Line profile resulting from sinusoidal spot wobble (infinitely small scanning spot)



(b) Line profile resulting from triangular spot wobble (infinitely small scanning spot)



(c) Line profile not realizable by spot wobble

Fig. 2

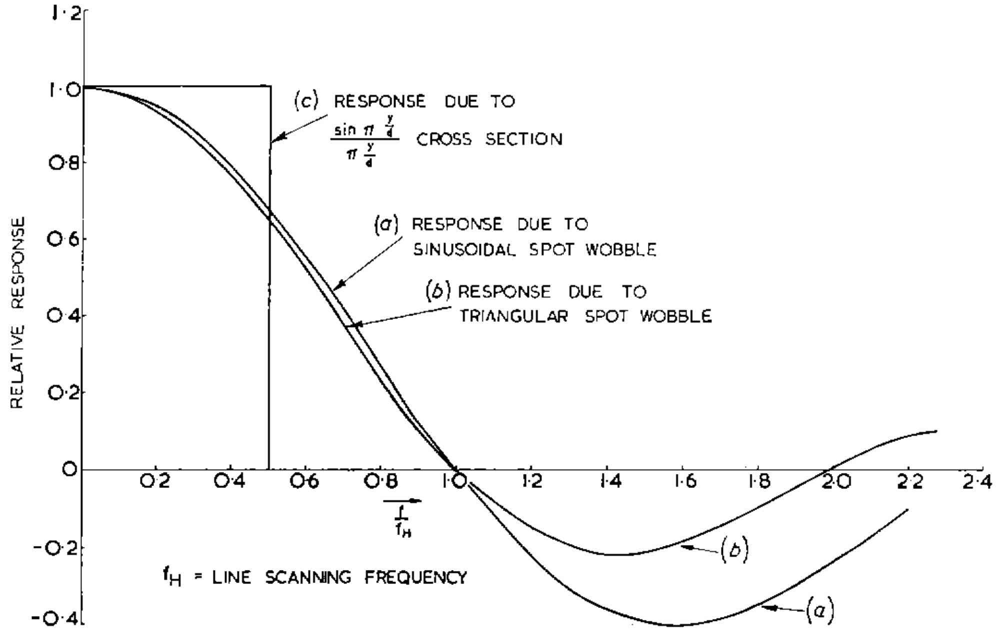


Fig. 3 — Responses as functions of vertical spatial frequency corresponding to the line profiles shown in Fig. 2

eliminated; the outer zero-order sidebands, however, suffer very slightly more attenuation than in the case of sinusoidal spot wobble.

The form of response, as a function of vertical spatial frequency, indicated as (c), shows ideal properties in eliminating all components above half the frequency of the input line scan and passing all components below this frequency without attenuation. Although this response is not exactly realizable, a method has been devised in which an approximation to it may be used in a standards converter; this will be discussed later.

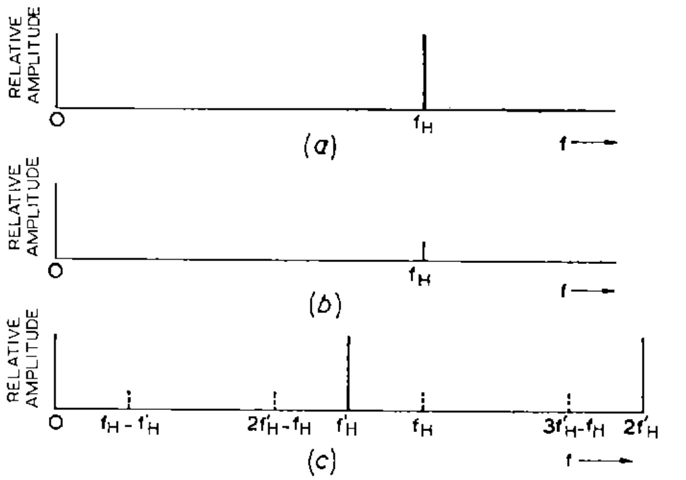


Fig. 4 — The result of failing to remove the input line-scan structure

The result of failing to remove the input line-scan structure is illustrated in Fig. 4. An elementary spectrum of the input is shown as spectrum (a); for convenience, components representing variations in brightness along the vertical strip of picture have been omitted. The incomplete removal of input line-scan structure is shown in spectrum (b) where the component of input line-scan frequency, f_H, is not zero. Spectrum (c) shows the result of reforming an elementary spectrum according to the required new line structure having a fundamental frequency, f_H; this is equivalent to convolving (b) with an elementary spectrum that represents the scanning, according to the output line-scan standard, of a vertical strip of picture of constant brightness. Spectrum (c) contains unwanted components at $(f_H - f'_H)$, $(2f'_H - f_H)$, f_H, $(3f'_H - f_H)$, etc.; the spectrum is thus identical with that produced by scanning a pattern, corresponding to a frequency $(f_H - f'_H)$, at a line frequency f'_H. This is the well-known 'line-beating' effect that is experienced in image-transfer conversion when employing an incorrect amplitude of spot wobble.

An effect that may occur when reducing the number of lines per field is shown in Fig. 5. If an input elementary spectrum (a) shows components of vertical detail extending beyond half the reduced line-scan frequency $f'_H/2$ (assuming no change of field frequency), filtering out the components from d.c. to $f_H/2$, using the characteristic (b), results in a set of zero-order sidebands, as shown in (c), which, when modulated upon the spectrum of the required output line-scan, having a fundamental frequency f'_H, produce the overlapping of sidebands extending outwards from each output line-scan spectrum component, including d.c., as shown in (d). In order to show the overlap more

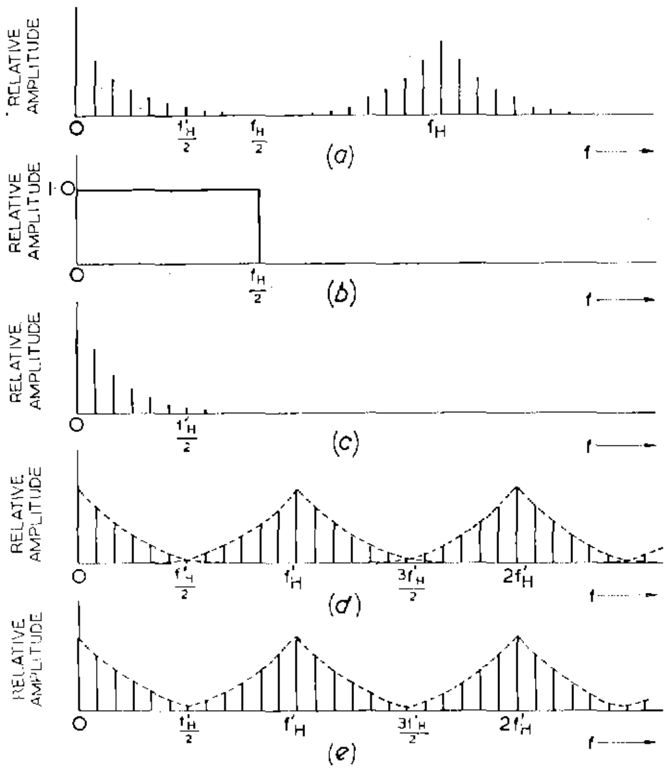


Fig. 5 — The effect of fine vertical detail in the input picture

clearly, the envelope of each set of sidebands is indicated by dotted lines. Such overlap of the sidebands produces moiré patterns in areas where the vertical detail of the input picture is finer than that which the output line-scan structure can carry. In such circumstances it would appear preferable to use a filter characteristic cutting off at $f'_H/2$; for the same input spectrum (a) the output spectrum (e) would result and no overlapping of sideband components could occur. Such an input filter would be very difficult to achieve in practice; however, provided that the filter has a small enough response, as a function of vertical spatial frequency, at the input line-scan frequency f_H, the output line frequency f'_H, and all harmonics of these frequencies, no serious moiré patterns are likely to result.*

2.2.1 *Interlacing*

The foregoing discussion concerning the properties of line structure has, as stated previously, assumed sequential scanning. However, interlacing is a usual feature of scanning in television and, in terms of the arguments used, may be regarded as a process in which each vertical array of points sampling the original scene (separated by the spacing of adjacent lines of the same field) is shifted alternately up and down by half this spacing at the end of each field. Such shifting of the sampling array results in modifications to each elementary spectrum. However, present forms of standards converter operate on a field-by-field basis; in the image-transfer converter, this results from the fact that the camera-tube scanning beam substantially discharges the whole target area during each output field. As a result, effects such as line beating etc. produce unwanted patterns on both the even and odd fields of the displayed output picture. When the output picture is displayed, these unwanted patterns may flicker at picture frequency or may appear fixed; their appearance is determined by the relationship between the two line-scanning standards.[2]

2.3 *Changing the Number of Fields per Second*

It has already been pointed out that the process of changing the field frequency consists of 're-scaling' those components of the input spectrum that accompany the d.c. or baseband component and appear as sidebands associated with every line-scan harmonic. The d.c. and low-frequency components of a typical spectrum are shown in Fig. 6(a). This limited spectrum is itself derived from a large number of other spectra each of which describes the brightness of a certain point in the picture when sampled once every field (ignoring interlacing). Thus in Fig. 6(b)

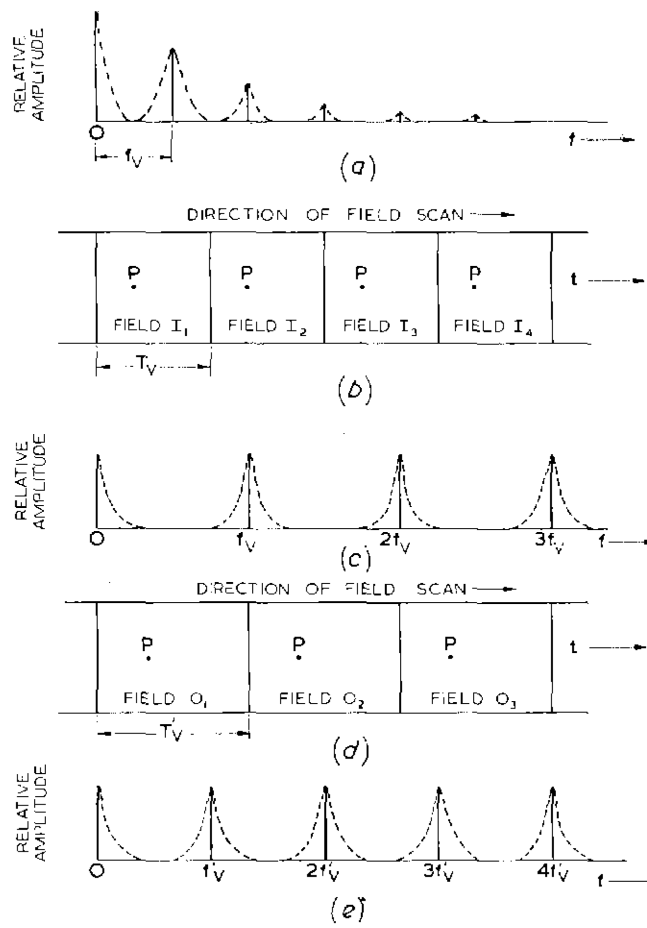


Fig. 6 — Diagrams illustrating a change in the number of fields per second

* This was pointed out by G. D. Monteath.

the point P is sampled once per input field, the field frequency being f_v and the field period T_v ($=1/f_v$); the diagram shows fields I_1 to I_4 inclusive. The corresponding spectrum is shown in Fig. 6(c); any sidebands accompanying the d.c. component and field-frequency harmonics are the result of brightness variations of P as a function of time. Fig. 6(d) shows the sampling of the point P once during each of the output fields O_1, O_2, and O_3; the field frequency is f'_v. For the purposes of illustration it has been assumed that the ratio of f'_v to f_v is 3 to 4; hence the period occupied by four input fields equals the period occupied by three output fields.

It will be apparent that the problem of changing field frequency is, in essence, one of changing spectra and that there is a considerable degree of similarity between this problem and that of changing the number of lines per field, using the concept of the elementary spectrum. Thus, by analogy, the process outlined in Fig. 7 suggests itself. The brightness of the point P, in Fig. 6(b), is indicated as a row of samples at input field-period intervals T_v, as shown in Fig. 7(a); the corresponding spectrum is shown in Fig. 7(b). The first part of the process consists of 'filtering' the samples and may be defined as forming, from each sample, a pulse of duration T_v whose magnitude is determined by that of the sample, such a pulse is shown in Fig. 7(c). The spectrum corresponding to the pulse is shown in Fig. 7(d). The result of this first operation is shown, as a time function, in Fig. 7(e); the associated spectrum, Fig. 7(f), shows that all traces of the input field frequency have been substantially removed. The process is completed by resampling the time function of Fig. 7(e) at output field-frequency intervals T'_v, as shown in Fig. 7(g); the corresponding spectrum shown in Fig. 7(h) has the required form. This process is, in essence, carried out in field-frequency converters employing helical tape recorders; these converters will be briefly described later.

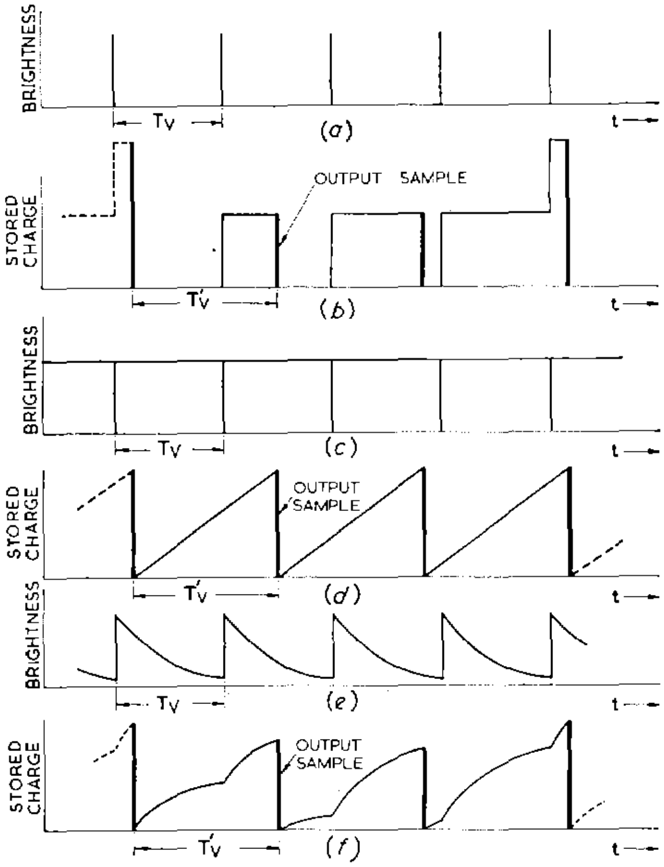


Fig. 8 — The process of changing field frequency using image-transfer conversion

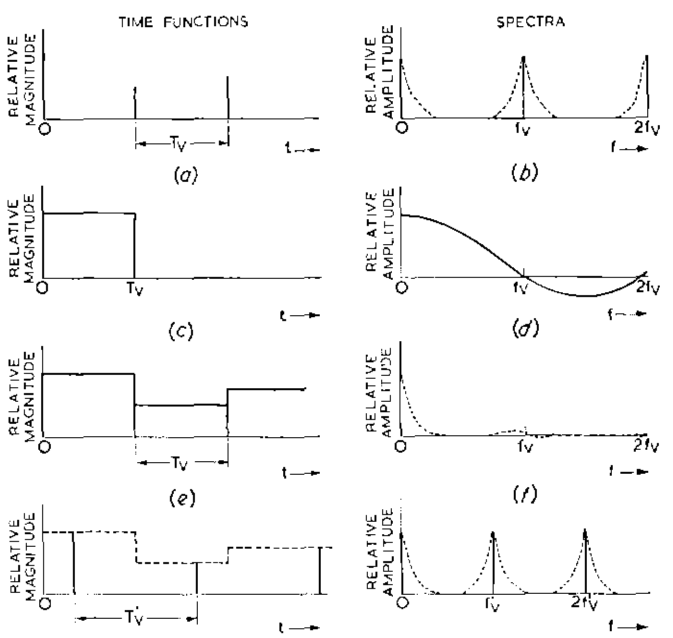


Fig. 7 — Time functions and spectra describing a method for changing the number of fields per second

In the image-transfer converter, however, the process of changing the field frequency is somewhat different, since charge accumulates continuously on the storage surface of the camera tube throughout each output field period. At any fixed point on the storage surface this may be regarded as a process of integration that commences immediately after the point has been discharged by the camera-tube or storage-tube scanning beam and continues until the same point is scanned again. The effect of integration is shown in Fig. 8, which illustrates the process and indicates some problems associated with changing the field frequency by means of an image-transfer converter; for convenience it has been assumed that the brightness of the picture point, in the original scene, is constant. As before, the ratio of the output and input field frequencies is 3 to 4. Fig. 8(a) shows a series of samples, taken every input field period, of the brightness of a certain picture point as displayed by a converter c.r.t. having negligible 'afterglow'. Fig. 8(b) shows the consequent formation of charge at the storage surface of the camera tube; each brightness sample results in a certain charge that remains until discharged by the

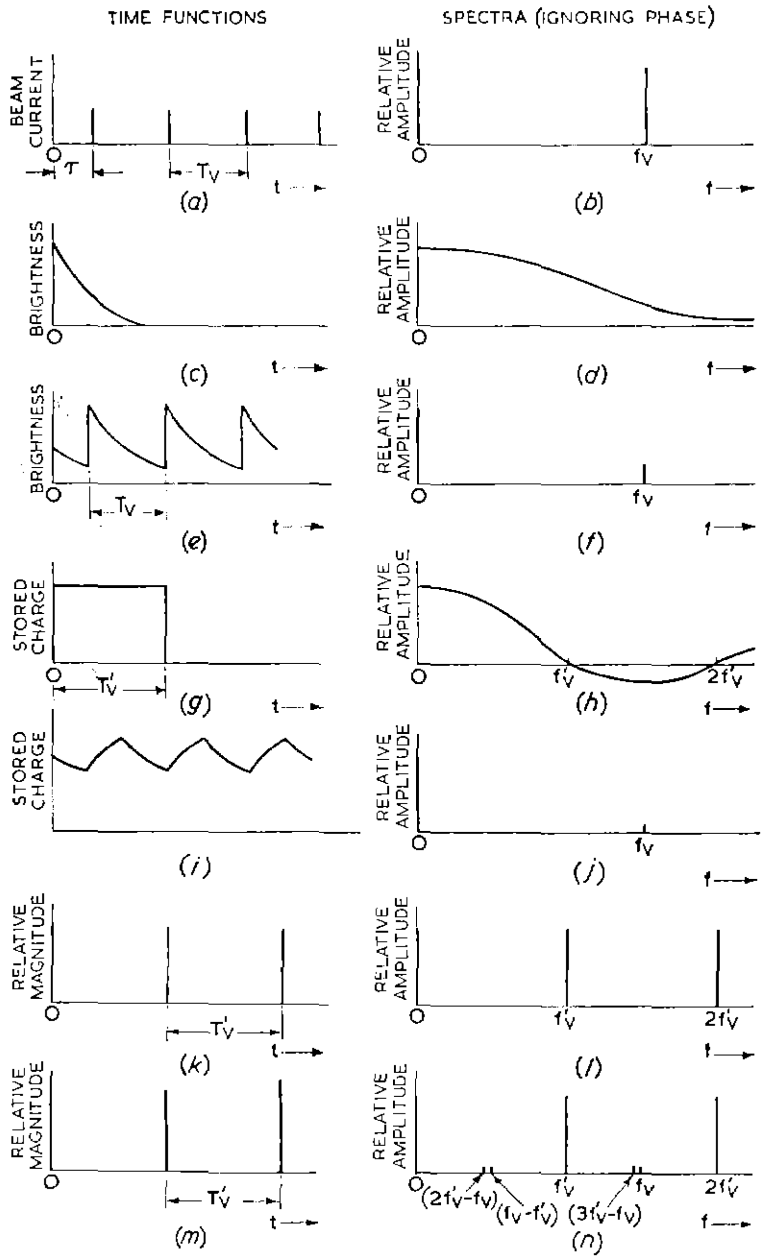


Fig. 9 — Time functions and spectra outlining a change of field frequency using image-transfer conversion

scanning beam. It will be seen that two out of four equal input samples result in equal charges that are, in turn, discharged to give two equal output samples. However, two of the input samples occur between successive output samples and result in charges that add to give a third output sample of double magnitude.

The effect of an afterglow that is constant for one input field period and then ceases is illustrated in Figs. 8(c) and 8(d). Here the equal input samples result in a constant excitation of the storage surface. Equal charges accumulate linearly during each output field and discharge gives rise to equal output samples. So far this form of afterglow has proved unrealizable in terms of the c.r.t./camera-tube combination. However, a suitable storage tube might be developed in which the stored charge pattern is erased when writing in new information and, in addition, is unaffected by the reading beam.

At present the problem of field-frequency change in image-transfer conversion is dealt with by using a conventional form of phosphor afterglow extending over a substantial fraction of the input field period; the greater the difference between the input and output field periods, the greater the phosphor afterglow required.[3] Figs. 8(e) and 8(f) illustrate the use of input samples with conventional afterglow and the build-up of charges during each output field which, in turn, results in output samples having unequal amplitudes. Such amplitude modulation of the output samples (or 'flicker' modulation) occurring at a frequency equal to the difference between the input and output field frequencies, must be dealt with by other means.

A more detailed outline* of the process of changing field frequency by means of an image-transfer converter is illustrated in Fig. 9. The time functions represent signals describing the brightness of one picture point; it has been assumed, for convenience, that a still picture is being televised. Fig. 9(a) represents the input to the display c.r.t. and shows repeated impulses spaced by the input field period T_v; Fig. 9(b) shows the corresponding spectrum, which consists of repeated spectral lines, in this case spaced by f_v. The brightness of the c.r.t. phosphor as a function of time for impulsive excitation is shown in Fig. 9(c). Convolving this function with that shown in Fig. 9(a) results in the brightness of the displayed picture point shown in Fig. 9(e); multiplication of the spectra in Figs. 9(b) and 9(d) gives the corresponding spectrum, Fig. 9(f).

Fig. 9(g) represents the storage characteristic of an ideal camera tube. It describes circumstances where charge, due to an impulse of light, is deposited on the target of the tube at the time t equal to zero, and is completely removed after one output field period; Fig. 9(h) describes the corresponding spectrum.

Multiplying the spectra of Figs. 9(f) and 9(h) [which is equivalent to convolving the function shown in Fig. 9(e) with that shown in Fig. 9(g) to obtain that shown in Fig. 9(i)] results in the spectrum of Fig. 9(j). The time function, Fig. 9(i), that corresponds with Fig. 9(j) must now be sampled, at the output field rate f'_v, by a train of impulses, Fig. 9(k); this is equivalent to convolving the spectrum of Fig. 9(j) with the spectrum representing the train of impulses, Fig. 9(l) (spectral lines spaced by f'_v). The resulting spectrum, Fig. 9(n), shows beat-frequency components that represent the flicker modulation referred to earlier. The corresponding time function, Fig. 9(m), shows the familiar amplitude-modulated samples occurring at output field rate. Using the method outlined above, the envelope of the flicker modulation may be computed by varying the relative timing of the display and camera scans (i.e. by varying τ, Fig. 9(a)).

The process and some problems of field-frequency change have been outlined in terms of a field-frequency reduction. In the case of a field-frequency increase the absence of afterglow, as in Figs. 8(a) and 8(b), results in one output sample per 'beat cycle' having zero amplitude. As before, rectangular afterglow provides uniform output samples, and conventional afterglow gives rise to output samples that are again flicker-modulated at beat frequency.

It is, perhaps, of interest to note that the problem of flicker modulation in conversion involving a change of field frequency is somewhat analogous to the problem of line beating when changing the number of lines per field; both arise as a result of failing to remove all traces of the input repetition-frequency from the output.

* Based on unpublished work by G. D. Monteath.

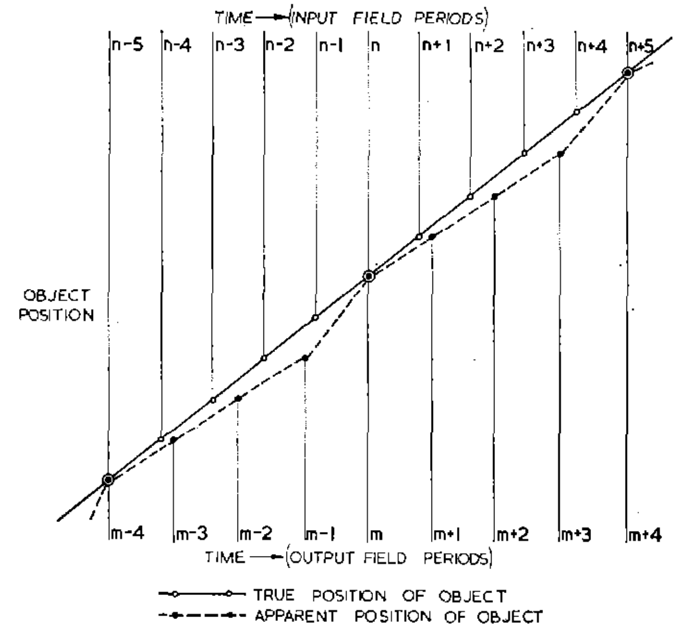


Fig. 10(a) — Distortion of the portrayal of a moving picture point (rectangular afterglow)

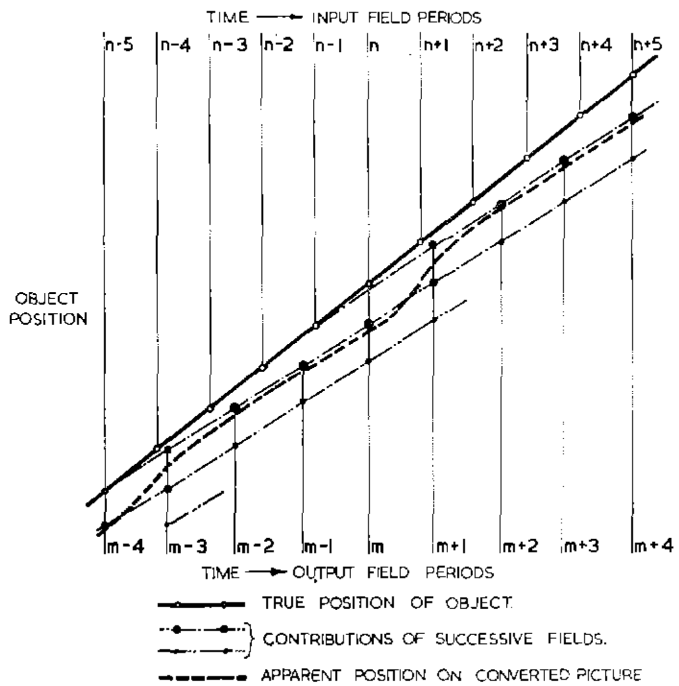


Fig. 10(b) — Distortion of the portrayal of a moving picture point (conventional afterglow)

Conversion involving a change of field frequency may also introduce distortion of the portrayal of movement. Figs. 10(a) and 10(b) illustrate the movement distortion introduced by a field-frequency reduction in the ratio of 5 to 4. Fig. 10(a) refers to conversion of the form referred to in Figs. 7, 8(c), and 8(d); and applies to converters based upon helical tape recorders. It will be seen that the apparent movement of a point, say across the picture, is discontinuous owing to the fact that, in one beat cycle, only four out of every five equally-spaced original point positions are reproduced; the beat cycle terminates with a jump to the correct position at the beginning of the next beat cycle. Fig. 10(b) illustrates the movement distortion resulting from conversion involving a change of field frequency in which the conventional form of phosphor afterglow is employed. Each apparent position of the point is the resultant of several displayed points having different brightness. This is due to the presence of weak images derived from previous input fields, and results in some blurring of the moving point which masks, to some extent, the discontinuity of movement.

Such movement distortion is analogous to the distortion of vertical detail which may be introduced when converting to a lower number of lines per field (without changing field frequency) when a camera beam having a very small diameter is used. The camera scan then completely misses certain sections of input scanning lines and the portrayal of vertical detail is distorted; in the converted picture the distortion appears as discontinuities in sloping edges.

3. Present-day Standards Converters

There are between fifteen and twenty operational standards conversion installations[4,5,6,7,8,9] in the world now. Most of these are in Europe and their greatest use is in Eurovision programme exchanges. The use of standards converters is essential to the Eurovision network, in which three different line-scanning standards are employed. The field frequencies of the European television systems and the frequencies of the national electricity supplies are all nominally 50 c/s, and in the majority of cases, each television system is operated with the field frequency identical to that of the local mains. Hour-to-hour differences in national power-supply frequencies, however, make it desirable that Eurovision converters handle field-frequency differences of up to 0·5 c/s. For this reason almost all the converters employ c.r.t.s with phosphor-afterglow decay time-constants of 5 to 10 msec. Such decay periods ensure that converted signals are substantially free of amplitude variations when small field-frequency differences exist.

Almost all the established types of camera tube are, or have been, used in the converters, including vidicons, image iconoscopes, image orthicons, and C.P.S. Emitrons. In some of these camera tubes the output signal current shares a common path with the photo-current, resulting in the addition of unconverted video signal to the output. This is a further reason for using phosphors with decay time-constants of several milliseconds.[3]

In recent years the exchange of topical television material between Europe and North America has been speeded up by the use of magnetic recordings carried by jet aircraft, together with mobile video-tape machines at the airports; on occasions, signals are relayed by means of active communications satellites. The necessary standards conversion involves a field-frequency difference of approximately 10 c/s. In order to reduce flicker modulation to a tolerable level solely by using a suitable cathode-ray tube phosphor, such a large difference in the input and output field frequencies would demand an afterglow time-constant of about 60 ms; the resulting portrayal of moving objects would be quite unacceptable. Consequently, it has become the practice to utilize an afterglow long enough to reduce the flicker modulation* of the output signal to some 10 to 20 per cent[10] and to remove the remainder by a correcting modulation of either the input or output video signal amplitude. Fig. 11 illustrates two ways in which correcting modulation may be applied.

Modulation of the video signal before the display[8] can offer the advantage of providing the camera with a constant exposure during each outgoing field period, and this results in a flicker-modulation performance which is unaffected by non-linear relationships in the signal-producing mechanism of the camera tube. However, this is possible only if there are one or more incoming fields during each outgoing field. When the output field frequency is higher than that at the input there is one occasion during each beat period when the camera target is scanned twice between successive input fields. The one exposure, available at the time the c.r.t. is scanned, must then be a compromise between the requirements of the two outgoing fields that will precede the next scanning of the display. This, naturally, prohibits the complete elimination of conversion flicker.

Correction of flicker modulation by operating upon the camera-tube output signal can take one of two forms. In the first,[3] a synthesized correcting signal, at beat frequency, modulates the output signal from the camera in a manner that opposes the flicker modulation; the correcting signal is derived from input and output field pulses and has a sawtooth-like waveform. In the second form,[11,9,8] a constant-amplitude reference signal, usually consisting of a narrow pulse, is added to each line of the c.r.t. input and is displayed as a narrow stripe alongside the displayed incoming picture. The stripe is included within the scanned area of the camera-tube storage surface so that the camera-tube output contains narrow pulses, due to the stripe, which suffer similar flicker modulation to that influencing the signal amplitude. Provided that the camera tube used has suitable characteristics, the amplitude of the output 'stripe' pulses may be sampled in order to derive a correction signal that is applied to a variable-gain amplifier preceding the pulse sampler; this constitutes an a.g.c. feedback loop.

4. Possible Improvements in Standards Converters

The impairment of picture quality introduced by standards conversion could be reduced by developments in instrumentation. The image-transfer converter could benefit very

* Where flicker modulation is defined as

$$\frac{\text{max. signal} - \text{min. signal}}{\text{max. signal} + \text{min. signal}} \times 100\%$$

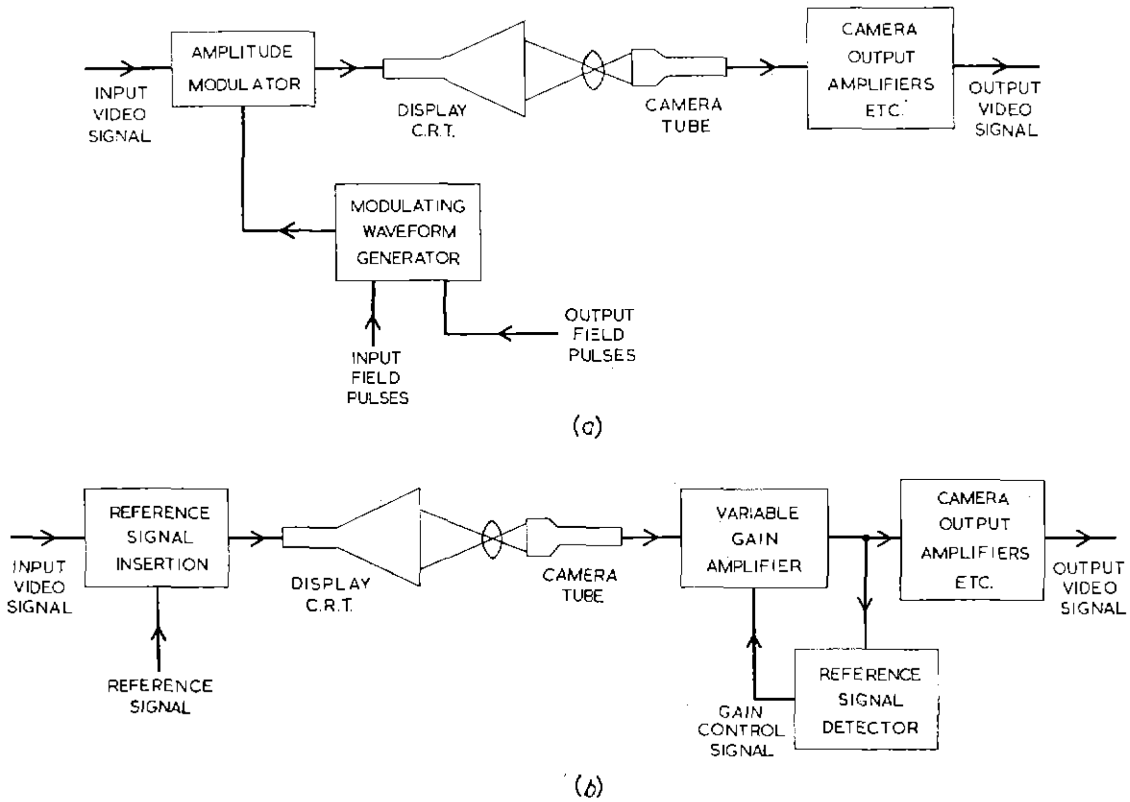


Fig. 11 — Two methods used for conversion between 50 c/s and 60 c/s standards

significantly from further improvements in the c.r.t. and the camera tube. Very-fine-grain phosphor screens and flare-reducing neutral-grey face plates are only two measures that would reduce picture impairment at the display. In the camera tube, full discharge of the storage surface by the scanning beam could improve the portrayal of movement.

Some of the arguments already outlined in connection with changing the number of lines per field suggest two further possible means for improving the performance of converters. The first of these consists of the 'vertical aperture corrector' described by Gibson and Schroeder.[12,13]

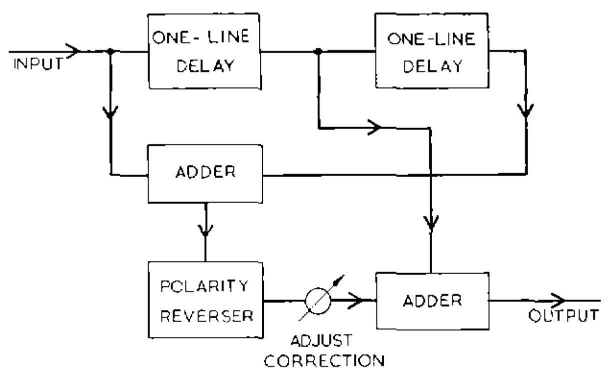


Fig. 12(a) — A vertical aperture corrector

In this device, outlined in Fig. 12(a), the input signal is fed to two one-line delay devices in cascade. The output consists of a positive principal component obtained from the junction of the two delay devices, together with two equal negative contributions, one obtained from the corrector input and the other from the output of the second delay device. The effective aperture (the time-function response to a very short pulse) produced by the corrector is shown in Fig. 12(b) and its equivalent response as a function of vertical spatial frequency is shown in Fig. 12(c).

Assuming that the output from the corrector forms the input to the standards converter, the improvement in converter performance may be seen from Figs. 12(d) to 12(h). Fig. 12(d) shows a typical line profile used in an image-transfer converter; it is that resulting from using spot wobble with a typical c.r.t. scanning-spot profile. The corresponding response is shown in Fig. 12(e). Convolving the effective vertical aperture of the corrector with the line profile of Fig. 12(d) is illustrated in Fig. 12(f), and the resulting line profile is shown in Fig. 12(g). The response, as a function of vertical spatial frequency, corresponding to Fig. 12(g) is illustrated in Fig. 12(h) and it will be seen that the response has been improved between d.c. and $f_H/2$ without affecting the response at f_H.

The second possible improvement could be achieved by means of 'conversion in pictures'. One embodiment[14] of this, as applied to image-transfer conversion, is shown in Fig. 13. In the arrangement, the converter employs two

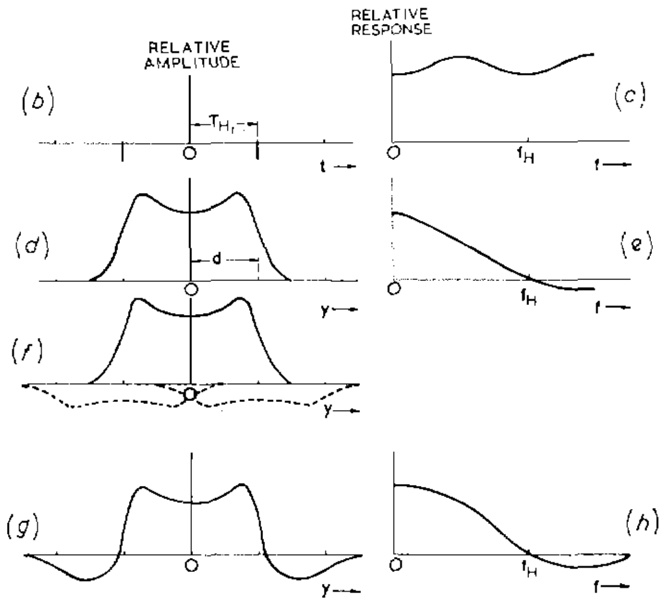


Fig. 12(*b*)–(*h*) — *Time functions and associated responses, as functions of vertical spatial frequency, illustrating vertical aperture correction*

c.r.t.s displaying images that are 'registered' at the sensitive surface of the camera tube. The first c.r.t. is fed and synchronized directly from the input signal; the second c.r.t. is driven and synchronized by input signals that have been subject to a delay of approximately one field period. The images of the two c.r.t. scanning spots at the camera trace out vertically adjacent points on input picture lines and the composite image consists of both even and odd input fields presented simultaneously; when even input fields are displayed by c.r.t. No. 1, the corresponding odd fields are displayed by c.r.t. No. 2, and vice versa. Spot wobble applied to both tubes need have only half the amplitude used in a conventional image-transfer converter. A further method[14] of obtaining conversion in pictures, which does not involve the use of two registered c.r.t., employs synchronous spot wobble. A single c.r.t. is used and the amplitude of the spot wobble is adjusted to correspond to half the spacing between adjacent lines of a picture. When the spot-wobble waveform causes peak spot deflection in one direction, the drive to the c.r.t. gun is obtained directly from the input. When peak spot-wobble deflection occurs in the opposite direction, the c.r.t. drive is obtained from the input through a device having a delay of one field period plus, or minus, half one line period; whether the half-line delay is added or subtracted depends upon whether the direct input is applied to the c.r.t. during the upper or lower peak of the spot-wobble waveform.

The aforementioned techniques are intended to reduce the loss of vertical resolution normally encountered in standards converters. In the opinion of the authors such loss contributes very significantly to the characteristics of image-transfer standards converters; experience has shown that they require high-quality input pictures if the output picture quality is to be acceptable.

5. Recent Developments and Proposals

The preceding discussion has led to some proposals for the further development of image-transfer standards converters, and their use could result in improved picture quality, particularly with respect to vertical resolution. However, the image-transfer converter would then become more complex and the problem of realizing a consistently high standard of operation might be aggravated.

During the last ten years there has been a clearer understanding of the fundamental processes of standards conversion and this, together with the availability of new techniques and components, has led to some radically new developments and proposals. These new ideas replace the display-tube phosphor and camera-tube target combination by other media capable of storing video information. Japanese engineers have developed some ingenious magnetic-tape standards converters;[15] one machine is used for recording at the input standard and a further machine is used for replay at the output standard. The conversion of field frequency is carried out by one pair of machines while a later proposal for changing the number of lines in a picture involves the use of a second pair of machines of different design.

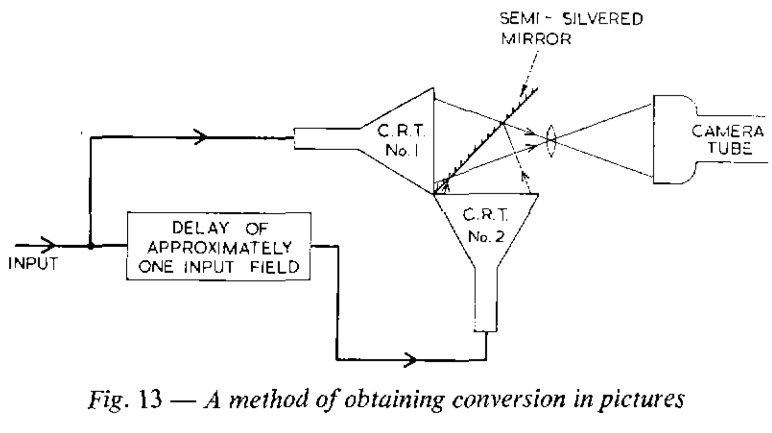


Fig. 13 — *A method of obtaining conversion in pictures*

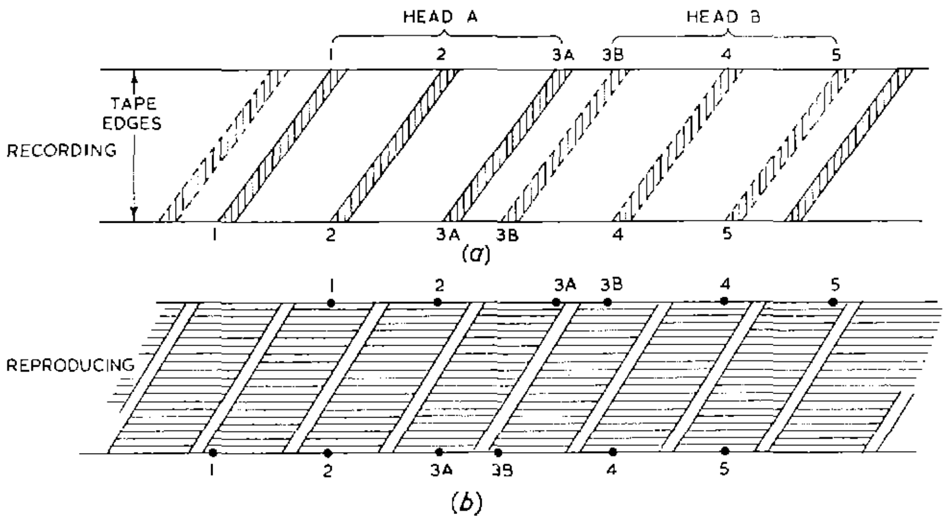


Fig. 14 — *N.H.K. field-frequency converter using helical magnetic recorder*

Notes (i) The diagram is illustrative only. In practice the tracks are inclined to the longitudinal tape axis by about 4°.
(ii) The numbers indicate recorded input fields

Both the field-conversion recording-and-replay machines are based upon the 'single-head' helical recorder. However, the recorder is equipped with a pair of recording heads which are positioned approximately side by side on the 'head wheel'. These heads can be simultaneously energized to write a pair of closely-spaced tracks such as those numbered 3A and 3B shown in Fig. 14(a). A switching arrangement applies the input signals to recording head A and recording head B in the following sequence, for a 50 c/s to 60 c/s field-frequency conversion:

field 1 to head A, field 2 to head A, field 3 to both A and B, field 4 to head B, and field 5 to head B.

Six tracks are thus recorded during five field periods. During the next five input fields the same sequence is repeated.

Fig. 14(b) illustrates the replaying of the field tracks in the field-conversion replay machine. A single broad replay head is used, wide enough to cover about one-sixth of the longitudinal distance travelled by the tape during five incoming fields. The replay head rotates at six-fifths the speed of the recording head, but the tape travels at the same speed as that used for recording. Thus each of the six field tracks recorded in every tenth of a second is read, resulting in an output at 60 c/s field frequency.

The number of lines per field is unchanged by this field-frequency conversion and change of line standard must be carried out by a further converter; an image-transfer converter has been used operationally for this purpose. However, a magnetic line-scan converter has also been described[15] which, in collaboration with the field-scan converter mentioned previously, is potentially capable of converting from 625 lines, 50 c/s, to 525 lines, 60 c/s. During the replay portion of the field conversion process five extra lines are added to every picture. This is carried out by using a head-drum cylinder whose diameter is 630/625 times the recording drum diameter, so as to scan the helical track in less than 1/60th of a second, leaving room for two and a half lines of synthetic blanking to be added to each field period. The signal is now passed to a recorder that uses a multiple-head wheel to scan the tape transversely, in a manner similar to conventional television tape recorders. However, there are seven heads around the wheel and these record, across the tape, 105 tracks during every picture period, each track being six picture lines in length. In the associated replay machine the head wheel again carries seven heads but has a diameter five-sixths of that used for recording. Both head wheels make the same number of revolutions per second; thus five outgoing lines are provided in the time taken to record six.

Distortion of vertical detail resulting from the omission of every sixth line is alleviated by a process of 'line correlation' or interpolation. In this process the output from each head of the line converter is delayed by approximately one field period and by these means video information is made available from picture lines adjacent to the line being reproduced; the overlapping of heads makes available, to the interpolator, information from all recorded lines including those which are subsequently omitted. By adding correct proportions of the adjacent-line signals to the main output a video signal is derived which more correctly describes that part of the picture occupied by the outgoing line of the new standard.

Other recent developments entail the use of reactances as the storage media for a standards converter with writing and reading effected by electronic switches. Such converters are fundamentally attractive as they can offer the possibility of storing much larger quantities of energy per picture element. However, only a few hundred such storage elements can be incorporated and such a number will accommodate only one line of video signal. The rasters of the input and output standards must therefore be maintained in vertical synchronism; the use of this type of converter is, in consequence, restricted to conversion between standards that differ only in the number of lines per field. Standards converters using this principle are referred to as 'line-store converters' and two fundamentally similar but instrumentally different designs have been developed.[16,17] The conversion from 625 lines to 405 lines is of particular importance in the United Kingdom, where these two standards will operate side by side for several years, and the line-store converters have been evolved primarily in order to perform this conversion. Nevertheless, the principle is adaptable to conversion between any other two field-synchronous standards, including conversion from a lower to a higher number of lines.

Two basic processes must be carried out by a line-store converter. These are:

(*a*) The selective rejection or repetition of input information (i.e. changing of the number of lines per field to suit the required standard) and the redistribution of the selected information on a new time scale (i.e. the lengthening or shortening of the duration of each selected line).

(*b*) The derivation of modified video signals, suited to the positions of output scanning lines, by interpolating between the signals corresponding to vertically adjacent points on successive input lines.

The first process is performed by the 'line-store' which in both designs consists of an array of about 600 reactive networks. During one line period of the input standard these networks are connected in turn, by electronic switches, to the incoming video signal, and each is thereby charged to a voltage representative of one of the picture elements from the incoming scanning line. Subsequently, a second system of electronic switches connects the array of storage networks to the output of the converter, these switches all being operated in turn during each line period of the output standard. The second requirement is met by taking weighted means of the video signals from consecutive input lines so that the video signal applied to any one outgoing line has a value obtained by interpolating between two or more input lines. This amounts to applying the input signal to a filter whose response, as a function of vertical spatial frequency (section 2.2), is related to the function which determines the proportions of the contributions to the weighted mean; this function is chosen so that the response has a zero at input line-frequency.

Fig. 15 shows diagrammatically one proposed design[17] for converting to an output standard having fewer lines than the input standard.

The weighted mean of successive input lines is obtained by means of an interpolation unit incorporating a delay of one input line period. The input and output signals of the delay device are modulated by weighting functions S and (1–S) respectively. The sum of these two modulated signals is the interpolated signal applied to the store. The store itself consists of two arrays of high-speed electronic switches, corresponding switches from each array being connected to a storage capacitor. One array connects each capacitor in turn to the video input; the instant at which each switch closes is determined by clock pulses whose frequency is such as to actuate the whole array in one input line period. A second train of slower clock pulses actuates the other array of switches in one output line period, thus connecting the capacitors in turn to the video output.

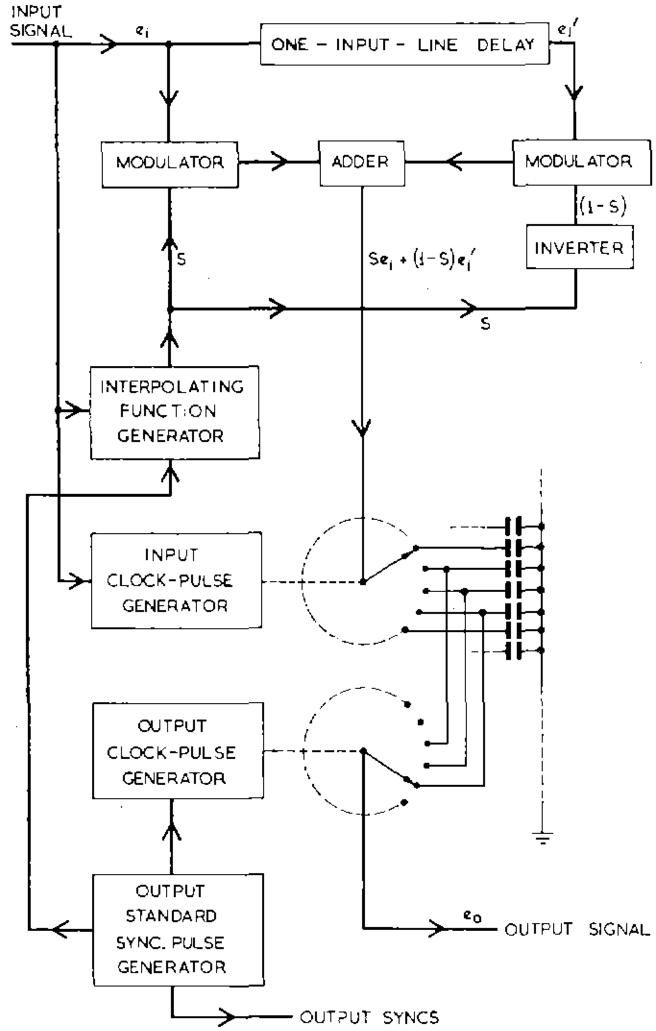


Fig. 15 — *A line-store standards converter using single stage switching and a line-delay interpolator*

In Fig. 16 the principle of the second proposed design[16] is illustrated for a simplified converter containing only eight stores. A two-stage switch is employed in which switches S_1 to S_8 are fast-acting, while switches S_{a1} to S_{b4} are relatively slow-acting devices. In this way, the larger number of switches can be of simpler and cheaper design since they operate relatively slowly. In this design, the storage is effected by an array of networks in each of which two capacitors are joined by a series inductance. The signals applied to the input capacitor, C_1, of each of the π-networks can be regarded as a succession of samples

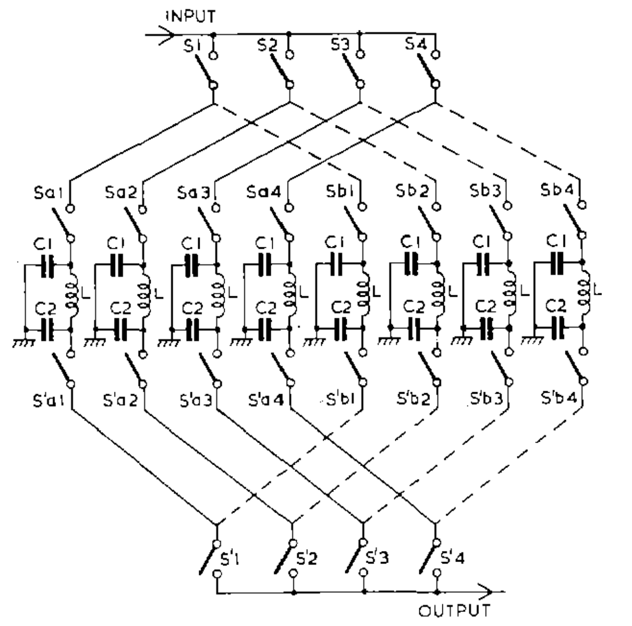


Fig. 16 — Simplified diagram (assuming only eight stores) of a line-store standards converter using two-stage switching and interpolating storage networks

at the line-frequency of the incoming standard. The values chosen for the inductance of L, and the capacitances of C_1 and C_2 cause the network to reject the input pulse-repetition frequency but allow the useful information carried by the input samples to appear at the output. These networks thus perform the two functions of storage and interpolation and the output voltages appearing on the capacitors C_2 are resampled by the second two-stage array of switches to form video signals appropriate to the output standard. In a practical converter of this type it has been proposed that sixteen slow-acting switches should be associated with each fast-acting switch.

6. Future Roles of Standards Converters

During the next decade it is possible that all European countries will originate their domestic programme material on the 625-line, 50 c/s, standard. However, the very factors that may simplify the exchange of monochrome programmes between the various countries of Europe will at the same time create a considerable problem within the domestic networks of those countries that are in the process of adopting a new standard. During the necessarily protracted transition period various factors such as frequency allocations, the vast numbers of old receivers in current use, the maximum rate at which transmitters can be built, etc., will make it necessary to broadcast, on the old standard, many hours each week of programmes that have originated on 625 lines. If the resulting picture quality is to be acceptable to those who view transmissions on the old standard and if the operating costs are to be acceptable to the broadcasting authorities, the standards converters employed must introduce very little picture degradation and have extremely high stability and reliability.

Any speculation about the future role of standards conversion in television broadcasting must lead ultimately to the question of colour. Fortunately there is a reasonable hope that a common subcarrier frequency and a standard system of chrominance modulation will be adopted throughout Europe, thus making the exchange of colour programmes within Europe a relatively simple matter. If this hope materializes only two standards will be involved when world-wide exchanges of programmes in colour are contemplated. Colour film may bridge the gap when topicality is not at stake, but the time will certainly come when live programme exchanges in colour are required. In the past, colour standards conversion has been carried out using the image-transfer method, but it is unlikely that such a converter can achieve the desired quality of performance without requiring a very great deal of further development. Alternative methods using either magnetic or lumped network storage would involve three separate processes, namely, field-frequency conversion, line-frequency conversion, and replacement of the original chrominance signal with one conforming to the parameters of the required outgoing standard. The logical sequence of processing would be to convert the composite signal to the new line and field standards, extract the colour-difference signals, modulate the new subcarrier, and then reform the composite signal. In practice, this may involve breaking down the input signal into its luminance and chrominance components, converting these separately, and then reforming the output signal from the individual converted components.

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A RECENT BBC TECHNICAL SUGGESTION

AN IMPROVED LOW-FREQUENCY MULTIVIBRATOR

In the well-known simple multivibrator shown in Fig. 1, a difficulty arises at low frequencies due to the physical size of the capacitors C1, C2. There is also a limit to the maximum value of R1 and R2 since during the conducting period of each transistor, these resistors must pass sufficient current to keep the appropriate transistor fully conducting and the loop gain above unity during the change-over period.

In the improved circuit of Fig. 2, the base resistors R1 and R2 are returned to taps on the collector loads. These resistors R1 and R2 must be reduced slightly from their previous maximum value so that R1 + R3 and R2 + R4 do not exceed this value. Now when VT1 is cut off the base conditions for VT2 are similar to those of the previous circuit, Fig. 1. Since VT2 is now bottomed, the potential to which R2 is returned is now much smaller than in the original circuit, thus the current recharging C2 is much less and for a given recurrence rate C2 may be correspondingly reduced in value. Similarly for the other half-cycle C1 may be correspondingly smaller than in the original circuit. The reduction in size of C1 and C2 increases as the ratios $\frac{R3}{R5}$ and $\frac{R4}{R6}$ increase. This ratio is limited, however, by the need to pass sufficient current through the base resistors R1 and R2 to enable the loop gain to reach unity and initiate the changeover. Also if this ratio is too great, some instability of operating frequency may occur. In practice reductions of up to 20:1 for C1 and C2 may be obtained.

Since the capacitors C1 and C2 have been reduced in value the rate of rise in collector potential when a transistor cuts off will be increased. The time constant of this rise is approximately (R3 + R5)C1 or (R4 + R6)C2; as this product may be reduced by up to 20:1 a considerable improvement in output waveform may be obtained.

The output waveform may be further improved by using an emitter-follower to supply the capacitors C1, C2 and any loads, as is commonly done with the multivibrator of Fig. 1. Any of the triggering methods normally used with the first multivibrator may be used with the improved multivibrator.

In the monostable multivibrator of Fig. 3, the coupling R1, C1 may be modified similarly to that of Fig. 4 with the same advantages as those of the multivibrator of Fig. 2.

In both of these circuits if the taps on the collector loads are made variable, the frequency becomes variable. The advantages of the improved circuit are now obtained at the lowest frequencies whilst the maximum stability is obtained at the highest frequency.

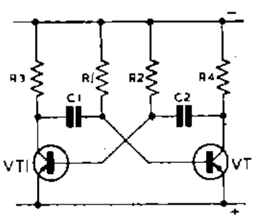

Fig. 1

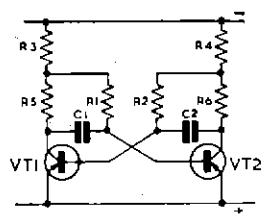

Fig. 2

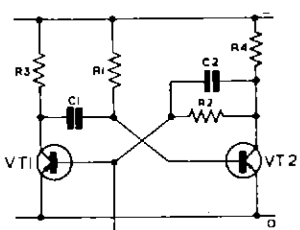

Fig. 3

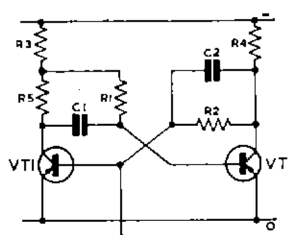

Fig. 4

D. E. SUSANS.

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