TECHNICAL INSTRUCTION P.5

Electronic Standards Conversion

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SECTION 1

INTRODUCTION

Electronic standards conversion is used in the following situations:—

(a) Conversion between standards with a common field frequency, but with a different number of lines per field.

(b) Conversion between standards with different field frequencies.

(c) Conversion between standards with the same line and field frequencies, to achieve either synchronism or a change of chrominance coding.

Sync-pulse waveforms are converted by conventional digital and pulse techniques which are described elsewhere.

Conversion of the picture signal is based on the scanning process used in television. That part of the picture signal which represents the information concerning any picture element in the scene being televised occurs once in every picture-period at times determined by the standards used. A change in standards implies a change in these times. The information has to be stored, therefore, for a period which depends upon the input and output standards. Fig. 1.1 shows the basic form of a standards converter which employs a delay path as a signal store and which operates in the manner outlined below.

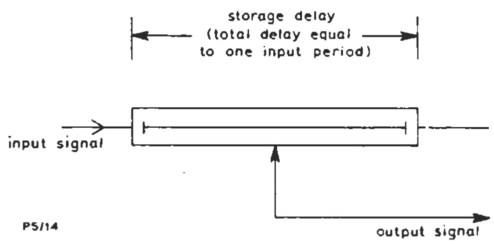

Fig. 1.1 Basic Form of a Standards Converter

Conversion from a higher-frequency input signal to a lower-frequency output signal is shown in Fig. 1.2(a), in which the periods shown can be either line or field periods. In this example, the duration of five input-periods equals the duration of four output-periods. The first picture-element of input-period *e* is presented as the first picture-element of output-period *q* without storage delay. Subsequent picture-elements are stored for an increasing period of time by moving the tap in Fig. 1.1 steadily from left to right, until this storage delay equals one input-period. The storage delay can then be reduced to zero, thus omitting input period *j*.

Similarly, conversion from the lower-frequency input signal to the higher-frequency output signal is shown in Fig. 1.2(b). The first picture-element of input-period *p* is stored for one input-period and is presented as the first picture-element of output-period *e*. Subsequent picture-elements are stored for a decreasing period of time by moving the tap in Fig. 1.1 steadily from right to left until the storage time becomes zero. Thus, the last picture-element of input-period *t* is presented as the last picture-element of output-period *j* without storage delay. It is necessary to repeat input-period *t* to produce output-period *k*.

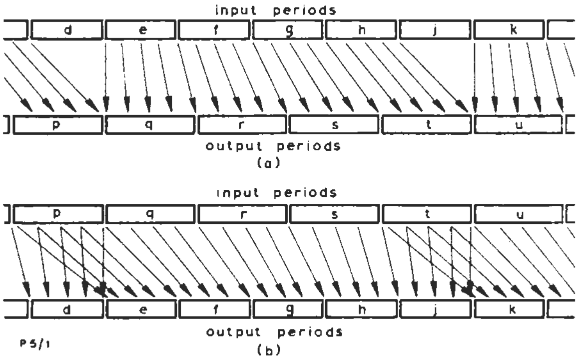

Fig. 1.2 Timing Diagram (a) down conversion (b) up conversion Slope of arrows indicates storage delay

At some time in both the processes described an instantaneous change of delay of one input period is necessary, and this, therefore, is the maximum required for conversion. In converting between standards with synchronous field signals but different numbers of lines, the maximum delay is one input line-period and a converter to do this is known as a line-store standards converter. In converting between standards with different field frequencies, the maximum delay is one input field period and a converter to do this is known as a field-store standards converter.

Discarding or repeating input-period signals results in an uneven presentation of output picture signal information either in position (with a change in the

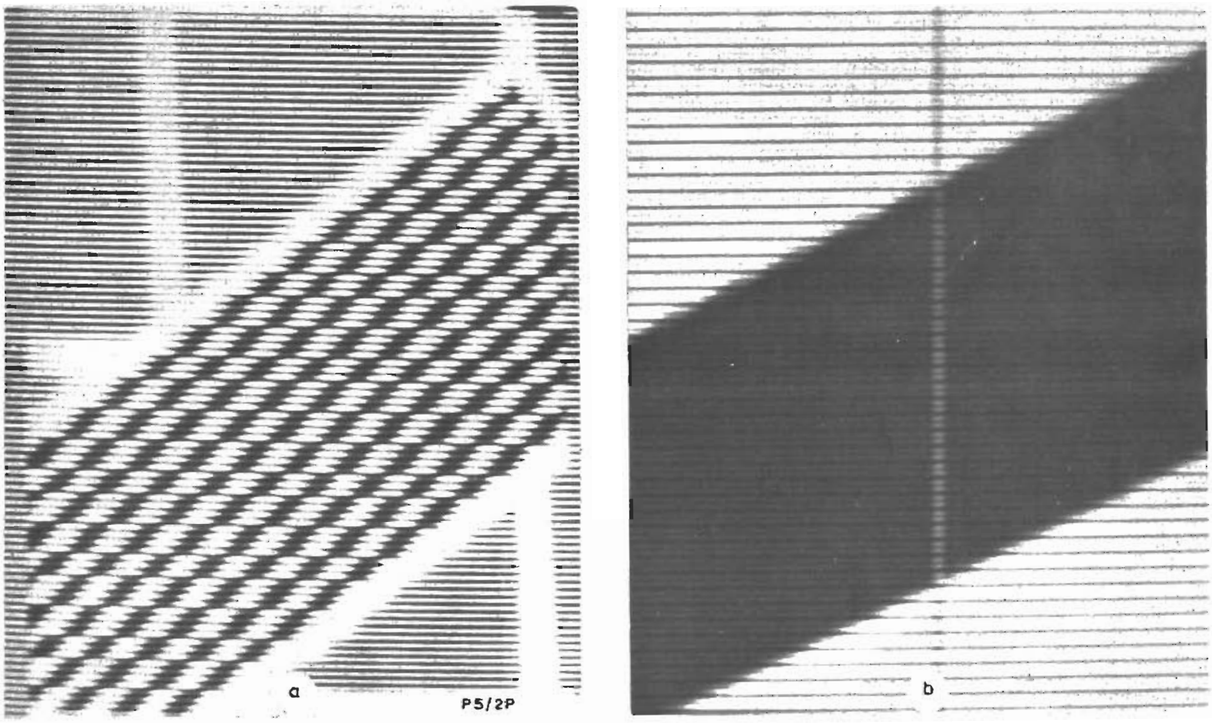

Fig. 1.3 The Reduction of Knotting by the Use of Interpolation (a) without interpolation (b) with interpolation The vertical line in (b) is one picture-element wide

number of lines per field) or in time (with a change of field frequency). The positional distortion is known as knotting and the corresponding time distortion is known as judder.

Knotting is illustrated in Fig. 1.3(a) which shows part of the corner of a test card display. As stated above, judder is a disturbance of time relationships and cannot therefore be illustrated by means of a still drawing. The observed effect can be described as a jerkiness of movement which is reminiscent of old-time cinematograph sequences. The expected smooth movement of displayed objects is interrupted by small positional displacements; these occur at an average rate which is equal to the difference between the input and output field frequencies.

The visible effects of both knotting and judder can be reduced by means of interpolation. This is a process whereby the signal present during a particular output period is derived from incoming signals present for two or more input periods of the same duration. This implies the use of delay paths in addition to those required for conversion as described previously.

The effect of interpolation on knotting is illustrated in Fig. 1.3(b), which shows part of a bar sinister to the same scale as that of Fig. 1.3(a). Interpolation is also illustrated by Fig. 1.4 in which simple television signals generated on standards with different numbers of lines but with the same field frequency are used. The 20-line picture shown in Fig. 1.4(a) is converted to a 16-line picture, by omitting four lines evenly distributed throughout the picture to give the resultant shown in Fig. 1.4(b). A picture element (A) of the 16-line picture occurs, in general, at a position (shown dotted) on the 20-line picture which falls between two adjacent lines. The use of interpolation in deriving the picture information in each line of the 16-line picture from two adjacent lines of the 20-line picture shows, in Fig. 1.4(c), a considerable reduction in knotting.

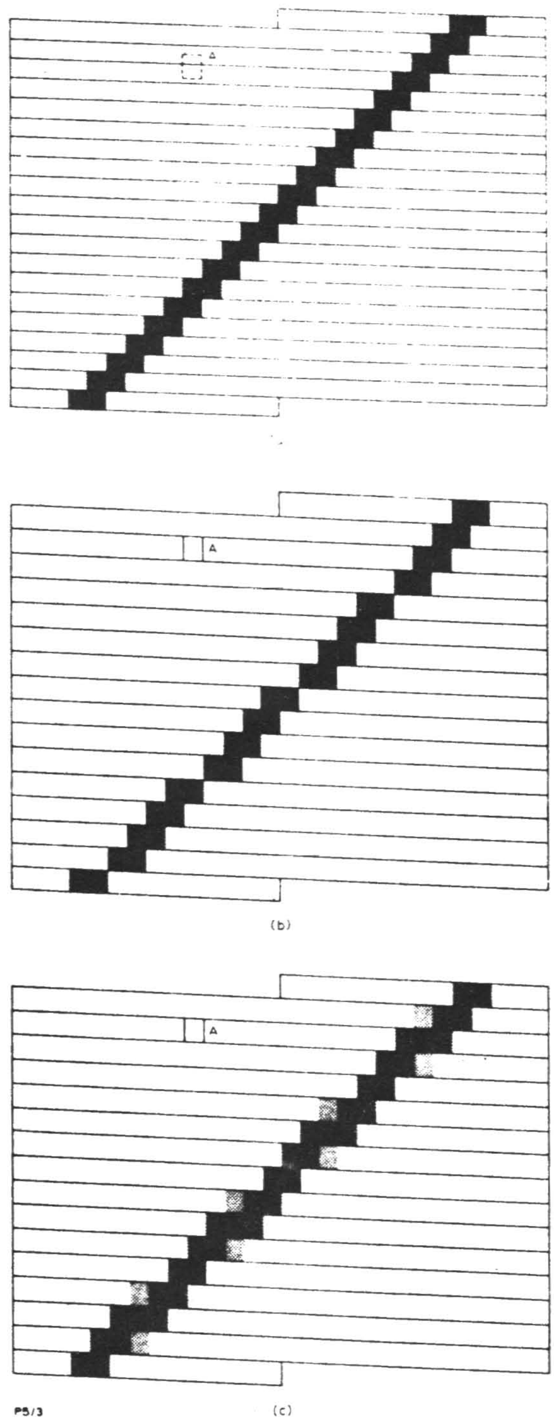

Fig. 1.4 Illustrates the Reduction of Knotting by Interpolation

(a) 20-line input-standard picture
(b) 16-line output-standard picture without interpolation
(c) 16-line output standard picture with interpolation

SECTION 2

LINE-STORE STANDARDS CONVERSION

As described in Section 1, a line-store standards converter has input and output signals which are field synchronous. A simplified block diagram of such a converter is given in Fig. 2.1. The input signal is fed via an electronic multiway switch to a number of store circuits. Every store circuit is fed with a sample of the input signal once in every line. The samples fed to any one store occur at the same relative instant in each line. Thus the samples fed to any one store have amplitudes corresponding to a signal which describes a thin vertical strip of the picture being televised.

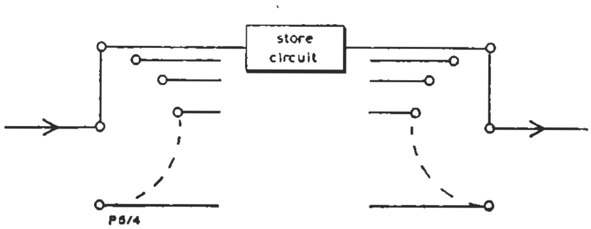

Fig. 2.1 Simplified Block Diagram of a Line-store Standards Converter

The output switch samples the signal from every store circuit once in each output-standard line period and thus builds up a signal at the output standard.

A capacitor can be used as a store circuit. If the input switch is fed from a low-impedance source the capacitor charges rapidly to the potential of the input signal while its input-switch contact is closed.

The number of stores required depends on the sampling process. Sampling theory requires that to preserve the signal being sampled, the sampling frequency should be twice the highest frequency contained in the signal. This gives a sampling frequency of 11 MHz for the British 625-line television system and, therefore, 574 stores for an active line period of 52·2 μs. Subjective tests have shown that as few as 546 stores give a picture of acceptable quality. In practice, 576 stores are used as this number has convenient factors.

To illustrate the conversion process, the simplified standards used in Fig. 1.3 are also used in this Section. It is assumed that the number of picture elements per line and hence the number of stores is 28. Lines for about half the raster for both the input standard (full lines) and the output standard (dotted lines) are shown superimposed in Fig. 2.2. The input picture information, the bar sinister shown in Fig. 1.3, is indicated by a thickening of the input-standard lines.

Because the two standards shown in Fig. 2.2 are field synchronous, vertical distance from the top of the diagram is proportional to time on a scale which is common to both standards.

Thus the vertical spacing between input-standard lines is proportional to the input-standard line period and the increasing vertical distance between input-standard and output-standard lines is proportional to the increasing storage delay.

A simple converter without interpolation omits picture information for a whole line period at regular intervals. The storage delay is shown as zero at the top of Fig. 2.2. The storage delay increases until it becomes one input-line period (at the middle of input line No. 4). The delay can be reduced to zero, omitting the last half of input line No. 4 and the first half of input line No. 5. This is illustrated in part of Fig. 2.3. Fig. 2.3(b) represents input-standard line periods and Fig. 2.3(c) represents output-standard line periods. The slope of the arrows joining these represents the storage delay as in Fig. 1.1.

Interpolation in a simple form consists of deriving picture information for the output-standard lines from two adjacent input-standard lines. This is achieved by one of two methods.

In the first method the input signal fed to the stores is a mixture of the input line above the required output line and the input line below the output line. The line above and the line below are made coincident in time by the use of an additional input-standard line-period delay. This is shown in Fig. 2.4, a block diagram of a simple interpolator. In Fig. 2.4 the amplitudes of the line-above and line-below signals are multiplied by varying amounts. The proportions taken of the input signals are known as interpolation functions.

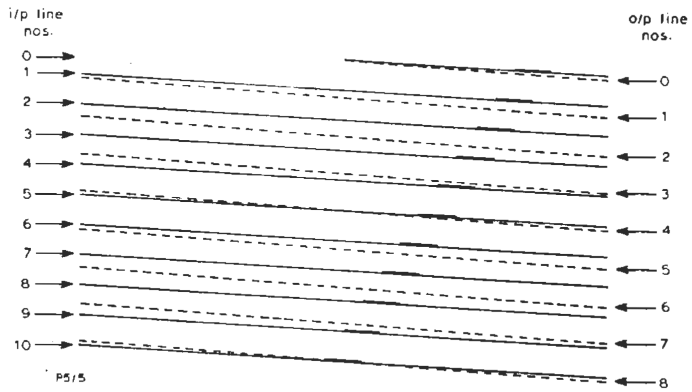

Fig. 2.2 Part of Input-standard and Output-standard Rasters from Fig. 1.3 shown Superimposed

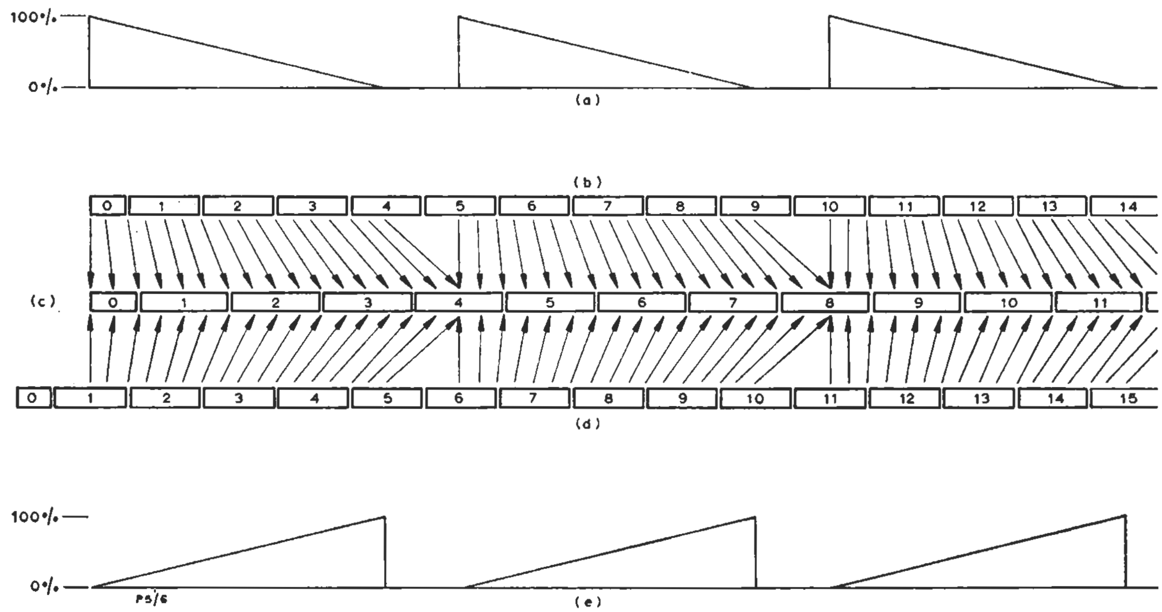

Fig. 2.3 Timing Diagram
(a) interpolation function for the line-above signal
(b) input-standard line periods for the line-above signal
(c) output-standard line periods
(d) input-standard line periods for the line-below signal
(e) interpolation function for the line-below signal

Slope of arrows indicate storage delay

A simple interpolation function is shown in Fig. 2.3(a) for the line-above signal, Fig. 2.3(b). The corresponding function for the line-below signal, Fig. 2.3(d), is shown in Fig. 2.3(e). Fig. 2.3 also shows that the same storage delay (slope of the arrows) is required for both the line-above and the line-below signals so that a mixture of these signals, their amplitudes multiplied by their interpolation functions, can be fed to one set of stores. In practice, more complicated interpolation functions are used instead of the linear functions shown in Fig. 2.3, but the sum of these functions is always 100 per cent for all the lines in the line-above and the line-below signals which are not discarded.

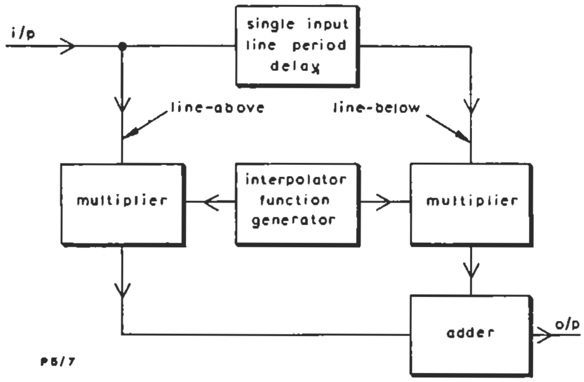

Fig. 2.4 Block Diagram of a Simple Interpolator

The second method of interpolation is achieved within the stores themselves. The signal fed to each store comprises a series of pulses at input-standard line frequency, the amplitudes of which describe a low-frequency signal representing a thin vertical strip of the picture being televised. The frequency spectrum of these pulses comprises the low-frequency signal together with the low-frequency signal amplitude-modulated onto the fundamental and harmonics of line frequency. Filtering can be used to remove all frequencies other than the required low-frequency signal; thus interpolation has been achieved by removing the input-standard line-frequency information. Filtering can also be used to introduce a degree of vertical aperture correction.

Further information on line-store standards conversion is given in Reprint Article A.79.

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SECTION 3

FIELD-STORE STANDARDS CONVERSION

General

A field-store standards converter is used to change a television signal generated at one field frequency (as defined by the input standard) into a signal which has a different field frequency (as defined by the output standard). In general, a difference in field frequency is associated with a difference in the number of lines in each field period. There are, therefore, two basic processes in effecting conversion between standards which have different field frequencies; a change of field frequency must be accompanied by a suitable change in the number (and duration) of lines.

The basic form of a field-store converter is illustrated by Fig. 1.1 in Section 1; i.e. it comprises a tapped storage delay with a maximum value equal to one input-standard field period. A continuously-variable delay of such a large total value (and which possesses the required bandwidth) is impractical however and it is necessary to use a number of smaller-value delays which can be switched into and out of circuit at appropriate times; these switched delays can be of any convenient value provided that the total delay available is sufficient. The values actually chosen depend both on the switching system used and on the relative field rates of the input and output standards.

In a simple method of conversion the individual delays have values which are comparable to the duration of an input field and are switched into circuit in the field-blanking intervals so that the average field frequency is appropriately changed. The resulting converted signal could be displayed on a monitor operating at the output-standard field frequency although the geometry of displayed objects would be distorted because the number and duration of lines in each field is incorrect. A converter employing this simple method must include means to compensate for these discrepancies.

In more complex conversion equipment the switched delays have values which are comparable to the duration of an input line and are introduced as required in line-blanking intervals. Thus, in addition to the required change of field frequency, the number and duration of lines in each field period is suitably adjusted. Such converters can, in fact, produce a signal which corresponds in all respects to the output standard.

Field-store conversion is described by considering the two processes of field-frequency change and line-number change separately. The simple conversion method, in which only the field rate is changed, forms an initial description and is followed by some details of extensions to the method and also of additional processes which enable other signal parameters to be appropriately changed.

For the purpose of initial description, suppose the input field rate is 60 per second and the output rate is 50 per second. These are the respective field rates of the American monochrome (nominal) and European television systems, which are two of the three standards normally concerned in field-store conversion. The remaining standard is that used for American N.T.S.C. colour signals in which the field frequency is 59.94 Hz. Because the relationship between this field frequency and that used for all European colour signals (which is 50.0 Hz irrespective of the coding system) is not a simple ratio of small numbers, there is additional complexity in the instrumentation of conversion, although the basic process is unchanged.

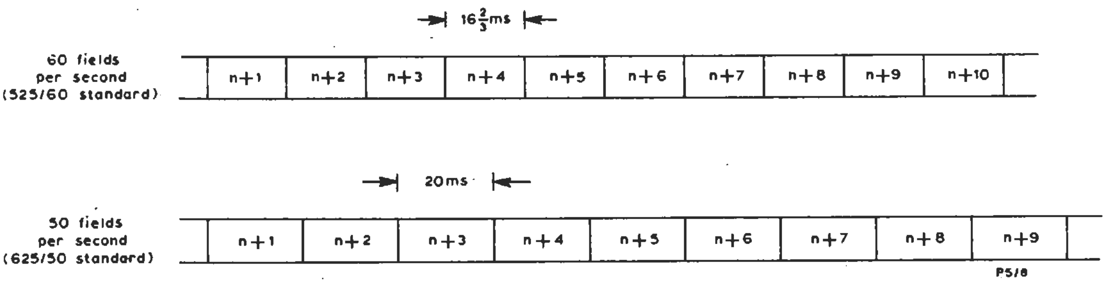

Fig. 3.1 Diagram Illustrating Relation Between 60-Hz Fields and 50-Hz Fields

Simple Method of Conversion

In Fig. 3.1, each of the numbered blocks in the top row represents a continuous sequence of television signals having the total duration of one field period at the input standard (60-Hz frequency). Similarly, the blocks in the bottom row are fields occurring at 50 Hz according to the output standard. Thus, each field in the top row has a duration of $16^2/_3$ ms whereas those in the bottom row are of 20 ms duration.

change equal to the total is made; information is repeated if the output field frequency is higher than that of the input and, conversely, is omitted if the output field frequency is lower. The omissions or repetitions must occur at predictable intervals so that continuity of output information can be maintained by adding signals obtained from interpolation processes.

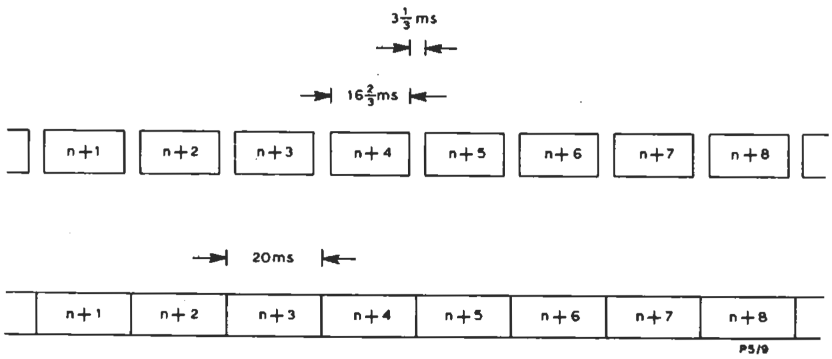

Fig. 3.2 Relation Between Input and Output Fields for the Simple Method of Conversion

For the required change of field rate, it is necessary to delay input fields by a continually increasing amount so that each of these and the corresponding output fields has the same relative timing; Fig. 3.2 illustrates this action in respect of a small number of fields. This diagram also shows that the required delay increases by $3\,^1/_3$ ms after each field period and it is evident that such a rate of increase could not be sustained for more than a very short time. In practice, as described previously, a small number of delay elements is employed and these are switched into and out of circuit in a repetitive sequence. Because of the limited number of delays, however, it is necessary for sections of incoming information to be either omitted from the output, or repeated each time the available delay range is exceeded and a delay

Basic Circuit

For a change of field rate according to the method and requirements outlined above, a circuit of the form shown in Fig. 3.3 can be used. In this circuit, the switch moves from one contact to the next at the end of each incoming field period so that the circuit delay path increases in steps of $3\,^1/_3$ ms. Fig. 3.4 illustrates the circuit function in a similar manner to that used for Fig. 3.2. As before, incoming fields are increasingly displaced in time so as to maintain a constant relationship with output fields. After five input fields, however, the switch moves back to the first contact whereby a complete input field (the sixth, which is being transmitted through the delay at this time) is omitted. This effect is indicated in Fig. 3.4 by the adjacent upper-row blocks (n+5) and (n+7).

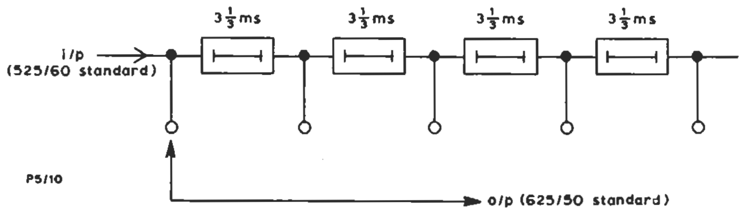

Fig. 3.3 Basic Circuit for Simple Method of Conversion

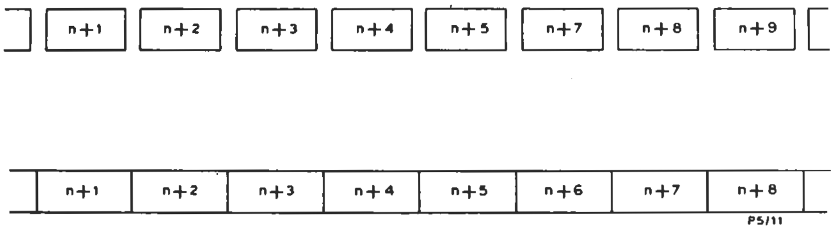

Fig. 3.4 Relation between Input and Output Fields for a Simple Converter

The drawing of Fig. 3.4 also shows that, because the blanking periods between fields are extended by 3 1/3 ms, the proportion of each field period containing picture information is reduced; thus, the vertical dimensions of displayed objects are decreased relative to the horizontal dimensions. In a practical converter which changes the field rate according to the simple method, therefore, it is also necessary to reduce the duration of each line (by time contraction) so that the displayed objects retain the correct geometric proportions (i.e. have the correct aspect ratio). Such a change of line duration can be effected by means of a line-store converter (of the type described in Section 2 of this Instruction) which is modified so that it operates with different rates of signal insertion and extraction. Thus, if during each line period the extraction rate exceeds the insertion rate, the output line duration is reduced by the difference between these rates.

Two other requirements must be considered. First, if switching between delays takes place immediately at the end of an output field, it is necessary to provide special field blanking pulses for addition to the output signal so that lines relating to the end of one field are not repeated at the beginning of the next (in the displayed picture). Second, to maintain a constant and particular phase between input and output signals (such that output fields are suitably disposed with respect to input fields as indicated by Figs. 3.2 and 3.4), the two sets of sync-pulses must bear a fixed relationship; i.e. the output pulses, must be derived from the input pulses by some form of sync-pulse converter. (Because of this requirement, the output from the simple converter cannot be displayed on a monitor locked to the local output-standard sync-pulse distribution system.) Fig. 3.5 shows how the added functions are incorporated in the basic circuit of Fig. 3.3. It also shows that interpolation is arranged in the simple converter by adding an extra delay of 3 1/3 ms to the four already present and feeding the resulting output (which is the incoming signal delayed by one whole field period) back to the input in such a way that a proportion of each omitted field is added to the preceding and succeeding fields.

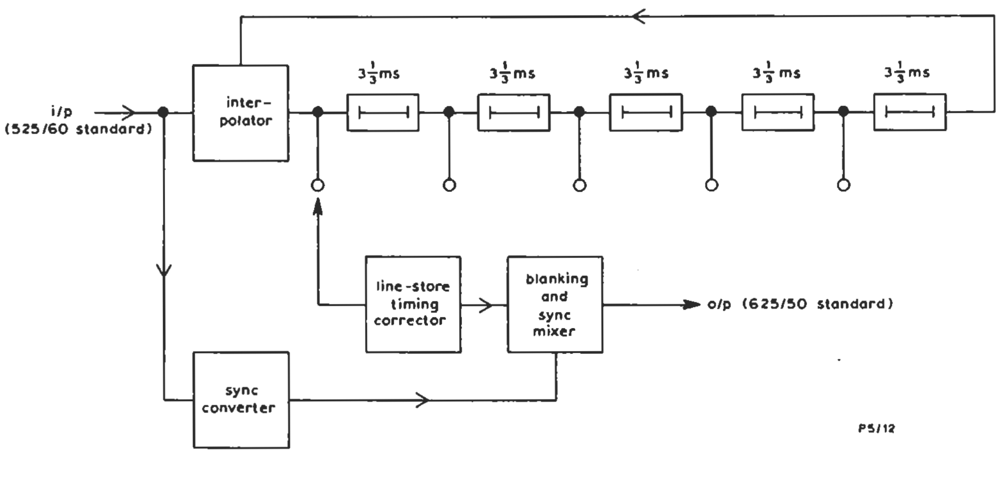

Fig. 3.5. Circuit Showing Development of Simple Converter

Extension of Simple Method for Colour Signals

The conversion method outlined above specifically describes conversion from the 525/60 (American monochrome) standard to a 625/50 standard but could be applied to any two television signals with simply-related field frequencies; (e.g. conversion in the opposite direction is possible; for this process, incoming fields would have to be repeated instead of omitted). Further, provided that the field-delay elements and the line-store circuits have sufficient bandwidth, such a simple system could also be used for colour-coded signal conversion. When converting between American 525-line NTSC colour signals and a European 625-line colour standard, however, the imposed limitation of a simple relationship between field frequencies would result in an output field frequency which was outside the permitted tolerance (because of the input field frequency of 59·94 Hz); the converted colour subcarrier frequency would similarly be incorrect.

It would, in fact, be possible to obtain a standard output signal using the simple conversion system by first recording the converted signal on to video tape, and then replaying this recording at a different speed so as to compensate for the frequency errors. Such an intervening process represents a severe limitation on practical use of the simple method.

system, this amount of delay is added at the end of each incoming field. But, if the delay is added in small increments at nominally regular intervals throughout the field period, the average line-rate is changed to that of the output standard. Further, by repeating an input line at each of these intervals, the total number of lines occurring in each field period can be made equal to that required for the output standard.

Fig. 3.6 illustrates a more complex form of the converter circuit given in Fig. 3.5 and shows in addition to other alterations concerning the functions of interpolation and timing correction that a 3 ⅓ ms delay path is interposed in series with the output from the delay-change switch. This extra delay is variable in equal increments of about one input line period.

Considering again conversion between the 525/60 and 625/50 standards, it is evident that 100 extra television lines are required during each picture period in addition to those arriving normally at the input. This additional delay can supply these extra lines as part of the necessary re-timing action.

Suppose the delay is increased by one increment at the end of every fifth input line. The first five input lines will appear (undelayed) at the output, and will be followed by the fifth line repeated but

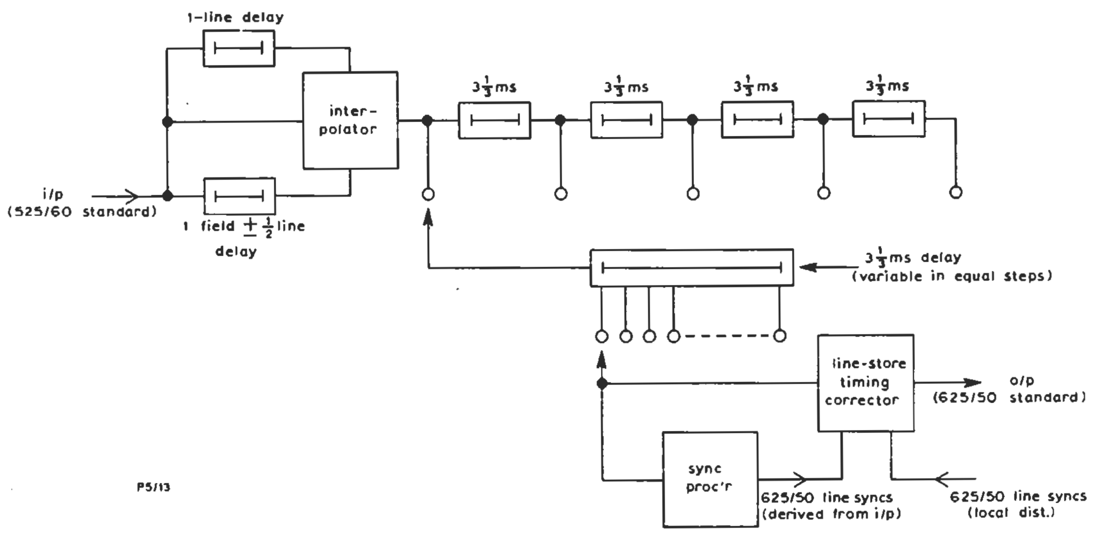

Fig. 3.6 Circuit of More Complex Converter

More Complex Method of Conversion

The change of a 60-Hz field frequency to one of 50-Hz requires the addition of a 3 ⅓ ms signal-path delay during each incoming field period; in the simple

re-timed as a sixth output line. Similarly, the next five input lines will be delayed by one line period at the output, and will be followed by another repeated input line (now delayed by two line periods) which forms the twelfth output line. This process continues until, at the end of a period equal to one input field, the incremental delay is fully in circuit and has the required total value of 3 1/3 ms; additionally, the number of lines presented at the output has been increased to form a complete (output-standard) raster.

Further consideration of the process described above shows that if the delay increments were exactly equal to one input line period, and if extra lines were inserted at the constant rate suggested (one for each five incoming lines) then each output field would comprise (262½ x 6/5) i.e. 315 lines instead of 312½. To obtain the correct number of lines, therefore, each delay increment is chosen to be 1/50 times the difference between the respective field periods (because 50 extra lines have to be inserted during each field period). These delay increments are made at irregular intervals (but pre-determined under the control of a logic circuit) such that the correct average insertion rate of 50 per field is maintained.

As shown in Fig. 3.6, only one incremental delay is required which can be used for each of the consecutive sequences of 3 1/3 ms. This is arranged by switching the variable delay input between the fixed delays at the same time as the tapping point is returned to the zero-delay position (thus exchanging the information stored in the incremental delay for the identical sequence which is contained in the fixed delay). This exchange takes place at the end of each field period until, when all the available delay, both fixed and incremental, is in circuit (usually after five input field periods) the delayed information forms one complete input field which can be omitted. At this time, the whole circuit delay value is returned to zero, and the process is then repeated.

Interpolation

The processes of line repetition and of irregular delay insertion and extraction interfere with timing relationships in the output signal and therefore cause geometric distortion of objects in the display. In a practical converter, therefore, it is necessary to compensate for these distortions and this is done by means of interpolation and timing-correction functions (represented by various blocks in Fig. 3.6) which are discussed below.

Because the use of a small number of delays in the basic conversion process gives rise to instantaneous changes in signal timing which are equivalent to either a line period or a field period, two types of interpolated signal are required for correction purposes. Both are formed from a mixture of incoming signals which arrive at different times but which are made coincident by means of delay paths.

To produce a mixture of signals describing time-adjacent television lines (i.e. a correction signal containing information from successive lines occurring in one field), a delay having the duration of one input-standard line period is required. A simple interpolator performing such a function is described in Section 2 with reference to a block diagram (Fig. 2.4) and a timing diagram (Fig. 2.3). These descriptions and diagrams show that signals derived from the input and output of the one-line delay element are mixed together in a proportion which varies at line rate according to a pre-determined law. The output from this circuit is termed a line-interpolated signal because the contributing signals initially arrive with a time displacement of one line period. (In the converted-signal display, pairs of lines which share information by virtue of the line interpolation process are, of course, separated by an interlaced line which has not contributed any information.)

In a similar way, interpolation between positionally-adjacent lines (i.e. lines which occur in successive fields and are therefore adjacent in the display) requires a signal-path delay with a duration exactly equal to that of one field plus or minus half a line (at the input standard). Again, a similar arrangement can be used to produce the varying mixture of signals entering and leaving the delay; the resulting signal shares information from two fields and is termed a field-interpolated signal.

Thus, two sets of interpolated signals are produced, and either can be used to form the converted output signal. However, because the interpolated signals are derived by combining different parts of the incoming signal, they provide compensation for different forms of distortion. Particularly, line-interpolated signals provide correction for geometric distortion (of the type illustrated by Figs. 1.3 and 1.4 in Section 1), whereas field-interpolated signals are effective in reducing the characteristic distortion of object movement known as judder. For the best compromise, the two signals must be alternately selected according to a pre-set pattern whereby both forms of distortion are reduced. Such systematic switching between line and field interpolated signal sources produces an output which is termed the resultant of mixed interpolation.

Timing Correction

The converted signal (including interpolated components) has the form of the output standard but is affected by random timing variations. These timing errors can be corrected by means of a modified line-store converter in a similar way to the line-contraction process required for the simple field-rate converter. In this instance, however, instead of continually changing the relative reading and writing rates during each line period, the rates are held at constant values but are under the separate control of line-sync-pulses derived from the input signal (these determine the writing rate) and line-sync-pulses taken from the local pulse distribution system (for the reading rate). The line-store therefore acts as a variable delay mechanism which adopts the appropriate delay value for each line produced by the basic conversion process.

Extension of Complex Method for Colour Signals

The systems of field-store conversion described above can be modified to enable a fully compatible European colour signal to be obtained from an American NTSC signal; i.e. apart from the change in colour coding the system can be made to accommodate input and output field frequencies of 50·0 Hz and 59·94 Hz respectively.

The principle modification concerns the function of omitting (or repeating) an input field whenever the available storage delay is exceeded. For simply related field frequencies, omission or repetition occurs at a constant rate (in the example discussed, every sixth field was omitted). For conversion between the American and European colour signals, the rate must obviously be changed by one part in 1000 (because 59·94 Hz differs from 60·00 Hz by this amount). The new rate cannot, of course, be maintained at a constant value because this would involve omission (or repetition) of information during the active field period. The rate must therefore be changed at suitable intervals so as to maintain a correct average rate. This is done by omitting (or repeating) every sixth incoming field in the majority of instances, but choosing the seventh field for omission (or repetition) at certain times so that the average rate is that required. The control of this changing field omission/repetition sequence is by means of logic circuits which are necessarily complex and are not discussed here.

Transcoding

Conversion between colour signals of different standards also necessitates a change in the coding system (e.g. a change from NTSC to PAL). This is termed transcoding, and is normally performed by equipment which is not directly involved in the conversion process; i.e. it can be considered as a subsidiary function of the standards converter. Transcoding is the subject of Section 4 of this Instruction.

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