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(71) We, EASTMAN KODAK COMPANY, a Company organized under the Laws of the State of New Jersey, United States of America, of 343 State Street, Rochester, New York 14650, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to telecine apparatus for scanning continuously moving image bearing media to produce an image signal, and more particularly, to a system for adjusting the scanning rate in accordance with the rate of movement of an image bearing medium.

For reproduction of a picture in a television receiver the face of the picture tube is scanned in a predetermined pattern with an electron beam while the intensity of the beam is varied by a video signal in synchronism with a scanning pattern to control the light emitted by the phosphor screen. The scanning procedures in current use differ from country to country because of differences in power supply characteristics and the independent development of different standards. For example, the scanning procedure in use in the United States employs horizontal linear scanning of the beam in an interlaced pattern that includes a total of 525 horizontal scanning lines in a rectangular frame having an aspect ratio of 4:3. The frames are repeated at a rate of 30 per second with two fields interlaced in each frame. The first field in each frame consists of 262½ odd scanning lines and the second field in each frame consists of the remaining 262½ even scanning lines. Thus the fields are repeated at a rate of 60 per second—the standard power supply frequency in the United States.

A standard image frame bearing medium such as motion picture film is normally exposed and projected at a rate less than the standard television frame scanning rate. To produce a

video signal corresponding to odd and even line television fields from standard motion picture film, it is necessary to scan in an interlaced manner each film frame at least twice while the film is moved at its standard frame rate. For instance, a standard motion picture film is exposed and projected at a rate of 24 frames per second. To produce a 30 frame per second video signal when scanning standard motion picture film, the practice has been to scan certain film frames in two fields, and the remaining film frames in three fields while the film is continuously moving.

In telecine transmission, flying spot scanning devices have been used to scan the frames of a motion picture film with a beam of light in the standard interlaced scanning pattern described above. The beam of light is modulated by the image pattern on the film frame, and the modulated light is detected and transformed into a video signal by photoresponsive devices. The transmitted video signal controls the intensity of the electron beam of the television receiver tuned to that station and reproduces the motion picture film frame on the television screen. Since the motion picture film is moved continuously and transversely to the beam of light produced by the flying spot scanning device at a frame rate less than the field scanning rate for the flying spot scanning device, it is necessary to deflect the scanning beam in the direction of movement of the film at the beginning of each frame. Therefore, the frame area of the film scanned remains constant for each scanning field.

Prior art systems have used optical image splitting apparatus or mechanical light directing apparatus to deflect the scanning beam to the same point on the film frame during each scanning field. These systems are relatively cumbersome and subject to mechanical failure.

A further prior art system contemplates the use of apparatus for applying a signal having an irregular amplitude sawtooth wave form to the vertical deflecting coils of a flying spot scanning device to deflect the scanning beam

in the direction of film movement. The substantially sawtooth wave form signal applied to the vertical deflecting coils is produced by combining a plurality of signals, namely, one 60 Hz sawtooth wave form signal and two 12 Hz sawtooth wave form signals. The amplitude and phase relationship of the signals are controlled so as to obtain a desired vertical deflection of the beam at the beginning of each scanning fields. Such a prior art system is disclosed in U.S. Patent 2,291,723 to Axel G. Jensen.

The sawtooth wave form signals of the latter system are generated under control of a 60 Hz alternating current source, and the vertical deflection wave is generated independently of the film frame rate. This approach, while theoretically feasible, does not take into account slight variations in the motion picture film frame rate that occur during exposure of the film, and, therefore, the vertical sweep wave may inaccurately deflect the scanning beam at the beginning of each frame. Another disadvantage of this system is that it cannot be employed to scan a single, stationary frame of film disposed in the scanning station. Furthermore, it is not possible to employ this apparatus to scan motion picture film exposed at different frame rates without recalibrating the sawtooth wave form generating circuits.

Accordingly, it is an object of the present invention to provide an improved telecine apparatus for scanning an image bearing medium which is stationary or is moving continuously at a variable rate to produce image signals therefrom.

According to the present invention there is provided a telecine apparatus for deriving an image signal from an information bearing medium having a plurality of successive image frames thereon, comprising drive means for driving the information bearing medium through a scanning station, raster generating means for generating a raster comprising a plurality of spaced lines upon the information bearing medium at the scanning station, a detector for detecting the frequency of passage of the image frames on the information bearing medium through the scanning station, signal generating means for generating first and second signals, each having a waveform of periodicity dependent upon the detected frequency, and having a frequency which is a submultiple of the detected frequency, and switching means for switching to the first or the second signal, and for controlling the position of the raster in dependence on the instantaneous value of the switched to signal.

The invention will be described further, by way of example, with reference to the accompanying drawings, in which:—

Figure 1 is a schematic illustration in partial perspective of one embodiment of a telecine apparatus in accordance with the invention;

Figure 2 is a schematic representation in block diagram form of a vertical deflection circuit employed in the apparatus of Figure 1;

Figure 3 is a view showing the wave forms of various signals developed at particular points in the block diagram of Figure 2;

Figure 4 is a diagram illustrating the scanning pattern employed in the apparatus of Figure 1; and

Figure 5 is an illustrative circuit diagram of a portion of the block diagram of Figure 2.

Referring now to the drawings and firstly to Figure 1, there is shown a flying spot scanning system for converting images on a medium into video signals suitable for television transmission or direct application to a television receiver. The scanning system includes a cathode ray tube 1 having a cathode 2 that emits an electron beam 3, the concentration of which is controlled by an intensity control circuit 4. A horizontal deflection yoke 5 operates in a well-known manner under the influence of a horizontal deflection circuit 6 to deflect the beam 3 horizontally across a scanning area 7 on the screen of cathode ray tube 1 at a scanning frequency of 15,750 Hz. A vertical deflection yoke 8 operates to deflect vertically the electron beam 3 in response to a complex vertical deflection signal generated by a vertical deflection circuit 9.

The screen of the cathode ray tube 1 preferably is composed of a wide band spectral emission fluorescent material such as zinc oxide (P24) phosphor, which, when excited by the electron beam 3, will produce a light spot on the tube face. The (P24) phosphor is described on page 5—26 of *Television Engineering Handbook*, by Fink, published by McGraw Hill, 1957. The scanning area 7 preferably has a rectangular configuration as shown so that the electron beam 3 may be swept across the face of the scanning area in discrete spaced apart lines to generate a scanning light beam 10.

The light beam 10 is condensed by a lens 11 and thereafter focused by a lens 12 onto an image bearing medium 13 located at a scanning station 14. Scanning station 14 may consist of, in the preferred embodiment of the invention, an opaque film gate having an aperture 16 therein. For purposes of illustration the film gate 15 is shown displaced from the surface of the film 13; in actual practice the film gate would be in very close proximity to the surface of the film 13. The aperture 16 of the film gate 15 has a dimension 17 in the longitudinal direction of the film 13 which is related to the rate of movement of the film and the height of film frames 18.

The image bearing medium may take the form of, for example, colour motion picture film which has been exposed in a motion picture camera and processed using known techniques. As is well known in the art, such

film is manufactured with spaced sprocket holes 19 along at least one side that enable the film to be advanced at a predetermined rate in a camera and exposed to record images therein in spaced discrete frames 18. The standard film exposure frame rate of the prior art is nominally 18 or 24 frames per second with minor variations or fluctuations in the frame rate appearing with variations in the distance between respective sprocket holes. In connection with the disclosed embodiment of the invention, any film frame rate from 0 to 30 frames per second is suitable, and any fluctuations or variations in the film frame rate will be compensated for by the apparatus hereinafter described.

The motion picture film 13 is advanced through the scanning station 14 in an upward direction (as viewed in Figure 1) by a sprocket wheel 20 driven in the clockwise direction by an electric motor 21. A variable speed drive 22 interposed between the electric motor and the sprocket wheel 20 may take various forms well known to those skilled in the art such as a gear box that can be controlled by the operator to select the correct rate for projection of the particular motion picture film. A stationary frame control 23 is effective when operated by the operator to halt the movement of film 13 and select a particular frame 18 for still viewing. The stationary frame control 23 may also take various forms known in the prior art such as a mechanical clutch for disengaging the electric motor 21 and positioning the particular frame within the scanning station 14.

The scanning light beam 10 passes through the film gate 15 and a frame 18 within the scanning station 14 in the raster pattern described and is modulated by the coloured image thereon. The modulated light beam is focussed by a lens 32 and is intercepted by dichloric mirrors 33 and 34 which are effective to separate and pass the blue, red and green colour components of the modulated light to respective photoresponsive devices 35, 36 and 37. The dichloric mirror 33 is effective to reflect the blue colour component to the surface of the photoresponsive device 35 and pass the green and red colour components to the surface of dichloric mirror 34. Dichloric mirror 34 is effective to transmit the green colour component to photoresponsive device 37 and reflect the red colour component to photoresponsive device 36. The photoresponsive devices 35, 36 and 37 translate the intensities of their respective colour components into electrical signals which are applied to the video colour signal processor 38 of the television transmitter or receiver.

The film 13 may also have a sound track which may be detected by an audio reproduction transducer 39 and translated into audio signals for the audio signal processor 40 of a television transmitter or receiver.

As is well known in the art, images displayed on the screen of a colour television tube are created electronically by the scanning of the screen with an electron beam using alternate odd and even line fields. In an odd line field the scanning electron beam of the television tube starts at the upper left corner of the screen and sweeps across the screen at uniform velocity to scan all the picture elements in one horizontal line. At the end of each trace the beam is rapidly returned to the left side of the screen to begin the next horizontal line. The horizontal line slopes downward in the direction of scanning because the vertical deflecting signal simultaneously produces a vertical scan motion which is very slow compared with the horizontal scanning speed. The slope of the horizontal line trace from left to right is greater than the slope of the retrace from right to left because the shorter time of the retrace does not allow much time for vertical deflection of the beam. Thus the electron beam is continuously and slowly deflected downwards as it scans the horizontal lines and its position is successively lower as the horizontal scanning proceeds through $262\frac{1}{2}$ lines.

At the bottom centre of the field, when the vertical retrace occurs, the electron beam is deflected back to the top centre of the screen by the vertical deflection signal to scan another $262\frac{1}{2}$ lines with an even line field. The horizontal line traces in the even line fields fall exactly between the horizontal line traces in the odd line fields. The standard television field rate in the United States is 60 fields per second. The successive combination of an odd line field and an even line field is referred to as a television frame having 525 scan lines. Therefore, the television frame rate in the United States is 30 frames per second.

The system as far as hereinbefore described with respect to Figure 1 is known in the prior art of telecine reproduction. In the past, practitioners of the art have either employed optical image deflecting apparatus interposed between the flying spot scanner and the scanning station or vertical deflection apparatus for producing a vertical deflection signal that compensates for movement of the film frames. These prior art approaches have required the employment of highly accurate film moving mechanisms to ensure that the scanning raster is properly registered with each moving film frame. In the practice of neither approach have the prior art practitioners provided a vertical deflection apparatus that automatically adapts to the detected rate of movement of the moving film. In this embodiment of the present invention, vertical deflection circuitry is provided that automatically adapts to a wide range of detected film frame rates, compensates for minor fluctuations or variations in the film frame rate and automatically provides the correct deflection signal when the

operator presents a stationary film frame for viewing.

Returning to Figure 1, there are shown two input conductors 41 and 42 to the vertical deflection circuit 9. A pulse generating circuit 43 applies an input signal LP on conductor 42 representative of the 60 Hz television field rate to the vertical deflection circuit 9. A light source 44 passes a beam of light through an aperture in a mask 45 and thereafter through each sprocket hole 19 as it becomes aligned with the mask aperture during movement of the film 13. A sprocket hole photosensor 46 detects the light passing through each sprocket hole 19 and generates an electrical signal SP in response thereto that has a frequency related to the film frame rate. This signal SP is applied on conductor 41 to another input of the vertical deflection circuit 9 which is responsive thereto to generate a signal having complex vertical deflection sawtooth wave form to control the vertical deflection of the electron beam in the direction of movement of the motion picture film 13. Thus the vertical deflection circuit 9 automatically adapts the vertical deflection of the electron beam to the frame rate of the film. In the event that a single stationary frame of film is scanned in the scanning station, the vertical deflection circuit 9 will respond to the absence of a signal output from photosensor 46 to deflect the electron beam in accordance with the standard television field scanning raster pattern.

The vertical deflection circuit 9 is shown in detail in the block diagram of Figure 2, and its operation is explained with reference to the exemplary wave form diagrams of Figure 3, the notations of which relate to the signals developed at specific points in the block diagram. In brief, the block diagram of Figure 2 includes multivibrator circuits 51 and 54 and N-AND gates 57 and 58 for transforming the detected output signal SP of sprocket hole photosensor 46 into two uniform half-frame rate frequency signals A' and B'. Sawtooth generators 61 and 62 are responsive to the signals A' and B' to produce two sawtooth wave form signals C and D. A logic and gating circuit including multivibrator circuits 92, 93 and 96 is responsive to signals A', B', and the 60 Hz signal LP, generated by pulse generating circuit 43, to control the passage of signals C and D alternately through OR gate 80 to the input of operational amplifier 87. A sawtooth wave form signal J is combined with the composite wave form signal C+D at the summing input of operational amplifier 87 to produce the complex vertical deflection wave form signal R for the flying spot scanner of Figure 1. The representative block diagrams of the multivibrator circuits have set S and reset R inputs and Y and $\bar{Y}$ outputs in accordance

with symbology employed by Millman and Taub in their textbook, *Pulse, Digital and Switching Wave Forms*, published by McGraw Hill Book Co., and in which suitable logic elements, multivibrator circuits and pulse generating circuits may be found to employ in this embodiment of the present invention. The

symbols Y and $\bar{Y}$ simply mean that the output signal on Y is the complement of the output signal on $\bar{Y}$.

The sprocket hole photosensor 46 of Figure 1 produces a signal SP shown in the wave form diagrams of Figure 3 when sprocket holes 19 pass between the sprocket hole sensor and the light source 44. The signal SP is a succession of pulses, the frequency of which is dependent upon the motion picture film frame rate, and the pulse width of which depends upon the sprocket holes. Therefore, the sprocket pulses of the signal SP may vary in width and affect the frequency of the signal SP. Referring to Figure 2, the signal SP is applied to a capacitive differentiating circuit 50 which produces the differentiated wave form SPD of Figure 3. In the absence of a positive transition of wave form SPD at the input terminal of monostable circuit 51, a positive output

appears at terminal $\bar{Y}$, whereas the other terminal Y is at ground potential. At the appearance of a positive transition of wave form SPD at its input, monostable multivibrator circuit 51 is effective to instantly produce a positive output at terminal Y for a fixed interval of time during which no positive output is developed at terminal $\bar{Y}$. The wave

forms FP and $\bar{FP}$ of Figure 3 result therefore on conductors 53 and 52 from the application of the wave form SPD to the input of monostable circuit 51.

Wave form FP is applied on conductor 53 to the input of frequency divider 54 which is effective to produce complementary half-frame rate frequency wave forms A and B at its out-

put terminals Y and $\bar{Y}$. Wave form A is applied by conductor 55 to one input of a NAND gate 57. Output wave form B is applied by conductor 56 to one input of a

NAND gate 58. The wave form $\bar{FP}$ is simultaneously applied to the other inputs of NAND gates 57 and 58.

NAND gate 57 is effective to produce an output signal when neither a pulse of wave

form A nor a pulse of wave form $\bar{FP}$ is applied to its inputs and thus will produce a wave form A' in response to wave forms A and $\bar{FP}$. In like manner, NAND gate 58 is only effective

tive to produce an output signal when neither a pulse of wave form B nor a pulse of wave

form FP is applied to its inputs and thus will produce an output wave form B' in response

5 to wave forms B and FP. It will be noted that wave forms A' and B' have pulse frequencies half the frequency of waveform FP and each is in phase with alternate pulses of wave form FP. Furthermore, the pulses of wave
10 forms A' and B' have periods selected for convenience as equal to the vertical retrace time period between successive scanning fields.

Wave forms A' and B' are applied by conductors 59 and 60 to the input terminals of sawtooth generators 61 and 62, respectively, whereby the positive transitions of wave forms A' and B' cause the generation of sawtooth wave forms C and D, respectively. Referring to Figure 3, sawtooth wave form C, for example, commences in synchronism with a negative transition of wave form A' and increases from ground potential to a positive potential sufficient in magnitude during uniform movement of the film to deflect vertically the scanning beam of the flying spot scanner through a distance equal to two film frames. When the positive transition of wave form A' repeats, sawtooth wave form C immediately decreases to ground potential and then increases again to the positive potential. In like manner, sawtooth wave form D repetitively increases from ground potential and decreases to ground potential in response to the positive transitions of wave form B'. The frequency of wave forms C and D is equal to half the frequency of wave forms FP.

Sawtooth wave forms C and D are applied by conductors 63 and 64 to the input terminals of a differential amplifier 65 which is effective to continuously detect the absolute voltage difference between wave forms C and D and to produce an output signal representative of such difference. Referring now to Figure 3, it will be observed that linear rate and frequency of sawtooth wave forms C and D and constant in the interval between t_0 to t_{10} . Therefore, the absolute voltage difference between sawtooth wave forms C and D at any instant during uniform movement of the film frames will be constant at one-half the peak voltage of the wave forms, although the voltage difference, with respect to either of the wave forms C or D, will change polarity during the positive transitions of wave forms A' and B'. The constant voltage output of differential amplifier 65 is applied by conductor 66 to one input terminal of a differential amplifier 67. Conductor 68 applies to the other input terminal a reference potential K equal in magnitude to that of the vertical deflection voltage necessary to deflect vertically the scanning beam of Figure 1 through a single film frame. The output signal of differential ampli-

fier 67 is applied by conductor 69 to a current source 70 to control the rate at which current is applied to sawtooth generators 61 and 62. In the event that the output of differential amplifier 65 increases above or decreases below the reference potential K due to a change in output of the sawtooth generators 61 and 62 over a relatively long period of time, the output signal of differential amplifier 67 is effective, when applied to current source 70, to increase or decrease the current supplied to sawtooth wave form generators 61 and 62. Effectively, the output of differential amplifier 67 represents a negative feedback signal to stabilize the amplitude of the outputs of sawtooth generators 61 and 62. If the frequency of waveforms C and D increases, the output of differential amplifier 65 will decrease, thus causing an increase in the slope of waveforms C and D so as to maintain their amplitude.

A single frame control circuit 73 is also responsive to the output signal of differential amplifier 65. The circuit 73 develops on conductors 74 and 75 a clamping signal that results in the substitution of a DC voltage level for the sawtooth wave forms C and D when the wave forms A' and B' have ceased. Wave forms A' and B' cease whenever the operator of the scanning device of Figure 1 halts the movement of film through operation of the stationary frame control 23 to view a single film frame within the scanning station.

The sawtooth wave forms C and D are also applied by conductors 76 and 77 to the input terminals 78 and 79 of OR gate 80. OR gate 80 is normally effective under the control of the logic and gating circuitry to be described hereinafter to switch portions of the sawtooth wave forms alternately by conductor 81 and resistor 84 to the summing input of the operational amplifier 87. A sawtooth wave form generator 82 is effective to produce a recurring signal having a field rate frequency saw tooth wave form depicted as J in Figure 3 in response to the positive transitions of signal LP appearing on conductor 42. Sawtooth wave form J is applied by conductor 83 and resistor 85 to the summing input of the operational amplifier 87. An adjustable DC centering potential is also applied through resistor 86 to the summing input of the operational amplifier 87. The wave form J, the centering potential, and the alternate portions of wave forms C and D switched through OR gate 80 are combined and amplified by operational amplifier 87. A resistor 88 connects the output of operational amplifier 87 to the summing input of the amplifier to determine its gain. The output of the operational amplifier 87 is thereafter applied to the vertical deflection yoke 8 of the flying spot scanner of Figure 1.

The bistable multivibrators or flip-flops 92, 93 and 96 are provided for alternately selecting portions of the two half-frame rate saw-

tooth wave forms C and D for combining with the television field rate sawtooth wave form J at the summing input of operational amplifier 87. The wave forms A' and B' are applied by conductors 89 and 90 to the "set" inputs S of bistable multivibrators 92 and 93, respectively. The pulse wave form LP is applied by conductors 42 and 91 to the "reset" input R of each bistable multivibrator. A positive going transition of wave form A' sets the state of the bistable multivibrator 92 to remove a positive

output voltage from terminal $\bar{Y}$. The positive going transition of pulse wave form LP resets the bistable multivibrator 92 to produce a posi-

tive output voltage at the output terminal $\bar{Y}$. The resultant wave form, designated AS in Figure 3, appears on line 94, and the time period in which the positive output voltage is

removed from the terminal $\bar{Y}$ is a measure of the difference in time between occurrences of the positive going transitions of wave forms A' and LP. In like manner wave forms B' and LP act on bistable multivibrator 93 to pro-

duce at its $\bar{Y}$ output terminal the wave form BR. The wave forms AS and BR are applied by conductors 94 and 95 to the set and reset inputs of bistable multivibrator 96. The result-

ant conditions E and F at the Y and $\bar{Y}$ outputs of bistable multivibrator 96 have an irregular period related to the difference in time between positive going transitions of wave forms AS and BR. The conditions represent open (dotted lines) and closed (solid

lines) current conduction paths at the Y and $\bar{Y}$ outputs of bistable multivibrator 96. In the closed condition, conductors 97 and 98 conduct current to ground potential. In the open condition, conductors 97 and 98 do not conduct current. The conductors 97 and 98 connected to input terminals 78 and 79 of OR gate 80 are therefore effective, during the closed period, to shunt the wave forms C and D, respectively, to ground.

Therefore, as shown by conditions E and F, the wave forms C and D pass alternately through the OR gate 80. The composite wave form C+D on line 81 at the exemplary 24 frame per second rate depicted in Figure 3 has an irregular period equal to $1/20$ th and $1/30$ th of a second in a repeating pattern. At transitions in the wave form, such as at times t_1 and t_2 , the amplitude of the wave form changes by an amount equal to the film frame height. The 60 Hz sawtooth wave form J has a vertical deflection at each of the time periods t_0 , t_1 , etc., equal to the deflection of an electron beam at the beginning of each television field. As indicated hereinbefore, the 60 Hz sawtooth wave form J is summed with the

composite wave form C+D at the summing input of the operational amplifier 87. The resultant complex vertical deflection raster wave form R necessarily has a slope different from the slopes of either wave form J or composite wave form C+D, and the actual vertical deflections of the scanning fields of the flying spot scanner are equal to $3/5$'s of a film frame height at the exemplary 24 frames per second rate.

Referring now to Figure 4, there is shown in the upper portion thereof motion picture film 13 (the usual sound track and sprocket holes being omitted for simplicity) in six successive positions designated A to F inclusive, the film being in these positions at the starting times of six successive field scanning periods. The successive frames of the film are designated by the Roman numerals I, II, III, etc., and the film is moved in the direction of the arrows continuously at the exemplary rate of 24 frames per second. In the lower portion of Figure 4 there is shown the resultant wave form R during the interval t_3 to t_6 of Figure 3.

At time t_3 , film frame I in position A is within the scanning station 14 of Figure 1. Superimposed upon the film frame I is an odd line scanning raster that starts at the top left of the film frame and proceeds downward in accordance with the slope of wave form R until t_4 . At time t_4 the scanning raster pattern has scanned an area in the scanning area on the face plate of the flying spot scanner equal to $3/5$'s of the film frame. However, as the dotted line a indicates, the film frame I has advanced in the direction of movement of the film so far that the odd line scanning raster generated by the scanning beam has scanned the entire frame of film.

At time t_4 , as shown in the wave form R, the scanning beam is deflected vertically upward to the top center of film frame I in position B, and an even line field is scanned on the face of the flying spot scanner through an area equal to $3/5$'s of the film frame. At time t_5 , the scanning beam is deflected vertically upward to the top left of frame I and proceeds downward to produce a second odd-line scan. At time t_6 , the scanning beam of the flying spot scanner, as shown by the vertical deflection wave form R, is not deflected but continues downward. As shown at position D, the scanning raster begins at the top center of the film frame II and continues through $3/5$'s of the film frame height. At time t_7 , the scanning beam is deflected upward again to the top left of film frame II which is scanned in an odd line field. At time t_8 , the scanning raster continues to the top center of film frame III which now is in exactly the same position with respect to the scanning station as film frame I at position A. Therefore, it may be observed that film frame I is scanned in odd, even, and odd fields and film frame II is scanned in even and odd fields.

The vertical deflection wave form R accomplishes this scanning in the sequence of fields shown for all successive film frames entering the scanning station at the exemplary film frame rate.

It should be understood that the wave forms of Figure 3 are simply illustrative of the operation of the elements of Figure 2 in the production of a wave form R at one nominal frame rate.

In a similar manner, the circuit of Figure 2 is effective to produce a wave form R suitable for any integral or non-integral film frame rate. Only the wave forms LP and J of Figure 3 remain constant, whereas the period of sawtooth waves C and D and the period of conditions E and F depend upon the detected film frame rate and the constant field scanning rate. For example, each frame of a film recorded at 20 frames per second is scanned by three fields. For all the frame rates between 20 and 30 frames per second, the film frames are scanned by either two or three fields. For all the frame rates between 10 and 20 frames per second, the film frames are scanned by from three to six fields. For frame rates between 1 and 10 frames per second, the film frames are scanned by from 60 to 6 fields in each second.

The deflection circuit 9 is also effective to produce a signal R that compensates for any minor fluctuations in the distance between sprocket holes in the film created during the manufacture of the film or by film shrinkage. Referring back to Figure 3, and particularly to sprocket pulse SP1, there is shown a detected fluctuation in the spacing of the film frames. The pulses of wave forms A' and B' generated in response to the detection of wave form SP1 are effective to cause sawtooth wave forms C and D to decrease to ground potential and restart at a time earlier than they normally would. The voltage difference between wave forms C and D at time t_{10} is decreased until the next sprocket pulse wave form B', at which time the voltage difference will stabilize as the period between successive sprocket pulses becomes constant. Wave forms AS and BR are also reduced to ground potential at respective times earlier than they normally would. Complementary conditions E and F at time t_{10} also change in duration since they are dependent upon the positive transitions of wave forms AS and BR. The durations of conditions E and F after time t_{10} are reversed with respect to the durations existing before time t_{10} , that is previous to time t_{10} signal C is switched to for a period of two rasters, and signal D for a period of three rasters, and after time t_{10} the periods are three rasters and two rasters, respectively.

An examination of the composite wave form C+D at time t_{10} reveals a transition of a magnitude less than a full frame height. When the composite wave form C+D and wave form

J are summed, the resultant wave form R at time t_{10} differs from the previous pattern of the wave form. Since the positioning of the sprocket pulse SP1 indicates that the film frame to be scanned appears in the scanning station earlier than it regularly should, the wave form R at time t_{10} is effective to deflect the scanning beam at the start of the field to be scanned a distance effective to reach the top of the film frame. Thereafter, the wave form R repeats itself in the sequence shown before sprocket pulse SP1. In like manner, any variation in the spacings of the sprocket pulse SP1 will be compensated for in the production of the resultant sawtooth wave form R.

Referring now to Figure 5, there is shown a circuit diagram representative of preferred embodiments of the components within the dotted line 99 of Figure 2 which include sawtooth generators 61 and 62, differential amplifiers 65 and 67, current source 70, single frame control circuit 73 and OR gate 80.

Referring now to sawtooth generator 61, the input wave form A' of Figure 2 is applied to the base of transistor Q1 which is normally nonconductive. A positive transition of wave form A' causes transistor Q1 to conduct current from +V1 to the base of normally nonconductive transistor Q2. Transistor Q2 is rendered conductive for the duration of each positive voltage pulse of the wave form A'. When transistor Q2 is rendered conductive, it rapidly discharges capacitor C1, which had been positively charged through the operation of the current source 70. Upon the termination of each positive voltage pulse of wave form A', transistor Q2 is rendered nonconductive and capacitor C1 begins to charge to +V1 through the collector-emitter conduction path of transistor Q3. The conduction of current source transistor Q3 is controlled by a negative feedback signal generated on conductor 69 by the output of the differential amplifier 67 in a manner that will be described hereinafter.

When the capacitor C1 is initially discharged to ground potential, transistors Q4 and Q5, arranged in a Darlington circuit configuration, are rendered heavily conductive. Transistor Q6 is immediately rendered nonconductive as its base terminal is switched by transistor Q5 to ground potential. As C1 gradually recharges to the positive voltage source, transistors Q4 and Q5 conduct less and less current at a linear rate, and transistor Q6 conducts more current at the linear rate as the voltage rises at its base terminal. The sawtooth wave form C is therefore created by the linear increase in conduction of transistor Q6.

The sawtooth wave generator 62 operates in like manner to produce the sawtooth wave form D at the emitter terminal of transistor Q6'. In both cases the linearly increasing sawtooth wave forms are terminated at the occurrence of each positive transition of wave

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105

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120

125

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forms A' and B' at the base terminal of transistors Q1 and Q1', respectively.

Sawtooth wave forms C and D are applied by conductors 76 and 77 to the base electrodes of transistor Q7 and Q7', respectively, that constitute OR gate 80. The conditions E and F are applied to the base electrodes of transistors Q7 and Q7', by conductors 97 and 98, respectively. The composite wave form C+D appears at the emitter terminals of transistors Q7 and Q7' on conductor 81.

The base-emitter potential drop of transistors Q6 and Q7 is offset by the base-emitter potential gain of the Darlington circuit constituted by transistors Q4 and Q5. Therefore, temperature dependent voltage variations in the composite wave form C+D are substantially minimized.

It is essential that the transitions from one sawtooth to the other in the composite wave form C+D always produce (at stable frame rates) a vertical deflection of the scanning beam that, when imaged on the film, has a magnitude equal to the centre to centre spacing of adjacent film frames. This is accomplished by producing the absolute value of the potential difference between wave forms C and D in differential amplifier 65. The sawtooth wave forms C and D are applied by conductors 63 and 64 across resistive networks R2 and R2' to the base terminals of transistors Q8 and Q8', respectively, that constitute the differential amplifier 65. The output signal of the differential amplifier 65 is applied, through two filter circuits RC1 and RC2 and by conductor 66, to one input of differential amplifier 67.

Differential amplifier 67 consists of transistors Q9 and Q10 that generate a negative feedback signal to control the conduction of current source transistors Q3 and Q3' through comparison of the output signal on conductor 66 with a reference signal K having a magnitude equal to the voltage necessary to achieve a deflection equal to the centre to centre spacing of adjacent film frames. The output signal of differential amplifier 65 is applied to the base terminal of transistor Q9, whereas the reference signal K, determined by variable resistor R4, is applied to the base terminal of transistor Q10. Any difference between the reference signal and the output signal over a period of time determined by the time constant of filter circuit RC2 alters the negative feedback signal level on conductor 69. Conductor 69 is connected to the base terminals of transistors Q3 and Q3', and the negative feedback signal is effective to control the rate at which capacitors C1 and C1' are charged. Therefore, if, over a period of several film frames, the voltage difference between the wave forms C and D rises above or falls below the reference voltage, conduction of the transistors Q3 and Q3' is increased or decreased respectively, until the potential difference

stabilizes. Variable resistors R3 and R3' are adjusted to compensate for any difference in individual conduction characteristics of the transistors Q3 and Q3'.

It should be noted at this point, that the differential amplifier 67 controlling the current source circuits 70 in the manner described above will automatically adjust the slope and maximum amplitude of the sawtooth wave forms to conform with the frame rate of the film to be scanned. If the centre to centre spacing of the film frames is changed, variable resistor R4 need only be adjusted to produce the proper sawtooth wave forms.

Filter circuit RC2 referred to hereinbefore has a relatively long time constant, so that it is only gradually responsive to a change in the absolute difference voltage $|C-D|$. Filter circuit RC1, however, has a relatively short time constant so that it closely responds to changes in the difference voltage $|C-D|$. The voltage developed across filter circuit RC1 is applied by conductor 72 to the input of the single frame control circuit 73.

Reference to the wave forms of Figure 3 is necessary to describe the operation of single frame control circuit 73. As described hereinbefore, the wave forms A' and B' are developed in response to the detected sprocket pulses of the signal SP. When the operator of the scanning system desires to scan a single frame, he will halt movement of the film by operating the stationary frame control 23 and prevent the further generation of sprocket pulses. During still frame scanning, only the wave form J is necessary to deflect the electron beam to scan the film frame.

For example, assume that at instant t_1 film movement is halted; wave form C as usual will continue to rise until it reaches its peak voltage after t_2 , whereupon it will continue to rise at its previous rate until transistor Q6 reaches current saturation. Since pulse A' is not generated after t_2 , wave form C will not restart at ground potential, and its output potential at resistor R2 will become, at saturation, relatively constant. Wave form D, appearing at resistor R2', however, will continue to rise in voltage at its predetermined rate. The voltage difference between wave forms C and D at some point after t_2 , will begin to rapidly decrease on network RC1, whereas it will slowly decrease on network RC2.

The single frame control circuit 73 contains transistor Q11 which is rendered normally conductive by the potential difference on conductor 72, to prevent transistor Q12 from conducting current. In the nonconductive state of transistor Q12, a voltage developed at a point between resistors R7 and R5 is greater than the maximum potential developed by the sawtooth generators 61 and 62 to conductors 76 and 77, respectively. Therefore, the conduction of diodes D1 and D2 during continuous movement of the film is always blocked.

However, as the voltage difference decreases after time t_5 , transistor Q11 is rendered non-conductive and transistor Q12 is rendered conductive to bypass resistor R6. A potential equal to the average potential of the composite sawtooth wave forms C+D is developed at the connection point of resistors R7 and R5 and applied to the cathodes of diodes D1 and D2.

At time t_5 , it will be observed that condition E appearing on conductor 97 is effective to clamp the base electrode of transistor Q7 to ground potential. Therefore, diode D2 will remain reverse biased. However, diode D1 will be rendered conductive as wave form D increases in potential above the average potential of composite wave form C+D. The conduction of diode D1 is effective to clamp the base electrode of transistor Q7' to the average potential of the composite wave form C+D. A DC level output signal is therefore generated on line 81 by the conduction of transistor Q7'.

Therefore, the 60 field per second sawtooth wave form J and the DC output signal on conductor 81 may be summed at the input of the operational amplifier 87 to produce a vertical deflection signal effective to scan a single film frame centered in the scanning station.

From the description of the preferred embodiment set forth above, it is apparent that the invention can be practiced in many alternative ways. For example, the single frame control circuit of Figure 5 could be replaced by a switch operated in conjunction with the stationary frame control 23 of Figure 1 that would substitute for the wave form C+D the average DC signal.

Furthermore, it is apparent that the preferred embodiment of the invention, without modification, will operate in substantially the same manner at the European, 50 fields per second, television field rate or any other standard field rate.

Also, it is apparent that the rate of movement of the motion picture film or other image bearing media may be detected from indicia recorded on the medium or on a timing disc associated with the sprocket wheel.

As may be seen, a system has been disclosed for transforming the images and sound track of an ordinary, inexpensive motion picture film into respective video and audio signals for television transmission or direct connection to the antenna terminals of a conventional television receiver. The system is compatible with professional and amateur motion picture films, both black and white and color and with or without sound tracks.

In summary, it will be readily apparent that by virtue of the arrangements disclosed whereby the vertical deflection circuit is directly controlled by the detected film frame rate, deflection of the scanning beam is readily effected in exact synchronism with the film

movement. The vertical deflection circuit disclosed automatically adapts to a wide range of detected film frame rates, compensates for minor fluctuations in the spacing between film frames or the frame rate itself, and senses that a single frame is to be scanned and automatically applies the proper vertical deflection to the scanning beam to scan the stationary frame.

The invention has been described in detail with particular reference to preferred embodiments thereof, but it will be understood that variations and modifications can be effected within the scope of the invention as defined by the appended claims.

WHAT WE CLAIM IS:—

1. A telecine apparatus for deriving an image signal from an information bearing medium having a plurality of successive image frames thereon, comprising drive means for driving the information bearing medium through a scanning station, raster generating means for generating a raster comprising a plurality of spaced lines upon the information bearing medium at the scanning station, a detector for detecting the frequency of passage of the image frames on the information bearing medium through the scanning station, signal generating means for generating first and second signals, each having a waveform of periodicity dependent upon the detected frequency, and having a frequency which is a submultiple of the detected frequency, and switching means for switching to the first or the second signal, and for controlling the position of the raster in dependence on the instantaneous value of the switched to signal.

2. An apparatus as claimed in Claim 1 wherein the information bearing medium is a motion picture film.

3. An apparatus as claimed in Claim 1 or 2 wherein the raster generating means comprises a flying spot scanning device having horizontal and vertical deflection circuit means for repetitively generating the raster at a predetermined frequency, equal to a predetermined television field rate frequency and the apparatus further comprises photosensitive means arranged with respect to the scanning station for providing said image signal which is representative of the information on the scanned image frames.

4. An apparatus as claimed in any preceding claim, wherein the information bearing medium consists of motion picture film having a sprocket hole associated with each image frame thereon and wherein the detector is disposed with respect to the path of movement of the film for producing a signal at the detected frequency upon the movement of the sprocket hole past the detector.

5. An apparatus as claimed in Claim 4 wherein the detector comprises means for directing radiation towards the path of move-



However, as the voltage difference decreases after time t_0 , transistor Q11 is rendered non-conductive and transistor Q12 is rendered conductive to bypass resistor R6. A potential equal to the average potential of the composite sawtooth wave forms C+D is developed at the connection point of resistors R7 and R5 and applied to the cathodes of diodes D1 and D2.

At time t_0 , it will be observed that condition E appearing on conductor 97 is effective to clamp the base electrode of transistor Q7 to ground potential. Therefore, diode D2 will remain reverse biased. However, diode D1 will be rendered conductive as wave form D increases in potential above the average potential of composite wave form C+D. The conduction of diode D1 is effective to clamp the base electrode of transistor Q7' to the average potential of the composite wave form C+D. A DC level output signal is therefore generated on line 81 by the conduction of transistor Q7'.

Therefore, the 60 field per second sawtooth wave form J and the DC output signal on conductor 81 may be summed at the input of the operational amplifier 87 to produce a vertical deflection signal effective to scan a single film frame centered in the scanning station.

From the description of the preferred embodiment set forth above, it is apparent that the invention can be practiced in many alternative ways. For example, the single frame control circuit of Figure 5 could be replaced by a switch operated in conjunction with the stationary frame control 23 of Figure 1 that would substitute for the wave form C+D the average DC signal.

Furthermore, it is apparent that the preferred embodiment of the invention, without modification, will operate in substantially the same manner at the European, 50 fields per second, television field rate or any other standard field rate.

Also, it is apparent that the rate of movement of the motion picture film or other image bearing media may be detected from indicia recorded on the medium or on a timing disc associated with the sprocket wheel.

As may be seen, a system has been disclosed for transforming the images and sound track of an ordinary, inexpensive motion picture film into respective video and audio signals for television transmission or direct connection to the antenna terminals of a conventional television receiver. The system is compatible with professional and amateur motion picture films, both black and white and color and with or without sound tracks.

In summary, it will be readily apparent that by virtue of the arrangements disclosed whereby the vertical deflection circuit is directly controlled by the detected film frame rate, deflection of the scanning beam is readily effected in exact synchronism with the film

movement. The vertical deflection circuit disclosed automatically adapts to a wide range of detected film frame rates, compensates for minor fluctuations in the spacing between film frames or the frame rate itself, and senses that a single frame is to be scanned and automatically applies the proper vertical deflection to the scanning beam to scan the stationary frame.

The invention has been described in detail with particular reference to preferred embodiments thereof, but it will be understood that variations and modifications can be effected within the scope of the invention as defined by the appended claims.

WHAT WE CLAIM IS:—

1. A telecine apparatus for deriving an image signal from an information bearing medium having a plurality of successive image frames thereon, comprising drive means for driving the information bearing medium through a scanning station, raster generating means for generating a raster comprising a plurality of spaced lines upon the information bearing medium at the scanning station, a detector for detecting the frequency of passage of the image frames on the information bearing medium through the scanning station, signal generating means for generating first and second signals, each having a waveform of periodicity dependent upon the detected frequency, and having a frequency which is a submultiple of the detected frequency, and switching means for switching to the first or the second signal, and for controlling the position of the raster in dependence on the instantaneous value of the switched to signal.

2. An apparatus as claimed in Claim 1 wherein the information bearing medium is a motion picture film.

3. An apparatus as claimed in Claim 1 or 2 wherein the raster generating means comprises a flying spot scanning device having horizontal and vertical deflection circuit means for repetitively generating the raster at a predetermined frequency, equal to a predetermined television field rate frequency and the apparatus further comprises photosensitive means arranged with respect to the scanning station for providing said image signal which is representative of the information on the scanned image frames.

4. An apparatus as claimed in any preceding claim, wherein the information bearing medium consists of motion picture film having a sprocket hole associated with each image frame thereon and wherein the detector is disposed with respect to the path of movement of the film for producing a signal at the detected frequency upon the movement of the sprocket hole past the detector.

5. An apparatus as claimed in Claim 4 wherein the detector comprises means for directing radiation towards the path of move-



ment of the sprocket holes; and means responsive to the radiation modulated by the sprocket holes for producing the signal at the detected frequency.

5 6. An apparatus as claimed in any preceding claim, wherein each image frame has a first dimension along the length of the information bearing medium, the raster has a second dimension along the length of the information bearing medium, and having control means responsive to the instantaneous value of the switched to signal to control the second dimension to be smaller than said first dimension by an amount sufficient to compensate for movement of the scanned image frame relative to the scanning station.

7. An apparatus as claimed in any preceding claim, wherein the frequency of the first and second signals is equal to one-half the detected frequency and the second signal is out of phase by 180° with respect to the first signal.

8. An apparatus as claimed in Claim 4, or any claim appendent thereto, wherein the switching means is effective to switch to the first or the second signal at the commencement of the raster next following detection of a sprocket hole.

9. An apparatus as claimed in any preceding claim, wherein the drive means has a first mode of operation in which the information bearing medium is continuously driven through the scanning station and a second mode of operation in which the information bearing medium is stationary at the scanning station.

10. An apparatus as claimed in Claim 9, further comprising means whereby a stationary image frame is scanned at the scanning station in the second mode of operation.

11. An apparatus as claimed in any preceding claim, wherein the switching means is responsive to the commencement of a raster that immediately succeeds, in time, switching of the switching means to the first or the second signal, for producing a clamping signal

arranged to clamp the second or the first signal respectively.

12. An apparatus as claimed in Claim 11, including combining means for selecting the unclamped signal of the first and second signals, and combined the selected signal with the vertical scanning signal produced by the raster generating means.

13. An apparatus as claimed in Claims 9 and 12 further comprising means responsive to operation of the drive means in the second mode for producing a further clamping signal and means for applying the further clamping signal to the combining means to inhibit the selected signal.

14. An apparatus as claimed in any preceding claim, wherein the signal generating means comprises first and second respective sawtooth wave form generating circuits, for producing, as said first and second signals, respective first and second sawtooth wave form signals having equal amplitudes and substantially equal durations.

15. An apparatus as claimed in Claim 14, further including means for controlling said amplitudes, which means comprises a negative feedback network including a first differential circuit responsive to the first and second sawtooth wave form signals for producing a first potential equal to the absolute value of the instantaneous potential difference between the sawtooth wave form signals, means for providing a reference potential, a second differential circuit responsive to the absolute difference potential and the reference potential for producing a second potential, and a current source having its output connected to the first and second sawtooth wave form generating circuits and responsive to the second potential for controlling the amplitudes of the first and second sawtooth wave form signals.

16. A telecine apparatus as hereinbefore described, with reference to and as illustrated in the accompanying drawings.

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