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(54) GAIN CONTROL APPARATUS

(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 apparatus for generating a complex sawtooth waveform signal for use in film reproduction television apparatus, and more particularly, to a gain control circuit for regulating the gain of the signal generating circuit.

In apparatus of the type described in British Patent No. 1,361,457 a flying spot scanning device is used to scan the frames of a motion picture film with a beam of light in the standard interlace scanning pattern. The beam of light is modulated by the image pattern on the film frame, and the modulated light is detected and transformed into a television video signal, (for example, an NTSC video signal which is the television waveform used in the United States) by optical-to-electrical signal transducer apparatus. The video signal may be used to control the intensity of the electron beam of a television receiver, and thus the reproduction of the motion picture film frame on the television screen. Since the motion picture film frame is moved relative to the beam of light produced by the flying spot scanning device at a frame rate which is generally less than the field scanning rate for the spot scanning device, the scanning beam is deflected 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.

In the aforementioned British Patent No. 1,361,457 means are provided for continuously moving the motion picture film past a scanning station at the nominal rate at which the

image frames are recorded on the motion picture film. A sensing device detects the actual rate of movement of the film frames and generates a first signal having a first frequency rate related to the rate of movement of the motion picture film. The first signal is applied to a vertical deflection circuit including logic circuitry for producing, alternately, first and second trigger signals in response to alternate pulses of the train of pulses of the first signal. The first and second trigger signals are applied to first and second saw-tooth waveform signal generators to control the production of respective first and second, 180° out-of-phase, sawtooth waveform signals, each of the sawtooth waveform signals having a second frequency equal to an integral sub-multiple of the frequency of the first signal. In the preferred embodiment of the invention, disclosed in the aforementioned British Patent No. 1,361,457 the second frequency of each sawtooth waveform signal is equal to one-half the frequency of the first signal.

In the aforementioned British Patent No. 1,361,457 the first and second sawtooth waveform signals are continuously applied to differential amplifiers which compare the instantaneous difference between the amplitudes of the first and second sawtooth waveform signals with a reference amplitude for regulating the gain of the first and second sawtooth waveform signal generating circuits. The differential amplifier gain control circuit, disclosed in the aforementioned British Patent No. 1,361,457 incorporates first and second differential amplifiers and complex filter circuits for detecting long term and short term variations in the difference between the amplitudes of the first and second sawtooth waveform signals. Because the polarity of the difference signals applied to the filter circuits reverses at each occurrence of the trigger signal, the gain control circuit becomes very complicated in order to prevent instability. Furthermore, due to their construction, the first and second sawtooth waveform signal

generating circuits tend to be unstable under some conditions which reduce the effectiveness of the vertical deflection circuit consistently to control the deflection of the flying spot scanner with respect to the actual movement of the film through the scanning station of the telecine apparatus.

It is an object of the present invention to provide an improved gain control circuit and a method of controlling the gain of a circuit.

According to the present invention, there is provided an apparatus for encoding information from a motion picture film into electrical signals having a format which is compatible with a television receiver, in which two vertical deflection signals, substantially 180° out-of-phase, are generated and are alternately fed to a vertical deflection apparatus, and in which the slope of the vertical deflection signals is controlled by gain control means, as a function of the rate of travel of the motion picture film, said gain control means comprising means for sampling each of the vertical deflection signals at a point approximately midway in its cycle, means for comparing the sampled signals with a reference signal, and means for controlling the slope of the vertical deflection signals as a function of the output of the comparing means.

The invention also provides a method of regulating the rate of change of an output signal having a linearly changing waveform established in accordance with the frequency of occurrence of a first signal in response to a reference signal having a reference level, said method comprising the steps of:

determining the instantaneous level of the linearly changing waveform of the output signal at each occurrence of the first signal;

comparing such determined level with the reference level of the reference signal and producing a comparison signal having a control level related thereto;

storing the comparison signal during the period between successive occurrences of the first signal; and controlling the output signal in accordance with the said stored 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 of a vertical deflection circuit; and

Figure 2 is a view showing the waveforms of various signals developed at particular points in the vertical deflection circuit of Figure 1.

In the aforementioned British Patent No. 1,361,457, a telecine apparatus, in which the preferred embodiment of deflection circuit in accordance with the present invention is to be employed, is shown in greater detail. Briefly, the telecine apparatus includes a flying spot scanning system for converting image frames on a continuously moving

motion picture film into video signal frames suitable for television transmission or for direct application to a television receiver. The flying spot scanning system includes a cathode ray tube which produces a light beam which is deflected over the film frame area under the control of a horizontal and vertical deflection circuit. The vertical deflection circuit develops a vertical deflection signal having a complex sawtooth waveform for controlling the vertical deflection of the flying spot scanner in response to a first input signal developed by a film perforation sensor and a second signal developed from the standard (U.S.) 60 Hz. a.c. power line frequency. The first signal constitutes a train of pulses developed by the perforation sensor having a frequency of repetition equal to the frame rate of movement of the continuously moving motion picture film through the scanning station of the flying spot scanning system.

The beam of light generated by the cathode ray tube under the control of the horizontal and vertical deflection circuits passes through the film frame and is directed upon optical-to-electrical signal transducer apparatus for converting the optical image of the film frame into NTSC color video field signals for transmission or direct application to a colour television receiver for reproduction of the scanned image frames at the standard (U.S.) 60 Hz. television field rate frequency. As described in the aforementioned British Patent No. 1,366,457 the vertical deflection circuit is designed to produce a complex sawtooth waveform, vertical deflection signal suitable to control flying spot scanning at 60 television fields per second of any integral or non-integral motion picture film rate of movement. For example, the vertical deflection circuit develops a complex sawtooth waveform signal having a 60 Hz. frequency that automatically scans three times each frame of a motion picture film moved through the telecine apparatus at a frame rate of 20 frames per second. For all the frame rates between 20 and 30 frames per second, film frames are scanned two or three times. For all the frame rates between 10 and 20 frames per second, each film frame is scanned either three or four times. For frame rates between 0 and 10 frames per second, the film frames are scanned from 60 to 6 times per second. Furthermore, the vertical deflection circuit is designed automatically to compensate for changes in the positioning of film frames on the motion picture film with respect to each other and for changes in the rate of movement of the film frames. The speed and accuracy of the vertical deflection circuit in following the rate of movement of the film frames is highly important to the successful operation of the telecine apparatus. Failure of the vertical deflection circuit accurately to track the moving film frames may contribute to an unsteady

picture displayed by the colour television receiver.

Referring now to the drawings and firstly to Fig. 1, as one preferred embodiment of the present invention, there is shown a vertical deflection circuit including a logic circuit 10, a sawtooth waveform signal generating circuit 12, a 60 Hz. sawtooth waveform signal generator 16, and a vertical deflection amplifier 18, the output terminal 20 of which is applied to the vertical deflection yoke of the cathode ray tube of the telecine apparatus disclosed in the aforementioned British Patent No. 1,361,457. The operation of the vertical deflection circuit of Fig. 1 is explained with reference to the exemplary waveform diagrams of Fig. 2, the notation of which relate to the signals developed at specific points in the block diagram of Fig. 1 at a frame rate of movement of 24 frames per second.

The logic circuit 10 of Fig. 1 includes a first input terminal 22 connected to the output of a perforation sensor for receiving a first signal SP and applying it to a pulse shaping circuit 24. An output signal FP of the pulse shaping circuit 24 is applied to first input terminals of AND gates 26 and 28 and to a Trigger T input terminal of a first bistable multivibrator 30. As shown in Fig. 2, the first bistable multivibrator 30 divides by 2 the frequency of the first signal SP and develops, the half frame rate frequency complementary squarewave signals A and B at its output terminals Y and Y'. The half frame rate frequency signals A and B are applied to the second input terminals of the AND gates 26 and 28. The AND gates 26 and 28 respond to the alternate half frame rate frequency signals A and B, respectively, shown in Fig. 2 and to the output signal FP to develop the first and second, half frame rate frequency, trigger signals A' and B'. Thus the logic circuit 10 as described produces first and second, half frame rate frequency, trigger signals A' and B' in response to the train of pulses constituting the first signal SP.

The first and second trigger signals A' and B' are applied to first and second sawtooth waveform signal generating circuits 32 and 32' respectively. The circuit 32 includes an operational amplifier 34 having an input terminal 36 and an output terminal 38, a capacitor 40 connected to the input terminal 36 and the output terminal 38 of the operational amplifier 34, and a field effect transistor (FET) 42 whose source and drain terminals are connected, in parallel with capacitor 40, to the input terminal 36 and the output terminal 38. The FET 42 is normally nonconductive when the positive going pulse of the first trigger signal A' is not present at its gate electrode. Therefore, in the absence of a positive going pulse of the first trigger signal A', the operational amplifier 34 is operative in conjunc-

tion with the capacitor 40 to invert the polarity of the current signal applied to the input terminal 36 and to integrate the current signal, over the period of time between succeeding positive going pulses of the first trigger signal A', through the charging action of the capacitor 40. Thus, as shown in Fig. 2, during the time interval between times t_1 and t_2 , the current signal applied to the input terminal 36 is inverted by the operational amplifier 34, and the inverted current signal at the output terminal 38 linearly charges the capacitor 40. As the capacitor 40 charges, a first linearly changing sawtooth waveform signal C shown in Fig. 2 develops at the output terminal 38. Upon each occurrence of the first trigger signal A', the field effect transistor 42 is rendered conductive to discharge the voltage stored by the capacitor 40 to ground potential. In like manner, the similarly numbered elements of the second sawtooth waveform signal generating circuit 32' develop the second sawtooth waveform signal D during the time intervals between the positive going pulses of the second trigger signal B'.

As shown in Fig. 2, the first and second sawtooth waveform signals C and D have positive going polarities and linearly changing waveforms. The employment of the operational amplifiers 34 and 34', and the capacitors 40 and 40', insures that the positive going slope or rate of change of the first and second sawtooth waveform signals is extremely linear. The FET's 42 and 42' are operative, when rendered conductive, consistently to discharge the capacitors 40 and 40' to ground potential in the time period of the positive going pulses of the first and second trigger signals A' and B'. The fact that the sawtooth waveforms of the first and second sawtooth waveform signals C and D are positive in polarity indicates that the current input signal applied to the input terminals 36 and 36' is negative in polarity. It will be apparent that the first and second sawtooth waveform signal generators 32 and 32' could as well produce first and second sawtooth waveform signals C and D that are negative in polarity in response to positive current input signals applied to the input terminals 36 and 36'. Similarly, it will be apparent that the pulses of the first and second trigger signals A' and B' could be negative in polarity, and that the FET's 42 and 42' could be selected to be rendered conductive in response to negative pulses of the first and second trigger signals A' and B'. For sake of convenience, the symbol employed for the FET 42 and 42' is generalized, and it will be apparent that any FET type may be employed, with proper biasing, to perform the discharge function for the capacitors 40 and 40' depending on the polarity of the trigger signals A' and B' and the polarity of the voltage stored by the capacitors 40 and 40'. Also for sake of convenience, the conventional

biasing of the operational amplifiers 34 and 34' have been omitted from Fig. 1.

As described in greater detail hereinbelow, the first and second sawtooth waveform signals C and D are selectively and alternatively combined with a third sawtooth waveform signal J of Fig. 2 which is negative in polarity and has a frequency of 60 Hz., the NTSC television field rate frequency in use in the United States, to produce the vertical deflection signal R which has a complex sawtooth waveform signal that repeats, in the example of 24 frames per second shown in Fig. 2, every five fields. Since the standard vertical deflection signal J has a constant slope sufficient vertically to scan the stationary film frame, the slope of the first and second sawtooth waveform signals C and D determines the resultant slope of the complex sawtooth waveform of the vertical deflection signal R. The slope of the vertical deflection signal R over the television field period insures that the scanning raster pattern compressed in amplitude in an amount sufficient to control the deflection of the scanning beam over a continuously moving film frame which effectively expands the compressed raster pattern to cover the film frame. The instantaneous amplitudes (governed by the slope) of the first and second sawtooth waveform signals C and D also control the position of the scanning beam at the beginning of each vertical deflection field with respect to the moving film frames. Therefore, the slopes of the sawtooth waveforms of the first and second sawtooth waveform signals C and D are representative of the instantaneous position of the motion picture film frames with respect to the scanning beam of the flying spot scanner. Accordingly, it is preferred that the slopes of the first and second sawtooth waveform signals C and D are regulated as a function of the rate of movement of the motion picture film frames with respect to the flying spot scanner.

The improved regulating circuit of the present invention for regulating the slope or rate of change of the first and second sawtooth waveform signals C and D in relation to the detected velocity of the moving film frames comprises first and second sampling FET's 44 and 46 connected to the output terminals 38 and 38' of the first and second sawtooth waveform signal generating circuits 32 and 32' to pass the first and second sawtooth waveform signals C and D, respectively, to a common negative input terminal 47 of the operational amplifier 48. FET's 44 and 46 are rendered conductive by each positive going pulse of the second and first trigger signals B' and A', respectively. The integrating capacitor 50 is connected across the negative input terminal 47 and the output terminal 52 of the operational amplifier 48. A reference signal is applied to the positive input terminal 54 of the operational ampli-

fier 48. The output terminal 52 is connected through the inverter 56, the variable resistor 58, and the feedback resistors 60 and 62 to the input terminals 36 and 36' of the operational amplifiers 34 and 34', respectively. The gain control circuit establishes the level of the slope control current input signal applied to the input terminals 36 and 36' of the operational amplifiers 34 and 34', and the level of the slope control current input signal establishes the charging rate for the charge accumulated by the capacitors 40 and 40'. Therefore, the higher the level (in absolute terms) of the slope control current input signal, the faster the capacitors 40 and 40' are charged by the operational amplifiers 34 and 34'. The slopes of the first and second sawtooth waveform signals C and D increase as the charging rate of the capacitors 40 and 40' increase. The level of the slope control current input signal is established by the charge accumulated by capacitor 50 at the output terminal 52 (shown as signal H in Fig. 2) in response to the sampled amplitudes of the first and second sawtooth waveform signals C and D applied to the negative input terminal 47 and in response to the reference amplitude of the reference signal applied to the positive input terminal 54 of the operational amplifier 48. Referring to Fig. 2, the first trigger signal A' resets the first sawtooth waveform signal C to zero shortly after the time t_0 , for example, and simultaneously, by rendering the second sampling FET gate 46 conductive, passes the second sawtooth waveform signal D to the negative input terminal 47 of the operational amplifier 48. The operational amplifier 48 subtracts the amplitude of the second sawtooth waveform signal D from the amplitude of the reference signal applied to the positive input terminal 54 of the operational amplifier 48, and the resulting difference signal H is accumulated by the capacitor 50. As shown in Fig. 2, the signal H is relatively steady over a period of time as the detected film frame rate remains relatively constant and the first and second sawtooth waveform signals C and D are sampled, alternately, by the second and first trigger signals B' and A', respectively. The signal H is inverted by the inverter 56 and is applied through the variable resistor 58 and the resistors 60 and 62 as the slope control current input signal to the input terminals 36 and 36' of the operational amplifier 34 and 34'.

The amplitude of the reference signal applied to the positive input terminal 54 of the operational amplifier 48 is selected so that the level of the slope control current input signal applied to the input terminals 36 and 36' of the operational amplifiers 34 and 34' is sufficient to produce, when integrated, maximum amplitudes of the first and second sawtooth waveform signals C and D that are

equal to twice the amplitude of a vertical deflection signal which, when applied to the vertical deflection yoke of the flying spot scanner, is sufficient to deflect the scanning beam over a distance equal to twice a stationary film frame height. Thus, the reference signal amplitude is one-half the maximum amplitude of the sawtooth waveform signals C and D. The movement of the film at a stable rate produces the first and second sawtooth waveform signals C and D and the signal H which has an amplitude that reflects the actual rate of movement of the motion picture film frames. As the rate of movement decreases, the absolute amplitude of the signal H decreases, the current input signal decreases, and the slope of the first and second sawtooth waveform signals decreases, so that, over the period of time between successive pulses of the first and second trigger signals A' and B', the maximum amplitudes of the first and second sawtooth waveforms C and D remain constant at the reference signal level. Conversely, as the film frame rate of movement increases, the time periods between successive pulses of the first and second trigger signals A' and B' decrease, the signal level of the signal H increases, the current input signal increases in absolute value, and the slopes of the first and second sawtooth waveform signals C and D increase.

The variable resistor 58 is adjusted with respect to resistors 60 and 62 and the capacitors 40 and 40' so that the RC time constants of the first and second sawtooth waveform signal generating circuits 32 and 32' may be equalized. A further pair of resistors 64 and 66 are connected between a common variable resistor 68 and the input terminals 36 and 36'. The wiper arm of the variable resistor 68 is connected by diode 70 to ground potential and by resistor 72 to the positive voltage source f V. The wiper arm of the variable resistor 68 is set to equalize the bias currents of the operational amplifiers 34 and 34'. It will be apparent that other equalization schemes may be employed to equalize the response of the first and second sawtooth waveform signal generating circuits 30 and 32.

Referring now to Fig. 2 in greater detail, it will be apparent that during the time period from t_0 to t_1 , the first signal SP is developed at a relatively constant frequency. However, after time t_0 , the next succeeding pulse 100 of the first signal SP occurs earlier than it should have indicating that the rate of movement of the film has momentarily increased or that the distance between the perforations producing the pulses at times t_0 and t_1 has shrunk. In response to this aberration, the pulse 102 of the first trigger signal A' is produced earlier than it should be and the sampled amplitude of the second sawtooth waveform D is relatively lower than the previously sampled amplitude of the first saw-

tooth waveform signal C at the time t_1 . Consequently, as shown at the time t_{10} , the amplitude of the different signal H increases. As the amplitude of the different signal H increases, the absolute amplitude of the current input signal applied to the input terminal 36 and 36' of the operational amplifier 34 and 34' increases and the slope of the first and second sawtooth waveform signals C and D tends to increase. As shown in Fig. 2, the succeeding pulses of the first signal SP return to the same frequency after time t_{12} as they were before time t_{10} ; therefore with the continued operation of the automatic gain control circuit of the invention, the amplitude of the signal H tends to normalize. The vertical deflection signal R shows a slight jump at times t_{10} due to the fact that the first and second gating signals E and F switch in amplitude at time t_{10} in response to the aberrant pulse 100 of the first signal SP. Therefore, the position of the flying spot scanner raster pattern is altered at time t_{10} to track the corresponding film frame.

The sensitivity of the automatic gain control circuit may be varied over a wide range. It may be desirable to prevent any immediate adjustment in the positioning of the flying spot scanning raster in response to only a single aberration in the period between detected sprocket hole perforations. For example, wear of the sprocket holes may result in deterioration of the leading or trailing edges of the sprocket holes detected by the perforation sensor, whereby the period of the first signal may be erratic. Also, the variations in the widths of successive sprocket hole perforations may influence the regularity of the period of the first signal SP when the trailing edge of the sprocket perforation is sensed by the perforation sensor. These deficiencies may be overcome by providing synchronizing indicia on the motion picture film in a predetermined relationship with each film frame and the indicia may be sensed to produce the first signal SP. In absence of such indicia however, it may be desirable to smooth the signal H over a period of several film frames automatically to regulate the slopes of the first and second sawtooth waveform signals C and D in response to long term changes in the film frame rate by varying the loopgain of the gain control circuit.

The remaining circuit elements of Fig. 2 operate in a manner very similar to those corresponding elements shown in the aforementioned, British Patent No. 1,361,457 selectively to combine alternate periods of the first and second sawtooth waveform signals C and D into the combined sawtooth waveform signal C f D, shown in the dotted line representation in Fig. 2, and to sum the combined sawtooth waveform signal C f D with the third sawtooth waveform signal J to produce the vertical deflection signal R having

the complex resultant sawtooth waveform. Also, a single frame control circuit may be provided which is similar to the frame control circuit disclosed in the aforementioned British Patent No. 1,361,457 to disconnect the combined sawtooth waveform signal C or D from the vertical deflection amplifier 18 when the first and second sawtooth waveform signals C and/or D increase in amplitude beyond the maximum amplitude, indicating that the production of the first signal SP has ceased.

Referring to the remaining elements of the circuit diagram of Fig. 1 in greater detail, the 60 Hz. line frequency is detected at the input terminal 74 of the logic circuit 10 and applied to a second pulse shaping circuit 76 which produces the second signal LP shown in Fig. 2 having a frequency of 60 Hz. The second signal is applied to the 60 Hz. sawtooth waveform signal generator 16 which generates the 60 Hz. vertical deflection sawtooth waveform signal J that is applied by resistor 78 to the summing input terminal 80 of the operational amplifier 82. A dc. centering voltage source V_c is connected through variable resistor 84 to the summing input terminal 80 of the vertical deflection amplifier 82. The variable resistor 84 may be adjusted to center the scanning raster on the cathode ray tube of the flying spot scanner. The combined first and second sawtooth waveform signal C or D is applied through resistor 86 to the summing input terminal 80. The operational amplifier 82, in conjunction with the feedback resistor 88, sums the amplitudes of the signals provided to the summing input terminal 80 to produce the vertical deflection signal R at the output terminal 20 of the vertical deflection amplifier 18.

The combined first and second sawtooth waveform signal C or D is generated by the alternate conduction of the first and second FET's 90 and 92 which are alternately rendered conductive by the high amplitude state of the gating signals E and F. The gating signals E and F are generated by the second bistable multivibrator 94 which is connected to receive at the J and K input terminals the second and first half-frame rate frequency signals B and A, respectively. The second signal LP is applied to the Clock C input terminal of the second bistable multivibrator 94. Therefore, as shown in Fig. 2, each positive impulse of the second signal LP that is applied to the C input terminal of the second bistable multivibrator 94 simultaneously with or immediately succeeding in time the application of a positive going pulse of the first or second half-frame rate frequency signal A or B switches the state of the Y and M output terminals of the second bistable multivibrator circuit 94. Therefore, as shown in Fig. 2, the gating signals E and F are alternately high and low in amplitude with respect to each

other and have respective periods that are integral multiples of the periods of the second signal LP. For example, the first and second half-frame rate frequency signals A and B switch polarity in response to the negative going transitions of the pulse FP in the interval between time t_1 and t_2 . At the time t_1 the pulse of the second signal LP applied to the T input terminal of the second bistable multivibrator 94 responds to the high amplitude state of the K input terminal to switch the state of the Y output terminal to the high amplitude level and the state of the M output terminal to the low amplitude level, whereby the high amplitude level of the gating signal E applied to the first FET 90 renders it conductive to pass that portion of the first sawtooth waveform C indicated by the dotted line noted by C or D in Fig. 2 to the summing input terminal 80 of the vertical deflection amplifier 18. Thus, as shown in Fig. 2, the combined first and second sawtooth waveform signals C or D is generated during successive integral periods of the 60 Hz. second signal LP.

By virtue of the fact that the amplitudes of the first and second sawtooth waveform signals C and D are alternately sampled only during short intervals stored for the interval between successive pulses of the first and second trigger signals A and B and compared with the amplitude of a reference signal, the gain of the first and second sawtooth waveform signal generating circuits 32 and 32' may be carefully regulated. These features of the automatic gain control of the present invention coupled with the employment of operational amplifiers and field effect transistors in the sawtooth waveform signal generating signal 12 represent a significant improvement in performance for the vertical deflection signal generating circuit of the present invention.

WHAT WE CLAIM IS:

1. An apparatus for encoding information from a motion picture film into electrical signals having a format which is compatible with a television receiver, in which two vertical deflection signals, substantially 180° out of phase, are generated and are alternately fed to a vertical deflection apparatus, and in which the slope of the vertical deflection signals is controlled by gain control means, as a function of the rate of travel of the motion picture film, said gain control means comprising means for sampling each of the vertical deflection signals at a point approximately midway in its cycle, means for comparing the sampled signals with a reference signal, and means for controlling the slope of the vertical deflection signals as a function of the output of the comparing means.

2. An apparatus as claimed in Claim 1 further including means for generating a first



the complex resultant sawtooth waveform. Also, a single frame control circuit may be provided which is similar to the frame control circuit disclosed in the aforementioned British Patent No. 1,361,457 to disconnect the combined sawtooth waveform signal C f D from the vertical deflection amplifier 18 when the first and second sawtooth waveform signals C and/or D increase in amplitude beyond the maximum amplitude, indicating that the production of the first signal SP has ceased.

Referring to the remaining elements of the circuit diagram of Fig. 1 in greater detail, the 60 Hz. line frequency is detected at the input terminal 74 of the logic circuit 10 and applied to a second pulse shaping circuit 76 which produces the second signal LP shown in Fig. 2 having a frequency of 60 Hz. The second signal is applied to the 60 Hz. sawtooth waveform signal generator 16 which generates the 60 Hz. vertical deflection sawtooth waveform signal J that is applied by resistor 78 to the summing input terminal 80 of the operational amplifier 82. A dc centering voltage source f V, is connected through variable resistor 84 to the summing input terminal 80 of the vertical deflection amplifier 82. The variable resistor 84 may be adjusted to center the scanning raster on the cathode ray tube of the flying spot scanner. The combined first and second sawtooth waveform signal C f D is applied through resistor 86 to the summing input terminal 80. The operational amplifier 82, in conjunction with the feedback resistor 88, sums the amplitudes of the signals provided to the summing input terminal 80 to produce the vertical deflection signal R at the output terminal 20 of the vertical deflection amplifier 18.

The combined first and second sawtooth waveform signal C f D is generated by the alternate conduction of the first and second FET's 90 and 92 which are alternately rendered conductive by the high amplitude state of the gating signals E and F. The gating signals E and F are generated by the second bistable multivibrator 94 which is connected to receive at the J and K input terminals the second and first half-frame rate frequency signals B and A, respectively. The second signal LP is applied to the Clock C input terminal of the second bistable multivibrator 94. Therefore, as shown in Fig. 2, each positive impulse of the second signal LP that is applied to the C input terminal of the second bistable multivibrator 94 simultaneously with or immediately succeeding in time the application of a positive going pulse of the first or second half-frame rate frequency signal A or B switches the state of the Y and Y output terminals of the second bistable multivibrator circuit 94. Therefore, as shown in Fig. 2, the gating signals E and F are alternately high and low in amplitude with respect to each

other and have respective periods that are integral multiples of the periods of the second signal LP. For example, the first and second half-frame rate frequency signals A and B switch polarity in response to the negative going transitions of the pulse FP in the interval between time t_0 and t_1 . At the time t_1 , the pulse of the second signal LP applied to the T input terminal of the second bistable multivibrator 94 responds to the high amplitude state of the K input terminal to switch the state of the Y output terminal to the high amplitude level and the state of the Y output terminal to the low amplitude level, whereby the high amplitude level of the gating signal E applied to the first FET 90 renders it conductive to pass that portion of the first sawtooth waveform C indicated by the dotted line noted by C f D in Fig. 2 to the summing input terminal 80 of the vertical deflection amplifier 18. Thus, as shown in Fig. 2, the combined first and second sawtooth waveform signals C f D is generated during successive integral periods of the 60 Hz. second signal LP.

By virtue of the fact that the amplitudes of the first and second sawtooth waveform signals C and D are alternately sampled only during short intervals, stored for the interval between successive pulses of the first and second trigger signals A' and B' and compared with the amplitude of a reference signal, the gain of the first and second sawtooth waveform signal generating circuits 32 and 32' may be carefully regulated. These features of the automatic gain control of the present invention coupled with the employment of operational amplifiers and field effect transistors in the sawtooth waveform signal generating signal 12 represent a significant improvement in performance for the vertical deflection signal generating circuit of the present invention.

WHAT WE CLAIM IS:—

1. An apparatus for encoding information from a motion picture film into electrical signals having a format which is compatible with a television receiver, in which two vertical deflection signals, substantially 180° out of phase, are generated and are alternately fed to a vertical deflection apparatus, and in which the slope of the vertical deflection signals is controlled by gain control means, as a function of the rate of travel of the motion picture film, said gain control means comprising means for sampling each of the vertical deflection signals at a point approximately midway in its cycle, means for comparing the sampled signals with a reference signal, and means for controlling the slope of the vertical deflection signals as a function of the output of the comparing means.
2. An apparatus as claimed in Claim 1 further including means for generating a first

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signal of frequency dependent upon the rate of travel of the film, the first signal being utilized to produce two further 180° out of phase signals each having a frequency equal to half the frequency of the first signal.

3. An apparatus as claimed in Claim 2 wherein the first signal is fed to a bistable multivibrator, the two further 180° out of phase signals being alternate outputs of said multivibrator.

4. An apparatus as claimed in Claim 2 or 3 wherein the two further 180° out of phase signals are fed to saw tooth wave generators respectively to produce the two vertical deflection signals.

5. An apparatus as claimed in Claim 4 wherein each sawtooth wave generator comprises an operational amplifier paralleled by a capacitor and an FET, the two further 180° out of phase signals being fed to the gates of the respective FET.

6. An apparatus as claimed in Claim 2 or any claim appendant thereto wherein each of the two further 180° out of phase signals is utilized to trigger a sampling circuit for sampling circuit for sampling the level of the respective other vertical deflection signal at substantially the midpoint of the rise thereof.

7. An apparatus as claimed in Claim 6 wherein the sampled levels are alternatively fed to the comparing means whereto the reference signal is fed, the output of the comparing means being fed to an inverter and thence to the input of the respective sawtooth wave generator to control the slope of the vertical deflection signal produced thereby.

8. An apparatus as claimed in any preceding claim further including means for providing a sawtooth wave signal of field frequency equal to that of said television receiver and means for combining the two vertical deflection signals and the field frequency sawtooth wave signal, said combining means

providing an output for a vertical deflection means of a flying spot scanner which analyses said motion picture film.

9. An apparatus as claimed in Claim 3 or any claim appendant thereto and Claim 8 further including a second bistable multivibrator whereto signals corresponding to said field frequency and to the two outputs of the first multivibrator are fed, the second multivibrator having outputs arranged to gate respective means for feeding the alternate vertical deflection signals to the combining means.

10. An apparatus substantially as hereinbefore described with reference to and as illustrated in the accompanying drawings.

11. A method of regulating the rate of change of an output signal having a linearly changing waveform established in accordance with the frequency of occurrence of a first signal in response to a reference signal having a reference level, said method comprising the steps of:

determining the instantaneous level of the linearly changing waveform of the output signal at each occurrence of the first signal;

comparing such determined level with the reference level of the reference signal and producing a comparison signal having a control level related thereto;

storing the comparison signal during the period between successive occurrences of the first signal; and controlling the output signal in accordance with said stored signal.

12. A method of Claim 11 wherein the first signal is arranged to produce alternately selected 180° out of phase signals, each having a frequency equal to half the frequency of occurrence of the first signal, which are combined to form the output signal.

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