

[54] STRIP POSITIONING APPARATUS

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[58] Field of Search **242/188, 189, 190, 184, 75.51, 242/75.5, 186; 353/12**

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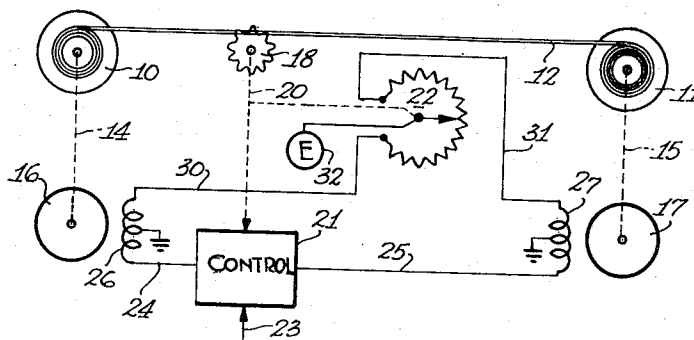
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 3,208,336 9/1965 Vago **353/12**
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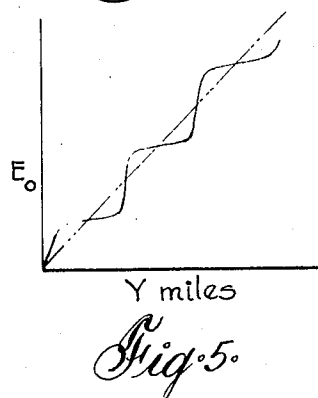
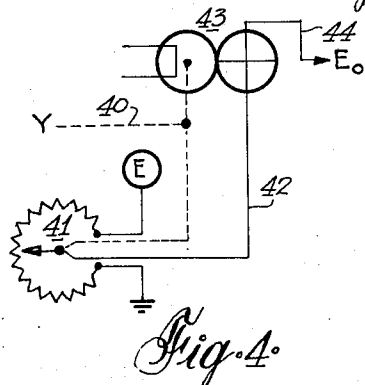
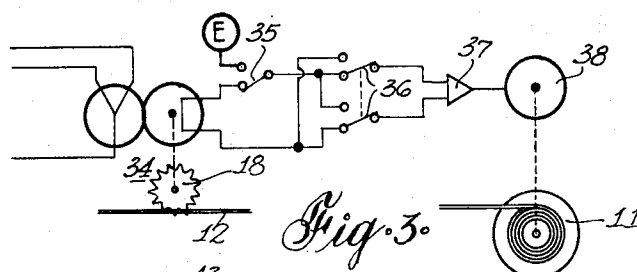
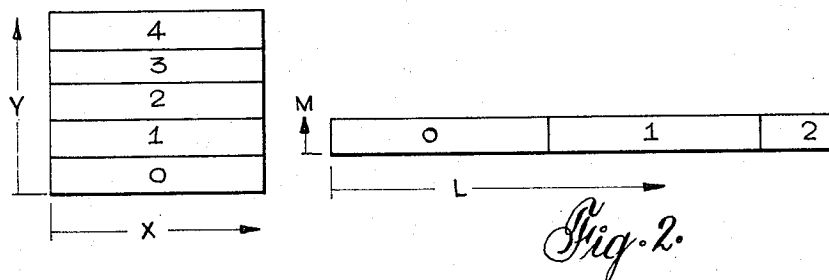
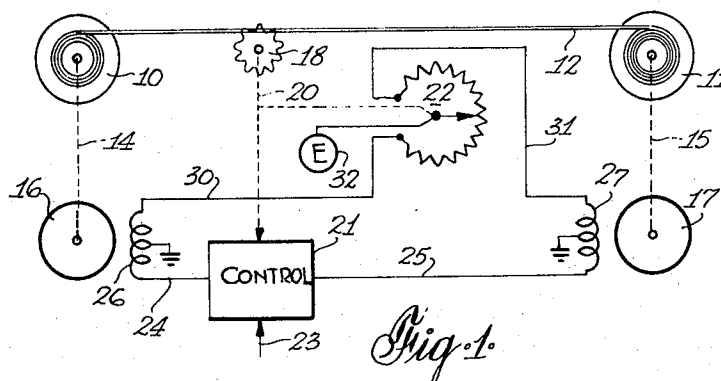
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[57] ABSTRACT

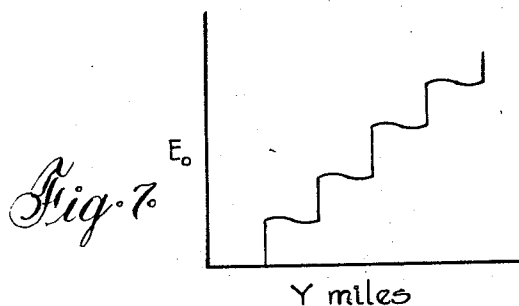
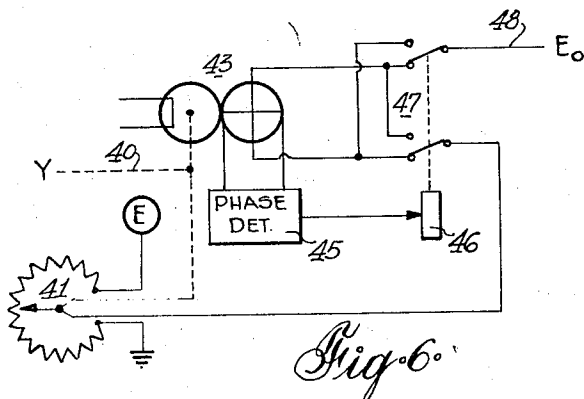
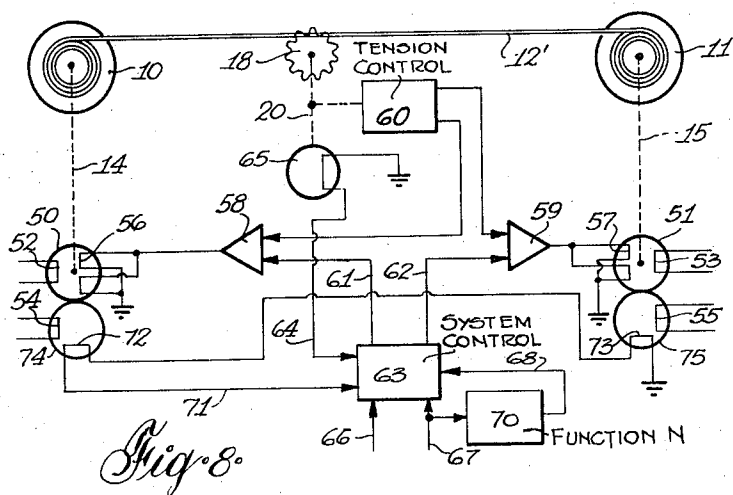
A strip positioning apparatus in which the strip is wound between two motor driven spools. A sensor provides a signal representing actual position to a control. A desired position signal is also applied to the control and a difference signal applied to control windings on the motors. Tension is maintained on the strip material by applying signals to the control windings in an opposite sense and the signals varied in accordance with the amount of strip material on each spool.

4 Claims, 8 Drawing Figures





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STRIP POSITIONING APPARATUS

BACKGROUND OF THE INVENTION

The invention relates to strip positioning apparatus, and in particular relates to apparatus for accurately positioning strip material which is wound from one spool to another.

The invention is particularly useful in positioning accurately a strip of film, such as for example a strip of film used for a projected navigational display, and it will be described in detail in this type of apparatus. However, it will be apparent that the apparatus according to the invention may be adapted to the positioning of any strip material.

In U.S. Pat. No. 3,208,336 to R. E. Vago, issued Sept. 28, 1965, and assigned to the same assignee as the present invention, there is described a navigational apparatus which displays on a screen a map projection indicating the present position of a craft (or the position of some desired place). The map display is projected onto a screen from a strip of transparencies. The film strip is wound from one spool to another and a spring at each spool keeps tension on the film strip. A sprocket engages holes in the edge of the film strip between the two spools and is used to position the film strip.

The film transport arrangement using spring loaded spools and a sprocket drive has several disadvantages. One disadvantage is in the changing of one film strip for another. When the film strip is changed the tension in the springs must be adjusted and reset making a film change inconvenient. A second disadvantage is that variations in film tension resulting from the spring biasing means acting through different spool radii must be taken up by the sprocket drive and overcome by the positioning forces applied via the sprocket. A third disadvantage is that the positioning force is transmitted to the film via the same sprocket holes used for sensing the film position. This results in inaccuracies in film positioning, a high rate of film wear particularly at the sprocket holes, and a low range of driving or film positioning speeds.

The present invention seeks to provide an improved film strip positioning apparatus or film transport.

SUMMARY OF THE INVENTION

In a broad aspect of the invention a strip positioning apparatus comprises a motor for driving each of two spools on which the strip material is wound, each motor having a field winding which controls the torque at the motor shaft, and means to provide a signal representative of the position of the strip material. A control means receives the signal representing strip position and an external signal representing the desired strip material position and provides a voltage to the field windings of the motors to cause them to drive the strip material to the desired position. A voltage source is controlled by the actual position of the strip material to provide to the field windings of the motors a voltage which is related to the amount of strip material on the respective spools to bias the spools in opposite directions and maintain a tension in the strip material.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a simplified schematic diagram of one form of the invention,

FIG. 2 is a drawing used in explaining the invention,

FIG. 3 is a simplified schematic diagram showing a portion of the circuitry used in one form of the apparatus,

FIG. 4 is a simplified schematic diagram useful in explaining another portion of the circuitry used in one form of the apparatus,

Fig. 5 is a graph used in connection with the description of FIG. 4,

FIG. 6 is a simplified schematic diagram showing a portion of the circuitry used in one form of the apparatus,

FIG. 7 is a graph used in describing the circuitry of FIG. 6, and

FIG. 8 is a simplified schematic diagram of another form of the apparatus according to the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 1 shows in simplified schematic form a basic form of the apparatus according to the invention. Spools 10 and 11 have strip material 12 wound on them and extending between them. The spools 10 and 11 are driven by shafts 14 and 15 extending from motors 16 and 17 respectively. A sensor 18 engages the strip material 12. It is intended that the word "sensor" as used herein should have a broad meaning. That is, that the word "sensor" should mean that which senses either remotely or by mechanical engagement a physical condition of something which is in this case the physical position of a strip. In FIG. 1 sensor 18 is shown in the form of a sprocket having teeth which engage holes in the strip material. However, sensor 18 may be in any form that can detect position of the strip material, such as, for one example, optical means which may include a light source and a light detector positioned to provide an output pulse for each sprocket hole as the film passes the detector, or for another example direct mechanical means connected to spools 11 and 12. A shaft 20 is connected with and extends from sensor 18 to a control means 21 and to a potentiometer 22. Prior to the operation of the apparatus the strip material is placed on the apparatus in a known position (i.e. with the amount of material on each spool known) and sensor 18 with shaft 20 adjusted accordingly. Therefore, the rotational movement of shaft 20 is related to the movement of the strip material, and the shaft position at any time is related to the position of the strip material. Control means 21 thus receives a signal from shaft 20 representing strip position and also receives a signal at input 23 which represents the desired position of the strip material 12. The input signal at input 23 may be a manual input set in by an operator desiring a specific position of the strip material, or it may be an input from a computer or the like calling for a specific position of the strip material. Control means 21 compares the signal from sensor 18 with the signal at input 23, derives a difference or "error" signal and provides a voltage proportional to the difference signal on conductors 24 and 25 which causes motors 16 and 17 to operate to reduce the difference signal as is known in servo systems. Potentiometer 22 has its end terminals connected by conductors 30 and 31 to field windings 26 and 27, and has its center terminal or movable tap connected to a source of voltage 32. As mentioned above, when strip material is placed on the apparatus its position is known and sensor 18 with shaft 20 is set at a corresponding and related position. Thus the movable tap of potentiometer 22 will also be set to a position which corresponds with the position of the strip material. For example, when the strip material is equally divided between spools (in its mid position), the movable tap may be in its mid position. The voltage from source 32 is applied to the field windings according to the position of the strip material and in an opposite sense, that is so that the motors are biased in opposite directions to maintain a tension on the strip material and the tension will be constant.

The drive torque and the strip tension are produced by the same motors. A constant tension may be obtained in the strip material even if it is substantially all on one spool with little on the other spool.

The operation of the apparatus of FIG. 1 will be apparent. When it is desired to move the strip material to a new position, an appropriate signal is applied at input 23. A difference signal in control means 21 provides a voltage to field windings 26 and 27 driving motors 16 and 17 which rotates spools 10 and 11. This causes strip material 12 to move and sensor 18 rotates providing a signal via shaft 20 to the control means 21. When the input signal at input 23 and the input via shaft 20 produce no difference signal the strip material is stopped at its new position. The voltage from potentiometer 22 acts on the motors in combination with the voltage from the control means to produce smooth rapid movement while maintaining a constant tension.

As was previously mentioned, the strip positioning apparatus is particularly suitable for use in navigational apparatus and this will now be described.

In a navigational apparatus which displays a map projection on a screen it is usually necessary to have map coverage for a large area available. This can be done conveniently by using a film strip, that is a strip of film having a plurality of transparencies, and projecting an image of the desired portion of a frame or single transparency onto a screen. Thus, for example, an area to be covered by a film strip may be divided into 12 horizontal rows and 12 columns requiring 144 frames. In the film strip each horizontal row would be represented by a group of 12 adjacent frames. To show a position change in the display in a direction corresponding to the horizontal direction (e.g. the east-west direction) the film strip changes or moves from one frame to an adjacent frame. To show a position change in the display when the position reaches the edge of the film in a direction corresponding to the vertical direction (e.g. the north-south direction) the film strip must move or change by 12 frames. This is explained in more detail in the aforementioned U.S. Pat. No. 3,208,336.

In the movement of the film strip it is necessary to maintain a high degree of accuracy during normal position changes within a frame, and a high rate during position changes from one group of frames to another. It is also essential that there should be no redundancy in the film positioning.

In order that the apparatus may be more easily understood, the underlying theory will be given very briefly.

It will be apparent that position changes which cross frame boundaries in a north-south direction present the most difficulty because the film strip must be moved by a constant number of frames. The description will therefore be directed mainly to north-south changes.

First considering the general conversion from a square to a strip where X and Y represent a position from a reference in the square, and L and M represent the same position in the strip. This is indicated in FIG. 2.

Let A = frame width

B = length of a contiguous group of frames

N = number of the group (i.e. the number of the horizontal strip of frames or row of frames)

The coordinate transformation is defined by

$$Y = AN + M \quad (1)$$

$$\text{or } M = Y - AN \quad (2)$$

$$L = BN + X \quad (3)$$

$$\text{or } X = L - BN \quad (4)$$

It can be seen that N is a discontinuous function equal to the discrete integral quotient of Y/A , and also that M is a repetitive function of Y .

Considering now a case where the position is the junction between group 0 and group 1

Then $Y = A$ and equation (2) becomes $M = A(1-N)$.

If $N = 0$ (i.e. approaching the junction from group 0) then $M = A$.

If $N = 1$ (i.e. approaching the junction from group 1) then $M = 0$.

Considering now a case where the position is the junction between group 1 and group 2,

Then $Y = 2A$

and equation (2) becomes $M = A(2-N)$.

If $N = 1$, then $M = A$.

If $N = 2$, then $M = 0$.

It will be seen that the total range of M is 0 to A for the total range of Y . It will be noted that N must be available as an independent input.

It could similarly be shown that X is a repetitive function of L . However, X is an input signal and L the derived function. Hence equation (3) should be considered.

$$L = BN + X \quad (3)$$

Again, in order to determine the value of L , the quantity N must be available as an input. Thus for any value of X

$$L = X + B, X + 2B, \dots, X + NB.$$

Therefore the quantities L and M may be obtained by algebraically adding fixed constants to X and Y , respectively.

In the apparatus of this invention in the embodiment convenient for navigational apparatus, the repetitive relationship between M and Y and between L and X is used. The value N is

generated as an approximation to position the film strip at the correct group, and the inputs X and Y are used to position the film strip accurately.

The repetitive characteristic of the relationships is conveniently obtained using synchro transmission since synchro signals have an ambiguity every 360° . However, when synchro signals are used to position a linear readout rather than a rotational one there is the added ambiguity caused by the servo driving to the closest null. The manner in which the first ambiguity is utilized and the second is overcome will be discussed prior to a discussion of the overall apparatus.

Referring now to FIG. 3, there is shown a servo system with a switching arrangement to provide a drive of 180° . The servo system includes a control transformer 34 with its output winding connected through a SPST switch 35 and a DPST switch 36 to an amplifier 37. The switch 36 is connected to reverse the voltage applied to amplifier 37, thus limiting the synchro range to 180° . This eliminates the second ambiguity since the closest null will always be within the designated 180° range. The amplifier 37 drives a motor 38 whose output shaft is connected to or is in common with the shaft of spool 11. The motor 38 is similar to motor 17 described in FIG. 1. The amplifier 37 would, of course, drive motors to rotate both spools although only one is shown in FIG. 3.

When switch 36 is operated to reverse the voltage, switch 35 is operated temporarily to provide a voltage which will start the motor 38 driving in the desired direction. When switch 35 again connects synchro 34 to switch 36 the motor 38 will continue to drive the sensor 18 to a position 180° from the original position. This drive may be made at a relatively rapid rate. The 180° rotational displacement is made equal to one film frame length B . This provides utilization of the first ambiguity and an accurate repetitive position signal.

The same arrangement may be used for across the film positioning where 180° rotational displacement would represent one film strip width A .

Since the accurate positioning signals M and L are repetitive functions of X and Y , the coordinates of map area, and since they are unambiguous in each frame, only an approximation of N is required to position the map strip somewhere within the correct frame. This means that the accuracy of the value N is not critical. It may be represented by a step function where the value of N is not critical, but where the change from one value to another should be sharp or rapid and fairly accurate.

The circuit shown in FIG. 4 will provide an approximate step function as indicated in FIG. 5. Referring first to FIG. 4 a shaft 40 carries a rotational signal representing Y miles. This shaft drives the movable contact or tap on potentiometer 41 giving a voltage on conductor 42 which varies with Y . The shaft 40 also is an input to synchro 43. The electrical output from synchro 43 is available on conductor 44 as E_o . FIG. 5 shows the output E_o plotted against Y . It will be seen that this is an approximate step function.

If a phase detector is added to the circuit of FIG. 4, as shown in FIG. 6, the waveform of the step function can be improved. Referring now to FIG. 6, a phase detector 45 is connected to one winding of synchro 43 and the output of the phase detector is connected to a solenoid 46 of a solenoid operated switch 47. The phase detector 45 operates to position the switch 47 in one position for the range of 0° and 180° and in the other position for the range 180° to 360° . The output is available on conductor 48 as E_o' . FIG. 7 shows the output E_o' plotted against Y . It will be seen that the switching of switch 47 causes the step function to be substantially vertical between one level and the next. Thus the output is sharp or rapid between levels, the occurrence of the levels can be accurately controlled, and the level itself is not very accurate. This is suitable for representing N .

The phase detector 45 could be used also to operate switches 35 and 36 (FIG. 3) and thus synchronize the coarse film positioning to a group of frames and the fine film positioning within a frame.

Referring now to FIG. 8, the apparatus is shown in simplified diagrammatic form with the portions just described included. As before the two spools 10 and 11 have a film strip 12' wound thereon. The spools 10 and 11 are connected to servo motors 50 and 51 by shafts 14 and 15 respectively. The servos comprise motors 50, 51 and generators 74 and 75. The generators 74 and 75 are for providing a rate feedback signal as will be described briefly hereinafter and are not essential to an understanding of the operation of the basic apparatus. The windings 52 and 53 may have a system alternating voltage applied at a 90° phase while windings 54 and 55 may have the voltage at a 0° phase. The driving or torque producing voltage is applied to windings 56 and 57 by amplifiers 58 and 59 respectively.

The amplifiers 58 and 59 each receive two input signals. One input signal is the servo error signal applied via conductors 61 and 62 from the system control 63. The other input signal to amplifiers 58 and 59 is the tension creating signal from the tension control 60 (which was described generally in connection with FIG. 1 but may also consist of a electronic voltage generator). The tension control is responsive to the position of the film strip 12' as detected by sensor 18.

The system control 63 receives several inputs. One input is the fine film position signal received over conductor 64 from a feedback control transmitter 65 which is driven by shaft 20 from sensor 18. The transmitter 65 is, of course, excited in the normal manner. Other inputs are the desired map position signals X and Y received at inputs 66 and 67. Another input is the value of N received over conductor 68 from the function generator 70 which has Y as an input. The manner in which N may be generated was described in connection with FIGS. 4, 5, 6 and 7. The remaining input to system control 63 is via conductor 71. The conductor 71 connects windings 72 and 73 of the servo generators 74 and 75. The conductor 71 provides a signal representative of the rate of change or rate of rotation of the servo drive, and thus it is a rate feedback signal used to stabilize the servo.

Apparatus according to the invention may be arranged to operate digitally. That is, the map position signals X and Y may be digital in nature, the calculations or conversions and the determination of N may be carried out digitally, and a digital to analog conversion may be made prior to the signals being applied to the field windings or control windings of the spool driving motors.

It is believed that an apparatus has been described for translating a position as represented by two signals into a position of a film strip suitable for projection in a navigational apparatus, and an improved apparatus for accurately positioning the strip.

I claim:

1. Strip positioning apparatus comprising
 - first and second strip material receiving spools,
 - first and second motors having respectively a first and second driving shaft and a first and second field winding, the torque at each of said first and second driving shafts being related to a characteristic of a signal applied to the respective field winding,
 - said first and second driving shafts being connected respectively to rotate said first and second spools,
 - a strip position sensor positioned between said first and second spools for mechanically engaging said strip material to provide a first signal representing strip position, control means connected to receive said first signal and a second signal representing desired strip position and providing a third signal relating to the difference between said first and second signals, means applying said third signal to said field windings for causing rotation of said spools in the same direction to move said strip material to said desired position, and
 - tension means responsive to said first signal for applying fourth and fifth signals representing amounts of strip material on the first and second spools to said field windings creating a rotational bias in opposite strip tensioning directions.

2. Apparatus for positioning a film strip having a plurality of adjacent frames, each frame representing a portion of a map area, said frames being arranged in said film strip in a plurality of groups of frames with each group having the same number of frames representing a row in said map area and adjacent groups in the film strip representing adjacent rows, said groups being represented by consecutive numbers 1 - - - n , said apparatus comprising

- first and second film strip receiving spools,
- first and second motors having respectively a first and second driving shaft and a first and second field winding, the torque at each of said first and second driving shafts being related to a characteristic of an electrical signal applied to the respective field winding,
- said first and second driving shafts being connected respectively to rotate said first and second spools,
- means to sense the position of the film strip and provide a first signal representing film strip position,
- control means connected to receive said first signal and to receive a second and third signal representing coordinates X and Y of a map position,
- said control means providing a fourth signal L representing a desired position of the film strip where L is defined by the expression

$$L = BN + X$$

- where B is the length of the film strip of said group of frames, and N is the number of the group of frames in the series 1 - - - n , and comparing said first and fourth signal to derive a fifth signal representing the amount of movement required to position said film strip in accordance with said first signal,
- means connecting said control means with said first and second field windings applying thereto said fifth signal for causing rotation of said spools in the same direction moving said film strip to said desired position, and
- tension means responsive to said first signal for applying sixth and seventh signals representing amounts of film strip on said first and second spools to said field windings creating a rotational bias in opposite film strip tensioning directions.

3. Apparatus as defined in claim 2 in which said means to sense the position of the film strip is a sensor positioned between said first and second spools mechanically engaging said film strip and having a shaft whose rotational position represents said first signal, and in which said control means includes

- a control transformer having a shaft coupled to the shaft of said sensor and having an electrical output winding,
- an amplifier having an input and an output,
- the output of said amplifier being connected to said field windings for applying thereto said fifth signal, and
- a circuit interconnecting said output winding and the input of said amplifier and including switch means operable from a first condition to a second condition and from the second condition to the first condition,
- said switch means being responsive to a change in the value of N to change from one condition to the other reversing the polarity of the signal applied to the input of said amplifier and temporarily opening said circuit and applying a fixed signal thereto causing movement of said film strip by an amount B and rotation of said shaft of said control transformer by 180°.

4. Apparatus as defined in claim 2 in which said control means includes circuitry for providing a signal representing N and comprising

- a synchro resolver having an input shaft whose rotational position is responsive to said third signal representing Y and having a first and second output winding,
- reversing switch means connected to said first output winding of said synchro resolver and having first and second terminals,
- a variable voltage source having a control responsive to said third signal representing Y to provide a voltage variable with said third signal to the first terminal of said reversing switch means,

a phase detector connected across said second output winding of said synchro resolver,
actuating means connected to said reversing switch means and to said phase detector to actuate said reversing switch means with a detected change of phase in said second output winding of said synchro resolver,
said signal representing N being available at said second terminal of said reversing switch means.

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