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Krysiuk et al.

[11] **3,741,357**
[45] **June 26, 1973**

[54] **POSITION CONTROLLING SYSTEM**

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[52] **U.S. Cl.** .... **192/12 D,** 192/127, 271/47, 271/57

[51] **Int. Cl.** **F16d 67/02,** F16d 71/00, B65h 7/14

[58] **Field of Search** .... 192/12 D, 18 B, 125 A, 192/127, 144; 271/47, 57

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[57] **ABSTRACT**

A serial loop memory, such as a ring counter, for example, of capacity equal to the units of distance between a sensing station and a desired stopping station is operated in synchronism with a transport mechanism whenever an article in the transport system has been sensed and has not yet stopped. The complement in the loop memory is used as a feed-forward correction to modify the application of braking means to the transport system so that the brake application will take place at an appropriate time during the next document cycle.

7 Claims, 4 Drawing Figures

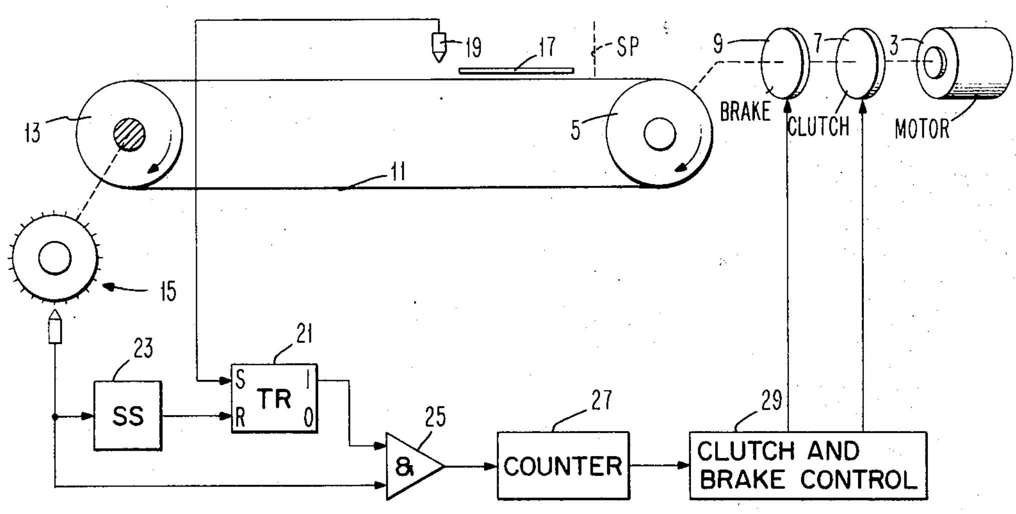
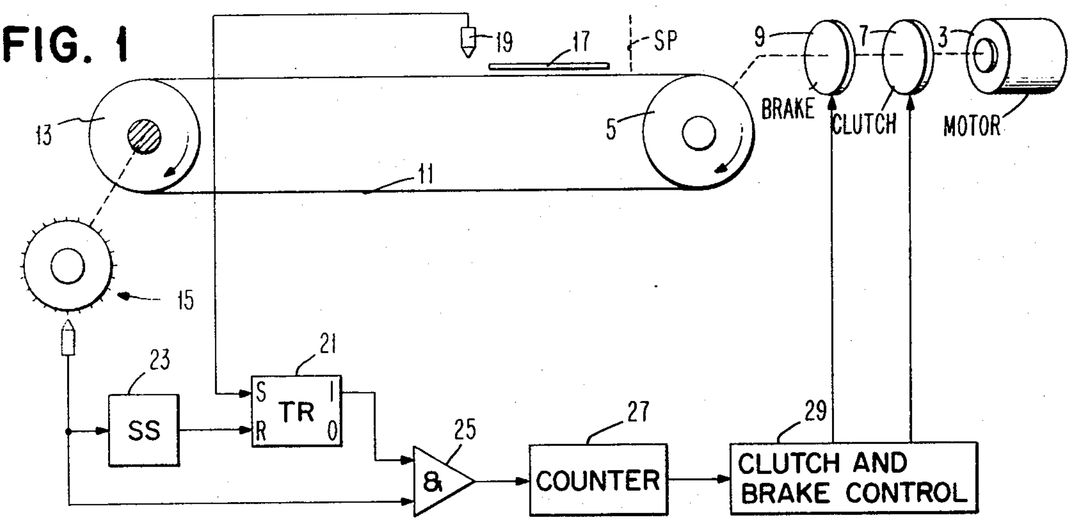


FIG. 1



BRAKE ACTION	COMMENTS	COUNTER READING WHEN INCOMING DOCUMENT PASSES SENSOR	EMITTER PULSES AND DOCUMENT TRAVEL BETWEEN SENSOR AND BRAKE APPLICATION	COUNTER READING AT INSTANT OF BRAKE APPLICATION	EMITTER PULSES AND DOCUMENT TRAVEL DURING BRAKING OPERATION	COUNTER READING AND DOCUMENT POSITION WHEN STOPPED (MEASURED FROM DOCUMENT SENSOR)
NORMAL	STEADY STATE	90	38 PULSES =0.76 INCH	128 = 0	90 PULSES =1.80 INCH	POSITION 90 2.56 INCH
GETTING SLIGHTLY WEAK AND STAYING SLIGHTLY WEAK	1 ST CYCLE	90	38 PULSES =0.76 INCH	128 = 0	91 PULSES =1.82 INCH	POSITION 91 2.58 INCH
	STEADY STATE	91	37 PULSES =0.74 INCH	128 = 0	91 PULSES =1.82 INCH	POSITION 91 2.56 INCH
GETTING SLIGHTLY STRONG AND STAYING SLIGHTLY STRONG	1 ST CYCLE	90	38 PULSES = 0.76 INCH	128 = 0	89 PULSES =1.78 INCH	POSITION 89 2.54 INCH
	STEADY STATE	89	39 PULSES =0.78 INCH	128 = 0	89 PULSES =1.78 INCH	POSITION 89 2.56 INCH
START-UP FROM POWER DOWN	1 ST CYCLE (DUMMY DOCUMENT)	0	128 PULSES =2.56 INCH	128 = 0	90 PULSES =1.80 INCH	POSITION 90 4.36 INCH
	STEADY STATE	90	38 PULSES =0.76 INCH	128 = 0	90 PULSES =1.80 INCH	POSITION 90 2.56 INCH

FIG. 2

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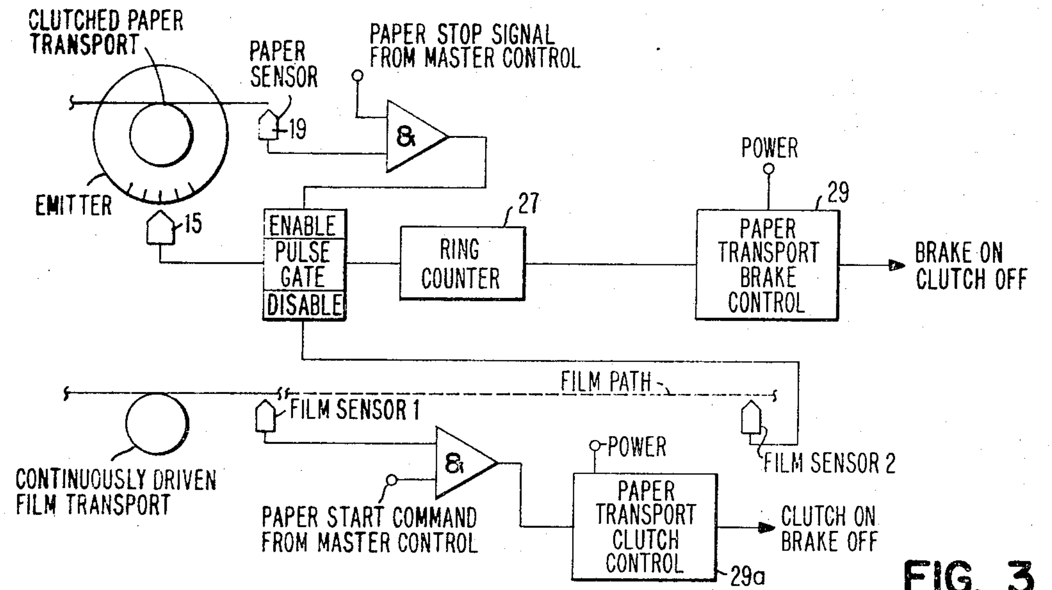
CLUTCHED PAPER TRANSPORT
PAPER SENSOR
PAPER STOP SIGNAL FROM MASTER CONTROL
19
&
EMITTER
15
ENABLE
PULSE GATE
DISABLE
27
RING COUNTER
POWER
29
PAPER TRANSPORT BRAKE CONTROL
BRAKE ON CLUTCH OFF
FILM PATH
FILM SENSOR 1
FILM SENSOR 2
CONTINUOUSLY DRIVEN FILM TRANSPORT
PAPER START COMMAND FROM MASTER CONTROL
POWER
PAPER TRANSPORT CLUTCH CONTROL
CLUTCH ON BRAKE OFF
29a

FIG. 3

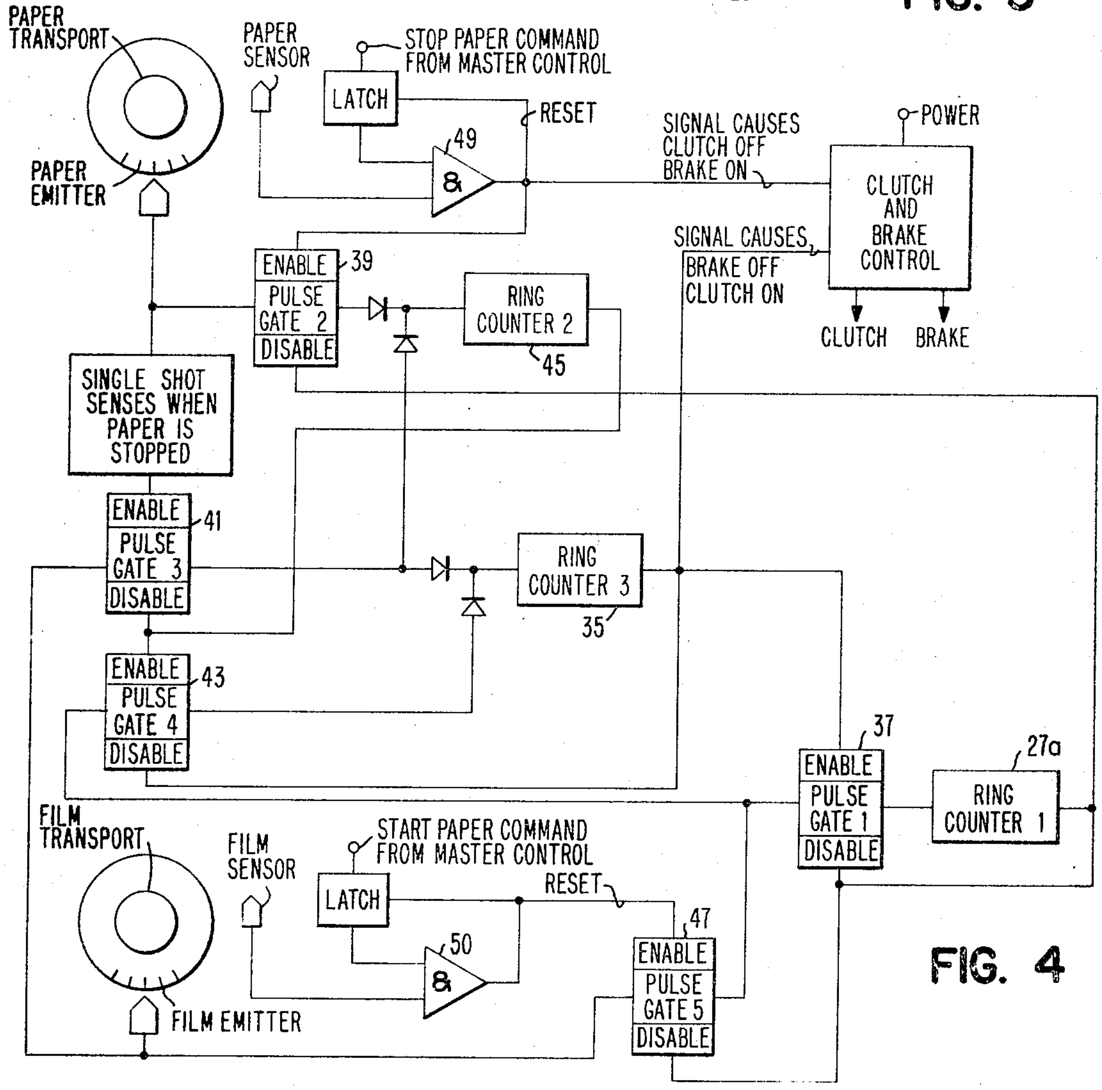
PAPER TRANSPORT
PAPER SENSOR
STOP PAPER COMMAND FROM MASTER CONTROL
LATCH
RESET
49
&
PAPER EMITTER
SIGNAL CAUSES CLUTCH OFF BRAKE ON
POWER
CLUTCH AND BRAKE CONTROL
SIGNAL CAUSES, BRAKE OFF CLUTCH ON
CLUTCH
BRAKE
ENABLE PULSE GATE 2 DISABLE
39
RING COUNTER 2
45
SINGLE SHOT SENSES WHEN PAPER IS STOPPED
ENABLE PULSE GATE 3 DISABLE
41
RING COUNTER 3
35
ENABLE PULSE GATE 4 DISABLE
43
37
ENABLE PULSE GATE 1 DISABLE
27a
RING COUNTER 1
FILM TRANSPORT
FILM SENSOR
START PAPER COMMAND FROM MASTER CONTROL
LATCH
RESET
47
50
&
ENABLE PULSE GATE 5 DISABLE
FILM EMITTER

FIG. 4

POSITION CONTROLLING SYSTEM

FIELD OF THE INVENTION

This invention relates generally to transport systems and in particular to a document transport system in which documents in the system must be brought to a stop within a predetermined tolerance during successive transport cycles.

DESCRIPTION OF THE PRIOR ART

Accurate position control systems, as previously proposed, usually encompass a closed-loop feedback system. It will be realized that with high-speed transport systems, particularly in modern, high-speed document handling equipment, such a feedback system must be extremely fast-acting and accordingly, its cost would be extremely high.

Simpler methods used in the past have also included the use of physical barriers such as the well-known card gates in business-card transport systems, which physically stop a card or document in the desired position. However, these arrangements require complicated mechanical assemblies and are not capable of the fast operation required in today's equipment. Moreover, the use of an actual physical barrier can cause damage to the leading edge of the document.

A simpler method would be to provide a sensor a certain distance ahead of the desired stop position and then to declutch the document transport or transport section that needs to be stopped and apply a brake in response to the passage of a document past the sensor. Such arrangement does not assure accurate stopping, however, because even with good brakes, for example, such as a magnetic particle clutch engaging a stationary shaft, the characteristics will change with time and temperature. Hence, there is a gradual drift in the stopping position of the document. From cycle to cycle of the transport operation, however, the operation would be quite consistent, that is, within the range of randomness of the brake itself. Accordingly, it is of primary importance to correct for medium and long-term drift of the brake performance, it being acknowledged that nothing can be done about cycle-to-cycle fluctuations except to select a brake in which these fluctuations are small. The foregoing objective can be obtained by measuring the braking distance for each cycle and then adjusting the distance between the document sensor and the point of brake application in the succeeding cycle. Thus, if the brake behaves exactly alike in two successive cycles, the document is stopped at exactly the correct place in the second cycle.

SUMMARY OF THE INVENTION

It is the principal object of the present invention to provide an improved positioning control system which is capable of accurately positioning devices in a transport system on a cycle-to-cycle basis.

A more particular object of the present invention is to provide a position control system which is relatively inexpensive compared to the more complex closed-loop feedback-control systems previously utilized for this purpose.

Still another object of the present invention is to provide a positioning control system for a document transport in which the documents can be halted with a high degree of precision on each operating cycle.

Still another object of the present invention is to provide a positioning control system which utilizes only a small number of relatively inexpensive and well-known circuit components.

Other objects of the invention and features of novelty and advantages thereof will become apparent from the detailed description to follow, taken in connection with the accompanying drawings.

In practicing the invention a pulse generator is provided which generates an output pulse for each selected unit of transport travel, such units preferably being quite small, for example, in the order of 0.01 inch. These pulses are selected so as to be able to actuate a serial loop memory device, which in turn actuates the brake mechanism. Preferably, a ring counter is used as the serial loop memory device and the supply of pulses from the document-transport generator is disabled after a document comes to a stop, and is then activated again by the leading edge of the next document passing a suitable sensing mechanism located some distance ahead of the stopping point, this distance being somewhat in excess of the braking distance. With such an arrangement, the nominal distance between the sensor and the stopping position is always equal to the product of the counts in the ring counter and the unit of transport travel for a single pulse. It is obvious that the distance thus determined must exceed any maximum braking distance under the least favorable conditions so that there is always a positive distance between the sensing device, which senses the leading edge of the oncoming document, and the point of brake application.

The brake is always applied when the counter reaches a certain count which, for convenience, may be the zero point since it is relatively easy to detect, but other points in the counter operation could be utilized. As the document decelerates, the counter advances from the zero position by as many positions as the document advances units of travel during its braking path. Then after the next document passes the sensor, the counter advances further and when it comes again to the zero point, the brake is applied. The distance between the sensor and the point of brake application then becomes the nominal distance between the sensor and the stopping position minus the braking distance of the previous cycle.

In modified forms, combinations of pulse generators and suitable counters operated thereby may be utilized by co-acting document transport systems for merging of different items, for example, merging a web of paper to a film web.

GENERAL DESCRIPTION OF THE DRAWINGS

In the drawings:

FIG. 1 is a diagrammatic illustration of a position control system comprising a first preferred embodiment of the present invention for accurately stopping single documents in a document transport system.

FIG. 2 is a table illustrating the operation of a system as shown in FIG. 1, for various operating conditions.

FIGS. 3 and 4 are diagrammatic illustrations of different forms of transport systems for merging paper and film in accordance with the present invention.

DESCRIPTION OF THE FIRST PREFERRED EMBODIMENT

Referring now to FIG. 1 of the drawings, there is shown in schematic form a document transport system which comprises a first embodiment of the present invention. A motor 3, which is in continuous operation, is arranged to selectively drive a feed roll or pulley 5 via a clutch 7 and a brake 9 arranged as shown. these elements are conventional, and it will be understood that when a suitable supply of energy to clutch 7 is enabled, the drum or drive pulley 5 will be rotated in the direction indicated by the arrow, and when clutch 7 is released and brake 9 is applied by the supply thereto of control signals, the drum or drive pulley 5 will be abruptly stopped. An endless transport belt 11 rides over the drive pulley or drum 5 and over a second pulley or drum 13, which may be considered as an idler. An emitter or pulse generator 15 is connected to the shaft of the pulley or drum 13, and this pulse generator may take any one of a number of forms, such as a magnetic or photoelectric device, the only requirement being that it supply a series of discrete pulses or signals during the rotation of the pulley or drum 13. The parts are selected and arranged so that for every predetermined unit of travel of the belt, for example, 0.02 inch, a pulse is emitted. The desired stopping location for documents 17 moving on this belt is indicated by the dotted line designated as SP. At a predetermined and fixed location in advance of the stopping point SP, there is located a document sensor device 19, which may be any one of a number of suitable devices such as a photo-electric cell or other device, which will cause an output signal to be generated when the leading edge of the document 17 passes the location of the document sensor 19.

Trigger 21 is turned on by a pulse from a document sensor 19 and reset to its off condition by the output of a single shot 23, the input of which is connected to the output of emitter 15. Emitter 15 also supplies signals to the input of an AND circuit 25, the other input of AND circuit 25 being connected to the output of trigger 21, which is enabled when the trigger is on. The output of AND circuit 25 is supplied as an input to a counter 27, the output of which is supplied as an input to clutch and brake control circuits 29, which control the clutch 7 and brake 9. Counter 27 is a ring-type counter, that is, one of the well-known type in which pulses cause the counter stages to successively count and to repeat after a certain maximum count is reached. The maximum count which counter 27 can attain is determined by the distance between the document sensor 19 and the stopping point SP. This distance, divided by the number of unit distances equivalent to the output of the emitter or generator 15 represents the number of counts which the counter 27 can contain. For example, if the transport travel is 0.02 inches per emitter pulse, and the document sensor is located 2.56 inches to the rear of the stopping point SP, then it will be apparent that a 128 position ring counter would be used for counter 27. Other forms of serial loop memory devices, for example serial delay lines, could be used in lieu of a ring counter.

In operation, let it be assumed that a document 17 on the belt 11, approaches the document sensor 19, the transport system already being in operation. When the leading edge of document 17 passes sensor 19, signal will be supplied to the trigger 21 to turn it on. With trigger 21 turned on, AND circuit 25 is enabled, and the pulses from emitter 15 are supplied therethrough to the input of counter 27. When counter 27 goes through a selected position, as can readily be determined by the circuitry, for example, a count of zero, an output signal is supplied from the counter to the clutch and brake control.

Accordingly, if the behavior of the brake is the same in the first and second cycles, which normally can be assumed will be the case because of the short time interval, in the second cycle the document travel will correspond to a value n-X1 emitter pulses before brake application and to X1 emitter pulses during braking. The total document travel between the reference point and the stopping position now becomes n, that is, the document comes to rest exactly at the desired location. If the brake behavior is not exactly the same in the second cycle as it was in the first, the number of emitter pulses over the braking distance of the second cycle, which may be represented by the value X2, would differ slightly from X1, and X2–X1 would represent the number of emitter pulses corresponding to the error in positioning. But whether or not X2 equals X1, the number of emitter pulses between the reference point and the point of brake application in the third cycle would be n-X2, and if brake behavior is the same in the third cycle as it was in the second, the document comes to rest in the third cycle exactly at the desired point. It is seen that no matter what the error in the previous cycle was, if brake behavior repeats itself in the current cycle, the document comes to rest at exactly the desired place in the current cycle.

This system requires deactivation of counter 27 between the time a document comes to rest at the stopping point SP, and the leading edge of the next document passes the reference point designated by the sensor 19. Such deactivation is achieved in the present instance by inhibiting the supply of signals from the emitter 15 to the memory means or counter 27, by; the single shot 23, which is timed in such manner that when the intervals between the emitter pulses become greater than a predetermined value, as will result from stopping of the transport by the brake 9, then single shot 23 will provide an output pulse to reset trigger 21, which will in turn disable the AND circuit 25 so that not further counts are supplied from source 15 to counter 27. The counter 27 could also be deactivated by means not shown, from the signal supplied to clutch 7, which will carry the document 17 forward from the stopping point SP after whatever operation is to be performed on the document at that point has been accomplished. In either case, the counter is activated again by the signal from sensor 19 that the next document is passing that point.

FIG. 2 of the drawings is a table illustrating the operation of the system shown in FIG. 1 under various operating conditions for the brake. It is assumed, for the purposes of the illustration shown in this table, that the document sensor is located 2.56 inches ahead of the stopping point, and with an emitter pulse delivered for each 0.02 inch travel of the transport, it will be apparent, as previously pointed out, that the counter would have 128 positions.

The various operating conditions indicated in the table are self-evident from a careful study of the situations proposed, and it is believed no detailed description is necessary other than in connection with the last row of data, indicated as start up from power down. In this case, it would be assumed that the ring counter would be standing with a count of zero, and in such cases a dummy document would be passed through the system on the first operating cycle. Under these conditions, 128 pulses would be supplied before initiation of the brake application, so that the entire distance between the document sensor and the stopping point would have been traversed. Assuming normal operation of the brake, it will be apparent that it will take another 90 pulses to stop the document, thus providing a total travel 4.36 inches. This is quite an overrun, but it will be noticed that for the next document, which would be the steady state condition, the system operates in its normal fashion to bring the second (and first used) document to a stop at the correct stopping position of 2.56 inches from the sensor.

As an alternate approach to the use of a dummy document, when the count is lost due to power off or in the initial start-up of the transport, use may be made of artificial count injection by supplying to the counter a count of 90 pulses upon start up, when power-on conditions occur. On the other hand, if the ring counter should be comprised of non-volatile storage elements, such as magnetic cores, even the first document will be positioned nearly correctly since the ring counter would be at about position **90** at the moment of start up, as it was reading when the machine was shut down after the last document had passed through.

FIGS. **3** and **4** illustrate elaborations of the arrangement shown in FIG. **1** and described hereinbefore, these latter arrangements providing a controlled merging of film and paper strips when a printing process on the paper has been briefly interrupted by stopping the paper while the film keeps running. The basic problem is that of matching a predetermined line on the paper with a predetermined line on the film, with the paper starting from rest and the film moving continuously. The arrangement shown in FIG. **3** is a relatively simple arrangement which corrects for deviations in braking and accelerating distances of the previous cycle. The arrangement shown in FIG. **4** is somewhat more elaborate but has the advantage that it corrects for the accelerating distance of the previous cycle and the braking distance of the current cycle; in other words, even short term deviations in the braking distance are fully compensated.

The physical sensors illustrated in these drawings and described in connection therewith form one way in which predetermined points on the moving document may be located. However, if this information is available from other sources as to where various reference points are on a moving system at a given time, this information can be substituted for the physical sensors shown.

It may also be noted that the arrangement in FIG. **3** utilizes two film sensors, whereas the arrangement in FIG. **4** shows only one film sensor and an additional ring counter. The second film sensor of FIG. **3** is fully interchangeable with an additional counter. One or the other is needed to compare film and paper positions at the merger point or any point nearby providing that at this point, the clutch is fully engaged even under worst-case conditions.

Considering FIG. **3** in detail, it will be seen that the upper portion of the arrangement shown therein, is similar to that previously described in connection with FIG. **1**, in that a suitable clutch-and-brake paper transport is provided with an emitter **15** which sends discrete pulses to a ring counter **27** after being enabled by the passage of the paper past a paper sensor **19** and in the presence of a paper stop signal from a master control unit, not shown. When the ring counter goes through its index or zero position, the paper-transport brake-control **29** becomes operative to take the clutch off and set the brake on, thereby stopping the paper. The paper-transport clutch-control **29***a* shown in the lower portion of FIG. **3** provides a signal to put the paper drive-clutch on and take the brake off to thereby put the paper in motion again, in accordance with signals supplied from the master control and also an indication from a film sensor **1**, that predetermined reference points on the continuously moving film have been indicated. Film sensor **2** is utilized to provide the disabling signal to the ring counter **27**, the output signal of which actuates the paper-transport brake-control.

The paper and film transports are, of course, suitably mechanically synchronized to perform the proper merging of the film and paper webs.

The objective is to register the sum of the braking distance and the acceleration distance of the previous cycle on the count in the ring counter. Then when the "Stop Paper" command is supplied, brake action is delayed for the number of pulses from the paper-transport emitter required to fill the counter. In other words, the further the paper travels during acceleration and deceleration in the previous cycle, the sooner the brake is applied.

The second film sensor is used as an arbitrary reference point merely to establish the end of the acceleration period. It must be in the area where paper and film travel in unison, but it need not necessarily be at the theoretical merging point.

As the counter goes through zero, the brake is applied. The sum of paper motion during braking and acceleration is recorded on the counter; at the end of the "acceleration" period, input to the counter is disabled. It is enabled again by the "Stop Paper" command and the paper reference point reaching the sensor. Brake action is delayed until the counter is filled.

If:

a = number of pulses from the paper-transport emitter during acceleration,

b = number of pulses from the paper-transport emitter during braking,

w = number of pulses from the paper-transport emitter during waiting to engage the brake,

N = counter capacity,

p = paper travel in the nth cycle (measured from paper sensor) during the time film advances from Film Sensor 1 to Film Sensor 2,

δ = paper travel per pulse (emitter resolution),

n as a subscript designates the nth cycle,

we have

$$p = (w_n + b_n + a_n)\delta$$

where

$$w_n = N - b_{n-1} - a_{n-1}\,.$$

Thus

$$\{N + (b_n - b_{n-1}) + (a_n - a_{n-1})\}\,\delta = p$$

If

$$b_n = b_{n-1} \text{ and } a_n = a_{n-1}\,,$$

$p = N\delta$ = constant, i.e. proper merger is obtained. It is seen that for consistent performance of clutch and brake, the paper travels the distance Nδ during the time the film advances from Sensor 1 to Sensor 2 -- irrespective of the particular characteristics of clutch and brake.

FIG. 4 again has a large portion thereof similar to the arrangement shown in FIGS. 1 and 3 except that now the film transport is provided with an appropriate emitter as well as the paper transport, and there are additional counters as previously pointed out.

The description of FIG. 4 will be enhanced by considering the operation of the apparatus for the various steps. First, let it be assumed that ring counter 3 (reference character 35) has been filled and at this instance provides an output. At this time the clutch and brake control causes the brake to disengage and the clutch to engage. Pulse gate 1 (37) becomes enabled and pulse gage 4 (43) becomes disabled by the output of ring counter 3, whereas, pulse gate 2 (39) and pulse gate 5 (47) stay enabled, which represents no change from their previous condition, and pulse gate 3 (41) stays disabled, which also represents no change.

The paper now accelerates and paper travel pulses are recorded starting from zero on ring counter 2 (45) via the paper emitter and the pulse gate 2 (39). Film travel pulses from the film emitter are counted starting with zero in ring counter 1 (27*a*).

When counter 1 is filled, it indicates that paper acceleration is complete or slightly more than complete and the following action takes place: The output from ring counter 1 causes pulse gates 1 (37), 2 (39), and 5 (47) to become disabled. The machine will now operate normally, with counter 2 showing the acceleration distance of the paper, with counters 1 and 3 at zero.

The machine continues to operate now until a signal from the master control gives a stop paper command, and a reference point on the paper reaches the paper sensor. At this time a signal will be passed by AND gate 49 causing the clutch to disengage and the brake to engage; the output of AND gate 49 also enables pulse gate 2 (39). At this time the paper transport emitter will add deceleration pulses to counter 2 (45) via pulse gate 2 (39). When the paper comes to rest, the reading on counter 2 (45) represents the sum of the acceleration pulses of the previous cycle and the deceleration pulses of the current cycle.

With the paper stopped, the single shot senses that the paper is at rest, since no pulses are supplied from the paper transport emitter and accordingly, will enable pulse gate 3 (41). Pulses from the film transport emitter are added simultaneously to counters 2 and 3.

When counter 2 (45) becomes filled, the pulse gate 3 (41) is disabled and pulse gate 4 (43) is enabled. At this time, of course, the counter 2 has a zero output, while counter 3 shows a complement of the sum of acceleration and deceleration pulses previously recorded on the counter 2, counters 2 and 3 being of equal capacity. At this time the paper is stationary and the film keeps moving. There is no change in the counter readings.

When the master control gives a command to start the paper, and the reference point on the film will subsequently reach the film sensor, an output signal will be provided from AND gate 50, which enables pulse gate 5. Pulses from the film emitter are then added via pulse gates 5 and 4, in series, to the existing reading on counter 3.

When counter 3 is filled, the brake will be disengaged and the clutch will be engaged and the cycle of operation will be repeated.

It will be seen from the foregoing that this invention provides an improved method of accurately controlling the stopping distance of a movable mechanism, particularly a document transport system.

The invention is applicable to multiple-operated devices, as long as they can be mechanically synchronized.

While the invention has been particularly shown and described with reference to preferred embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the spirit and scope of the invention.

What is claimed is:

1. A position controlling system for accurately positioning movable mechanical means, comprising, in combination,

a movable device to be operated in successive units of distance of substantially equal values,

power means for operating said device,

clutch means interposed between said device and said power means effective when energized to couple said device to said power means to thereby move said device through a plurality of successive units,

brake means interposed between said clutch means and said device, effective when energized to stop the motion of said device,

clutch and brake control means for selectively energizing said clutch means and said brake means to thereby put said device in motion or to stop said device,

serial loop memory means having an output connected to said brake or clutch control means and having a capacity equal to the number of said units between a first sensing location and a stopping location for said device,

a source of signals representative of said units,

sensing means at said sensing location for initiating the entry of signals representing said units from said source to said memory means, and

means for inhibiting the supply of signals from said source to said memory means,

said memory means supplying an output to said control means when a predetermined count is reached in said memory means.

2. A position controlling system as claimed in claim 1, in which said memory means is a ring counter.

3. A position controlling system as claimed in claim 1, in which said movable device is a document transport system.

4. A position controlling system as claimed in claim 3, in which said sensing means comprises means for sensing the passage of a document at said sensing location.

5. A position controlling system as claimed in claim 4, in which said sensing means comprises means for detecting the leading edge of a document.

6. A position controlling system as claimed in claim 1, in which said source of signals comprises pulse generating means operated in synchronism with said movable device.

7. A position controlling system as claimed in claim 1, in which said source of signals comprises an emitter coupled to said document transport.

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