United States Patent

Cuzner et al.

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[45] **June 6, 1972**

[54] ELECTROMAGNETIC ACTUATED DETENT APPARATUS

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[51] **Int. Cl.**.....**H02k 33/10**

[58] **Field of Search**.....188/1 B, 158, 161; 310/13, 310/27; 318/128

[56] **References Cited**

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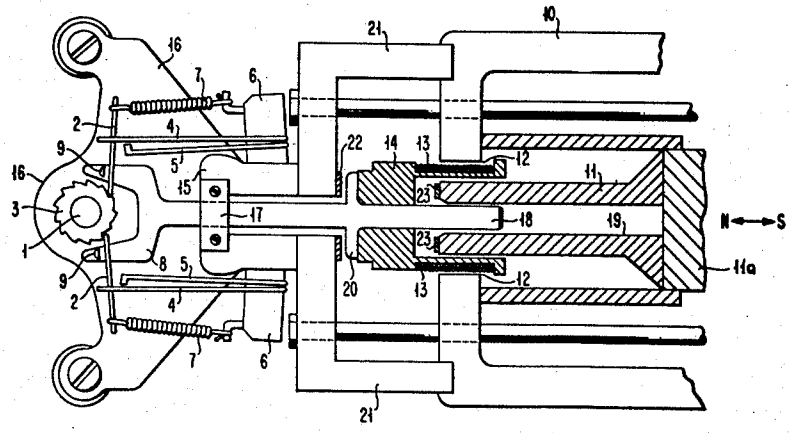
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[57] **ABSTRACT**

Locking and release for rotation of a threaded drive shaft or lead screw are selectively achieved by a detent apparatus, which includes an actuator element that is bidirectionally movable by a voice coil motor (VCM). A toothed detent wheel attached to the rotary drive shaft is engaged by detent pawls for locking. The detent wheel is released to allow rotation of the drive shaft by retraction of the actuator element, that is responsive to the VCM and that pulls the pawls out of engagement with the detent wheel. Stops limit the path of travel of the actuator element. A pulse generating circuit, in combination with a center-tapped coil of the VCM, provides an inhibit pulse to minimize bounce of the movable actuator element and associated mechanical members.

8 Claims, 4 Drawing Figures



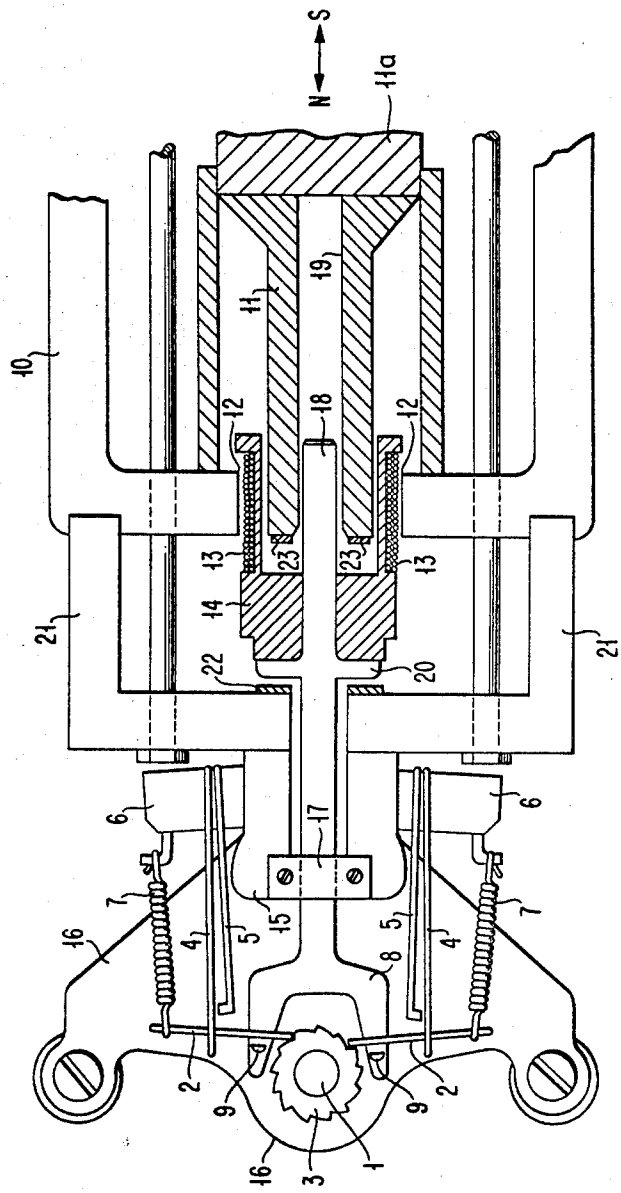


FIG. 1

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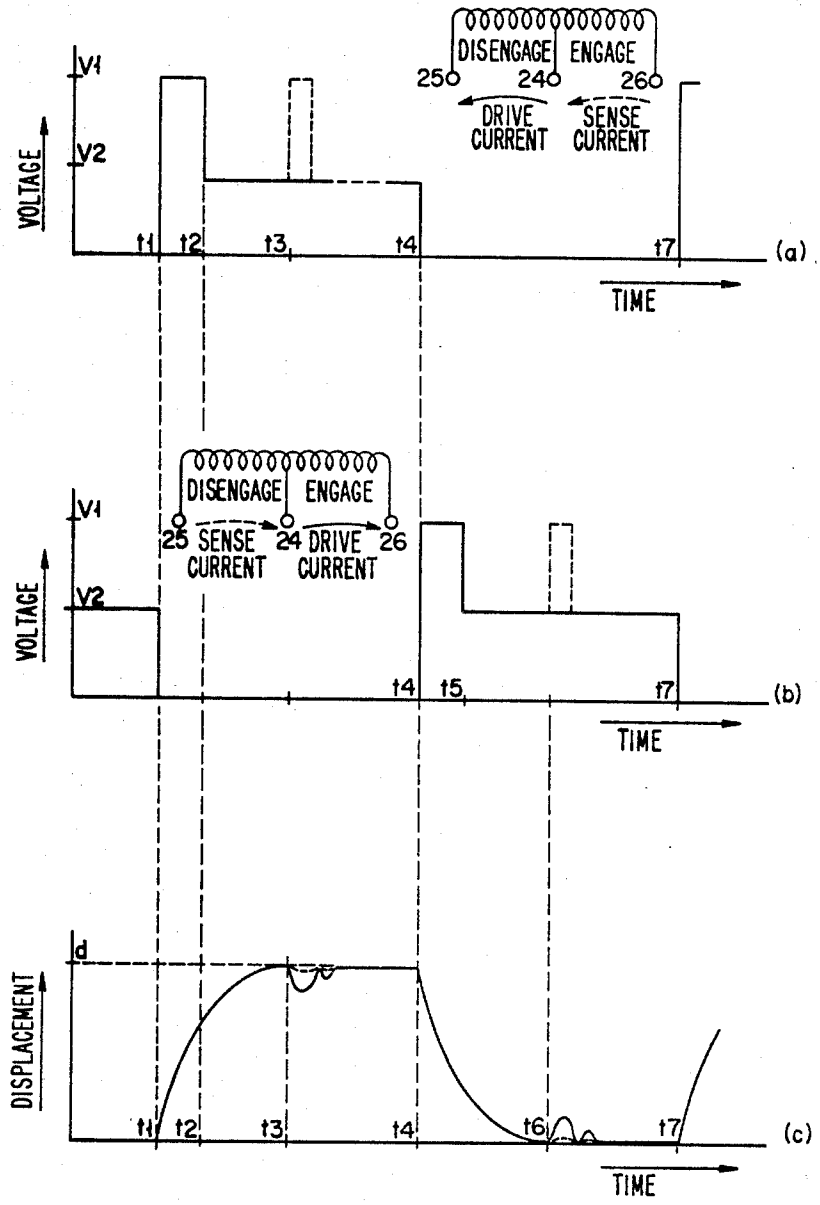

DISENGAGE
ENGAGE
250
240
260
DRIVE CURRENT
SENSE CURRENT
V1
V2
VOLTAGE
t1
t2
t3
t4
t7
(a)
TIME
DISENGAGE
ENGAGE
25
SENSE CURRENT
24
DRIVE CURRENT
26
V1
V2
VOLTAGE
t4
t5
t7
(b)
TIME
d
DISPLACEMENT
t1
t2
t3
t4
t6
t7
(c)
TIME

FIG. 2

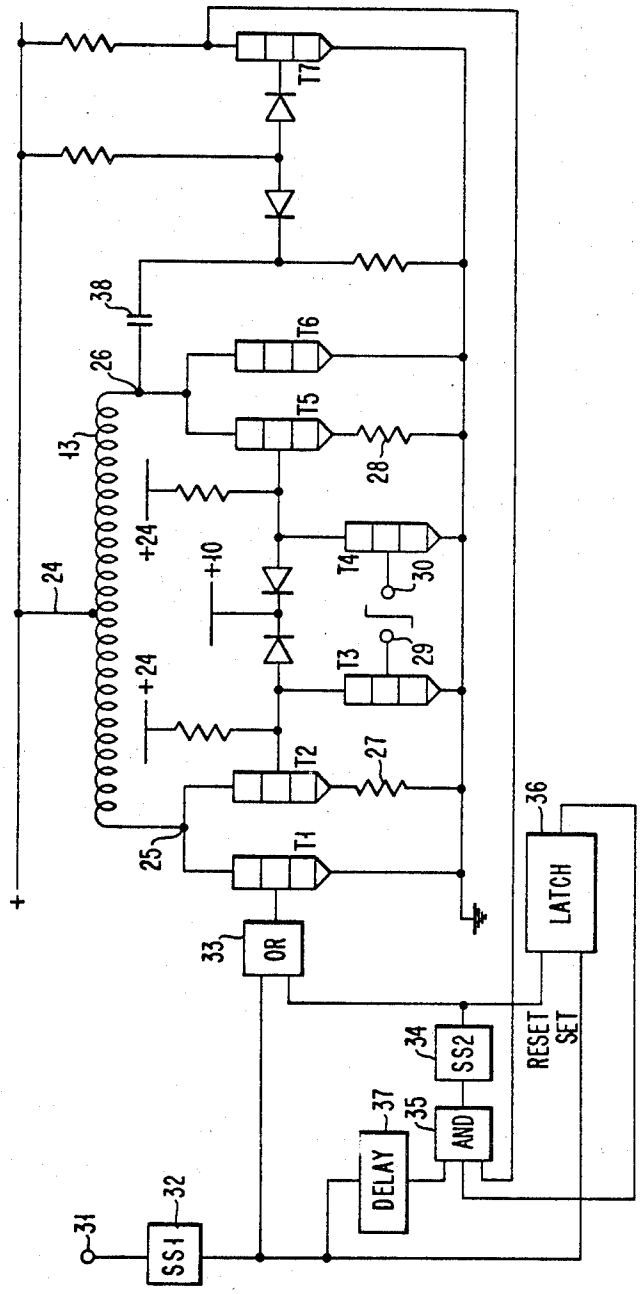
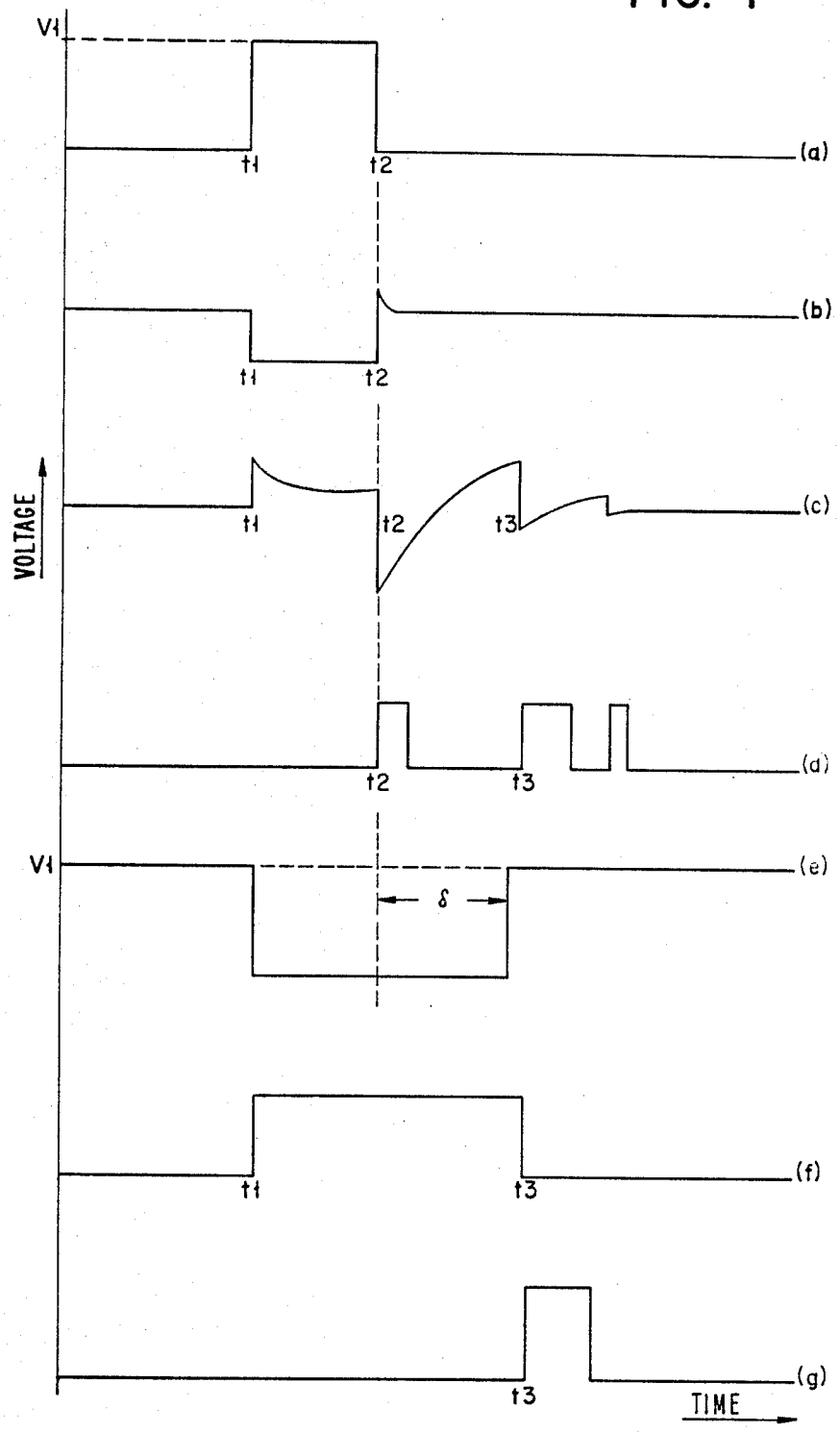

T7
38
T6
26
T5
28
13
+24
+10
T4
30
24
T3
29
+24
T2
27
25
T1
36
LATCH
33
OR
34
SS2
RESET
SET
37
35
AND
DELAY
32
31
SS1
+

FIG. 3

FIG. 4



ELECTROMAGNETIC ACTUATED DETENT APPARATUS

CROSS-REFERENCE TO RELATED APPLICATION

In copending U.S. Pat. application, Ser. No. 667,941 filed Sept. 15, 1967, now U.S. Pat. No. 3,566,381 and assigned to the same assignee, there is described a magnetic disk file utilizing a head accessing mechanism, including a drive lead screw. The magnetic head assembly is mounted on a carriage for radial movement across the disk surface, and the carriage is driven by rotation of the drive shaft or lead screw. This application discloses a novel apparatus affording an improvement in the detenting action associated with the lead screw.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to an improved detenting apparatus, and in particular to a detent mechanism and pulsing circuit that eliminates the tendency of mechanical members to bounce during detenting stop action and during release from the detent condition.

2. Description of the Prior Art

In presently used data storage apparatus, the rate of processing data is related directly to the speed of operation of the mechanical members incorporated in the apparatus. To attain maximum utilization, the operating speed of such mechanical members is pushed to the limit, with the result that, in some instances, undesirable bounce occurs, the bounce being of such magnitude that the apparatus operates incorrectly or not at an optimum desirable level.

One approach to this problem is to maintain the bounce of such members below an acceptable limit, but at the expense of reduced speed of operation, which means a reduction in performance of the apparatus. However, the performance of the apparatus usually has been specified at the outset to meet the requirements of an overall system, of which the apparatus forms a portion. In such cases, reduction in performance is unacceptable, and the problem must be resolved by other means. One proposed solution for the problem of mechanical bounce is the use of damping materials to absorb the energy of the mechanical member upon impact. Where further reduction in bounce is required, a more dynamic approach is necessary. When operating rapid data accessing devices, such as found in present day high frequency, high density disk storage systems, it is necessary to minimize the bounce of mechanical detenting devices in order to achieve the desired rapid and accurate access to data tracks.

SUMMARY OF THE INVENTION

An object of this invention is to provide a novel and improved actuated detent means, by which a driven member is precisely stopped at a desired position without bounce.

Another object of this invention is to provide an increase in speed of operation of mechanical elements that very frequently experience stops and starts.

Another object is to provide a rapid and accurate positioning means.

In accordance with one specific embodiment of this invention, a toothed detent wheel is attached to rotate with a drive shaft. A pair of detent pawls are spring-loaded to detent the wheel and maintain the shaft stationary. However, when the shaft is to be rotated to another angular position, a center-tapped coil of a voice coil motor or electromagnetic actuator is pulsed, thereby retracting a yoke that withdraws the pawls from the detent wheel. When the desired position is reached, the yoke is driven by the voice coil motor in the opposite direction, releasing the spring-loaded pawls for engagement with the toothed wheel and detent action. Stops are provided to limit the movement of the yoke in each direction. To prevent bounce of the yoke when it contacts a stop, and the bounce of cooperating mechanical members, an inhibit pulse is applied at the appropriate time to the other half of the center-tapped coil than that used to drive the yoke.

BRIEF DESCRIPTION OF THE DRAWING

The invention will be described in greater detail with reference to the drawings in which:

FIG. 1 is a plan view partly in section, of a portion of an accessing mechanism useful for a disk file, including an electromagnetic actuator, in accordance with this invention;

FIGS. 2*a–c* are a series of waveforms to aid in the explanation of the invention;

FIG. 3 is a schematic circuit diagram, partly in block, of an energizing circuit used with the access mechanism of this invention; and

FIGS. 4*a–g* are waveforms to help define the operation of the circuit of FIG. 3.

DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. 1 illustrates the end of a drive shaft or lead screw 1 which is used for transporting a head carriage assembly in a magnetic disk file, by way of example. Rotation of the lead screw 1 causes the recording head carriage assembly to move radially across a magnetic disk surface. When the head assembly reaches the selected track for the read or write operation, rotation is stopped, and the lead screw is locked in position by two identical detent pawls 2, that engage the teeth of a detent wheel 3 rigidly attached to the lead screw. The arrangement of this specific embodiment is such that rotation of the detent wheel from one tooth to the next produces a corresponding movement of the recording head from one track of the disk to the next. Consequently it is important that the pawls 2 accurately engage the detent wheel 3.

The pawls 2 are mounted on leaf springs 4 which reduce the effect of impact between the pawls and the detent wheel 3. Excessive movement of the leaf springs towards the detent wheel is restrained by stops 5 mounted with the leaf springs 4 on convenient parts 6 of the main frame 16. Pawl springs 7 attached to the remote ends of the pawls 2 urge the pawls into engagement with the detent wheel to prevent rotation of the lead screw 1 and the attendant movement of the recording head.

When it is desired to move the head to a different track on the disk, a voice coil assembly, shown in part on the right hand side of FIG. 1, is energized causing a yoke 8 to retract, i.e., move from left to right in the figure. Projections 9 on the surface of the yoke 8 engage the pawls 2, thus removing the pawls from the detent wheel 3 to permit rotation of lead screw 1 for repositioning the head.

The voice coil assembly includes a C-shaped magnet flux return path 10 and central pole piece 11 attached to a permanent magnet 11a defining a cylindrical gap 12 across which a strong magnetic field exists. A voice coil 13 is supported in the gap 12 on a cylindrical former 14 which surrounds the pole piece 11. The coil 13 is a center-tapped winding, one half of which is energized to drive the former 14 and the yoke 8 in one direction and the other half to drive them in the opposite direction. The yoke 8 is slidably mounted at one end in a grooved support 15 attached to the main frame 16 and closed by a removable plate 17. The yoke arm 18 extends through the center of the former 14 and into a hole 19 along the central axis of the pole piece 11. This provides a slidable support for the yoke and also accurately positions the former 14 and coil 13 in the gaps 12. Integral with the yoke arm 18 is a projecting disk 20 which is bonded to the former 14 to provide added rigidity.

The voice coil assembly is bolted to a support bar 21, which in turn is connected to the main frame 16. A pad 22 on the inside face of the support bar 21 acts as a stop to limit the movement of the yoke 8 in the left hand direction in the figure. A further pad 23 on the end of the pole piece 11 acts as a stop for movement of the yoke 8 in the right hand direction. Both pads 22 and 23 are made of a resilient material, such as a polyurethane rubber, to absorb impact energy of the yoke 8, at the ends of its stroke and so reduce the tendency of the yoke to bounce. Even so, it has been found that the remaining

bounce can cause the pawls 2 to either prematurely engage the detent wheel 3 before the heads have reached the required track, or to momentarily disengage the detent wheel after the head has reached the required track. In either event, the recording head is liable to come to rest over the wrong track on the disk.

Clearly the amount of bounce is related to the speed of the yoke on impact, which itself is determined by the access speed requirements of the disk file. Pressure is often bought to bear on designers to increase the speed of operation of mechanical and electromechanical components, which otherwise would limit the overall performance of a host system. In the present case the speed requirements are such that even with energy absorbing rubbers, the actuator mechanism still suffers from bounce, which causes malfunction of the mechanism.

The displacement curve shown in FIG. 2*c* represents the velocity of the yoke 8 during its movement between the two limiting stops 22 and 23. The voltages applied to one half of the voice coil, to disengage the detent wheel 3 to permit rotation, is represented by the voltage waveform in FIG. 2*a* and that applied to the other half for engaging and thus stopping the detent is shown in FIG. 2*b*. A representation of the voice coil 13 accompanies the waveforms to show the two halves of the coil used to generate the "disengage" and "engage" voltages.

A drive current applied from the center-tap 24 through one-half of the voice coil 13 to terminal 25 produces the voltage shown in FIG. 2*a* to disengage the detent 3. Initially a large pick voltage v_1 is applied to the winding producing rapid acceleration of the yoke 8 away from stop 22. Thus at time t_1 the yoke rapidly accelerates from its position of zero displacement towards the other stop 23 at displacement d as shown in FIG. 2*c*. The pick pulse is applied from time t_1 to time t_2 which is sufficiently long, say 1.8 milliseconds, to produce rapid acceleration of the yoke 8 but insufficient to cause overheating of the coil. At time t_2 the voltage is reduced to v_2, approximately half the value of the pick voltage, and is maintained at this value to continue to drive the yoke towards stop 23 and to hold the yoke against stop 23. AT time t_3 however, the yoke reaches the stop 23 traveling at a high velocity, from where it bounces, as shown by the dip in the curve in FIG. 2c. There may be several bounces before the yoke comes to rest held by pulse v_2 against the stop 23.

When it is required to engage and stop rotation of the detent wheel, the "disengage" pulse is terminated and a drive current applied from the center-tap 24 through the other half of the voice coil 13 to terminal 26. This is shown occurring at time t_4 in FIG. 2*c*. The similar voltage waveform produced to drive the yoke to engage the detent wheel is shown in FIG. 2*b*. Again this waveform consists of an initial pick voltage v_1 applied from time t_4 to t_5 followed by a hold voltage v_2 of approximately half the value. The pick voltage produces rapid acceleration of the yoke away from stop 23, as is seen from the displacement curve of FIG. 2*c*. The movement of the yoke continues under the influence of the hold pulse v_2 as before until it eventually contacts stop 22 at time t_6. Once again bounce occurs, as shown by the discontinuities in the curve in FIG. 2*c*. Once this has subsided the yoke is maintained against stop 22 by the hold pulse, although in this case the pawl springs 2 will continue to hold the pawls in engagement with the detent wheel 3 even when the hold pulse terminates.

When it is desired to reposition the recording head the procedure is repeated. Thus at time t_7 the "engage" pulse is terminated and the next "disengage" pulse is applied to the appropriate half of the winding 13. It is seen from FIG. 2*c* that the timing of this mechanism is critical, especially at time t_6 when the pawls 2 engage the detent wheel 3 to prevent rotation. Bounce at this time can cause the pawls 2 to disengage the wheel 3 permitting further rotation and incorrect positioning of the recording head. The time t_3 is also critical since the total movement of the yoke is sufficiently small for the bounce from the stop 23 to cause the pawls to interfere with the rotation of the detent wheel again causing incorrect positioning of the recording head.

This problem of bounce has been overcome by applying a short duration high current arresting pulse to the appropriate half of the voice coil 13 shortly after impact with the stop and in a direction to inhibit the bounce of the coil and yoke from the stop. Thus the bounce at time t_3 from stop 23 is inhibited by supplying an arresting pulse to the disengage half of coil 13 at time t_3, as shown in dashed outline in FIG. 2*a*. Similarly the bounce from stop 22 at time t_6 is inhibited by supplying a similar arresting pulse to the engage half of coil 13.

A convenient signal for triggering the arresting pulse is derived from the back e.m.f. generated in the unused half of the voice coil 13 as it moves through the magnetic field. At the instant the coil and yoke hit the stop, the generated back e.m.f. in the unused half changes direction and is of sufficient magnitude to trigger a circuit to generate the required pulse in the half of the coil 13 being driven at that time. Although the change in e.m.f. does not occur until the yoke and coil start to bounce, the response of the pulse generating circuit is so rapid that the arresting pulse is supplied before any significant bounce has occurred.

The circuit for energizing the voice coil 13 incorporating the invention is shown in FIG. 3, and voltage waveforms at various parts of the circuit are shown in FIG. 4. The operation of the circuit will now be described with reference to these two figures.

Transistors T_1 and T_2 are connected in parallel between a reference potential, such as ground, and terminal 25 of the voice coil 13, the center-tap 24 of which is connected to a positive supply. Transistors T_5 and T_6 are likewise connected in parallel between ground and terminal 26 of the voice coil 13. Thus by selective energization of these transistors, either the disengage current is caused to flow from center-tap 24 to terminal 25 or the engage current from the center-tap 24 to terminal 26.

The conductivity of transistors T_2 and T_5 is controlled by transistors T_3 and T_4 respectively. When T_3 is fully conducting the base electrode of transistor T_2 is substantially at ground or zero potential and this transistor is cut off. When transistor T_3 is cut off, transistor T_2 conducts and a defined current flows through the disengage half of the voice coil 13 through transistor T_2 and resistor 27 to earth. The resulting voltage across the coil 13 is shown in FIG. 2*a* as the hold voltage v_2 during time interval t_1 to t_4. The hold voltage v_2 across the engage half of the coil 13, shown in FIG. 2*b*, is generated at time t_4 by switching on transistor T_3 and switching off transistor T_4. A defined current then flows through the engage half of the voice coil 13, through transistor T_5 and resistor 28 to ground. Thus disengage or engage currents can be caused to flow through the appropriate halves of the voice coil 13 simply by supplying a differential signal between the base terminals 29 and 30 of transistors T_3 and T_4.

The pick pulse which imparts an initial high acceleration to the coil 13 and yoke 8 is generated separately. Only the circuitry for producing the pick pulse to move the coil and yoke in the disengage direction is shown in FIG. 3. The circuitry for producing the pick pulse to move the coil in the engage direction is identical and has not been included for the sake of simplicity and clarity. Further it will be apparent to those skilled in the art that many of the component parts shown can be common to both the disengage and the engage halves of the circuit.

A signal applied to input terminal 31 fires the pick single shot 32 producing an output waveform of duration t_1 to t_2 as shown in FIG. 4*a*. This voltage is applied to the base electrode of transistor T_1 via OR circuit 33. Transistor T_1 saturates and its collector voltage falls to substantially ground potential at time t_1 as shown in FIG. 4*b*. A relatively large current flows through the disengage half of the voice coil 13 from the center tap 24 to terminal 25 which imparts an initial high acceleration to the coil and yoke. When the pick pulse terminates at time t_2, the current flow through the winding falls to the value defined by transistor T_2 and resistor 27, which has been concurrently energized bya pulse applied to input terminal 29.

The waveform shown in FIG. 4*c* shows how the voltage changes at terminal **26** of the other half of the voice coil **13** in response to movement in the magnetic field, and the energization of the disengage coil with the voice coil **13** acting as a transformer. When the coil hits the limit stop, the generated back e.m.f. changes polarity as shown at time t_3 in FIG. 4*c*. The subsequent discontinuities indicate further bounces of the yoke and coil from the stop and are clearly of diminishing size. This voltage at terminal **26** is A.C. coupled to transistor T_7 through capacitor **38**. Transistor T_7 is normally in a conducting state and consequently its collector voltage is substantially at ground potential. The changes in potential at terminal **26** periodically switch transistor T_7 off giving rise to the waveform shown in FIG. 4*d*. It should be noted that the last two positive excursions of this waveform correspond in time to bounces of the yoke and coil from the limit stop. The waveforms in FIG. 4*d* are shown as they would occur if no further pulse was supplied to inhibit bounce. Application of such an arresting pulse will of course modify the waveforms after time t_3.

The arresting pulse is supplied from a second single shot **34** to the base of transistor T_1 via OR gate **33**. The single shot **34** is fired by the output of a three-input positive AND gate **35** whose inputs are derived from the collector of transistor T_7, the output from delay circuit **37** supplied with the pick pulse from single shot **32**, and the output from a latch **36** which is set by the undelayed pick pulse from single shot **32**. Delay circuit **37** produces a pulse, as shown in FIG. 4*e*, which coincides in time with the positive excursion of the collector voltage of transistor T_7 caused by bounce of the yoke from the limit stop. The delay δ is sufficiently long so that the pulse does not coincide in time with the first positive excursion produced by transistor T_1 turning off.

Thus at time t_1 latch **36** is set by the pick pulse from single shot **34** supplying a positive voltage to one input of AND gate **35**. At time $t_1 + \delta$ the delayed pick pulse appears from delay circuit **37** and a second input of AND gate **35** goes positive. As soon as the bounce occurs at time t_3 the collector of transistor T_7 goes positive and AND gate **35** is enabled, causing single shot **34** to fire, producing the second pick pulse as shown in FIG. 4*g* to suppress the bounce. The output from single shot **34** resets latch **36** as shown in FIG. 4*f*.

While the description has been limited to one particular form of access mechanism for a magnetic disk file, it will be apparent that many modifications can be made within the scope of the invention. For example, in the preferred embodiment the voice coil itself moves in a stationary magnetic field. Clearly the invention would be equally applicable where the actuator mechanism is operated by causing a magnetic former to move within an energized stationary coil. Also in the preferred embodiment, the voice coil is shown as being center-tapped, which is particularly convenient, since it enables the unused half of the winding to be monitored for voltage changes indicative of bounce. Clearly, a single coil could be used which is driven in one direction for engage and in the other for disengage. A change in voltage in the coil would occur on bounce as before and could be used to generate the arresting pulse according to the invention.

What is claimed is:

1. A detent apparatus for controlling the movement of a mechanical member comprising:

a drive shaft;

mechanical detent means for selectively holding said shaft in a fixed position, and alternatively releasing said shaft for movement;

an electromagnetic actuator having a coil mounted in a magnetic field;

circuit means for pulsing said coil to provide bidirectional movement of said actuator;

stop means for limiting such movement of said actuator;

means for detecting the bounce of said detent means and said actuator whenever the limiting stop means is impacted; and

means responsive to said detecting means for pulsing the coil of said electromagnetic actuator to inhibit bounce of said detent means and said actuator.

2. A detent apparatus as in claim **1**, wherein said coil is center-tapped, one-half of said coil being energizable to drive the actuator towards the stop, and the other half being energizable to drive the actuator away from the stop.

3. A detent apparatus as in claim **2**, wherein said detent means comprises a bifurcated yoke.

4. A detent apparatus as in claim **3**, wherein said drive shaft is a rotary shaft, and said detent means includes a toothed wheel, rigidly attached to said shaft, a pair of spring-loaded detent pawls for engaging said wheel for detent action, and means associated with said yoke for retracting said pawls to release said shaft for rotation.

5. A detent apparatus as in claim **3**, wherein said stop means includes first and second stops that define the limits of longitudinal travel of said yoke.

6. A detent apparatus as in claim **5**, wherein the means for detecting bounce of the yoke includes a circuit responsive to the change in electromotive force produced in the coil upon impact of the yoke with the first or second stop.

7. A detent apparatus as in claim **6**, wherein said circuit detects at the moment of impact the change in electromotive force produced in the half of the coil not being driven, and supplies an arresting pulse to the driven half of the coil to inhibit the bounce of the yoke.

8. A detent apparatus as in claim **1**, wherein the voltage pulse supplied to the coil consists of an initial portion of higher amplitude than the remainder of the pulse.

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