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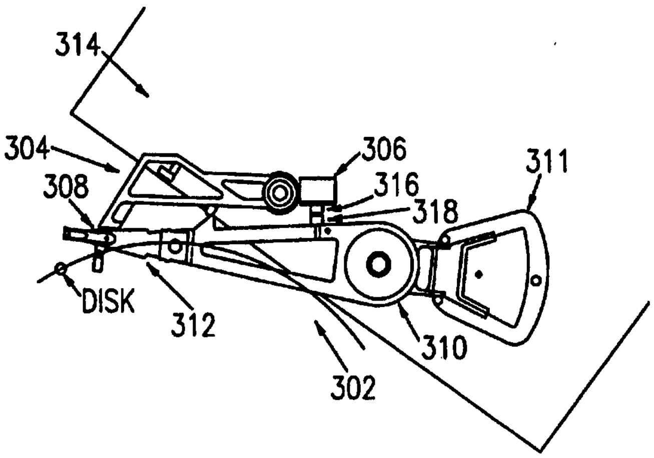

(57) Abstract

A magnetic latch for latching read/write heads on a moving ramp in a removable cartridge disk drive system includes a latch mechanism and a latch plate (318), at least one of which includes a magnetically-attractive plate. The latch mechanism is attached to a voice coil motor actuator and read/write head assembly (302). The magnetic attraction between the latch plate (318) and latch assembly (316) retains the read/write head (308) on the ramp (304) in the presence of shocks and vibration to the disk drive. An associated servo control algorithm (900) controls the read/write head velocity while the head (308) is loaded on a magnetic disk.

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DESCRIPTION

Magnetic Latch for a Movable Ramp and Associated Servo Control for Head Loading

Background of the Invention

Field of the Invention

The field of the present invention relates to removable cartridge disk drives in general and, more particularly, to a device and method for loading and unloading magnetic read/write heads onto a magnetic disk in a removable cartridge disk drive system.

Background of the Related Art

Removable cartridge disk drive systems have been available on the market for some time. Like fixed disk drives, removable cartridge disk drive systems provide large storage capacities with relatively rapid access times at low cost. However, unlike fixed disk drives, removable cartridge disk drive systems enable a user to easily replace a relatively high capacity disk, allowing for convenient exchange of large amounts of information between remote sites and for greatly increased system storage capacity.

Like fixed disk drives, removable cartridge disk drive systems use magnetic read/write heads to read and write data stored as magnetic fields on a magnetic disk surface. The disk surface is divided into a number of concentrically arranged tracks where data is stored. To read or write data to the disk, the disk surface is rapidly rotated and the read/write head(s) pass over the surface, following the circumferential path of the track or tracks where the data is to be stored or read. Thus the disk drive requires some means for positioning the read/write heads over the disk surface along a track wherein data is to be written or read.

Typically, the read/write head is attached to a voice coil motor (VCM) actuator which loads and unloads the head from the magnetic disk surface. To actuate the VCM, a control current is passed through the voice coil producing an acceleration and resulting angular velocity in the VCM and the attached read/write head. By controlling the voice coil current, the read/write head may be positioned over the disk wherein data is desired to be written or read.

When a removable cartridge is inserted into a removable cartridge disk drive, the read/write heads must be loaded onto the disk surface to begin read/write operations. Conversely, while not in use, or when a cartridge is to be removed from the disk drive, the read/write heads must be unloaded from the disk surface. When the heads are unloaded, it is desired to secure them in a parked position where they will be restrained from inadvertently moving back onto the disk surface in response to shocks or vibrations.

Figure 1 shows a prior art movable ramp and latch mechanism for loading and unloading read/write heads onto a disk in a removable cartridge disk drive. A VCM actuator and head assembly 102 comprises read/write heads 104 attached to a VCM actuator 106 by means of load beams 108. The VCM actuator and head assembly 102 is attached to a disk drive base 110.

Also attached to the disk drive base 110 is a movable ramp 112 with a pair of ramp surfaces 114, 116 which are sloped relative to the surfaces of the cartridge disk. During head loading or unloading operations, the read/write heads 104 (one on each side of the disk) are rotated by VCM actuator 106 down or up the ramp surfaces to load or park the heads. The movable ramp 112 has a pair of protuberances 118 on each ramp surface. While in a parked position, the VCM actuator and head assembly 102 is 3 restrained by the protuberances 118 from moving down the ramp 112 and onto the disk surface until locked by a linkage assembly.

As shown in Figure 2A, the movable ramp 112 may be moved into a fully retracted ramp back position while the read/write heads 104 are not in use, such as when a disk cartridge is being inserted or ejected from the drive. The movable ramp 112 is moved into the back position by means of a linkage assembly which is not shown.

As shown in Figure 2B, the movable ramp 112 also may be moved into a ramp forward position from which the read/write heads 104 may be loaded onto a disk surface. From the ramp forward position, the entire width of the head load beams 108 must proceed over the protuberances 118 before the torque required to move the heads toward the disk is significantly reduced. Similarly, for unloading and retraction of the heads, the load beams must completely clear the protuberances before the read/write heads are secured.

It is further desired to reduce the torque requirements for the VCM actuator in the disk drive as this can reduce the cost of the associated electronics in the disk drive. When unloading a head during power-off conditions, a tradeoff exists between the velocity of the load beams as they approach the ramp 4 and the amount of actuator torque which is required to ensure that the load beams can climb the ramp and pass over the protuberances. To reduce the torque, the load beam velocity must be increased as the assembly approaches and climbs the ramp. The resulting vertical acceleration up the ramp and over the protuberances during the head unloading process can damage the delicate head assembly.

The prior art arrangement of Figures 1 and 2 suffers from other disadvantages. The restraining force of the protuberances is limited by the need to insure that under worst case conditions the read/write heads can pass over the protuberances as the heads are unloaded. This results in some loss of immunity to shock, especially rotational shock, increasing the possibility that the heads may inadvertently move off the ramp and onto the disk. if the holding force of the protuberances is too light and the ramp moves forward too quickly, the load beams can be flung off the ramp and the read/write heads may land on the disk.

Accordingly, it would be advantageous to provide a more secure latch for restraining read/write heads in a parked position in a removable cartridge disk drive system. it would further be advantageous to provide an improved latch which allows the VCM actuator and head assembly to climb the movable ramp with lower kinetic energy. It would still further be advantageous to provide a servo control algorithm for loading and unloading read/write heads in a removable cartridge disk drive incorporating an improved latch. Other objects and advantages will appear hereinafter.

Summary of the Invention

The present invention comprises a device and method for loading and unloading magnetic read/write heads onto a magnetic disk in a removable cartridge disk drive system.

In one aspect of the present invention, a removable cart-ridge disk drive incorporates a magnetic latch to secure or latch a read/write head in a parked position on a movable ramp when the head is unloaded from a magnetic disk. The attractive force of the magnet tends to recapture the read/write head to its latched position even if a shock causes the head to move momentarily.

In another aspect of the present invention, an improved latch for securing a read/write head in a parked position allows the VCM actuator and head assembly to climb the ramp with relatively little kinetic energy or actuator torque. The kinetic energy required to climb the ramp is reduced both by the lack of a frictional engagement to be overcome due to the elimination of protuberances on the ramp, and by the attractive force of the magnetic latch urging the VCM actuator and read/write head assembly up the movable ramp.

In yet another aspect of the present invention, a servo control algorithm maintains a constant read/write head velocity during the head load process in a removable cartridge disk drive with a movable ramp having a magnetic latch.

Brief Description of the Drawings

The various objects, features and advantages of the present invention may be better understood by examining the Description of the Preferred Embodiment found below, together with the appended figures, wherein:

Figure 1 is a top view of a voice coil motor actuator and head assembly and a movable ramp with a prior art latch mechanism for parking read/write heads in a removable cartridge disk drive system.

Figure 2A is a top view of a voice coil motor actuator and head assembly retracted in a ramp back position on the movable ramp with the prior art latch mechanism of Figure 1.

Figure 2B is a top view of a voice coil motor actuator and head assembly in a ramp forward position on the movable ramp with the prior art latch mechanism of Figure 1.

Figure 3 is a top view of a voice coil motor actuator and head assembly in a ramp forward position on a movable ramp incorporating one embodiment of a magnetic latch constructed according to one or more aspects of the present invention.

Figure 4A is a front view of a latch assembly for securing a read/write head in a parked position on a movable ramp in a removable cartridge disk drive.

Figure 4B is a top view of the latch assembly of Figure 4A.

Figure 4C is a side elevation of the latch assembler Figures 4A and 4B.

Figure 4D is a perspective view of a magnetic latch.

Figure 5 is a side view of a steel spring for a magnetic latch.

Figure 6A is a front view of a bracket for a magnetic latch.

Figure 6B is a top view of the bracket of Figure 6A.

Figure 6C is a side elevation of the bracket of Figures 6A and 6B.

Figure 7 is top view of a voice coil motor actuator and head assembly retracted in a ramp back position on a movable ramp with a magnetic latch.

Figure 8 shows a servo control loop for controlling read/ write head velocity in a removable cartridge disk drive incorporating a magnetic latch.

Figures 9A-9C show a flow chart for a servo control algorithm for controlling the velocity of a read/write head during a head loading operation.

Description of the Preferred Embodiment

Fig. 3 shows a voice coil motor (VCM) actuator and read/write head assembly 302 in a ramp forward position on a movable ramp 304 with a magnetic latch 306 according to one or more aspects of the present invention, with the movable ramp in a ramp forward position. The VCM actuator and read/write head assembly 302 comprises read/write heads 308 attached to a VCM actuator 310 by means of load beams 312. The VCM actuator includes a voice coil 311. The VCM actuator and read/write head assembly 302 and the movable ramp 304 are each attached to a portion of the disk drive housing structure comprising a base plate 314. The magnetic latch 306 comprises a latch assembly 316 connected to the base plate 314, and a latch plate 318 connected to the VCM actuator and head assembly 302.

A preferred embodiment of the latch assembly 316 is shown in Figs. 4A-4C. The latch assembly 316 comprises a magnet 410 attached to a spring 412. The magnet 410 radiates a flux field of sufficient strength to attract and hold the latch plate 318 on the VCM actuator and head assembly 302 while the read/write heads 308 are parked on the movable ramp 304 in a fully retracted position. In a preferred embodiment, the magnet 410 may be a samarium cobalt 80 magnet, such as part number 18DRE0704 manufactured by Magnet Sales Co.

While the movable ramp 304 is in a ramp forward position, the magnetic latch 306 holds the heads 308 on the ramp.

As shown in Fig. 3, as the heads are loaded onto a disk from the ramp, the magnet 410 begins to separate from the latch plate 318, opening the magnetic latch 306.

Although in the preferred embodiment, the latch assembly 316 is mounted on the base plate 314, it is to be understood that the latch assembly may be attached to any suitable portion of the disk drive housing structure. The latch assembly 316 is located with respect to the movable ramp 304 such that the magnet 410 is in contact with the latch plate 318 when the read/write heads 308 are parked on the movable ramp. The latch assembly also must be located far enough away from the voice coil 311 so that the field of the magnet 410 does not influence the operation of the voice coil. In a preferred embodiment, the latch assembly 316 is located approximately 3, C-M from the closest point of the voice coil 311.

In a preferred embodiment, the latch plate 318 is fabricated from a magnetically-attractive material, such as a steel plate, a steel f lat head screw, or a similar device, and is fastened to the actuator 310 on the VCM actuator and head assembly.

Although in the disclosed preferred embodiment, magnet 410 is included in the latch assembly 316, it would be understood that other arrangements are possible without departing from the scope and spirit of the present invention. In one variation, the latch plate 318 may be magnetized with a polarity opposite to the polarity of the magnet 410 such that latch plate 318 and magnet 410 attract each other. In another variation, the latch plate 318 may be magnetized and the latch assembly may comprise a nonmagnetized magnetically-attractive plate in place of the magnet 410. Fig. 4D shows a preferred embodiment of the magnetic latch 306 comprising the latch assembly 316 and the latch plate 318.

Fig. 5 shows a preferred embodiment of the spring 412. Conveniently, in the illustrated embodiment of Figs. 4A-4C, the latch assembly 316 also is provided with a bracket 414. The spring 412 is fastened to the bracket 414 by fastening means 416, which may be a bolt and nut, a threaded screw, a spot weld, or a similar device. Bracket 414 is in turn attached to the base plate 314.

As seen to better advantage in Figs. 6A-6C, bracket 414 has a first arm 610 including a slot 612 for receiving a screw or bolt for attachment to the base plate 314. The bracket also has a second arm 614 including an opening 616 through which the magnet 410 may pass to make initial contact with the latch plate 318. Although the preferred embodiment includes the bracket 414 it will be understood that the spring 412 may be directly fastened to the base plate 314 without the bracket 414. However, the bracket improves the operation of the magnetic latch 306 by restraining the forward movement of the magnet 410 and spring 412 toward the latch plate 318 when the read/write heads 308 are being loaded onto a disk. The opening 616 in the bracket 414 allows the magnet 410 to remain in contact with the latch plate 318 when the spring 412 is compressed.

Fig. 7 shows the VCM actuator and read/write head assembly 302 retracted on the movable ramp 304 with the magnetic latch 306 of Fig. 3, while the movable ramp itself is retracted in a ramp back position. The ramp 304 is moved into a back position by a linkage assembly as discussed above, not shown or forming a part of the present invention. The magnet 410 and latch plate 318 are in contact with each other while the read/write heads 308 are in a fully retracted position. with the ramp 304 in the back position, the spring 412 is compressed.

When it is desired to execute a read and/or write operation with a magnetic disk, the voice coil motor actuator 310 loads read/write head 308 onto a disk surface. To accomplish this, the disk drive passes a control current though the voice coil 311, producing a force which translates to an acceleration and resulting angular velocity in the read/write head 308. A servo control loop may be used to control the read/write head velocity.

To determine the read/write head velocity, the voltage developed across the voice coil of the VCM actuator 310 is measured. The measured voice coil voltage is the sum of two components: the back electromotive force (EMF) , which is proportional to the read/write head angular velocity, and the IR voltage drop across the coil's wiring resistance. By subtracting the IR voltage drop from the measured voice coil voltage, the EMF is obtained and the read/write head angular velocity is calculated. An appropriate control current then may be applies to the voice coil to maintain a target velocity. More details regarding this method of controlling read/write head velocity be found in U.S. Patent No. 4,864,437, entitled "HEAD LOADING VELOCITY CONTROL" assigned to the assignee of the present invention and hereby incorporated herein by reference.

Fig. 8 shows a preferred embodiment of a servo control loop 800 for controlling read/write head velocity in a disk incorporating a magnetic latch. The servo control loop includes differential amplifier 802 which measures the voltage across the coil in the voice coil motor 804. The measured voltage is provided to an analog-to-digital converter (ADC) 806 where it is periodically sampled and converted into a digital word, suitable to be processed by a digital microprocessor 808.

The digital microprocessor 808 executes an algorithm to periodically update an output digital control voltage word, based on the measured voice coil voltage. The digital control voltage word is provided to a digital-to-analog converter (DAC) 810 to produce an analog voltage signal. The analog voltage signal is provided to a transconductance amplifier 812 which in turn supplies the control current to the voice coil.

In a preferred embodiment, a servo control algorithm according to one or more aspects of the present invention controls the read/write head velocity by switching between two control modes, depending upon the magnitude of the voice coil control current through the voice coil. In response to the magnitude of the control current exceeding a predetermined threshold, the algorithm operates in a chopped high current velocity control servo mode, as will he explained in more detail below. Otherwise, the algorithm operates in a continuous low current velocity control servo mode.

The algorithm operates in the chopped high current velocity servo control mode in response to the magnitude of the voice coil control current being sufficient to cause the differential amplifier input to saturate on the resulting IR component of the voice coil voltage. The chopped high current velocity control mode prevents saturation of the differential amplifier input during measurement of the voice coil voltage by removing the voice coil current.

The chopped high current velocity servo control mode operates in two phases, i.e., a velocity control phase and a measurement phase. During the velocity control phase, the voice coil control current is set to a value calculated to produce target read/write head velocity.

During the measurement phase, the voice coil control current is removed. After a delay period over which the coil current decays substantially to zero, voice coil voltage is measured. By removing the current, the voice coil voltage is measured without saturation of the differential amplifier.

With the voice coil control current removed, there remains a residual current through the coil due to the decay time constant, L/R. The remaining voltage produced by this residual current after the delay period is subtracted from the measured voice coil voltage to obtain the back EMF which is proportional to read/write head angular velocity. From the measured back the read/write head angular velocity is calculated and compared to a target value, producing a velocity error value. The voice coil control current is then adjusted to reduce the velocity error.

In the continuous low current velocity mode, the voice coil control current is continuously applied to the voice coil. Periodically, the algorithm samples the differential amplifier output to obtain the voice coil voltage. Using the known value of the voice coil control current measured during system calibration, the IR voltage is calculated and subtracted from the measured voice coil voltage to yield the back EMF. From the back EMF, the read/write head angular velocity is calculated and compared to a target value, producing a velocity error value. The voice coil control current is then adjusted to reduce the velocity error.

An algorithm having a chopped high current velocity servo control mode is particularly well suited to a disk drive having a movable ramp with a magnetic latch more according to one or more aspects of the present invention. During the start of a head loading process, as the read/write heads are parked on the ramp, they are held in place by the magnetic latch. To overcome this force, the voice coil control current may be increased to a level where the resultant IR voltage voice across the voice coil saturates the differential amplifier. By operating in the chopped high current velocity servo control mode, the read/write head velocity may be measured and used in a servo control loop. Although an algorithm having a chopped velocity mode is particularly well suited to a disk drive having a movable ramp with a magnetic latch, it is also useful in conjunction with prior art movable ramp and latch mechanisms, for example, such as the system described above with respect to Fig. 1.

Figs. 9A-9C comprises a flow chart of an algorithm 900 for servo control of the velocity of a read/write head during a head loading operation according to one or more aspects of the present invention. The algorithm 900 may be executed whenever it is desired to load a read/write head onto a magnetic disk to initiate a data read or data write operation. A complete firmware code listing for a preferred embodiment of a servo control algorithm is provided at the end of this specification pursuant to 37 C.F.R. § 1.96. The firmware code may be executed using an 80C196KR microprocessor manufactured by Intel Corp.

In a first subroutine 910, shown in Fig. 9A, the algorithm 900 calibrates the servo control loop prior to loading or unloading the read/write heads from a magnetic disk. In the calibration routine, the algorithm measures the offset voltages produced by the servo control loop circuitry, such as the differential amplifier, and the voltage produced by residual current through the voice coil due to the L/R decay time constant.

In a first series of steps from 912 through 934 an offset value for the chopped high current velocity servo control mode is measured. With the control current set to zero, 64 periodic measurements of the voice coil voltage are taken. The 64 high current offset voltage measurements are then averaged to yield a high current offset value.

In a second series of steps beginning at 936, and branching back to 916 through 934, both an offset value and a voice coil resistance value for the continuous low current velocity servo control mode are measured. As before, 64 periodic measurements of the voice coil voltage are performed with the control current set to zero. The 64 low current offset voltage measurements are averaged to yield a low current offset value.

The 64 low current offset measurements are alternate- with another 64 measurements of the voice coil voltage wherein the voice coil control current is set to a nominal value. The nominal voice coil control current is selected such that the voice coil is urged in a direction up the ramp and against the latch so that no net movement results. Thus, the measured voice coil voltage, with the voice coil control current set to the nominal value, corresponds to the IR voltage loss through the voice coil windings. The 64 measurements are averaged to yield a low current IR correction factor.

In a second subroutine 940, shown in Fig. 9B, the algorithm 900 operates in a chopped high current velocity servo control mode to control the velocity of the read/write heads. In a first series of steps 942 through 946, comprising a measurement phase, the control current is set to zero and the back EMF across the voice coil is measured. The high current offset value is subtracted and the result is scaled to yield the read/write head velocity.

Next, the measured read/write head velocity is compared to a target velocity to generate a velocity error. The velocity error is then limited, if necessary, to insure that its magnitude does not exceed predetermined positive and negative error limits. At steps 952 though 958, the velocity error is proportionally integrated with previous error measurements to produce a servo loop filter response. The integrated error signal is limited, if necessary, to insure that its magnitude does not exceed predetermined positive and negative limits.

In a preferred embodiment, the measurement phase of subroutine 940 has a duration of approximately 300 μsec and occurs with a period of approximately 1.3 msec. Part of the time for the measurement phase is a delay time corresponding to the L/R time constant required for the voice coil control current to dissipate toward zero.

Following a first series of steps comprising the measurement phase, the subroutine 940 executes a second series of steps 966 through 970 comprising a velocity control phase. The integrated error signal is used to program the DAC in the servo control loop with a voltage to be applied to the voice coil during the velocity control phase. The updated DAC voltage produces an updated voice coil control current and a corresponding read/write head velocity during the velocity control phase.

Also, the updated voice coil control current is calculated and its magnitude is compared to predetermined saturation thresholds. As long as the magnitude of the current exceeds the thresholds, the algorithm continues to operate in the chopped high current velocity servo control mode. If the current is low enough to insure that the differential amplifier will not be saturated by the IR voltage across the coil, the algorithm switches to the continuous low current velocity servo control mode.

In a third subroutine 972, shown in Fig. 9C, the algorithm 900 operates in a continuous low current velocity servo control mode to control the velocity of the read/write heads. The voice coil voltage is measured and its magnitude is compared to predetermined positive and negative saturation limits of the ADC in the servo control loop. If the limits are exceeded, the magnitude of the voice coil current is reduced and in steps 994 and 996 a new voice coil voltage measurement is made after a fixed delay. In a preferred embodiment, the fixed delay is approximately 200 μsec.

If the voice coil voltage is within the ADC saturation limits, then the low current voltage offset and low current IR correction factor are subtracted from the measured voice coil voltage and the result is scaled to yield the read/write head velocity.

Next, the measured read/write head velocity is compared to a target velocity to generate a velocity error. The velocity error is then limited, if necessary, to insure that its magnitude does not exceed predetermined positive and negative error limits. The velocity error is then proportionally integrated with previous error measurements to produce a servo loop filter response. The integrated error signal is limited, if necessary, to insure that its magnitude does not exceed predetermined positive and negative limits.

The integrated error signal is used to program the DAC with a voltage to be applied to the voice coil during the next measurement period. In a preferred embodiment, each measurement period for the continuous low current velocity servo control mode is 200 μsec. The updated DAC voltage produces a voice coil current and a corresponding read/write head velocity during the measurement period.

Also, the new voice coil current is calculated and its magnitude is compared to predetermined saturation thresholds. As long as the magnitude of the current does not exceed the thresholds, the algorithm continues to operate in the continuous low current velocity servo control mode. If the saturation limits are exceeded, then the algorithm switches to the chopped high current velocity servo control mode.

Thus, the algorithm 900 provides servo control of the velocity of a read/write head as it is loaded onto a magnetic disk. The algorithm 900 may also be executed when it is desired to unload a read/write head from a magnetic disk.

The present invention has been set forth in the form of its preferred embodiment. It is nevertheless intended that modifications to the magnetic latch and associated servo control algorithm disclosed herein may be made by those skilled in the art without departing from the scope and spirit of the present invention.

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;=================================================================
;--------------------------
;--- Head load constants ---
;--------------------------
C_hd_ref        equ   00140H       ;Target velocity
C_hd_calib      equ   0FF00H       ;Calibration Ivcm
ADC_P_LIMIT     equ   00390H       ;+Vbemf saturation (chopped)
ADC_N_LIMIT     equ   00020H       ;-Vbemf saturation (chopped)
LOW-P-LIMIT     equ   002A0H       ;+Velocity Limit   (chopped)
LOW-N-LIMIT     equ   0FC9CH       ;-Velocity Limit   (chopped)
HIGH-P-LIMIT    equ   002AO0+80H   ;+Velocity Limit(continuous)
HIGH-N-LIMIT    equ   0FC9CH-80H   ;-Velocity Limit(continuous)
INT-P-LIMIT     equ   07C00H       ;+Integrator rail
INT-N-LIMIT     equ   08400H       ;-Integrator rail
UN-P-SAT        equ   00180H       ;+Vbemf saturation(continuous)
UN-N-SAT        equ   -00180H      ;-Vbemf saturation(continuous)
VEL-OFFSET      equ   00080H       ;Velocity offset
;=================================================================
hdldv_setup:
        clru    un                 ;Initialize current DAC output
        ldb     all,P2REG          ;Set high gain mode
        orb     all,#B_HGAIN
        stb     all,P2REG
        ret
;=================================================================
vsns1_setup:
        ld      c,#dac_zero        ;Set zero VCM current
        st      c,DAC
        ld      c,#C_hd-ref        ;Initialize target velocity
        st      c,D_hd_ref
        ld      c,#C_hd-calib      ;Initialize calibration current
        st      c,D_hd-calib
        st      RO,D_hd_ofst       ;Clear Vbemf offset register
        st      RO,D_hd-sns        ;Clear Vbemf sense register
        ldb     cl,#40H            ;Average 64 conversions
```

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```
        stb     cl,AVE_COUNT
        ld      c,#05C4H            ;Start A/D by OC on TIMER2
        stb     ch,AD_CMD           ;Set A/D to convert Vbemf/ch5
        stb     cl,EPA_CTRL5        ;Set EPA5 to start A/d on TIMER2
        ld      c,TIMER2            ;Get TIMER2 value
        add     c,-#09C40H          ; add to it 10 msec
        st      c,EPA_TIME5         ;Set OC time to start A/D in
                                     10 msec
        ldb   state_lvl,#LOAD_HEADS ;Set next interrupt state
        ret
;======================================================================
;-----------------------------------------------
Calibration and Setup for head load states ---
;-----------------------------------------------
load_heads:                              ;--- VCM current ON state ---
        ld      al,AD_RSLT               ;Read Vbemf
        shr     al,#06H
        add     hd_ofst,al               ;Accumulate Vbemf for average
        ldb     al,P2REG                 ;IF HGAIN is set calibration
        jbs     all,BN_HGAIN,load_heads10 :at Ivcm = 0 is in progress
        add     un,hd_calib,#dac_zero    ;Set DAC = calibration level
        st      un,dac                   ; (Ivcm ! = 0)
load_heads10:
        ldb     all,#05H                 ;Setup A/D to convert Vbemf
        stb     all,AD_CMD
        ld      al,TIMER2                ;Setup EPA5 to initiate A/D
        add     al,#usec400              ; conversion 400us from now
        st      al,EPA_TIME5
        ldb     state_lvl,#LOAD_HEADS20  ;Set next interrupt state
        br      DONE_INTERRUPT           ;END of INTERRUPT
load-heads20:                            ;--- VCM current OFF state---
        ld      al,AD_RSLT               ;Read Vbemf
        shr     al,#06H
        add     hd_sns,al                ;Accumulate Vbemf for average
        ld      un,#dac_zero             ;Set DAC=0 (Ivcm = 0)
        st      un,DAC
        ld      al,TIMER2                ;Compute time 400us from now
        add     al,#usec400
        ldb     state_lvl,#LOAD_HEADS    ;Set next interrupt state
        djnz    AVE_COUNT,load_heads25   ;Repeat cycle 64 times
;--- Process after calibration measurements ---
       shr    hd_ofst,#06H          ;Compute average Vbemf for Ivcm=0
```

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```
        shr   hd_sns,#06H                 ;Compute average Vbemf forIvcm!=0
        ldb   all,P2REG                   ;If HGAIN is not set (low gain)
        jbc   all,BN_HGAIN,Load_heads23; calibration is complete
        andb  all,#not B_HGAIN            ;ELSE setup to calibrate at
        stb   all,P2REG                   ; low gain
        st    hd_ofst,hd_ofst_h           ;Store high gain offset value
        call  vsns1_setup                 ;Repeat calibration for low gain
        br    DONE_INTERRUPT              ;END of INTERRUPT
; --- Setup for head load velocity control ---
load_heads23:
        sub   hd_cc,hd_ofst,hd_sns        ;Compute Voffset - Vcal
        ldb   state_lvl,#LOAD_HEADS30     ;Set next interrupt state
        ldb   all,#0ffh                   ;Initialize integrator reset
        stb   all,xh_tmp                  ; flags
        clr   x2                          ;Initialize velocity
        add   un,#dac_zero                ;Initialize DAC output
        st    un,DAC
        ldb   all,P2REG                   ;Set high gain mode
        orb   all,#B_HGAIN
        stb   all,P2REG
        ld    al,TIMER2                   ;Set A/D conversion start
        add   al,#usec500                 ;500us from now
;--- Enable next A/D conversion ---
load_heads25:
        st    al,EPA_TIME5                ;Set A/D conversion start time
        ldb   all,#05H                    ;Setup A/D to convert Vbemf
        stb   all,AD_CMD
        br    DONE-INTERRUPT              ;END of INTERRUPT
;-----------------------------------------------------
;--- High VCM current "chopped" velocity control servo ---
;-----------------------------------------------------
load_heads3O:                             ; --- VCM current OFF state ---
        ld    hd_sns,AD_RSLT              ;Read Vbemf (unused)
        ld    un,#dac_zero                ;Set DAC=0 (Ivcm = 0)
        st    un,DAC
        ldb   all,#05H                    ;Setup next A/D cycle
        stb   all,AD_CMD                  ; to convert Vbemf
        ld    al,TIMER2                   ; 300us from now
        add   al,#usec300
        st    al,EPA_TIME5
        ldb   state_lvl,#LOAD_HEADS40     ;Set next interrupt state
```

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```
        br     DONE_INTERRUPT              ;END of INTERRUPT
load_heads40:                              ; --- VCM control state ---
        ld     hd_sns,AD_RSLT              ;Read Vbemf
        shr    hd_sns,#06H
        sub    hd_sns,hd_ofst_h            ;Adjust Vbemf by offset level
                                           ; VELOCITY = Vbemf - Voffset
        mul    a,hd_sns,#256               ;Scale velocity
        shral  a,#4
        ld     x2,al                       ;Save scaled velocity
        clr    bh                          ;Compute velocity error
        sub    bl,hd_ref,#VEL_OFFSET
        sub    bl,al
        subc   bh,ah
        ld     un,bl
        ld     al,#HIGH_N_LIMIT            ;Saturate velocity
        ld     ah,#0ffffh                  ; for velocity limits exceeded
        cmpl   b,a
        jlt    load_heads43
        ld     al,#HIGH_P_LIMIT
        cLr    ah
        cmpl   b,a
        jle    load_heads44
        ld     un,#HIGH_P_LIMIT
        sjmp   load_heads44
load-heads43:
        ld     un,#HIGH_N_LIMIT
load-heads44:
        add    x4,un                       ;Integrate X4 = X4 + UN
        cmp    x4,#INT_N_LIMIT             ;Saturate X4
        jle    load_heads45
        cmp    x4,#INT_P_LIMIT
        jle    load_heads46
        ld     x4,#INT_P_LIMIT
        sjmp   load_heads46

load_heads45:
        ld     x4,#INT_N_LIMIT

load_heads46:
        ld     al,x4                       ;Apply integrator gain
        shra   al,#05H
```

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```
        add   un,al                    ;Add proportional term
                                       ; to integrator
        cmp   un,#HIGH_N_LIMIT         ;Saturate UN
        jle   load_heads47
        cmp   un,#HIGH_P_LIMIT
        jle   load_heads48
        ld    un,#HIGH_P_LIMIT
        sjmp  load_heads48
load_heads47:
        ld    un,#HIGH_N_LIMIT
load_heads48:
        ldb   all,xh_tmp               ;Skip high-velocity reset
        jbc   alt,0,dac_output         ; if reset occurred before
        cmp   x2,#VEL_TRIP             ;Check for velocity outside
        jgt   null_integrator          ; trip limits
        cmp   x2,#-VEL_TRIP
        jlt   null_integrator
        sjmp  dac_output
null-integrator:
        ld    x4,RO                    ;Reset integrator if velocity
        ld    un,RO                    ; is outside trip limits
        stb   RO,xh_tmp
dac_output:
        add   al,un,#dac_zero          ;Set DAC to control Level
        st    al,DAC
        cmp   al,#800H+80H             ;Check for VCM current over
        jh    load_heads49z            ; threshold
        cmp   al,#800H-80H
        jnh   load_heads49z
        call  switch2low               ;Switch to low gain
        br    load_heads59             ; "continuous" control
load_heads49z:
        ldb   all,#05H                 ;Setup A/D to convert Vbemf
        stb   all,AD_CMD               ; 1ms from now
        ld    al,TIMER2
        add   al,#msec001
        st    at,EPA_TIME5
        ldb   state_lvl,#LOAD_HEADS30  ;Set next interrupt state
        br    DONE-INTERRUPT           ;END of INTERRUPT
;-----------------------------------------------------------
;--- Low VCM current "continuous" velocity controL servo ---
;-----------------------------------------------------------
```

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```
load_heads50:
        ld      hd_sns,AD_RSLT          ;Read Vbemf
        shr     hd_sns,#06H
        cmp     hd_sns,#ADC_P_LIMIT     ;Process saturation of Vbemf
        jnh     load_heads51
        cmp     un,#UN_P_SAT
        je      load_heads510
        ld      un,#UN_P_SAT
        sjmp    load_heads65
load_heads51:
        cmp     hd_sns,#ADC_N_LIMIT
        jh      load_heads52
load_heads510:
        ld      un,#00H
        sjmp    load_heads65
load_heads52:
        sub     hd_sns,hd_ofst_h        ;Adjust Vbemf by offset level
                                        ; VELOCITY = vbemf - Voffset
        mul     a,hd_sns,#256           ;Scale velocity
        mul     b,un,hd_cc              ;Compute velocity adjustment
        sub     al,bl                   ;Velocity=hd_sns_(un*hd_cc)
        subc    ah,bh
        shral   a,#4
        ld      x2,al                   ;Save velocity
        clr     bh
        sub     bl,hd_ref,al            ;Compute velocity error
        subc    bh,ah                   ; VE = hd_ref - velocity
        ld      un,bl
        ld      al,#LOW_N_LIMIT         ;Saturate velocity
        ld      ah,#0ffffh              ; for velocity limits exceeded
        cmpl    b,a
        jlt     load_heads55
        ld      al,#LOW_P_LIMIT
        clr     ah
        cmpl    b,a
        jle     load_heads57
        ld      un,#LOW_P_LIMIT
        sjmp    load_heads57
load_heads55:
        ld      un,#LOW_N_LIMIT
load_heads57:
```

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```
        add   x4,un               ;Integrate X4 = X4 + UN
        cmp   x4,#INT_N_LIMIT     ;Saturate X4
        jle   load_heads58
        cmp   x4,#INT_P_LIMIT
        jle   load_heads59
        ld    x4,#INT_P_LIMIT
        sjmp  load_heads59
load_heads58:
        ld    x4,#INT_N_LIMIT
load_heads59:
        ld    al,x4               ;Apply integrator gain
        shra  al,#05H
        add   un,al               ;Add proportional term
                                  ; to integrator
        cmp   un,#LOW_N_LIMIT     ;Saturate UN
        jle   load_heads60
        cmp   un,#LOW_P_LIMIT
        jle   load_heads65
        ld    un,#LOW_P_LIMIT
        call  switch2high         ;Switch to high gain "chopped"
        br    load_heads49        ; mode if saturated
load_heads60:
        ld    un,#LOW_N_LIMIT
        call  switch2high         ;Switch to high gain "chopped"
        br    load_heads49        ; mode if saturated
load_heads65:
        add   al,un,#dac_zero     ;Output control to DAC
        st    al,DAC
        ldb   all,#05H            ;Setup A/D to convert
        stb   all,AD_CMD          ; Vbemf 200us from now
        ld    al,TIMER2
        add   al,#usec200
        st    al,EPA_TIME5
        br    DONE_INTERRUPT      ;END of INTERRUPT
;-----------------------------------------------------------
;--- Switch from continuous to chopped velocity control ---
;-----------------------------------------------------------
switch2high:
        st    un,al               ;Initialize DAC Level
        st    al,DAC
        lcb   all,P2REG           ;Set high gain mode
        orb   att,#B_HGAIN
```

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```
        stb   all,P2REG
        ret
;------------------------------------------------------------
;--- Switch from chopped to continuous velocity control ---
;------------------------------------------------------------
switch2low:
        ldb   all,P2REG                 ;Set low gain mode
        andb  all,#not(B_HGAIN)
        stb   all,P2REG
        ldb   state_lvl,#LOAD_HEADS50   ;Set next interrupt state
        ret
```

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Claims:

1. An apparatus for latching a voice coil motor actuator and read/write head assembly in a parked position on a movable ramp mounted inside a housing structure in a removable cartridge disk drive comprising:

a magnet; and

a magnetically-attractive structure, one of said magnet and said magnetically-attractive structure attached to a portion of the disk drive housing structure, and the other of said magnet and said magnetically-attractive structure connected to the voice coil motor actuator and read/write head assembly, said magnet in contact with said magnetically-attractive structure while the read/write head is parked on the movable ramp in a retracted position.

2. The apparatus of claim 1, wherein said magnet is movably attached to the portion of the disk drive housing structure.

3. The apparatus of claim 2, further comprising spring means movably attaching said magnet to the portion of the disk drive housing structure.

4. The apparatus of claim 3, wherein said magnet has a magnetic pole perpendicularly oriented with respect to the portion of the disk drive housing structure.

5. The apparatus of claim 4, further comprising a bracket, said bracket having a first arm connected to the portion of the disk drive housing structure and a second arm, substantially perpendicular to the first arm, having an opening through which said magnet may pass to make contact with said magnetically-attractive structure.

6. The apparatus of claim 5, wherein said spring means movably attaches said magnet to the portion of the

disk drive housing structure by connecting said magnet to said bracket.

7. The apparatus of claim 1 wherein said magnetic attractive structure comprises a second magnet having a polarity opposite to the polarity of said first magnet.

8. A removable cartridge disk drive comprising: a read/write head for reading data from and writing data to a magnetic disk;

a movable ramp for parking said read/write head; and

a magnetic latch for latching said read/write head while parked on said movable ramp.

9. The removable cartridge disk drive of claim 8, further comprising:

a voice coil motor actuator connected to the read/write head for loading said read/write head from said movable ramp onto the magnetic disk; and

a servo control loop for controlling the velocity of said read/write head by passing a voice coil control current through the voice coil of the voice coil motor actuator while loading said read/write head onto the magnetic disk.

10. The removable cartridge disk drive of claim 9, wherein said servo control loop operates in a chopped high current velocity servo control mode when the magnitude of the voice coil current exceeds a predetermined threshold, and wherein said servo control loop operates in a continuous low current velocity servo control mode when the magnitude of the voice coil current does not exceed the predetermined threshold.

11. A method of controlling an angular velocity of a read/write head as it is loaded onto a magnetic disk in a disk drive, comprising the steps of:

passing a voice coil control current through a voice coil actuator connected to the read/write head to produce the angular velocity; in response to the voice coil control current exceeding a preselected threshold, setting the voice coil control current to zero while measuring a back EMF, scaling the back EMF by a proportionality factor to obtain a measured angular velocity, comparing the measured angular velocity with a target angular velocity to produce a velocity error signal, and integrating the velocity error signal to produce an updated voice coil current to control the angular velocity of the read/write head; and

in response to the voice coil control current not exceeding a preselected threshold, measuring the voice coil voltage, subtracting an IR correction factor from the measured voice coil voltage to obtain the back EMF, scaling the back EMF by the proportionality factor to obtain the measured angular velocity, comparing the measured angular velocity with the target angular velocity to produce the velocity error signal, and integrating the velocity error signal to produce the updated voice coil current to control the angular velocity of the read/write head.

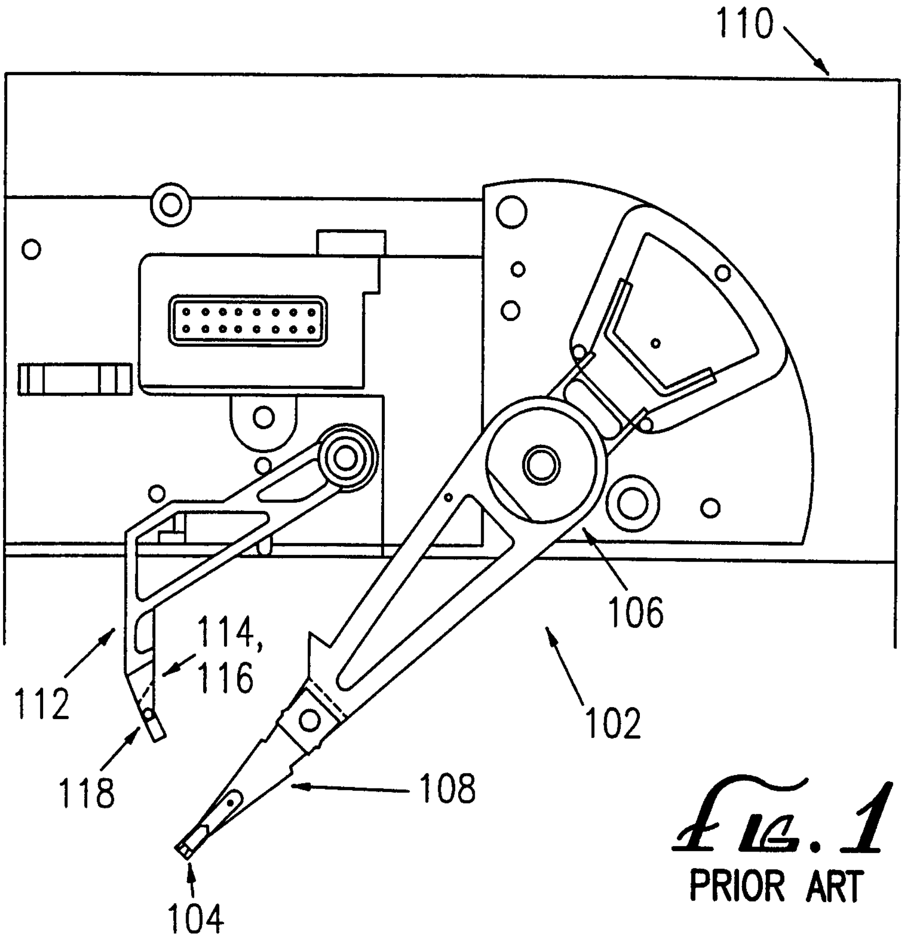


FIG. 1
PRIOR ART

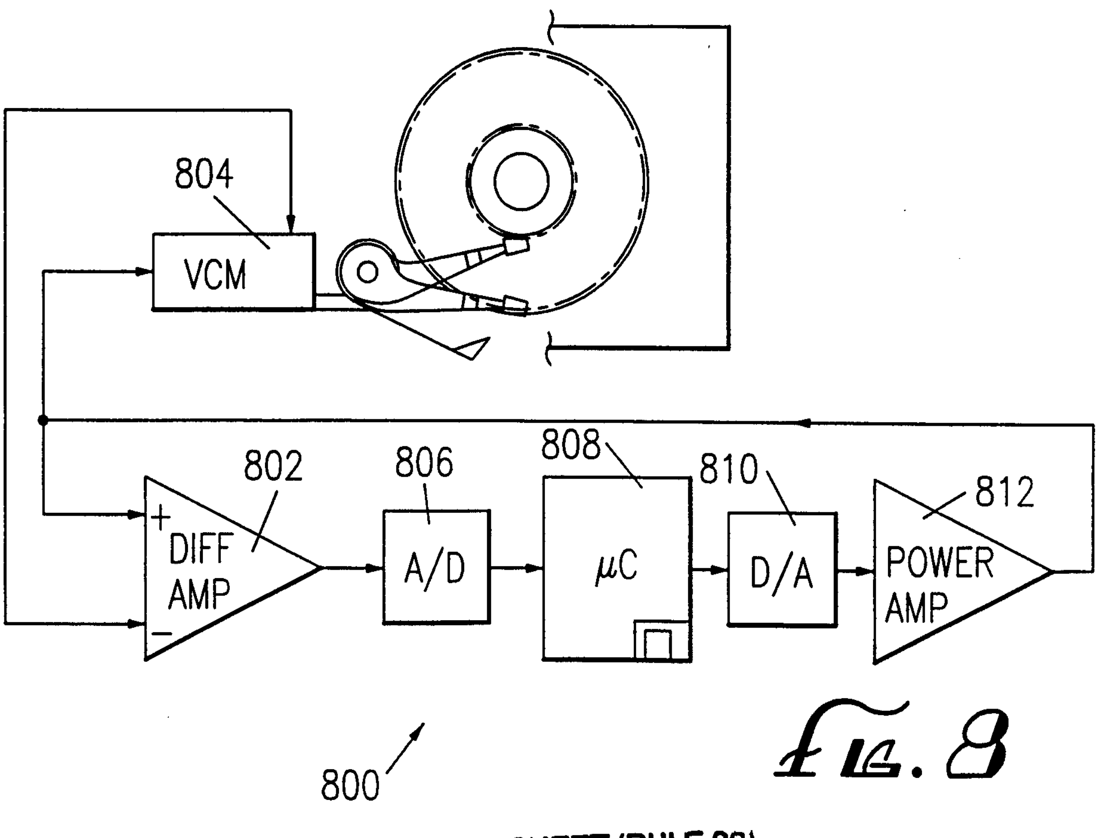


FIG. 8

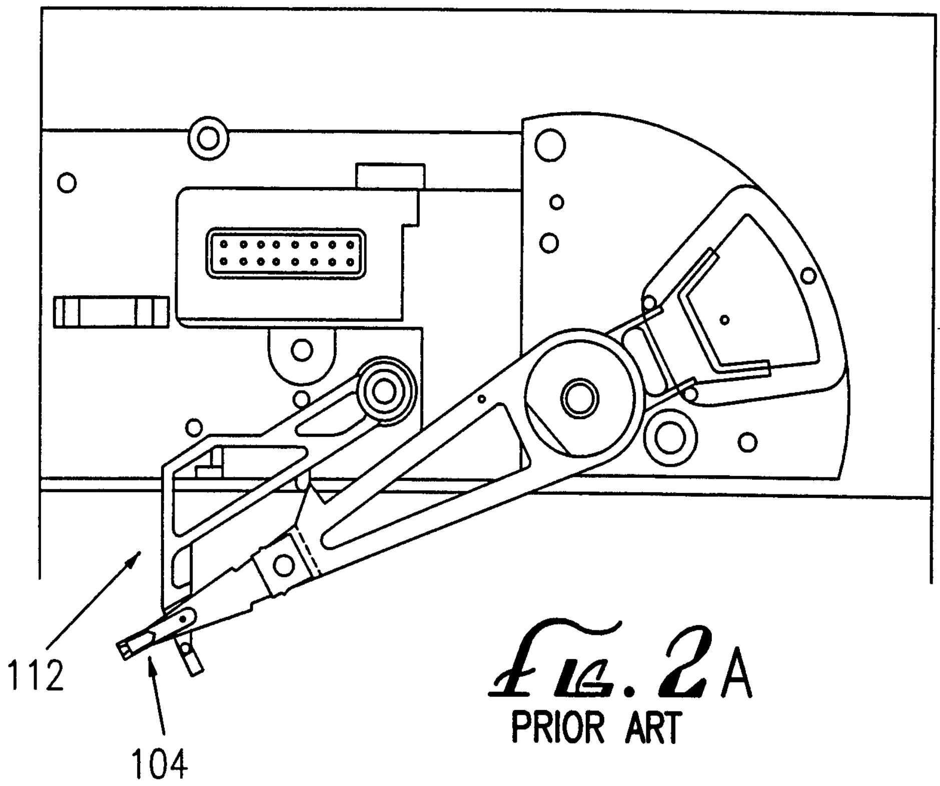


FIG. 2A
PRIOR ART

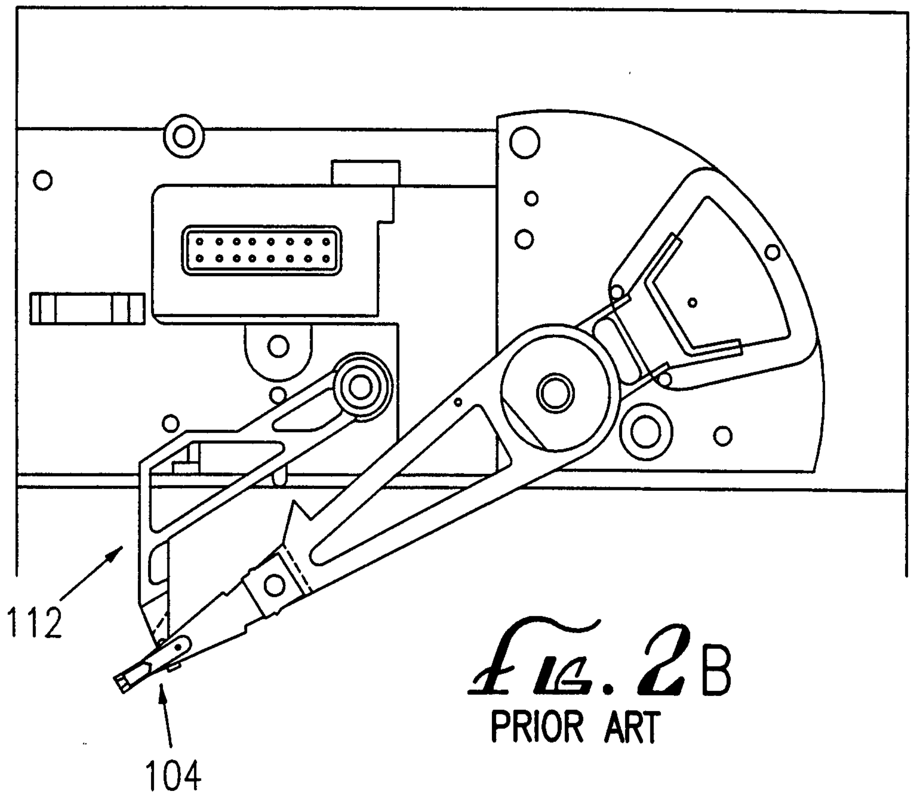


FIG. 2B
PRIOR ART

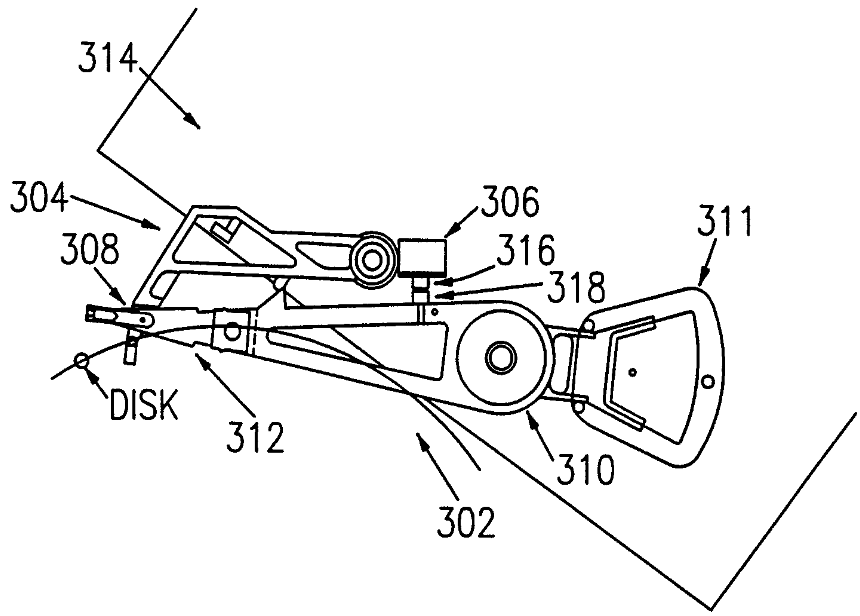

314
304
306
311
308
316
318
DISK
312
310
302

FIG. 3

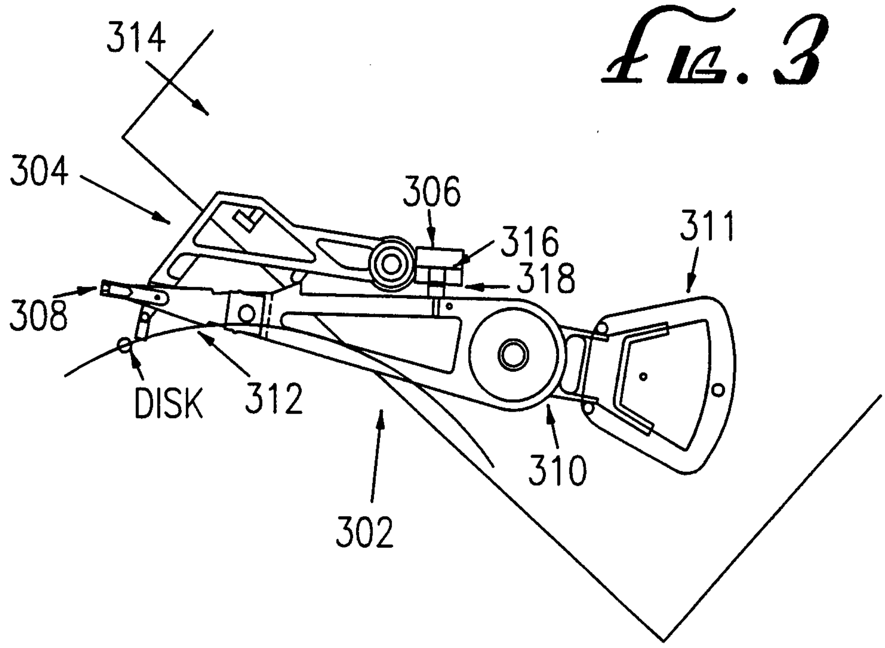

314
304
306
316
311
318
308
DISK
312
310
302

FIG. 7

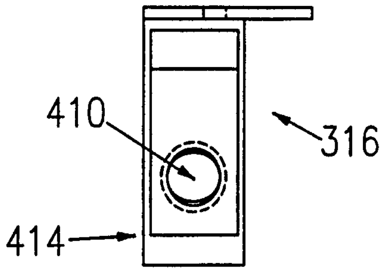


FIG. 4A

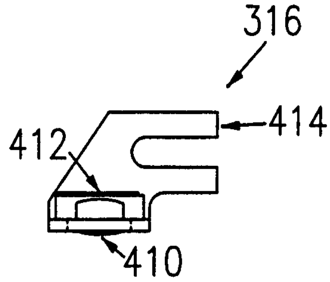


FIG. 4B

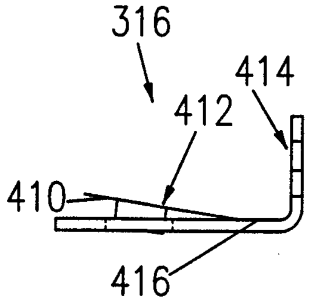


FIG. 4C

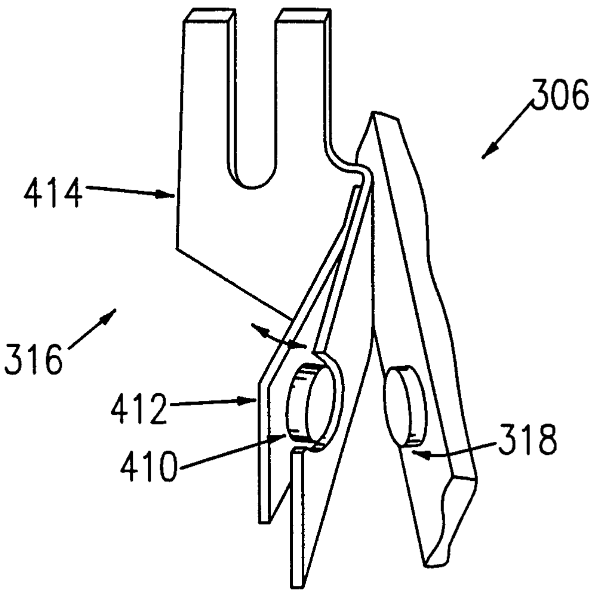


FIG. 4D

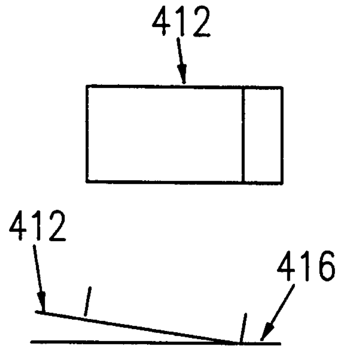


FIG. 5

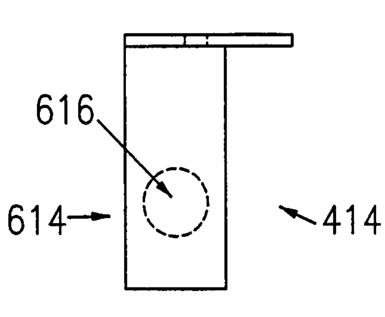


FIG. 6A

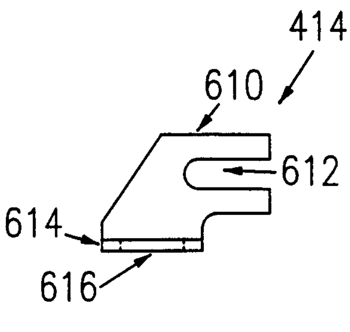


FIG. 6B

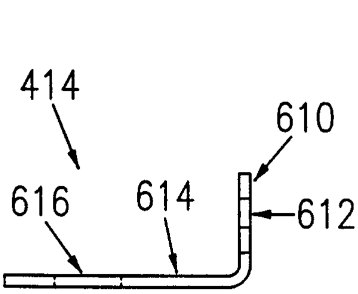


FIG. 6C

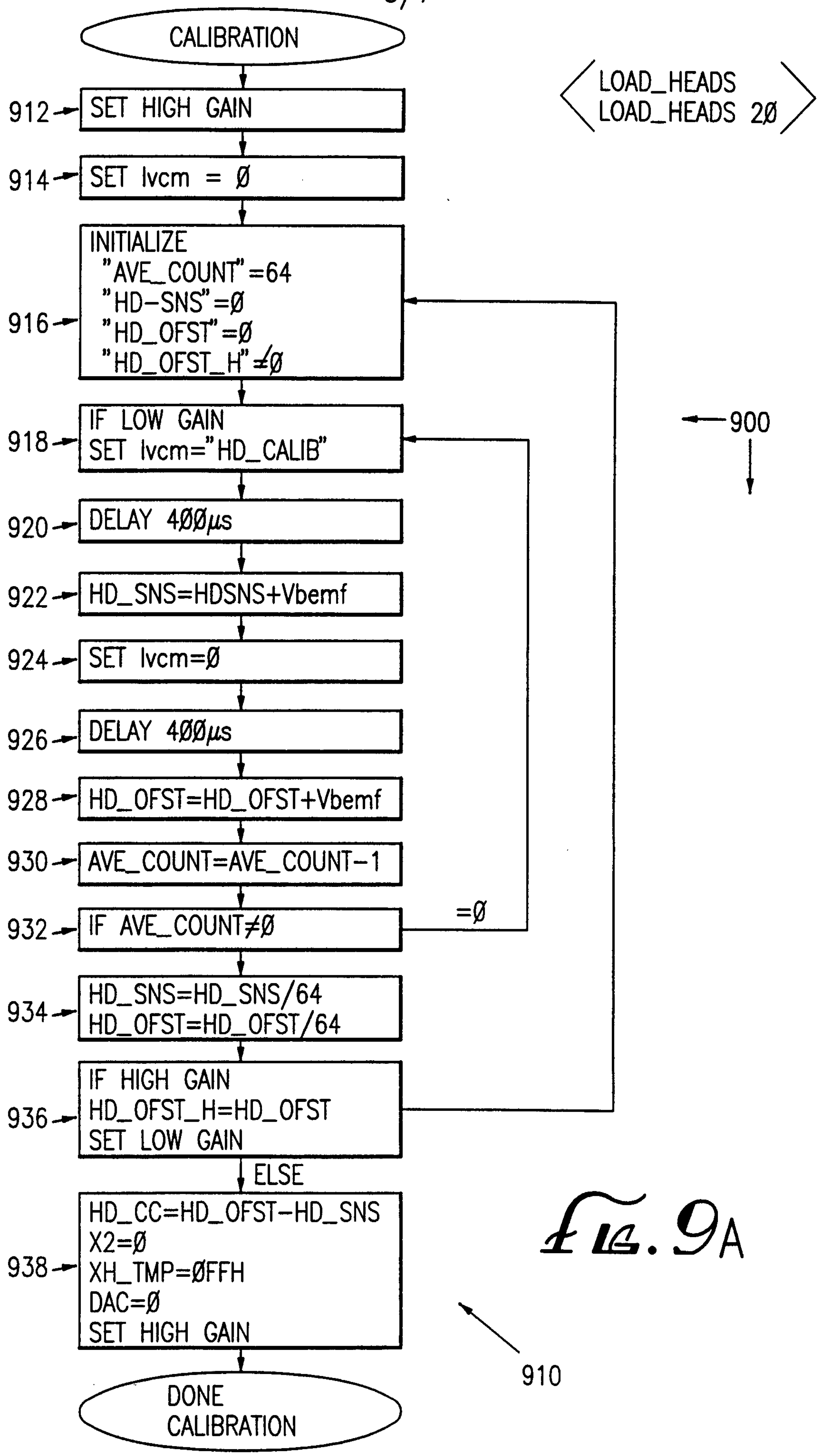
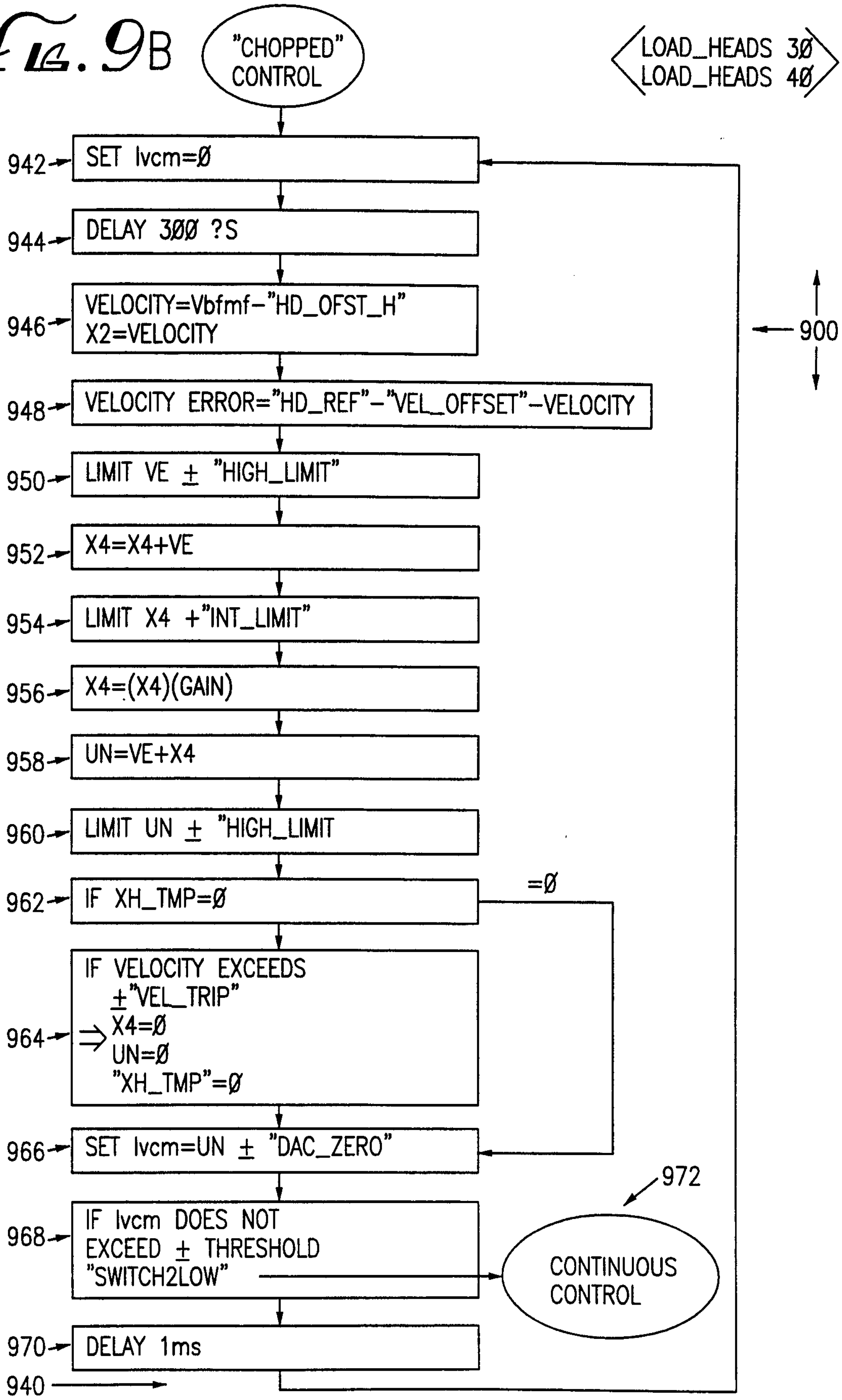

CALIBRATION
912
SET HIGH GAIN
914
SET Ivcm = Ø
916
INITIALIZE
"AVE_COUNT"=64
"HD-SNS"=Ø
"HD_OFST"=Ø
"HD_OFST_H"≠Ø
918
IF LOW GAIN
SET Ivcm="HD_CALIB"
920
DELAY 4ØØμs
922
HD_SNS=HDSNS+Vbemf
924
SET Ivcm=Ø
926
DELAY 4ØØμs
928
HD_OFST=HD_OFST+Vbemf
930
AVE_COUNT=AVE_COUNT-1
932
IF AVE_COUNT≠Ø
=Ø
934
HD_SNS=HD_SNS/64
HD_OFST=HD_OFST/64
936
IF HIGH GAIN
HD_OFST_H=HD_OFST
SET LOW GAIN
ELSE
938
HD_CC=HD_OFST-HD_SNS
X2=Ø
XH_TMP=ØFFH
DAC=Ø
SET HIGH GAIN
DONE
CALIBRATION
LOAD_HEADS
LOAD_HEADS 2Ø
900
910

FIG. 9A

FIG. 9B


"CHOPPED" CONTROL
LOAD_HEADS 3Ø
LOAD_HEADS 4Ø
942
SET Ivcm=Ø
944
DELAY 3ØØ ?S
946
VELOCITY=Vbfmf-"HD_OFST_H"
X2=VELOCITY
948
VELOCITY ERROR="HD_REF"-"VEL_OFFSET"-VELOCITY
950
LIMIT VE ± "HIGH_LIMIT"
952
X4=X4+VE
954
LIMIT X4 +"INT_LIMIT"
956
X4=(X4)(GAIN)
958
UN=VE+X4
960
LIMIT UN ± "HIGH_LIMIT
962
IF XH_TMP=Ø
=Ø
964
IF VELOCITY EXCEEDS ±"VEL_TRIP"
⇒ X4=Ø
UN=Ø
"XH_TMP"=Ø
966
SET Ivcm=UN ± "DAC_ZERO"
972
968
IF Ivcm DOES NOT EXCEED ± THRESHOLD "SWITCH2LOW"
CONTINUOUS CONTROL
970
DELAY 1ms
940
900

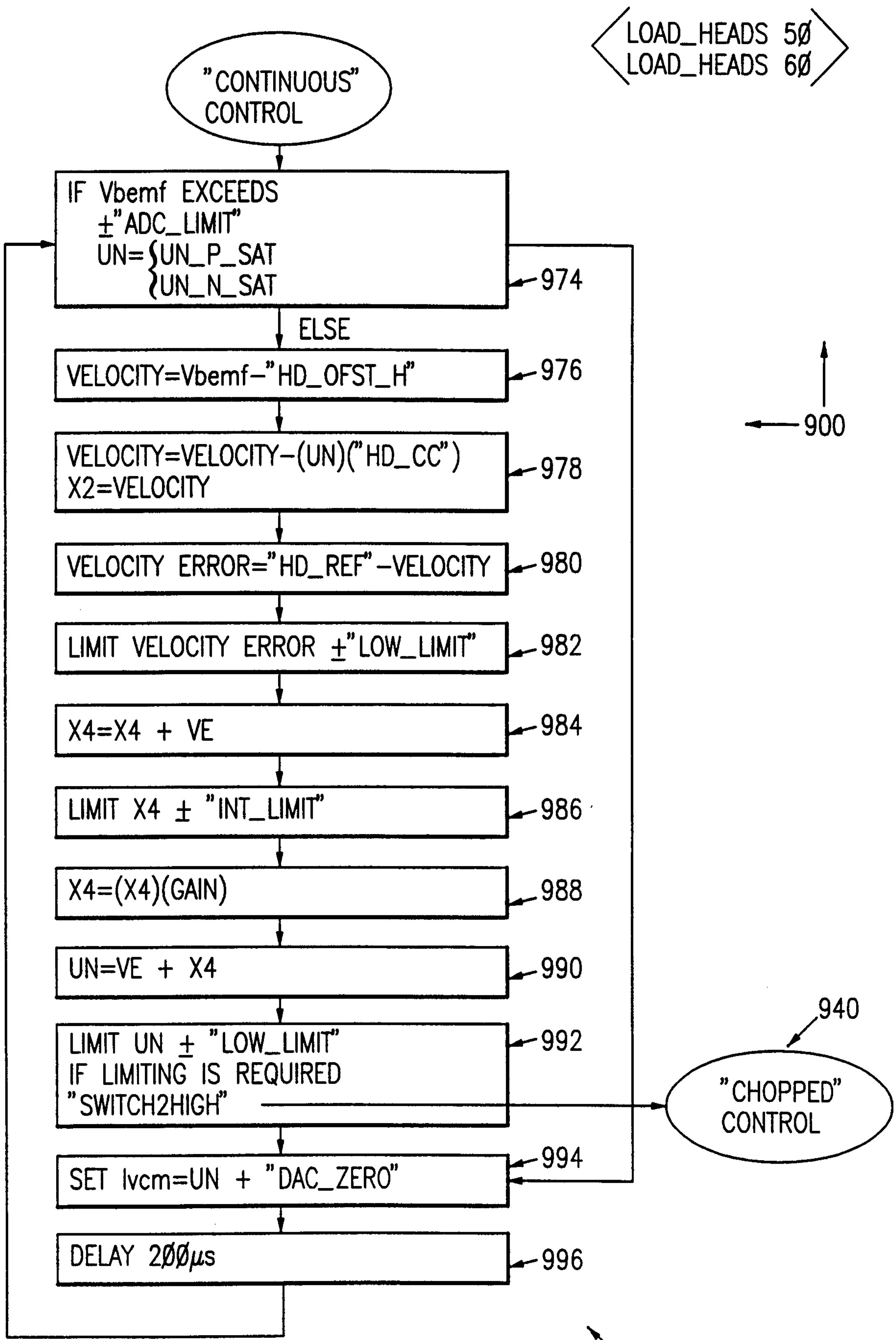

LOAD_HEADS 5Ø
LOAD_HEADS 6Ø
"CONTINUOUS" CONTROL
IF Vbemf EXCEEDS ±"ADC_LIMIT" UN={UN_P_SAT UN_N_SAT
974
ELSE
VELOCITY=Vbemf−"HD_OFST_H"
976
VELOCITY=VELOCITY−(UN)("HD_CC") X2=VELOCITY
978
VELOCITY ERROR="HD_REF"−VELOCITY
980
LIMIT VELOCITY ERROR ±"LOW_LIMIT"
982
X4=X4 + VE
984
LIMIT X4 ± "INT_LIMIT"
986
X4=(X4)(GAIN)
988
UN=VE + X4
990
LIMIT UN ± "LOW_LIMIT" IF LIMITING IS REQUIRED "SWITCH2HIGH"
992
"CHOPPED" CONTROL
940
SET Ivcm=UN + "DAC_ZERO"
994
DELAY 2ØØμs
996
900
972

FIG. 9C

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US96/13242

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :G11B 21/12, 21/22
US CL :360/75, 105
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 360/75, 105

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

APS, JPOABS, EPOABS

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US, A, 5,303,101 (HATCH et al.) 12 April 1994, Figures 1-3 and 5-7.	1-3 and 8-9
Y	JP, A, 4-147476 (TSUKADA) 20 May 1992, Figures 2(a-c).	1-6 and 8-9
A	JP, A, 1-307066 (OKAUCHI) 12 December 1989, Figures 1-3.	1-4 and 8
Y	JP, A, 6-76511 (MARUO) 18 March 1994, Figures 1-18.	1-2 and 8
A	JP, A, 4-111273 (OKAMURA) 13 April 1992, Figure1.	8-11
A	JP, A, 1-229453 (NAKAZATO) 13 September 1989, Figure 2.	8-11

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
27 NOVEMBER 1996	19 DEC 1996

Name and mailing address of the ISA/US
Commissioner of Patents and Trademarks
Box PCT
Washington, D.C. 20231
Facsimile No. (703) 305-3230

Authorized officer
JAMES L HABERMEHL
Telephone No. (703) 305-3498

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US96/13242

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP, A, 4-30376 (ITO) 03 February 1992, Figures 6-7.	8-11

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US96/13242

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This international report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

Please See Extra Sheet.

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☒ No protest accompanied the payment of additional search fees.

BOX II. OBSERVATIONS WHERE UNITY OF INVENTION WAS LACKING
This ISA found multiple inventions as follows:

This application contains the following inventions or groups of inventions which are not so linked as to form a single inventive concept under PCT Rule 13.1. In order for all inventions to be examined, the appropriate additional examination fees must be paid.

Group I, claims 1-7, drawn to a head mounting apparatus for latching and unlatching a head assembly when moving the assembly into and out of a transducing position on the disk, classified in class 360, subclass 105.
Group II, claims 8-11, drawn to a servo control loop apparatus and method for controlling the velocity of a head assembly when moving the assembly into and out of the transducing position on the disk, classified in class 360, subclass 75.

The inventions listed as Groups I and II do not relate to a single inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons: Group II could be used with apparatus for parking heads that is not movable, while Group I could be used with an apparatus and method for controlling velocity of the head assembly without switching between chopped high current and continuous low current control modes.