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TITLE OF THE INVENTION

METHOD FOR RETRACTING HEAD UPON INTERRUPTION OF POWER,
AND DISK DRIVE EMPLOYING THE METHOD

BACKGROUND OF THE INVENTION

5 The present invention relates to a disk drive
with a head used to read and write data from and to a
disk. More particularly, it relates to a method for
retracting the head to a ramp provided near the disk,
upon the interruption of power to the disk drive, and
10 relates to the disk drive employing the method.

As typical disk drives using a disk as a
recording medium, hard disk drives (HDDs) are well
known. HDDs comprise a head (magnetic head) used to
read and write data from and to a disk, and a spindle
15 motor used to rotate the disk. The head is supported
by an actuator so that it can move radially over the
disk. The actuator has a voice coil motor used to
drive the actuator.

When the HDD is in a state in which the head is
20 ready for a read or write operation, the head is
positioned above the disk. More specifically, the
head is floating over the disk in accordance with the
rotation of the disk. When the head performs a read
or write operation, it is moved to a target position
25 on the disk by the actuator. In contrast, when the
HDD is in the inoperative state, the head is retracted
on a particular place (retraction area) called a ramp.



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The ramp is located outside the recording area of the disk.

If unintentional interruption of power occurs when the head is floating over the disk, it is strongly possible that the head will stick to the disk. To avoid this, various head retraction methods for automatically retracting the head to the ramp upon the interruption of power to the HDD have been proposed so far. Jpn. Pat. Appln. KOKAI Publication No. 2002-298530 discloses one (hereinafter referred to as "the prior art") of such retraction methods. The prior art is characterized in that the back electromotive force (back EMF) of the spindle motor and the charge accumulated in a capacitor are utilized for head retraction. The head retraction performed upon the interruption of power, disclosed in the prior art, is mainly realized by first and second retract operations. In the first retract operation, the voice coil motor is powered by the back EMF of the spindle motor. As a result, the head is moved to the position (retraction switching position) near the ramp. In the second retract operation, the voice coil motor is powered by the charge accumulated in the capacitor, whereby the head is moved to the ramp.

In accordance with the recent development of microfabrication of HDDs (microfabrication of disks), 1.8-inch HDDs, 1-inch HDDs and even 0.85-inch HDDs

have come to be available. In accordance with the reduction of the HDD size, the torque (inertia) of the spindle motor inevitably reduces. Accordingly, when the power to the HDD is interrupted, the smaller the HDD (the smaller the diameter of the disk of the HDD), the more quickly the rotational speed of the spindle motor reduces. Therefore, in the prior art, it is possible that before the head reaches the ramp, the rotational speed of the spindle motor will become less than a value that is required to keep the floating level of the head constant. The lower the ambient temperature, the more conspicuous this tendency. In the prior art, when the supply of power is interrupted at, in particular, low temperature, it is difficult to prevent the head from contacting the disk.

BRIEF SUMMARY OF THE INVENTION

In accordance with an embodiment of the invention, there is provided a method of retracting a head to a ramp upon interruption of power to a disk drive. The head is used to read and write data from and to a disk when the disk is spun by a spindle motor. The ramp is located near the disk. The method comprises supplying a current to the spindle motor upon the interruption of the power to the disk drive, using discharge of a capacitor charged with the power, and performing retract control for retracting the head to the ramp upon the interruption of the power. The

performing the retract control includes supplying a current to a voice coil motor which drives an actuator supporting the head, using the discharge of the capacitor.

5 BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

The accompanying drawings, which are incorporated in and constitute a part of the specification, illustrate embodiments of the invention, and together with the general description given above and the
10 detailed description of the embodiments given below, serve to explain the principles of the invention.

FIG. 1 is a block diagram illustrating the configuration of a hard disk drive (HDD) according to an embodiment of the invention;

15 FIG. 2 is a block diagram illustrating, along with the peripheral circuit, the configuration of the motor driver 18 appearing in FIG. 1;

FIG. 3 is a circuit diagram illustrating the structure of the charge and discharge controller 184
20 appearing in FIG. 2;

FIG. 4 is a view illustrating changes in the rotational speed RS_{SPM} of a spindle motor (SPM) 13 and a VCM current I_{VCM} with respect to the period ranging from the time when interruption of power occurs, to
25 the time when head retraction has been finished, which are detected in the embodiment;

FIG. 5 is a view illustrating changes in the

states of the circuits incorporated in the motor driver 18 in the embodiment;

FIG. 6 is a block diagram illustrating, along with the peripheral circuit, the configuration of a motor driver 28 according to a modification of the embodiment;

FIG. 7 is a circuit diagram illustrating the structure of the charge and discharge controller 284 appearing in FIG. 6;

FIG. 8 is a view illustrating changes in the rotational speed RS_{SPM} of an SPM 13 and a VCM current I_{VCM} with respect to the period ranging from the time when interruption of power occurs, to the time when head retraction has been finished, which are detected in the modification of the embodiment;

FIG. 9 is a view illustrating changes in the states of the circuits incorporated in the motor driver 28 in the modification of the embodiment; and

FIG. 10 is a matrix view illustrating how to combine VCM current sources for powering the VCM 15, along with information as to whether the SPM 13 is powered.

DETAILED DESCRIPTION OF THE INVENTION

An embodiment in which the present invention is applied to a hard disk drive (HDD) will be described with reference to the accompanying drawings. FIG. 1 is a block diagram illustrating the configuration of

the HDD according to the embodiment of the invention. In FIG. 1, a disk (magnetic disk) 11 has two, i.e., upper and lower, surfaces. At least one of the disk surfaces serves as a recording surface for magnetically recording data. The disk 11 is, for example, a small disk medium with a diameter of 0.85 inches. A head (magnetic head) 12 is provided opposing the recording surface of the disk 11. The head 12 is used to read and write data from and to the disk 11. In the configuration of FIG. 1, it is assumed that the HDD has a single disk 11. However, the HDD may have a plurality of disks stacked on each other.

A large number of concentric tracks 110 are formed on the recording surface of the disk 11. Each track 110 includes servo information items pre-written (embedded) discretely at regular intervals. Each servo information item includes position information necessary for the control of positioning the head 12 to a target track. The position information includes a cylinder code indicating the position, on the disk 11, of the cylinder (track) on which each servo information item is written.

The disk 11 is spun at high speed by a spindle motor (SPM) 13. The SPM 13 is, for example, a three-phase brushless motor. The head 12 is attached to an actuator (carriage) 14. More specifically, the head

12 is attached to a suspension 141 extending from an arm 140 that is incorporated in the actuator 14. The head 12 is moved radially over the disk 11 in accordance with the pivoting operation of the actuator 14. As a result, the head 12 is positioned on a target track. The actuator 14 has a voice coil motor (VCM) 15 for driving the actuator 14.

The disk 11 has inner and outer peripheries. A ramp 16 is provided, displaced from the recording surface of the disk 11, for example, near the outer periphery of the disk 11. Alternatively, the ramp 16 may be provided near the inner periphery of the disk 11. The ramp 16 provides a retraction area (parking area), displaced from the recording surface of the disk 11, for retracting the head 12 when the HDD is in the inoperative state. Actually, however, a tab 144 incorporated in the head 12 is placed on the ramp 16, instead of the head 12, and the ramp 16 is provided at a location on the movement route of the tab 144. To avoid a complicated expression, it may be described that the head 12 is retracted to the ramp 16. On the other hand, when the HDD is in the operative state, the head 12 exists over the disk 11.

Basically, the inoperative state of the HDD means a state in which the HDD is stopped. Depending upon the type of HDD, a plurality of power-saving states corresponding to power-saving levels may be defined.

In an HDD of this type, the head 12 is retracted to the ramp 16 in a particular power-saving state that exceeds a preset power-saving level. In other words, in this type of HDD, the inoperative state includes a particular power-saving state, as well as the HDD-stop state. On the other hand, the operative state of the HDD means a state in which reading or writing of data from or to the disk 11 can be performed at once. This state may include power-saving states other than the above-mentioned particular power-saving state.

A through hole is formed in the substantially center of the actuator 14. An axis 142 is fitted in the through hole of the actuator 14 so that the actuator 14 can pivot about the axis 142. As a result, the head 12 can pivot along with the arm 140 and suspension 141, whereby it can move radially over the disk 11. The actuator 14 further comprises a, for example, V-shaped support frame 143 extending in the opposite direction to the arm 141. The support frame 143 has a voice coil 150 integrally embedded therein. The voice coil 150 is interposed between top and bottom yokes. The voice coil 150, the yokes and a permanent magnet (not shown) fixed to the bottom yoke provide the VCM 15.

The HDD of FIG. 1 includes an outer-periphery stopper 17. The outer-periphery stopper 17 is used to restrict the operation of the actuator 14 so that the

head 12 does not jump to the outside of the ramp 16 when it is retracted to the retraction area of the ramp 16. To this end, the outer-periphery stopper 17 is placed at a location at which it is brought into
5 contact with a distal end 143a of the V-shaped support frame 143 closer to the disk 11 when the head 12 is urged to jump to the outside of the ramp 16.

The SPM 13 and VCM 15 are powered by an SPM current and a VCM current supplied thereto from the
10 motor driver 18, respectively. The motor driver 18 sequentially executes 1st and 2nd retract operations, described later, upon the interruption of power to the HDD. The motor driver 18 is connected to capacitors C1, C2 and C3. The capacitors C1, C2 and C3 are kept
15 at the power supply voltage +V of the HDD in the HDD operative state.

The capacitor C1 is used as a power supply (SPM current supply) for powering the SPM 13, when the 1st retract operation is performed upon the interruption
20 of power to the HDD. Therefore, the capacitor C1 may be referred to as "the SPM-powering capacitor C1". The capacitor C1 is also used as a power supply (VCM current supply) for powering the VCM 15 during the 1st retract operation. The 1st retract operation means
25 the operation of moving the head 12 in a certain direction to a position near the retract switching position for a 1st retract period immediately after

the interruption of power to the HDD. The retract switching position is set as, for example, a certain position near the ramp 16. In the embodiment, the retract switching position is a preset position over
5 an outer peripheral portion of the disk 11.

The capacitor C2 is used as a power supply (current supply) for powering the VCM 15 during the 2nd retract operation. Therefore, the capacitor C2 may be referred to as "the 2nd-retract capacitor C2".
10 The 2nd retract operation means the operation of retracting the head 12 to the ramp 16 after the 1st retract operation is completed, i.e., after the 1st retract period elapses from the start time of the 1st retract operation.

15 The capacitor C3 is used as a backup power supply for the operation of the motor driver 18 itself, while the 1st and 2nd retract operations are executed. Therefore, the capacitor C3 may be referred to as "the backup capacitor C3". The operations of the motor
20 driver 18 itself mean the operations (motor driving control) of, for example, an SPM controller 181 and retract controller 182, described later. Thus, the capacitor C3 is not used for motor powering operations (i.e., mechanical operations), unlike the capacitor C1
25 or C2. Accordingly, the electrostatic capacitance of the capacitor C3 may be sufficiently smaller than that of the capacitor C1 or C2.

The head 12 is connected to a head IC (head amplifier circuit) 19. The head IC 19 has a read amplifier for amplifying a read signal read by the head 12, and a write amplifier for converting write data into a write current. The head IC 19 is connected to a read/write IC (read/write circuit) 20. The read/write IC 20 is a signal processing device for performing various types of processing, such as analog-to-digital conversion of a read signal, encoding of write data and decoding of read data.

The read/write IC 20 is connected to a disk controller (HDC) 21 and main controller 22. The HDC 21 is connected to the main controller 22 and a host (host system). The host is a digital device, such as a personal computer, which utilizes the HDD of FIG. 1. The HDC 21 has an interface control function for controlling the reception of a command (e.g., a read/write command) from the host, and controlling data transfer between the host and the HDC 21. The HDC 21 also has a disk control function for controlling data transfer between the disk 11 and HDC 21.

The main controller 22 controls the entire HDD. Control by the main controller 22 include seek control for moving the head 12 to a target track designated by a command (read/write command) from the host. The main controller 22 includes a retract-period

determination circuit 221 and random access memory (RAM) 222. Part of the memory area of the RAM 222 is used as a work area for the main controller 22.

5 The retract-period determination circuit 221 operates when the main controller 22 performs seek control. Each time a new head position is detected by the seek control of the main controller 22, the retract-period determination circuit 221 computes the 1st retract period. The 1st retract period indicates
10 the period necessary to move the head 12 from the detected head position to the preset retract switching position. The 1st retract period is set in the retract controller 182 of the motor driver IC 18 (see FIG. 2). The head position indicates the cylinder
15 position of the head 12.

FIG. 2 shows the configuration of the motor driver 18, along with its peripheral circuit. As shown, the motor driver 18 comprises an SPM controller 181, retract controller 182, power supply monitor 183
20 and charge and discharge controller 184.

When the power supply of the HDD is in a normal or steady state, the SPM controller 181 is powered by the power supply voltage +V of the HDD applied via a power supply line 185. The SPM controller 181
25 performs control for rotating the SPM 13 at a rated speed. The SPM controller 181 is also powered by the charge of the backup capacitor C3 during the

interruption of power to the HDD (1st retract operation). At the initial stage of the 1st retract operation, the SPM controller 181 supplies, to the SPM 13 as an SPM current, the current (part of the
5 current) supplied from the SPM-powering capacitor C1 under the control of the charge and discharge controller 184. After the discharge of the capacitor C1 is advanced during the 1st retract operation, the SPM controller 181 supplies, to the VCM 15 as a VCM
10 current, the current generated by the back EMF of the SPM 13. To this end, the SPM controller 181 contains a rectifier circuit (not shown) for rectifying the current generated by the back EMF of the SPM 13.

The retract controller 182 contains a retract
15 timer (RT) 182a. Each time a new head position is detected, the 1st retract period is set in the retract timer 182a by the main controller 22. In the normal state, the retract controller 182 is stopped. Only when the supply of power to the HDD is interrupted
20 (only during the 1st and 2nd retract periods), the retract controller 182 is powered by the voltage caused by the electric charge accumulated in the backup capacitor C3. At the initial stage of the 1st retract operation, the retract controller 182
25 supplies, to the VCM 15 as a VCM current, the current (part of the current) supplied from the SPM-powering capacitor C1 under the control of the charge and

discharge controller 184. After the discharge of the capacitor C1 is finished during the 1st retract operation, the retract controller 182 supplies, to the VCM 15 as a VCM current, the current generated by the back EMF of the SPM 13. Further, during the 2nd retract period, the retract controller 182 supplies, to the VCM 15 as a VCM current, the current discharged from the 2nd-retract capacitor C2.

The power supply monitor 183 monitors the state of the power supply of the HDD to detect the interruption of the power supply. Specifically, the power supply monitor 183 detects the interruption of power when the power supply voltage +V of the HDD applied thereto via the power supply line 185 is lower than a predetermined voltage. Alternatively, the interruption of power may be detected when the power supply voltage +V of the HDD is lowered by a predetermined ratio or more. The power supply monitor 183 generates a power monitor signal 183a indicating the power monitoring result. The power monitor signal 183a is at low level (in the OFF state) when the power supply of the HDD is in the normal or steady state, and is at high level (in the ON state) when the supply of power is interrupted.

The charge and discharge controller 184 controls the charge and discharge of the capacitor C1. Namely, in the steady state of the power supply (in which the

power monitor signal 183a is at low level), the charge and discharge controller 184 causes the capacitor C1 to be kept at the power supply voltage +V. In contrast, in the power-interrupted state (in which the power monitor signal 183a is at high level), the charge and discharge controller 184 causes the capacitor C1 to discharge.

FIG. 2 does not show a VCM controller. The VCM controller operates in the steady state of the power supply, and supplies the VCM 15 with a VCM current designated by the main controller 22. As well known, the VCM controller is used for seek control for moving the head to a target track, and for positioning control (tracking control) for positioning the head 12 at a target position on the target track.

FIG. 3 shows the structure of the charge and discharge controller 184. As shown, the charge and discharge controller 184 comprises diodes 184a and 184b, field effect transistors (FETs) 184c and 184d and inverter 184e. The FET 184c is used as a discharge start switch, and the FET 184d is used as a power supply switch. The anode of the diode 184a is connected to the power supply line 185, and the cathode of the diode 184a is connected to one end of the capacitor C1 and the source of the FET 184c. The other end of the capacitor C1 is grounded. The drain of the FET 184c is connected to the anode of the diode

184b, and the anode of the diode 184b is also connected to the drain of the FET 184d. The cathode of the diode 184b is connected to the SPM controller 181 and retract controller 182. The source of the FET 184d is connected to the power supply line 185. The gate of the FET 184c is supplied with the power monitor signal 183a from the power supply monitor 183. The power monitor signal 183a is also supplied to the input of the inverter 184e. The output of the inverter 184e is connected to the gate of the FET 184d.

Referring to FIGS. 4 and 5, the operation of the embodiment will be described. FIG. 4 is a view illustrating changes in the rotational speed RS_{SPM} of the SPM 13 and a VCM current I_{VCM} with respect to the period ranging from the time when interruption of power occurs, to the time when head retraction has been finished. FIG. 5 is a view illustrating changes in the states of the circuits incorporated in the motor driver 18. Assume here that the power supply voltage +V is normally applied to the HDD of FIG. 1. The power supply voltage +V is also applied via the power supply line 185 to the power supply monitor 183 and charge and discharge controller 184 of the motor driver 18 installed in the HDD of FIG. 1. The power supply monitor 183 keeps the power supply monitor signal 183a at low level when the power supply voltage

+V applied via the power supply line 185 is in the normal or steady state.

When the power supply monitor signal 183a is at low level, the gate of the FET 184c of the charge and discharge controller 184 is at low level. In this state, the FET (discharge start switch) 184c is in the OFF state. The inverter 184e of the charge and discharge controller 184 inverts the level of the power supply monitor signal 183a. Accordingly, the output of the inverter 184e, i.e., the gate of the FET 184d of the charge and discharge controller 184, is at high level. This being so, while the power supply monitor signal 183a is at low level, the FET (power supply switch) 184d is in the ON state.

As described above, when the power supply monitor signal 183a is at low level, i.e., when the power supply voltage +V is in the normal or steady state, the power supply voltage +V is applied to the SPM controller 181 and retract controller 182 via the power supply line 185, FET 184d and diode 184b. When the power supply voltage +V is applied, the SPM controller 181 operates in accordance with the power supply voltage +V. As a result, the SPM controller 181 controls the SPM 13 to rotate it at a rated rotational speed RS_R . On the other hand, the retract controller 182 is kept inoperative when the power monitor signal 183a is at low level.

In the above-described steady state, the FET 184c is in the OFF state. Accordingly, the power supply voltage +V is applied by the diode 184e to the SPM-powering capacitor C1, therefore the capacitor C1 is kept at the voltage +V. Further, in the steady state, the power supply voltage +V is also applied to the 2nd-retract capacitor C2 and backup capacitor C3, and hence the capacitors C2 and C3 are kept at the voltage +V. FIG. 2 does not show power supply lines for applying the power supply voltage +V to the capacitors C2 and C3.

In the above state, assume that the supply of power to the HDD is interrupted at time t11 and the power supply voltage +V applied via the power supply line 185 is reduced to a value less than the preset value. At this time, the 1st retract period is set in the retract timer 182a of the retract controller 182. The 1st retract period indicates the period required to move the head 12 from the present cylinder position of the head 12 to the retract switching position. Assume that the 1st retract period is T1.

When the power supply monitor 183 has detected reduction of the power supply voltage +V to a value less than the preset value, it determines that the interruption of power to the HDD is detected, thereby switching the power supply monitor signal 183a from low level (OFF state) to high level (ON state). At

this time, in the charge and discharge controller 184, the gate of the FET 184c becomes high level, and the gate of the FET 184d becomes low level. Namely, the FET 184c is turned on, and the FET 184d is turned off.

5 As a result, the application of the power supply voltage +V to the SPM controller 181 (and retract controller 182) via the FET 184d and diode 184b is interrupted. At the same time, accumulation of electricity in the capacitor C1 is stopped and the
10 electricity charged in the capacitor C1 in the steady state is discharged. Thus, a current corresponding to the amount of the electricity discharged from the capacitor C1 is generated. This current is supplied to the SPM controller 181 and retract controller 182
15 via the FET 184c and diode 184b. At this time, the diode 184a connected between the capacitor C1 and the power supply line 185 prevents the current from reversely flowing from the capacitor C1 to the power supply line 185.

20 Upon the interruption of power to the HDD, the SPM controller 181 uses the capacitor C3 as a backup power supply, and starts to perform an operation (control operation) in accordance with the voltage of the capacitor C3. Specifically, the SPM controller
25 181 supplies the SPM 13 with the current from the capacitor C1. As a result, even if the supply of power to the HDD is interrupted at time t11, the

rotational speed RS_{SPM} of the SPM 13 is maintained at the rated speed RS_R as far as possible (see FIG. 4), which prevents the floating level of the head 12 from becoming lower than a preset level.

5 On the other hand, the retract controller 182 is set in a 1st retract mode when the supply of power to the HDD is interrupted and the power supply monitor signal 183a becomes high. In this state, the retract controller 182 uses the capacitor C3 as a backup power
10 supply and starts an operation (control operation) in accordance with the charge of the capacitor C3. Specifically, the retract timer 182a of the retract controller 182 starts to measure time when the power supply monitor signal 183a is switched to high level.
15 Further, the retract controller 182 starts to perform a 1st retract operation (1st retract control operation). In the 1st retract operation, the current from the capacitor C1 is supplied to the VCM 15 so that the actuator 14 retracts the head 12. The VCM 15
20 drives the actuator 14 in a direction in which the head 12 is retracted to the ramp 16.

 At this time, the SPM 13 is supplied with the current from the capacitor C1 by the SPM controller 181, as is described above. As a result, the
25 rotational speed RS_{SPM} of the SPM 13 is maintained at the rated speed RS_R . In this state, at least at the initial stage of the 1st retract operation, the head

12 cannot be retracted using the back EMF, unlike the prior art. Therefore, the embodiment employs a structure in which the current resulting from the discharge of the capacitor C1 is supplied to the VCM
5 15 by the retract controller 182. This structure enables the retract operation of retracting the head 12 to be performed even if the SPM 13 is spun by the current resulting from the discharge of the capacitor C1.

10 When the discharge of the capacitor C1 is started upon the interruption of power to the HDD, i.e., at time t11, the potential of the capacitor C1 (i.e., the potential at the cathode of the diode 184a) gradually decreases with time. Assume that at time t12 later
15 than time t11 by period T11 ($T11 < T1$), the potential at the capacitor C1 is reduced to a value less than the potential generated by the back EMF of the SPM 13. At this time, the discharge of the capacitor C1 is finished, whereby the supply, by the charge and
20 discharge controller 184, of a current from the capacitor C1 to the SPM controller 181 and retract controller 182 is stopped. Instead, from time t12, the current generated by the back EMF of the SPM 13 is supplied to the retract controller 182 via the
25 rectifying circuit of the SPM controller 181.

As described above, in the embodiment, when the discharge of the capacitor C1 is advanced, and the

potential of the capacitor C1 is reduced to a value lower than the potential generated by the back EMF of the SPM 13, the current supply source (VCM current source) for powering the VCM 15 is automatically
5 switched from the capacitor C1 to the back EMF of the SPM 13. Namely, the embodiment does not require any special mechanism to switch the use of the VCM current source from the electricity discharged from the capacitor C1 to the back EMF of the SPM 13.

10 The retract controller 182 continues the 1st retract operation even after time t12, by supplying the VCM 15 with the current generated by the back EMF of the SPM 13. The diode 184b is provided across the path for guiding a current from the capacitor C1 to
15 the SPM controller 181 (and retract controller 182). The diode 184b prevents the current generated by the back EMF of the SPM 13 from reversely flowing to the capacitor C1.

Assume here that 1st retract period T1 has
20 elapsed from time t11. Namely, assume that the retract timer 182a of the retract controller 182 has measured period T1. In this case, the timer 182a generate a timeout. Upon generation of the timeout, the retract controller 182 is switched from the 1st
25 retract mode to the 2nd retract mode. Assume that this switching is performed at time t13. At time t13, i.e., when the 1st retract operation is completed, the

head 12 is positioned near the retract switching position as a result of the 1st retract operation.

5 In the 2nd retract mode, the retract controller 182 executes a 2nd retract operation (2nd retract control operation) using the capacitor C2 as the VCM current source. Specifically, the retract controller 182 causes the capacitor C2 to discharge, and supplies the VCM 15 with the current resulting from the discharge, the current serving as a VCM current. As a
10 result, the retract controller 182 retracts the head 12 from the position near the retract switching position to the ramp 16. When the head 12 is retracted to the retract area of the ramp 16, the tip 143a of the support frame 143 of the actuator 14 is
15 latched by the outer-periphery stopper 17.

As described above, in the embodiment, during period T11 ranging from time t11 to time t12 and included in period T1 (the 1st retract mode period) that ranges from time t11 to time t13, the SPM 13 is
20 spun and the 1st retract operation is performed, using the current supplied from the capacitor C1. Period T1 is the 1st retract mode period, and period T11 is the beginning portion of the 1st retract mode period. Assume here that the period ranging from time t12 to
25 time t13 is T12 ($T12 = T1 - T11$). Period T12 is the remaining period of the 1st retract mode period. In the embodiment, during period T12, the 1st retract

operation is continued by the current generated by the back EMF of the SPM 13. From t13, the 2nd retract operation is performed using the current supplied from the 2nd retract capacitor C2.

5 In the embodiment, from time t12, the spin of the SPM 13 is continued using the inertia of the spin. Namely, unlike the prior art, the SPM 13 continues its spin from time t12 later than time t11 by period T11, using the inertia. As a result, the period required
10 for the rotational speed RS_{SPM} of the SPM 13 to be reduced to a lower limit value (lower-limit rotational speed) RS_{MIN} that is necessary for maintaining the floating level of the head 12 at a preset level can be made longer by substantially T11 than in the prior
15 art.

 Therefore, in the above embodiment, the rotational speed RS_{SPM} of the SPM 13 is prevented from being reduced to the lower-limit rotational speed RS_{MIN} before the head retract operation (the 2nd
20 retract operation following the 1st retract operation) performed upon interruption of power is completed, regardless of whether the SPM 13 has a small inertia (torque), or regardless of whether the ambient temperature is low. As a result, the head 12 is
25 prevented from contacting the disk 11 during the retract operation, and reliably retracted to the ramp 16. It is preferable to design the electrostatic

capacitance of the capacitor C1 in accordance with the sum of first and second capacitances. The first capacitance is the capacitance necessary to maintain the lower-limit rotational speed RS_{MIN} at the lowest temperature at which the HDD operation is guaranteed by the specification, until the head retraction is completed. The lower-limit rotational speed RS_{MIN} is, as mentioned above, the lowest rotational speed RS_{SPM} of the SPM 13 necessary to guarantee the floating level of the head 12. Further, the second capacitance is the capacitance necessary to supply the VCM 15 with the current required for the retract operation (2nd retract operation) and generated by the back EMF of the SPM 13.

15 If the capacitor C1 has a greater electrostatic capacitance than that employed in the above embodiment, it is possible to use the capacitor C1 for powering both the SPM 13 and VCM 15 till the end of the 1st retract mode (i.e., till time t_{13}). In this case, also during period T12 ranging from time t_{12} to time t_{13} , the 1st retract operation using the capacitor C1 is continued. Namely, the 1st retract operation using the back EMF of the SPM 13 can be omitted.

25 In the embodiment, it is assumed that the outer-periphery stopper 17 is formed of a magnet latch. In this case, when the head 12 is retracted to the ramp

16, the tip 143a of the support frame 143 of the actuator 14 is latched by the magnetic force of the outer-periphery stopper 17. Therefore, if the magnet latch is used as the stopper 17, the VCM current
5 necessary for the 2nd retract operation can be reduced, compared to the case where no magnetic latch is used as the stopper 17. In this case, the 1st retract operation using the capacitor C1 can be also continued during period T12 ranging from time t12 to
10 time t13. Furthermore, from time t13, the 2nd retract operation can also be executed using the back EMF of the SPM 13. In this case, the 2nd retract capacitor C2 is not necessary.

In the embodiment, it is assumed that the retract
15 switching position is the preset position over the outer periphery of the disk 11. However, the retract switching position may be another position, for example, a preset position on the retract area of the ramp 16. To this end, it is sufficient if the
20 capacitor C1 has a greater capacitance than that employed in the embodiment. In this case, period T11 can be set longer, without reducing the rotational speed RS_{SPM} of the SPM 13 to the lower-limit rotational speed RS_{MIN} or less. As a result, at time
25 t13 later than time t11 by period T1 ($= T11 + T12$), the head 12 can be made to reach the retract area of the ramp 16, or a position near the retract area.

When the head 12 is placed on the retract area of the ramp 16 or the position near it, the tip 143a of the support frame 143 of the actuator 14 is positioned near the outer-periphery stopper 17. At this time, if
5 a current is supplied to the VCM 15 by the 2nd retract operation, the support frame 143 of the actuator 14 is pressed against the outer-periphery stopper 17, with the head 12 placed on the ramp 16. In this state, the 2nd retract operation can be performed, using the back
10 EMF of the SPM 13 instead of the capacitor C2.

[Modification]

A modification of the embodiment will now be described. The modification is characterized in that the VCM current sources used in the initial stage and
15 remaining stage of the 1st retract operation are opposite to those used in the embodiment. More specifically, in the modification, the back EMF of the SPM 13 is used as a VCM current source at the initial stage of the 1st retract operation, and the capacitor
20 C1 is used as another VCM current source during the remaining stage of the 1st retract operation.

FIG. 6 illustrates, along with the peripheral circuit, the configuration of a motor driver 28 according to the modification of the embodiment. The
25 modification differs from the embodiment in that the motor driver 28 shown in FIG. 6 is used instead of the motor driver 18 shown in FIG. 2. In FIGS. 2 and 6,

like elements are denoted by like reference numerals.

As shown in FIG. 6, the motor driver 28 comprises an SPM controller 181, retract controller 282, power supply monitor 183, charge and discharge controller 284 and rotational speed monitor 285. The retract controller 282 and charge and discharge controller 284 correspond to the retract controller 182 and charge and discharge controller 184 shown in FIG. 2, respectively.

The retract controller 282 differs from the retract controller 182 in the following two points. Firstly, in the initial stage of the 1st retract mode, the retract controller 282 supplies, to the VCM 15 as a VCM current, the current supplied from the SPM controller 182 and generated by the back EMF of the SPM 13. Secondly, when the rotational speed RS_{SPM} of the SPM 13 is reduced to a particular rotational speed called a monitor rotational speed RS_M , the retract controller 282 supplies, to the VCM 15 as another VCM current, the current supplied from the capacitor C1 under the control of the charge and discharge controller 284. The monitor rotational speed RS_M is set equal to or lower than the rated rotational speed RS_R , and higher than the lower-limit rotational speed RS_{MIN} ($RS_{MIN} < RS_M \leq RS_R$). The retract controller 282 contains a retract timer 182a, like the retract controller 182.

The charge and discharge controller 284 differs from the charge and discharge controller 184 in the discharge start time of the capacitor C1.

Specifically, the charge and discharge controller 284 causes the capacitor C1 to start to discharge not upon the interruption of power, but when the rotational speed RS_{SPM} of the SPM 13 is reduced to the monitor rotational speed RS_M . As a result, the SPM controller 181 supplies, to the SPM 13 as an SPM current, the current supplied from the capacitor C1 under the control of the charge and discharge controller 284, after the rotational speed RS_{SPM} of the SPM 13 is reduced to the monitor rotational speed RS_M .

The rotational speed monitor 285 monitors a rotational speed signal 181a generated by the SPM controller 181 when the power supply monitor signal 183a is at high level. The rotational speed signal 181a is a frequency signal proportional to the rotational speed RS_{SPM} of the SPM 13 and formed of a sequence of pulses that appear at the cycles determined from the rotational speed RS_{SPM} . The rotational speed monitor 285 monitors the rotational speed signal 181a to monitor the rotational speed RS_{SPM} of the SPM 13. The rotational speed monitor 285 outputs a high-level monitor rotational-speed detection signal (particular rotational-speed detection signal) 285a when the rotational speed RS_{SPM}

of the SPM 13 is reduced to the monitor rotational speed RS_M . The detection signal 285a is sent to the retract controller 282 and charge and discharge controller 284.

5 FIG. 7 shows the structure of the charge and discharge controller 284. In FIG. 7, elements similar to those of FIG. 3 are denoted by corresponding reference numerals. The charge and discharge controller 284 differs from the charge and discharge
10 controller 184 in that in the former, the monitor rotational-speed detection signal 285a is supplied to the gate of the FET 184c, instead of the power supply monitor signal 183a.

Referring to FIGS. 8 and 9, the operation of the
15 modification will be described. FIG. 8 shows changes in the rotational speed RS_{SPM} of an SPM 13 and a VCM current I_{VCM} with respect to the period ranging from the time when interruption of power occurs, to the time when head retraction has been finished. FIG. 9
20 shows changes in the states of the circuits incorporated in the motor driver 28.

Firstly, assume that the power supply monitor 183 has detected the interruption of power to the HDD at time t_{21} . At this time, the power supply monitor 183
25 switches the power supply monitor signal 183a from low level to high level. When the power supply monitor signal 183a is shifted from low level to high level,

the retract timer 182a of the retract controller 282 starts to measure the 1st retract period set therein. Assume that the 1st retract period is T2, and the retract switching position is the preset position over
5 the outer periphery of the disk 11, as in the embodiment.

When the power supply monitor signal 183a is shifted to high level, the retract controller 282 starts to perform the 1st retract operation (1st
10 retract control operation), thereby supplying, to the VCM 15 as a VCM current, the current generated by the back EMF of the SPM 13 and supplied from the SPM controller 181. At this time, the VCM 15 moves the actuator 14 to retract the head 12 to the ramp 16.

15 The FET 184c of the charge and discharge controller 284 is still in the OFF state when the power supply monitor signal 183a is shifted to high level. Thus, even when the power supply monitor signal 183a is shifted to high level, and the retract
20 controller 282 starts the 1st retract operation, the discharge of the capacitor C1 is not started. In this case, no SPM current is supplied from the SPM controller 181 to the SPM 13, and the SPM 13 keeps spinning by inertia.

25 On the other hand, when the power supply monitor signal 183a is shifted to high level, the rotational speed monitor 285 monitors the rotational speed RS_{SPM}

of the SPM 13 based on the rotational speed signal 181a generated by the SPM controller 181. Assume here that the rotational speed RS_{SPM} of the SPM 13 that is spinning by inertia from time t_{21} is reduced to the monitor rotational speed RS_M at time t_{22} , time 22 being different from time t_{21} by period T_{21} shorter than the 1st retract period. At time t_{22} , the rotational speed monitor 285 outputs the high-level monitor rotational-speed detection signal 285a.

The FET 184c of the charge and discharge controller 284 is turned ON in accordance with the output of the high-level monitor rotational-speed detection signal 285a. At this time, i.e., at time t_{22} , the discharge of the SPM-powering capacitor C1 is started. As a result, the current resulting from the discharge of the capacitor C1 is supplied to the SPM controller 181 and retract controller 282 via the FET 184c and diode 184b.

The SPM controller 181 supplies, to the SPM 13 as an SPM current, the current (part of the current) supplied from the capacitor C1. As a result, the rotational speed RS_{SPM} of the SPM 13 reduced to the monitor rotational speed RS_M is kept, as far as possible, at the monitor rotational speed RS_M after time t_{22} (see FIG. 8). Thus, the floating level of the head 12 can be prevented even after time t_{22} from becoming lower than a preset level. On the other

hand, the retract controller 282 supplies, to the VCM 15 as a VCM current, the current (part of the current) supplied from the capacitor C1 when the monitor rotational-speed detection signal 285a becomes high at
5 time 22. As a result, the 1st retract operation is continued even after time t22.

As described above, in the modification of the embodiment, in period T21 ranging from time t21 at which the interruption of power to the HDD occurs, to
10 time t22 at which the rotational speed RS_{SPM} of the SPM 13 is reduced to the monitor rotational speed RS_M , the 1st retract operation is performed using the back EMF of the SPM 13. After time t22, the 1st retract operation is continued using the capacitor C1. The
15 1st retract operation using the capacitor C1 is continued by period T22 ranging from time t22 to time t23 to which the 1st retract period T2 ranges from time 21. Namely, the 1st retract operation using the capacitor C1 is continued by period T22 ranging from
20 time t22 to time t23 at which the timeout of the retract timer 182a occurs. When the timeout of the retract timer 182a occurs, the retract controller 282 starts the 2nd retract operation using the 2nd retract capacitor C2 as a VCM current source, as in the
25 retract controller 182 employed in the embodiment. In other words, the retract controller 282 supplies, to the VCM 15 as a VCM current, the current supplied from

the capacitor C2.

In the modification of the embodiment, it is assumed that the retract switching position is the preset position over the outer periphery of the disk
11. Alternatively, it may be another position, for example, a preset position on the retraction area of the ramp 16. To this end, it is sufficient if a capacitor having a greater electrostatic capacitance than the capacitor C1 of the modification is used. In
10 this case, the rotational speed RS_{SPM} of the SPM 13 is prevented from becoming lower than the lower-limit rotational speed RS_{MIN} , and the head 12 can be made to reach the retraction area of the ramp 16 or reach a position near the retraction area at time t_{23} later
15 than time t_{22} by period T_{22} . At time t_{23} , a current is supplied to the VCM 15 by the 2nd retract operation, and the support frame 143 of the actuator 14 is pushed against the outer-periphery stopper 17, with the head 12 shifted to the ramp 16. In this
20 case, the 2nd retract operation can be executed, using the back EMF of the SPM 13 instead of the 2nd retract capacitor C2.

FIG. 10 illustrates how to combine VCM current sources for powering the VCM 15, described in the
25 embodiment and its modification, along with information as to whether the SPM 13 is powered. In FIG. 10, T^*1 and T^*2 represent the initial part and

remaining part of the 1st retract period T* elapsing from the interruption of power, respectively.

Additional advantages and modifications will readily occur to those skilled in the art. Therefore,
5 the invention in its broader aspects is not limited to the specific details and representative embodiments shown and described herein. Accordingly, various modifications may be made without departing from the spirit or scope of the general inventive concept as
10 defined by the appended claims and their equivalents.

WHAT IS CLAIMED IS:

1. A method of retracting a head to a ramp upon interruption of power to a disk drive, the head being used to read and write data from and to a disk when
5 the disk is spun by a spindle motor, the ramp being located near the disk, comprising:

supplying a current to the spindle motor upon the interruption of the power to the disk drive, using discharge of a capacitor charged with the power; and
10 performing retract control for retracting the head to the ramp upon the interruption of the power, the performing the retract control including supplying a current to a voice coil motor which drives an actuator supporting the head, using the discharge of
15 the capacitor.

2. The method according to claim 1, further comprising determining a retract period required to move the head from a present position thereof to a preset retract switching position when the disk drive
20 is operating,

and wherein the performing the retract control includes supplying a current to the voice coil motor, using one of discharge of another capacitor charged with the power, and a back electromotive force of the
25 spindle motor, after the retract period elapses from the interruption of the power.

3. The method according to claim 2, wherein the

performing the retract control includes supplying a current to the voice coil motor, using the discharge of the capacitor, during at least initial part of the retract period elapsing from the interruption of the power.

4. The method according to claim 3, wherein:
an electrostatic capacitance of the capacitor is selected to a value sufficient for the discharge of the capacitor to be continued, and sufficient for the head to reach the retract switching position, at least until the retract period elapses; and

the supplying the current to the voice coil motor using the discharge of the capacitor is executed until the retract period elapses.

5. The method according to claim 3, wherein when the discharge of the capacitor is completed before the retract period elapses from the interruption of the power, the performing the retract control includes supplying a current to the voice coil motor during remaining part of the retract period, using the back electromotive force of the spindle motor.

6. The method according to claim 2, wherein the performing the retract control includes:

supplying a current to the voice coil motor during initial part of the retract period elapsing from the interruption of the power, using the back electromotive force of the spindle motor; and

supplying a current to the voice coil motor during remaining part, except for the initial part, of the retract period elapsing from the interruption of the power, using the discharge of the capacitor.

5 7. The method according to claim 6, further comprising monitoring rotational speed of the spindle motor upon the interruption of the power to detect whether the rotational speed of the spindle motor decreases to a particular rotational speed, the
10 particular rotational speed being higher than a preset lower-limit rotational speed and lower than a rated rotational speed of the spindle motor, the preset lower-limit rotational speed enabling a floating level of the head to be maintained at a lower-limit level,
15 and wherein the supplying the current to the voice coil motor using the back electromotive force of the spindle motor is executed during a period, as the initial part, ranging from the interruption of the power to a time when the rotational speed of the
20 spindle motor is detected to be reduced to the particular rotational speed.

8. A disk drive in which a head is used to read and write data from and to a disk, comprising:

 a spindle motor which spins the disk;
25 an actuator which supports the head to enable the head to move radially over the disk;
 a voice coil motor which drives the actuator;

a ramp located near the disk and used to retract the head thereto;

a capacitor charged by a power supply to the disk drive;

5 a power supply monitor configured to monitor a state of the power supply to detect interruption of power from the power supply to the disk drive;

a charge and discharge controller configured to cause the capacitor to be charged by the power supply,
10 and cause the capacitor to discharge in accordance with detection of the interruption of the power by the power supply monitor;

a spindle motor controller configured to supply a current to the spindle motor in accordance with the
15 detection of the interruption of the power by the power supply monitor, using discharge of the capacitor; and

a retract controller configured to perform retract control for retracting the head to the ramp in
20 accordance with the detection of the interruption of the power, the retract controller supplying, during the retract control, a current to the voice coil motor using the discharge of the capacitor.

9. The disk drive according to claim 8, further
25 comprising a backup power supply which enables the spindle motor controller and the retract controller to operate when supply of the power from the power supply

to the disk drive is interrupted.

10. The disk drive according to claim 8, further comprising:

5 another capacitor charged by the power supply to the disk drive; and

a retract-period determination circuit which determines a retract period required to move the head from a present position thereof to a preset retract switching position when the disk drive is operating,
10 and wherein the retract controller supplies a current to the voice coil motor, using discharge of said another capacitor, after the retract period elapses from the detection of the interruption of the power.

15 11. The disk drive according to claim 10, wherein the retract controller supplies a current to the voice coil motor, using the discharge of the capacitor, during at least initial part of the retract period elapsing from the detection of the interruption
20 of the power.

12. The disk drive according to claim 11, wherein when the discharge of the capacitor is completed before the retract period elapses from the detection of the interruption of the power, the
25 retract controller supplies a current to the voice coil motor during remaining part of the retract period, using the back electromotive force of the

spindle motor.

13. The disk drive according to claim 10,
wherein the retract controller supplies a current to
the voice coil motor during initial part of the
5 retract period elapsing from the detection of the
interruption of the power, using the back
electromotive force of the spindle motor, the retract
controller supplying a current to the voice coil motor
during remaining part, except for the initial part, of
10 the retract period elapsing from the detection of the
interruption of the power, using the discharge of the
capacitor.

14. The disk drive according to claim 13,
further comprising a rotational speed monitor which
15 monitors rotational speed of the spindle motor upon
the detection of the interruption of the power to
detect whether the rotational speed of the spindle
motor decreases to a particular rotational speed, the
particular rotational speed being higher than a preset
20 lower-limit rotational speed and lower than a rated
rotational speed of the spindle motor, the preset
lower-limit rotational speed enabling a floating level
of the head to be maintained at a lower-limit level,
and wherein the retract controller supplies the
25 current to the voice coil motor, using the back
electromotive force of the spindle motor, during a
period, as the initial part, ranging from the

detection of the interruption of the power to a time when the rotational speed monitor detects that the rotational speed of the spindle motor is reduced to the particular rotational speed.

5 15. The disk drive according to claim 14,
further comprising a backup power supply which enables
the spindle motor controller, the retract controller
and the rotational speed monitor to operate when
supply of the power from the power supply to the disk
10 drive is interrupted.

 16. The disk drive according to claim 8, further
comprising a retract-period determination circuit
which determines a retract period required to move the
head from a present position thereof to a preset
15 retract switching position when the disk drive is
operating,

 and wherein the retract controller supplies a
current to the voice coil motor, using a back
electromotive force of the spindle motor, after the
20 retract period elapses from the detection of the
interruption of the power.

 17. The disk drive according to claim 16,
wherein the retract controller supplies a current to
the voice coil motor, using the discharge of the
25 capacitor, during at least initial part of the retract
period elapsing from the detection of the interruption
of the power.

18. The disk drive according to claim 17,
wherein when the discharge of the capacitor is
completed before the retract period elapses from the
detection of the interruption of the power, the
5 retract controller supplies a current to the voice
coil motor during remaining part of the retract
period, using the back electromotive force of the
spindle motor.

19. The disk drive according to claim 16,
10 wherein the retract controller supplies a current to
the voice coil motor during initial part of the
retract period elapsing from the detection of the
interruption of the power, using the back
electromotive force of the spindle motor, and supplies
15 a current to the voice coil motor during remaining
part, except for the initial part, of the retract
period, using the discharge of the capacitor.

20. The disk drive according to claim 19,
further comprising a rotational speed monitor which
20 monitors rotational speed of the spindle motor upon
the detection of the interruption of the power to
detect whether the rotational speed of the spindle
motor decreases to a particular rotational speed, the
particular rotational speed being higher than a preset
25 lower-limit rotational speed and lower than a rated
rotational speed of the spindle motor, the preset
lower-limit rotational speed enabling a floating level

of the head to be maintained at a lower-limit level,
and wherein the retract controller supplies the
current to the voice coil motor, using the back
electromotive force of the spindle motor, during a
5 period, as the initial part, ranging from the
detection of the interruption of the power to a time
when the rotational speed monitor detects that the
rotational speed of the spindle motor is reduced to
the particular rotational speed.