



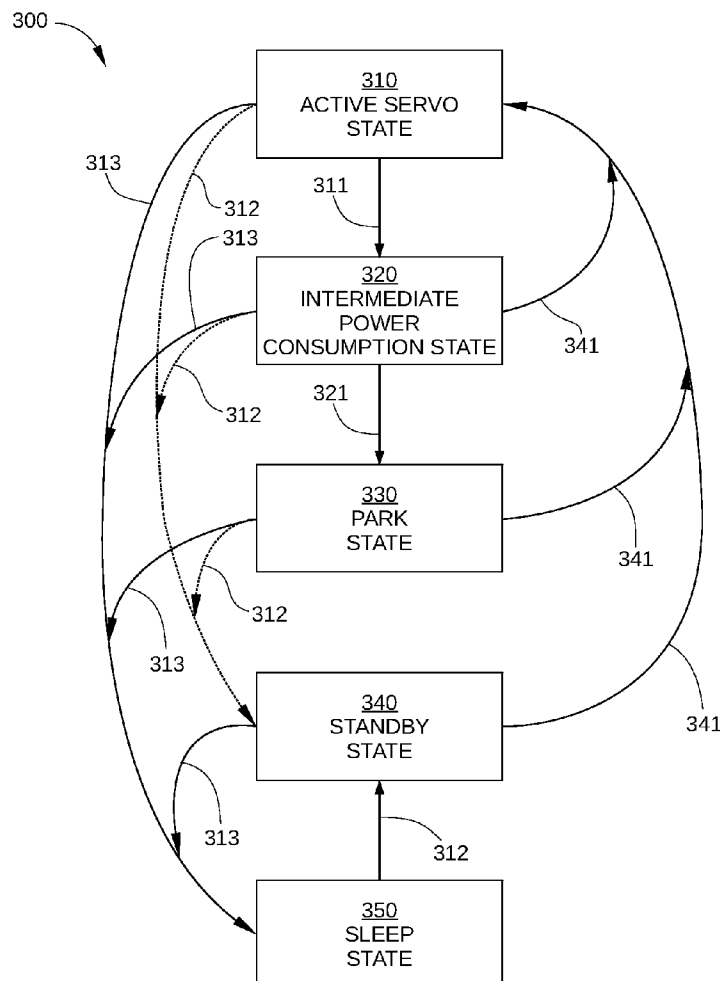
US 20140258745A1

(19) **United States**(12) **Patent Application Publication**  
**EHRlich et al.**(10) **Pub. No.: US 2014/0258745 A1**(43) **Pub. Date: Sep. 11, 2014**(54) **POWER STATE CHANGE IN DISK DRIVE  
BASED ON DISK ACCESS HISTORY****Publication Classification**(71) Applicant: **KABUSHIKI KAISHA TOSHIBA,**  
Tokyo (JP)(51) **Int. Cl.**  
**G06F 1/32**

(2006.01)

(52) **U.S. Cl.**  
CPC ..... **G06F 1/3268** (2013.01)  
USPC ..... **713/320**(72) Inventors: **Richard M. EHRlich**, Saratoga, CA  
(US); **Eric R. DUNN**, Cupertino, CA  
(US); **Daniel TCHEN**, San Jose, CA  
(US); **Annie Mylang LE**, San Jose, CA  
(US); **Mine Wonkyung BUDIMAN**,  
Livermore, CA (US); **Fernando Anibal  
ZAYAS**, Rangiora (NZ)(57) **ABSTRACT**

A data storage device that includes a magnetic storage device selects one or more power states of the magnetic storage device based on a time interval since a most recent time data has been read from or written to the magnetic storage device. The power state of the magnetic storage device can be changed from a higher power consumption state to a lower power consumption state when the time interval exceeds a predetermined value. The power consumption state may be changed from an active servo state to an intermediate power consumption state, a park state, and/or a standby state, depending on the time elapsed since the most recent time data has been read from or written to the magnetic storage device.

(73) Assignee: **KABUSHIKI KAISHA TOSHIBA,**  
Tokyo (JP)(21) Appl. No.: **13/788,502**(22) Filed: **Mar. 7, 2013**

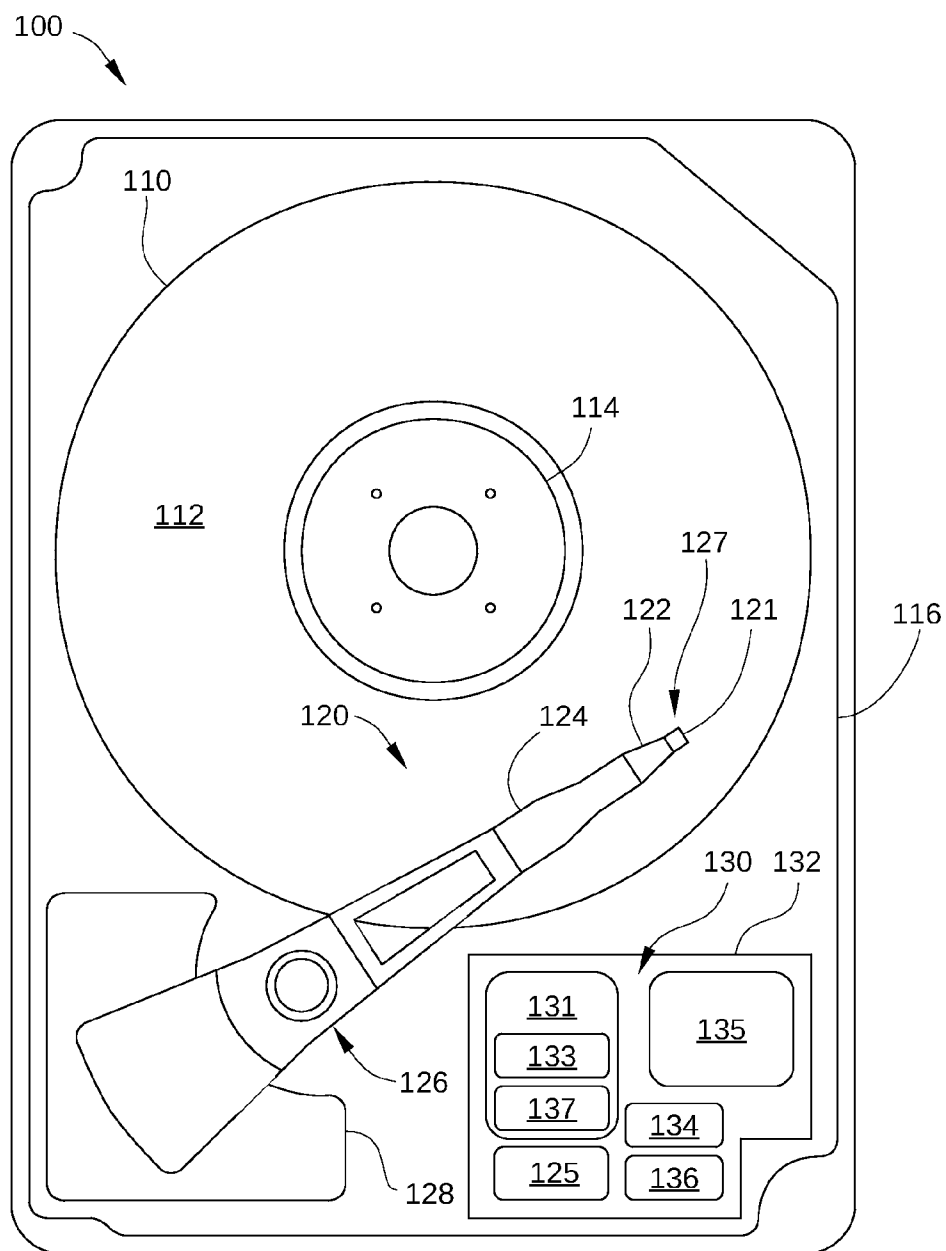


FIG. 1

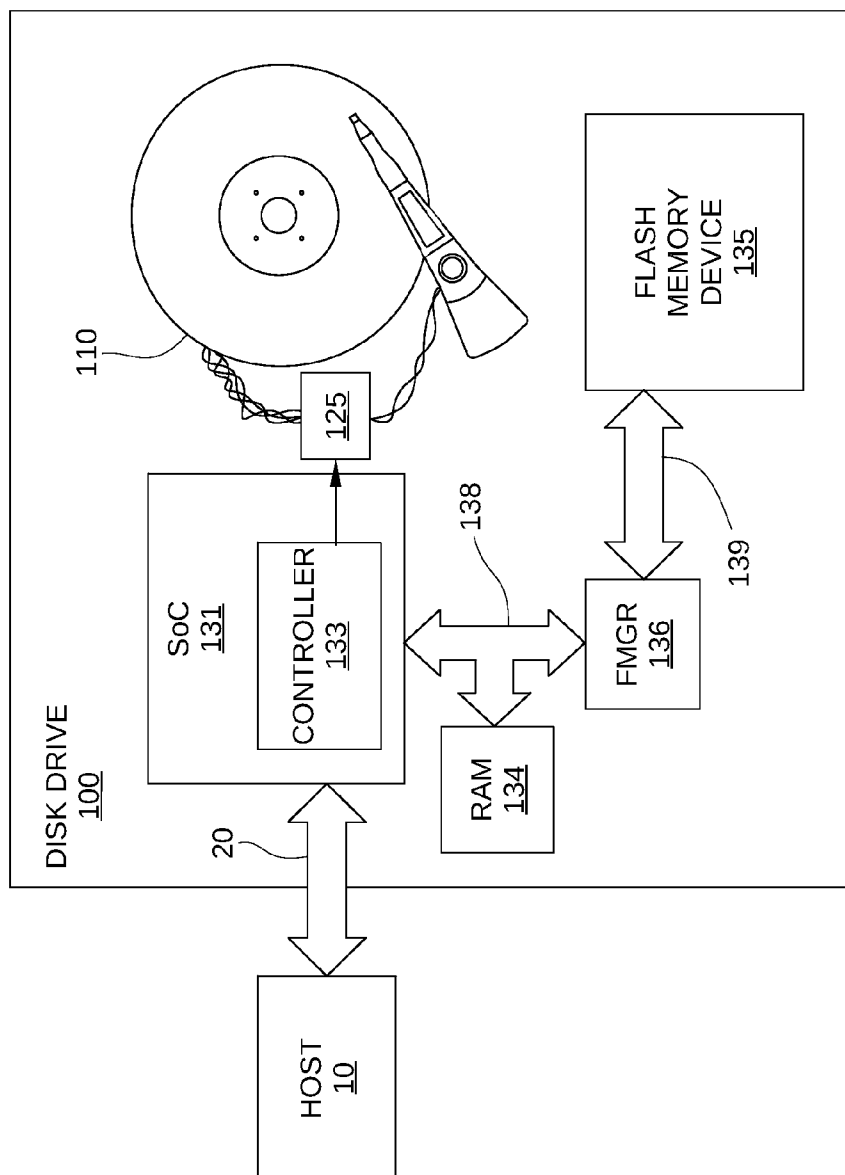


FIG. 2

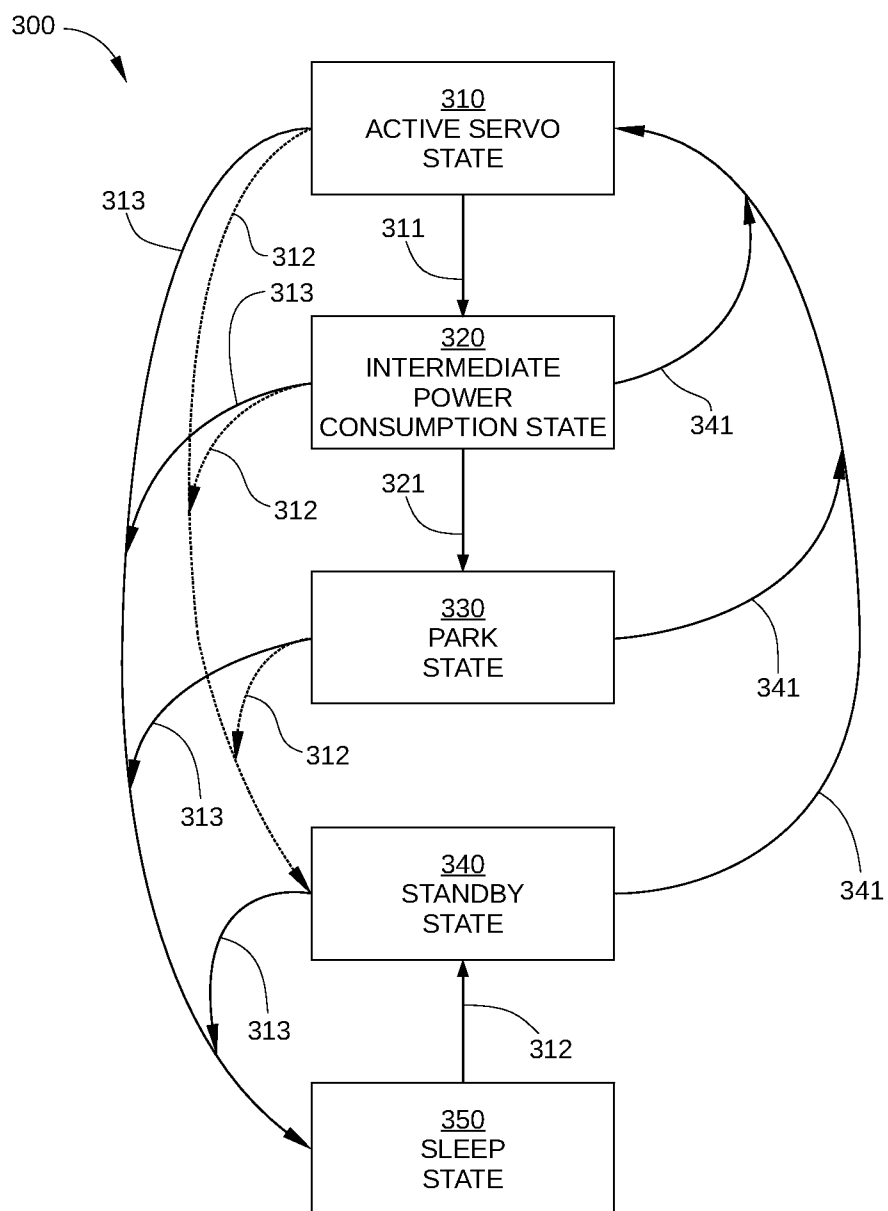


FIG. 3

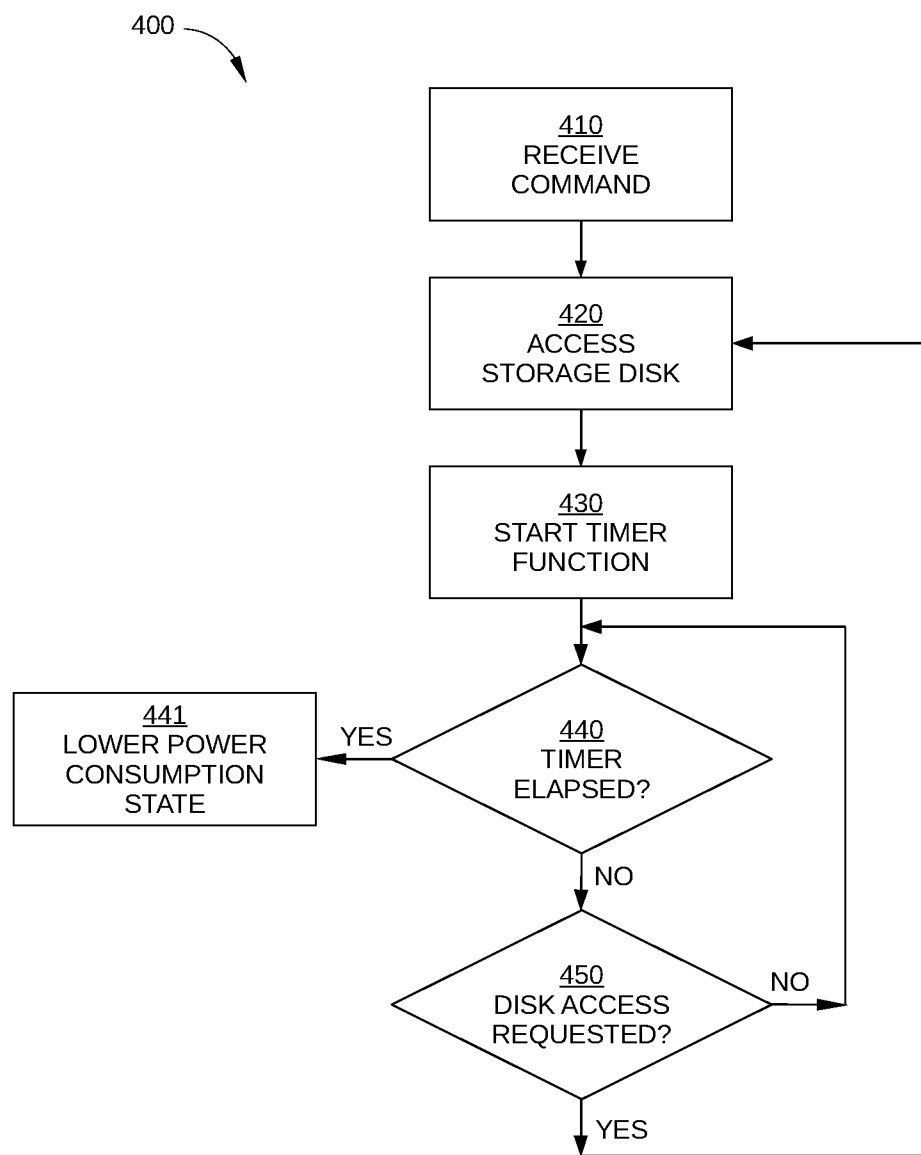


FIG. 4

## POWER STATE CHANGE IN DISK DRIVE BASED ON DISK ACCESS HISTORY

### BACKGROUND

[0001] Disk drives primarily store digital data in concentric tracks on the surface of a data storage disk and are commonly used for data storage in electronic devices. The data storage disk is typically a rotatable hard disk with a layer of magnetic material thereon, and data are read from or written to a desired track on the data storage disk using a read/write head that is held proximate to the track while the disk spins about its center at a constant angular velocity. To properly align the read/write head with a desired track during a read or write operation, disk drives generally use a closed-loop servo system that relies on servo data stored in servo sectors written on the disk surface when the disk drive is manufactured.

[0002] Some operations in a disk drive use a significant amount of energy, even when read or write commands are not being serviced by the disk drive. For example, continuously spinning the data storage disk requires approximately the same power whether or not read or write commands are being performed. Similarly, actively controlling read/write head position with the servo system involves performing servo sampling, signal processing, and associated decoding with a read channel, all of which utilize substantial computational resources, independent of read or write commands. Because disk drives are frequently used in portable electronic devices in which available power is limited, such as laptop computers, restricting such energy-intensive operations in a disk drive is generally desirable.

### SUMMARY

[0003] One or more embodiments provide systems and methods for storing data in a data storage device that includes a magnetic storage device. During operation, the data storage device selects one or more power states of the magnetic storage device based on a time interval since a most recent time data has been read from or written to the magnetic storage device. Specifically, the power state of the magnetic storage device can be changed from a higher power consumption state to a lower power consumption state when the time interval exceeds a predetermined value. For example, the power consumption state may be changed from an active servo state to an intermediate power consumption state, a park state, and/or a standby state, depending on the time elapsed since a most recent time data has been read from or written to the magnetic storage device.

[0004] A method of power management in a data storage device that includes a magnetic storage device comprises, according to one embodiment, measuring a time interval since a most recent time data has been read from or written to the magnetic storage device, and, in response to the time interval exceeding a predetermined value, changing a current power consumption state of the magnetic storage device to a lower power consumption state.

[0005] According to another embodiment, a data storage device comprises a magnetic storage device and a controller. The controller is configured to measure a time interval since a most recent time data has been read from or written to the magnetic storage device, and, in response to the time interval exceeding a predetermined value, change a current power consumption state of the magnetic storage device to a lower power consumption state.

[0006] According to another embodiment, a data storage device comprises a magnetic storage device, a non-volatile solid-state device, and a controller. The controller is configured to determine that a portion of the non-volatile solid-state device used to store data that are not also stored on the magnetic storage device is greater than a predetermined value, change a power state of the magnetic storage device from an initial power state to an active servo state, the initial power state being a lower power state than the active servo state, and control the writing to the magnetic storage device of at least a portion of the data that are not also stored on the magnetic storage device.

### BRIEF DESCRIPTION OF THE DRAWINGS

[0007] So that the manner in which the above recited features of the embodiments can be understood in detail, a more particular description of the embodiments, briefly summarized above, may be had by reference to the appended drawings. It is to be noted, however, that the appended drawings illustrate only typical embodiments and are therefore not to be considered limiting of its scope, for there may be other equally effective embodiments.

[0008] FIG. 1 is a schematic view of an exemplary disk drive, according to one embodiment.

[0009] FIG. 2 illustrates an operational diagram of a disk drive with elements of electronic circuits shown configured according to one embodiment.

[0010] FIG. 3 illustrates a power-state diagram of the disk drive of FIG. 1.

[0011] FIG. 4 sets forth a flowchart of method steps for power management in a data storage device that includes a magnetic storage device, according to one or more embodiments.

[0012] For clarity, identical reference numbers have been used, where applicable, to designate identical elements that are common between figures. It is contemplated that features of one embodiment may be incorporated in other embodiments without further recitation.

### DETAILED DESCRIPTION

[0013] FIG. 1 is a schematic view of an exemplary disk drive, according to one embodiment. For clarity, disk drive 100 is illustrated without a top cover. Disk drive 100 includes at least one storage disk 110 that is rotated by a spindle motor 114 and includes a plurality of concentric data storage tracks. Spindle motor 114 is mounted on a base plate 116. An actuator arm assembly 120 is also mounted on base plate 116, and has a slider 121 mounted on a flexure arm 122 with a read/write head 127 that reads data from and writes data to the data storage tracks. Flexure arm 122 is attached to an actuator arm 124 that rotates about a bearing assembly 126. Voice coil motor 128 moves slider 121 relative to storage disk 110, thereby positioning read/write head 127 over the desired concentric data storage track disposed on the surface 112 of storage disk 110. Spindle motor 114, read/write head 127, and voice coil motor 128 are coupled to electronic circuits 130, which are mounted on a printed circuit board 132. Electronic circuits 130 include a read/write channel 137, a microprocessor-based controller 133, random-access memory (RAM) 134 (which may be a dynamic RAM and is used as a data buffer), and/or a flash memory device 135 and flash manager device 136. In some embodiments, read/write channel 137 and microprocessor-based controller 133 are included in a

single chip, such as a system-on-chip **131**. In some embodiments, disk drive **100** may further include a motor-driver chip **125**, which accepts commands from microprocessor-based controller **133** and drives both spindle motor **114** and voice coil motor **128**.

**[0014]** For clarity, disk drive **100** is illustrated with a single storage disk **110** and a single actuator arm assembly **120**. Disk drive **100** may also include multiple storage disks and multiple actuator arm assemblies. In addition, each side of storage disk **110** may have an associated read/write head coupled to a flexure arm.

**[0015]** When data are transferred to or from storage disk **110**, actuator arm assembly **120** sweeps an arc between an inner diameter (ID) and an outer diameter (OD) of storage disk **110**. Actuator arm assembly **120** accelerates in one angular direction when current is passed in one direction through the voice coil of voice coil motor **128** and accelerates in an opposite direction when the current is reversed, thereby allowing control of the position of actuator arm assembly **120** and attached read/write head **127** with respect to storage disk **110**. Voice coil motor **128** is coupled with a servo system known in the art that uses the positioning data read from servo wedges on storage disk **110** by read/write head **127** to determine the position of read/write head **127** over a specific data storage track. The servo system determines an appropriate current to drive through the voice coil of voice coil motor **128**, and drives said current using a current driver and associated circuitry.

**[0016]** Disk drive **100** may be configured as a disk drive, in which non-volatile data storage is generally only performed using storage disk **110** in typical operation. Alternatively, disk drive **100** may be configured as a hybrid drive, in which non-volatile data storage can be performed using storage disk **110** and/or flash memory device **135**. In a hybrid drive, non-volatile memory, such as flash memory device **135**, supplements the spinning storage disk **110** to provide faster boot, hibernate, resume and other data read-write operations, as well as lower power consumption. Such a hybrid drive configuration is particularly advantageous for battery operated computer systems, such as mobile computers or other mobile computing devices. In a preferred embodiment, flash memory device **135** is a non-volatile solid state storage medium, such as a NAND flash chip that can be electrically erased and reprogrammed, and is sized to supplement storage disk **110** in disk drive **100** as a non-volatile storage medium. For example, in some embodiments, flash memory device **135** has data storage capacity that is orders of magnitude larger than RAM **134**, e.g., gigabytes (GB) vs. megabytes (MB).

**[0017]** FIG. 2 illustrates an operational diagram of disk drive **100** with elements of electronic circuits **130** shown configured according to one embodiment. As shown, disk drive **100** includes RAM **134**, flash memory device **135**, a flash manager device **136**, system-on-chip **131**, and a high-speed data path **138**. Disk drive **100** is connected to a host **10**, such as a host computer, via a host interface **20**, such as a serial advanced technology attachment (SATA) bus.

**[0018]** In the embodiment illustrated in FIG. 2, flash manager device **136** controls interfacing of flash memory device **135** with high-speed data path **138** and is connected to flash memory device **135** via a NAND interface bus **139**. System-on-chip **131** includes microprocessor-based controller **133** and other hardware (including read/write channel **137**) for controlling operation of disk drive **100**, and is connected to RAM **134** and flash manager device **136** via high-speed data

path **138**. Microprocessor-based controller **133** is a control unit that may include a microcontroller such as an ARM microprocessor, a hybrid drive controller, and any control circuitry within disk drive **100**. High-speed data path **138** is a high-speed bus known in the art, such as a double data rate (DDR) bus, a DDR2 bus, a DDR3 bus, or the like.

**[0019]** In general, data storage devices with rotatable storage disks, such as disk drives, can be configured to minimize energy use by changing to lower power-consumption states when the data storage device is not being used to satisfy read or write commands from a host device. This is particularly true for disk drives used in battery-powered devices, such as laptop computers. For example, when a data storage device has not received host commands for a predetermined time period, the data storage device may change from an active servo state to an intermediate power consumption state, a park state, or a standby state. In contrast, according to various embodiments, a data storage device changes from a first power consumption state to a second power consumption state based on a time interval in which a rotatable storage disk or disks of the data storage device are not accessed to satisfy read or write commands. For example, in reference to disk drive **100** illustrated in FIGS. 1 and 2, when read or write commands are exclusively satisfied using RAM **134** and/or flash memory device **135**, actuator arm assembly **120**, voice coil motor **128**, spindle motor **114**, read/write channel **137** and/or microprocessor-based controller **133** may be operated at a lower power consumption state, since storage disk **110** is not being accessed.

**[0020]** FIG. 3 illustrates a power-state diagram **300** for disk drive **100** that includes multiple power states and power state transitions of disk drive **100**. Power states in power-state diagram **300** include an active servo state **310**, an intermediate power consumption state **320**, a park state **330**, a standby state **340**, and a sleep state **350**. State transitions in power-state diagram **300** include a float timer expiration **311**, a standby transition **312**, a sleep command **313**, a park timer expiration **321**, and an active servo transition **341**. While the elements of power-state diagram **300** are described in terms of disk drive **100**, it should be recognized that power-state diagram **300** is applicable to any suitable data storage device that includes a rotatable storage disk.

**[0021]** Active servo state **310** represents normal operation of disk drive **100** to facilitate the execution of read and write commands, either from host **10** or initiated by disk drive **100** itself. In active servo state **310**, the servo system of disk drive **100** actively controls the position of read/write head **127** with respect to individual tracks on storage disk **110**, using voice coil motor **128**, actuator arm **124**, and read/write channel **137**. It is noted that disk drive **100** may be in active servo state **310** when read or write commands are not being serviced by disk drive **100**. However, because significant electrical energy is used by microprocessor-based controller **133** and read/write channel **137** in active servo state **310**, in some embodiments, disk drive **100** changes to a lower power consumption state when one or more conditions are met. As shown in FIG. 3, these conditions may include one or more of: float timer expiration **311**, standby transition **312**, and sleep command **313**.

**[0022]** When float timer expiration **311** occurs, disk drive **100** changes from active servo state **310** to intermediate power consumption state **320**, which is described below. Float timer expiration **311** can be configured to take effect when no commands are satisfied by accessing storage disk

**110** for more than a predetermined period of time. For example, a typical duration for such a predetermined time period may be approximately 50 to 150 milliseconds. In some embodiments, a float timer is started when a command, i.e., a read or write command, is satisfied by accessing storage disk **110**. The float timer is reset to zero and restarted when a received command is satisfied by accessing storage disk **110**. Thus, float timer expiration **311** takes effect when the float timer exceeds the predetermined time period described above, and disk drive **100** changes to intermediate power consumption state **320**. In some embodiments, any read or write commands satisfied by accessing storage disk **110** resets the float timer to zero, and in other embodiments, only read or write commands that are both satisfied by accessing storage disk **110** and that are received from host **10** reset the float timer to zero.

**[0023]** It is noted that commands (either received by disk drive **100** from host **10** or initiated by disk drive **100** itself) that are satisfied without accessing storage disk **110** do not reset the above-described float timer. Consequently, even though read and/or write commands are frequently received by disk drive **100** from host **10** and/or initiated by disk drive **100**, portions of disk drive **100** associated with storage disk **110** can be changed from active servo state **310** to intermediate power consumption state **320** when said commands are satisfied by accessing RAM **134** and/or flash memory device **135** but not storage disk **110**.

**[0024]** When standby transition **312** occurs, disk drive **100** changes from a current energy consumption state to standby state **340**, in which disk drive **100** spins down storage disk **110**, read/write head **127** is parked, and disk drive **100** expends essentially no energy on mechanical operations. Standby transition **312** may occur when disk drive **100** is in one of several power states, including active servo state **310**, intermediate power consumption state **320**, and park state **330**. In some embodiments, standby transition **312** can be configured to take effect when either one of two conditions are met: 1) no commands from host **10** are satisfied by accessing storage disk **110** for more than a predetermined period of time, and 2) when a “standby” command is received from host **10**. In other embodiments, standby transition **312** can be configured to take effect when: 1) no commands from host **10** or initiated by disk drive **100** are satisfied by accessing storage disk **110** for more than a predetermined period of time, and 2) when a “standby” command is received from host **10**.

**[0025]** Generally, the predetermined period of time associated with standby transition **312** is substantially longer than that associated with float timer expiration **311**. For example, a typical duration of time associated with initiating standby transition **312** can be on the order of several minutes rather than milliseconds. In some embodiments, a standby timer is started when a command is satisfied by accessing storage disk **110**, and the standby timer is reset to zero and restarted when a command is next satisfied by accessing storage disk **110**. In other embodiments, the standby timer is started when a command received from host **10** is satisfied by accessing storage disk **110**, while a command that is initiated by disk drive **110** and is satisfied by accessing storage disk **110** does not reset the standby timer to zero.

**[0026]** When standby transition **312** occurs, i.e., when the standby timer exceeds the predetermined time period described above, disk drive **100** changes to standby state **340**. In some embodiments, commands that are 1) received by disk drive **100** from host **10** or initiated by disk drive **100** itself, and

2) are satisfied without accessing storage disk **110**, do not generally reset the herein-described standby timer.

**[0027]** Sleep command **313**, when received from host **10**, causes disk drive **100** to change from a current power state to sleep state **340**. Sleep command **313** may occur when disk drive **100** is in one of several power states, including active servo state **310**, intermediate power consumption state **320**, and park state **330**.

**[0028]** Intermediate power consumption state **320**, in which the servo system of disk drive **100** is not used to provide continuous position control of read/write head **127**, uses less power than active servo state **310** and more power than park state **330**. For example, in some embodiments, microprocessor-based controller **133** may apply a predetermined constant bias to voice coil motor **128** to hold read/write head **127** in place, thereby “floating” read/write head **127** rather than actively servoing the position of read/write head **127**. In alternative embodiments, a low-frequency servo mode may be used in intermediate power consumption state **320**, in which limited servo control is used to position read/write head **127** in an approximate location. For example, the servo system of disk drive **100** may be activated for a single or a relatively small number of samples for each revolution of storage disk **110**, so that the position of read/write head **127** is approximately known without the relatively high energy cost associated with constantly servoing read/write head **127** over a particular data storage track of storage disk **110**.

**[0029]** While using less energy than active servo state **310**, intermediate power consumption state **320** allows relatively fast response to read or write commands that involve accessing storage disk **110**. For example, when disk drive **100** is in intermediate power consumption state **320** and receives a read or write command, seeking to a desired location on storage disk **110** in response to said command can be completed in a few milliseconds to a few tens of milliseconds. In contrast, when disk drive is in park state **330**, seeking to a desired location on storage disk **110** in response to said command generally requires a few hundred milliseconds. In some embodiments, disk drive **100** changes from intermediate power consumption state **320** to a lower power consumption state when one or more conditions are met. As shown in FIG. 3, these conditions may include one or more of: standby transition **312**, sleep command **313** (both described above) and park timer expiration **321**.

**[0030]** When park timer expiration **321** occurs, disk drive **100** changes from intermediate power consumption state **320** to park state **330**. In park state **330**, storage disk **110** continues to spin at the normal rotational velocity, but read/write head **127** is parked to reduce aerodynamic resistance to spinning the data storage disk. In this way, current required for the rotation of storage disk **110** is reduced. Furthermore, in park state **330**, read/write head **127** is protected from mechanical shock experienced by disk drive **100**. Park timer expiration **321** can be configured to take effect when no commands are satisfied by accessing storage disk **110** for more than a predetermined period of time. Alternatively, park timer expiration **321** can be configured to take effect when no commands from host **10** are satisfied by accessing storage disk **110** for more than a predetermined period of time.

**[0031]** Generally, the predetermined period of time associated with park timer expiration **321** is substantially longer than that associated with float timer expiration **311**. For example, a typical duration of time associated with park timer expiration **321** can be on the order of several minutes rather



than the milliseconds associated with float timer expiration 311. In some embodiments, a park timer is started when a command is satisfied by accessing storage disk 110, and the park timer is reset to zero and restarted when a command is satisfied by accessing storage disk 110. When park timer expiration 321 occurs, i.e., when the park timer exceeds the predetermined time period described above, disk drive 100 changes to park state 330. It is noted that commands that are satisfied without accessing storage disk 110 do not generally reset the herein-described park timer. Said commands can be either received by disk drive 100 from host 10 or initiated by disk drive 100 itself, such as when controller 133 determines that data stored in flash memory device 135 should be written on data storage disk 110.

[0032] In addition to changing to a lower power consumption state when certain events occur, e.g., float timer expiration 311, standby transition 312, sleep command 313, and park timer expiration 321, disk drive 100 may also change to a higher power consumption state when certain events occur. Specifically, when active servo transition 341 occurs, disk drive 100 may be configured to change to active servo state 310, as shown in FIG. 3. In some embodiments, active servo transition 341 takes place when a read or write command is satisfied by accessing storage disk 110. For example, if a current version of the data associated with a read command from host 10 is not stored in RAM 134 or flash memory 135, storage disk 110 is accessed by microprocessor-based controller 133 to satisfy said read command. Thus, even when disk drive 100 is in a low power consumption state, such as standby state 340 or park state 330, disk drive 100 changes to active servo state 310 so that storage disk 110 can be accessed to satisfy the command received from host 10.

[0033] In some embodiments, disk drive 100 may change to active servo state 310 in response to data being flushed to storage disk 110 from flash memory device 135. For example, when disk drive 100 is configured as a hybrid drive, a portion of flash memory device 135 may be used to store “dirty” data, which are data that are only stored in flash memory device 135 and are not also stored on storage disk 110. Furthermore, disk drive 100 may also be configured to maintain a predetermined maximum threshold for the portion of flash memory device 135 used to store dirty data. When said maximum threshold is exceeded, disk drive 100 generally “flushes” excess dirty data to storage disk 110, i.e., disk drive 100 writes a corresponding copy of the excess dirty data on storage disk 110, and flags the copied data in flash memory device 135 as “non-dirty” data. Thus, in some situations, disk drive 100 may flush dirty data to storage disk 110, even though disk drive 100 is in intermediate power consumption state 320, park state 330, or standby state 340. In such situations, disk drive 100 changes to active servo state 310 so that the data flushing process can be performed. For example, after disk drive 100 changes to a lower power consumption state as a result of float timer expiration 311, standby transition 312, sleep command 313, or park timer expiration 321, host 10 may then send write commands to disk drive 100. Ordinarily, disk drive 100 may accept write data directly into flash memory device 135 to prevent activating the portions of disk drive 100 associated with storage disk 110. However, if flash memory device 135 is full or already stores the maximum allowable quantity of dirty data, microprocessor-based controller 133 will change the power state of disk drive 100 to active servo state 310 and begin to copy dirty data in flash memory device 135 to storage disk 110.

[0034] In some embodiments, storage disk 110 may be accessed as a result of other activities besides in response to commands from host 10. Advantageously, in such embodiments, timers for measuring time elapsed since storage disk 110 was last accessed in response to a host command may not be affected when storage disk 110 is accessed as a result of said non-host related activities. For example, dirty data being flushed from flash memory device 135 or RAM 134 may be considered such non-host related activities.

[0035] FIG. 4 sets forth a flowchart of method steps for power management in a data storage device that includes a magnetic storage device, according to one or more embodiments. Although the method steps are described in conjunction with disk drive 100 in FIGS. 1 and 2, persons skilled in the art will understand that method 400 may be performed with other types of data storage systems. The control algorithms for method 400 may reside in and/or be performed by microprocessor-based controller 133, host 10, or any other suitable control circuit or system. For clarity, method 400 is described in terms of microprocessor-based controller 133 performing steps 410-450.

[0036] As shown, method 400 begins at step 410, where microprocessor-based controller 133 or other suitable control circuit or system receives a command that requires access to storage disk 110. For example, the command received in step 410 may be a read command when the only up-to-date version of data associated with the read command is stored on storage disk 110. In another example, the command received in step 410 may be a write command, where insufficient storage space is available in flash memory device 135 and/or RAM 134 for storing the data associated with the write command. In yet another example, the command received in step 410 may be a flush-cache command from host 10 requesting that disk drive 100 flush some or all dirty data in flash memory device 135 and/or RAM 134 to storage disk 110. In yet another example, the command received in step 410 may be a write command initiated by disk drive 100 itself, such as when flash memory device 135 stores equal to or greater than a maximum desired quantity of dirty data.

[0037] In step 420, microprocessor-based controller 133 controls access to storage disk 110 in response to the command received in step 410. In step 420, data are written to and/or read from storage disk 110 to satisfy the command received in step 410.

[0038] In step 430, microprocessor-based controller 133 starts a timer function or other technically feasible time measurement technique in response to storage disk 110 being accessed in step 420. Generally, the timer function is started upon completion of access to storage device 110 in step 420, but in some embodiments may be started in conjunction with said access.

[0039] In step 440, microprocessor-based controller 133 checks the time interval measured by the timer function started in step 430. In some embodiments, step 440 is performed periodically, for example every 10 milliseconds. When the time interval measured by said timer function exceeds a predetermined value, i.e., a desired time interval has elapsed, method 400 proceeds to step 441. When the time interval measured by said timer function does not exceed the predetermined value, i.e., the desired time interval has not yet elapsed, method 400 proceeds to step 450.

[0040] According to various embodiments, the time interval in question is associated with one of the power state transitions to a lower power consumption state, as described

above in conjunction with FIG. 3. Specifically, in some embodiments, the time interval referenced in step 440 is the time associated with float timer expiration 311, and may therefore be on the order of 10s to 100s of milliseconds in duration. In other embodiments, the time interval referenced in step 440 is the time associated with standby transition 312, and may therefore be on the order of a few minutes, to 10s of minutes in duration, and in some instances may be defined by host 10. In yet other embodiments, the time interval referenced in step 440 is the time associated with park timer expiration 321, and may therefore be on the order of a few minutes or longer in duration.

[0041] In step 441, microprocessor-based controller 133 changes the power state of disk drive 100 from the current power state, e.g., active servo state 310, to a desired lower power consumption state, such as intermediate power consumption state 320, park state 330, or standby state 340. In some embodiments, in step 441 additional power management processes described herein may be initiated, such as checking for a condition causing disk drive 110 to change to an even lower energy consumption state, such as standby state 340. In such embodiments, the condition may be an elapsed time since storage disk 110 has been accessed in order to satisfy a command. For clarity, blocks illustrating such an additional power management process are omitted from FIG. 4.

[0042] In some embodiments, during the course of method 400 disk drive 100 may be changed to standby state 340 in response to a standby command from host 10. In such embodiments, when a standby command is received by microprocessor-based controller 133 from host 10, microprocessor-based controller 133 terminates method 400 and immediately changes disk drive 10 to standby state 340.

[0043] In step 450, microprocessor-based controller 133 determines whether access to storage disk 110 has been requested in order to satisfy a command received since step 420. If such a request has been received by microprocessor-based controller 133, method 400 proceeds back to step 420, where said command is satisfied by accessing storage disk 110. If such a request has not been received by microprocessor-based controller 133 since step 420, method 400 proceeds back to step 440, as shown in FIG. 4.

[0044] It is noted that in step 450, one or more commands may be received by disk drive 100 since step 420 without resetting the timer function started in step 430, as long as storage disk 110 is not accessed in response to said host commands. For example, read or write commands from host 10 that are satisfied using RAM 134 and/or flash memory device 135 do not reset the timer function in step 401. Similarly, in some embodiments, flushing of dirty data from flash memory device 135 to storage disk 110, when performed internally as a non-host related activity by disk drive 100, does not reset said timer function. In other embodiments, flushing of dirty data from flash memory device 135 to storage disk 110, when performed internally as a non-host related activity by disk drive 100, resets the some timer functions (e.g., a float timer for float timer expiration 311 or a park timer for park timer expiration 321), but not for others (e.g., a standby timer for standby transition 312). Furthermore, it is noted that method 400 may be used to change disk drive 100 to any of the power states associated with disk drive 100 that are lower in power consumption than active servo state 310, including intermediate power consumption state 320, park state 330, and standby state 340.

[0045] While various embodiments described herein are in terms of a hard disk drive, embodiments also include data storage devices that include a data storage disk, such as an optical disk drive, etc.

[0046] In sum, embodiments described herein provide systems and methods for power management in a data storage device. The data storage device selects one or more power states of the magnetic storage device based on a time interval during which the magnetic storage device is not accessed in response to a host command. Consequently, the magnetic storage device can be advantageously changed to a lower power consumption state even though the data storage device is actively serving a host device.

[0047] While the foregoing is directed to specific embodiments, other and further embodiments may be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims that follow.

We claim:

1. A method of power management in a data storage device that includes a magnetic storage device, the method comprising:

measuring a time interval since a most recent time data has been read from or written to the magnetic storage device; and

in response to the time interval exceeding a predetermined value, changing a current power consumption state of the magnetic storage device to a lower power consumption state.

2. The method of claim 1, wherein the time interval measured is a time interval since a most recent time data has been read from or written to the magnetic storage device to satisfy a host command.

3. The method of claim 2, wherein the current power consumption state comprises an active servo state and the lower power consumption state comprises an intermediate power consumption state that uses less power than the active servo state and more power than a parked state.

4. The method of claim 3, wherein the intermediate power consumption state comprises a float state in which a servo system of the magnetic storage device is not used to provide continuous position control of a read/write head of the magnetic storage device.

5. The method of claim 3, wherein the intermediate power consumption state comprises a low-frequency servo state in which a servo system of the magnetic storage device provides position control of a read/write head of the magnetic storage device using no more than a portion of the servo wedges on a storage disk of the magnetic storage device.

6. The method of claim 1, wherein the current power consumption state comprises an intermediate power consumption state that uses less power than the active servo state and more power than a parked state.

7. The method of claim 6, wherein the lower power consumption state comprises one of a standby state in which a storage disk of the magnetic storage device is not spinning and a parked state in which a read/write head of the magnetic storage device is parked.

8. The method of claim 1, wherein the current power consumption state comprises a parked state in which a read/write head of the magnetic storage device is parked.

9. The method of claim 8, wherein the lower power consumption state comprises a standby state in which a storage disk of the magnetic storage device is not spinning.

**10.** The method of claim **1**, further comprising, during the time interval in which the magnetic storage device is not accessed:

receiving one or more commands; and  
satisfying the one or more commands using at least one of  
a volatile solid-state memory of the data storage device  
and a non-volatile solid-state memory device of the data  
storage device.

**11.** A data storage device, comprising:  
a magnetic storage device; and  
a controller configured to:

measure a time interval since a most recent time data has  
been read from or written to the magnetic storage  
device; and  
in response to the time interval exceeding a predeter-  
mined value, change a current power consumption  
state of the magnetic storage device to a lower power  
consumption state.

**12.** The data storage device of claim **11**, wherein the time  
interval measured is a time interval since a most recent time  
data has been read from or written to the magnetic storage  
device to satisfy a host command.

**13.** The data storage device of claim **12**, wherein the current  
power consumption state comprises an active servo state and  
the lower power consumption state comprises an intermediate  
power consumption state that uses less power than the active  
servo state and more power than a parked state.

**14.** The data storage device of claim **11**, wherein the current  
power consumption state comprises an intermediate power  
consumption state that uses less power than the active servo  
state and more power than a parked state.

**15.** The data storage device of claim **14**, wherein the lower  
power consumption state comprises one of a standby state in  
which a storage disk of the magnetic storage device is not  
spinning and a parked state in which a read/write head of the  
magnetic storage device is parked.

**16.** The data storage device of claim **11**, wherein the current  
power consumption state comprises a parked state in which a  
read/write head of the magnetic storage device is parked.

**17.** The data storage device of claim **16**, wherein the lower  
power consumption state comprises a standby state in which  
a storage disk of the magnetic storage device is not spinning.

**18.** The data storage device of claim **11**, wherein the con-  
troller is further configured to, during the time interval in  
which the magnetic storage device is not accessed:

receive one or more commands; and  
satisfy the one or more commands using one of a volatile  
solid-state memory of the data storage device, a non-  
volatile solid-state memory device of the data storage  
device, and a combination of both.

**19.** A data storage device, comprising:  
a magnetic storage device;  
a non-volatile solid-state device; and  
a controller configured to:

determine that a portion of the non-volatile solid-state  
device used to store data that are not also stored on the  
magnetic storage device is greater than a predeter-  
mined value;

change a power state of the magnetic storage device  
from an initial power state to an active servo state, the  
initial power state being a lower power state than the  
active servo state; and

control the writing to the magnetic storage device of at  
least a portion of the data that are not also stored on the  
magnetic storage device.

**20.** The data storage device of claim **19**, wherein the con-  
troller is further configured to, while the magnetic storage  
device is at the initial power state, control the writing of data  
from a host device to the non-volatile solid-state device.

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