

MOBILE DATA STORAGE DEVICE WITH POWER MANAGEMENT

Summary

A mobile data storage device may, in accordance with various embodiments, have at least a rotating data storage medium and a controller. The controller can be configured to alter a rotational speed of the data storage medium in response to a predicted change in a command queue.

Brief Description of the Drawings

FIG. 1 is a block representation of an example data storage system configured and operated in accordance with some embodiments.

FIGS. 2A and 2B respectively display a block representation and plotted operational data from an example data storage device.

FIG. 3 shows a block representation of a portion of an example mobile computing device configured and operated in accordance with various embodiments.

FIG. 4 provides an example command queue profile routine conducted in accordance with some embodiments.

FIG. 5 maps an example command logic carried out in accordance with various embodiments.

FIG. 6 displays an example power management scheme utilized in accordance with assorted embodiments.

FIG. 7 plots an example power conservation routine that may be carried out in accordance with various embodiments.

Detailed Description

The proliferation of semiconductor design and fabrication has allowed computing devices to become increasingly mobile and more powerful. Technology previously reserved for physically cumbersome, stationary, form factors can now be packaged into mobile electronic devices that provide broadband communication connectivity as well as generation of large amounts of data, such as with high definition video recording. A reduction in form factor of mobile computing devices, such as smartphones, tablet computers, watches, and laptop computers,

has reduced the space available for batteries. While battery technology continues to advance and alternative power supplies, like solar power, can recharge a battery, replenishing a battery is slower and more debilitating to a mobile computing device than conserving power usage.

5 Accordingly, a mobile data storage device may have at least a rotating data storage medium and a controller that alters the rotational speed of the data storage medium in response to a predicted change in a command queue. The proactive alteration of the medium's rotational speed can mitigate unnecessary power consumption while allowing responsive system function when accessed by a user.
10 That is, the rotational speed of the medium can be altered to a state that conserves power and can be returned to a fully operational state without a noticeable reduction in the performance of the mobile data storage device.

 While a mobile data storage device may be employed in an unlimited variety of systems and environments, various embodiments utilize a mobile data storage device in the example data storage system 100 shown as a block
15 representation in FIG. 1. The data storage system 100 may employ power management technology in accordance with some embodiments by engaging one or more local or remote data storage devices 102. One or more data storage devices 102 can be equipped with one or more transducing heads 104 that are suspended
20 over selected data bits 108 and data tracks 110 to program and sense data across an air bearing 114.

 The storage medium 106 can be attached to one or more spindle motors 112 that rotate the medium 108 to produce the air bearing 114 on which the transducing head 104 flies to access predetermined portion of the medium 106. In this way, one
25 or more local 116 processors and remote hosts 118 can provide controlled motion of the transducing head 104 and spindle 112 to adjust and align the transducing head 104 with selected data bits 108. With the advent of network computing has allowed remote hosts 118 and storage arrays 120 access to a controller 122 through a network 124 via appropriate protocol.

30 The remote host 118 and local processor 116 can act independently or concurrently to monitor and control one or more sensors 126 that continuously or sporadically read operating conditions of the data storage medium 106, like vibration and temperature, as well as the spindle 114, such as rotational speed

and power consumption. The local processor 116 and remote host 118 may further populate, organize, and execute command requests in a memory buffer 128 that can be configured as volatile and non-volatile memory cells to provide temporary storage of data and data information that are pending for execution by the data storage device 102 and controller 122.

Continued reduction in the physical dimensions of the data storage components, like the transducing head 104, can allow for implementation into mobile electronics that are continually striving for smaller form factors and greater computing capabilities. FIGS. 2A and 2B respectively illustrate different representations of an example mobile computing system 140 that can be used in the data storage system of FIG. 1. As shown in FIG. 2A, the mobile computing system 140 may comprise one or more mobile computing devices 142 that can communicate data via wired and wireless pathways to static and virtual mobile devices. For example, the mobile computing device 142 may have a serial bus capable of wired connection to a stationary desktop and server as well as a network protocol allowing wireless connection with a virtual cloud node, server, and other mobile computing devices.

While not required or limiting, a mobile computing device 142 can consist of a battery 144 that provides power and may, or may not, be rechargeable. A cache memory 146 can provide short-term storage for data that may be processed by a processor 148, graphically shown on a display 150, and moved to a hard disk drive 152 for long-term storage. While the mobile computing device 142 can function without means for cooling the constituent components, operation of the various mobile computing components individually and collectively can serve to produce heat through the consumption of power provided by the battery 144.

Regardless of the type, size, and performance of the data storage in the mobile computing device 142, the heat produced from operation can jeopardize the performance of the mobile computing device 142. In other words, heat is produced from solid-state memory arrays and hard disk drives and such heat can degrade the ability of those data storage means to read, write, and output data accurately. An example relationship between temperature of a mobile computing device 146 and power consumption of the device 146 over time is provided by solid line 154 and segmented line 156. It can be appreciated that heat is retained in the mobile

computing device due at least to the operation of constituent components, environmental conditions, and interaction with a user.

FIG. 3 is a block representation of a portion of an example mobile computing device 160 arranged in accordance with assorted embodiments. The mobile computing device 160 can have at least one data storage device 162 that has one or more dedicated or distributed controllers 164 that provide a range of computing capabilities through the execution of drivers. Various embodiments employ at least one driver to communicate with peripheral components to provide data caching 166, fall protection, 168, power management 170, and thermal management 172 capabilities. These capabilities can operate exclusively, redundantly, and collectively to optimize data storage device 162, and consequently mobile computing device 160, performance.

While the various capabilities can be utilized in any data storage device 162 that is part of mobile computing device 164 that may or may not have cooling means, it is contemplated that the controller 164 selectively monitors data storage device 162 conditions to employ one or more capabilities to balance power consumption with heat retention in a mobile computing device that lacks cooling means. For example, the thermal 172 and power 170 management schemes may be operating concurrently before data caching 166 is executed. As another non-limiting example, the fall protection 168 capability may suspend the power 170 and thermal 172 management schemes while conducting predictive and reactive data caching 166 that moves data to solid-state memory for temporary storage.

The ability to employ a variety of different capabilities may be retrofitted into a data storage device 162 that did not previously have a controller capable of such capabilities. However, a mobile enablement kit can alternatively be pre-loaded into the data storage device 152 during manufacture and prior to end-user data being stored to allow the various capabilities to be activated at any time. In a contemplated use, the data storage device 162, such as a hard disk drive, can be used in a stationary computer with cooling means and subsequently installed in a mobile computing tablet without cooling means where the mobile enablement kit recognizes the lack of cooling and establishes the predetermined capabilities through the utilization of a dynamic data driver. The dynamic data driver can be configured to establish communications between the controller 164 and the

peripheral components to execute the various capabilities. As such, the mobile enablement kit can optimize the implementation of capabilities with minimal need for supplemental software updates.

With or without a mobile enablement kit installed on the data storage device 162, the controller 164 can continually, sporadically, and routinely conduct proactive and reactive measures to establish and preserve optimal performance despite consuming power and generating heat in the device 162. FIG. 4 conveys an example command queue profile routine 180 that may be carried out in accordance with various embodiments to proactively allow at least one controller to maintain optimized mobile computing device performance while conditions, like device temperature and power consumption, change. The routine 180 can begin by logging at least one command queue activity over time in step 182. Such activity logging can be done locally and remotely in temporary or permanent storage locations.

Decision 184 next evaluates one or more logged command queue activities from step 182 to determine if a known activity profile is present. That is, decision 184 can evaluate the timing, situation, and sequence of logged activities to determine if a known activity profile is applicable. If no known profile fits the logged activities, step 186 starts a new profile that may stand alone or be implemented into another profile at a later time. If a known profile fits the logged activities, step 188 updates the known profile with the logged events, which may or may not alter the profile.

The registration of logged command queue activities in a new or known profile allows step 190 to predict future command queue activities based on the activities observed in step 182. As a non-limiting example, one or more algorithms can identify trends and situations from the activity profile that have a high probability of reoccurring, which is manifested in a prediction in step 190 of a reduction or increase in command queue activity volume. It is noted that a command queue may have a fixed execution rate and step 190 can predict the volume of unexecuted and partially executed commands, such as data reads, servo data maintenance, metadata updates, cache storage maintenance, and data writes.

Although sophisticated and simple algorithms may be employed in step 190, unexpected and previously non-encountered activities may occur. Decision

192 determines if the command queue activity predicted in step 190 is correct in an effort to validate, evolve, and maintain the accuracy of the activity profile as well as the algorithms used to predict future activity. A correct activity prediction triggers step 194 to note the command queue activity and the timing of the activity to allow the profile and associated algorithms to subsequently predict other future command queue events. If the predicted activity is wrong, decision 192 prompts step 190 to predict a new activity, which effectively deletes wrong predictions from inclusion into the activity profile or prediction algorithm.

With the ability to predict future command queue activities, like command volume and urgency, a controller can conduct measures that conserve power consumption in a mobile computing device. The command logic 200 of FIG. 5 is an example of how one or more controllers can respond to predicted and actual command queue activity in accordance with various embodiments. It should be noted that the command logic 200 is not exclusively conducted and may be partially executed while other controller capabilities, such as the thermal management scheme 180, data caching 166, and fall protection 168, are running. Returning to FIG. 5, the prediction or arrival of an actual command in step 202 triggers the evaluation of a temperature in the data storage device and a determination if a temperature threshold has been exceeded with decision 204. A temperature that exceeds the limit causes a controller to slow the rotational speed of the data storage media while suspending execution of at least one command queue in step 206. The reduction in media speed and suspension of command can allow heat to dissipate quickly while decreasing the amount of power being consumed.

Upon the media rotating at a reduced speed for a predetermined time, such as 30 seconds, decision 204 is revisited to determine if further rotational speed reductions are in order. If so, the data storage device can experience tiers of rotational speeds that eventually may result in powering the data storage device off. However, if decision 204 determines that the temperature of the device is safe to conduct command execution, step 208 then computes a command window based at least in part on a derived thermal profile predicting how the execution of commands will affect device temperature.

As a result of step 208, a window of time, power consumption, or amount of temperature fluctuation will be allowed that may, or may not, execute all the commands received in step 202 or resident in the command queue as step 210 increases the rotational speed of the data storage device and step 212 executes at least one command. It is contemplated that step 212 executes actual data access commands as well as time delays imposed by a thermal management scheme, but such execution is not required. The completion of step 212 for the designated command window from step 208 advances the logic 200 back to decision 204 where another evaluation of the temperature of the data storage device is conducted. Through the cyclical return to decision 204, the logic 200 can continually be focused on what the temperature of the data storage device is and take actions to reduce the temperature and power consumption of the device without degrading user experience as caching of data can service short term user requests.

The logic 200 of FIG. 5 can serve to strategically adjust data storage device temperatures by reducing the rotational speed of the data storage media via one or more intervals, such as 500, 1000, or 5000 rpm reductions. . While the data storage device could be simply powered off at the presence of an elevated temperature, such action would be detrimental to power consumption as it takes more power to spin the media up than is saved from spinning them down. In other words, logic 200 provides a balance of heat dissipation with power consumption by spinning the data storage media down gradually in response to elevated temperatures. During high volume command queue conditions, such as operating system loading, logic 200 can provide optimized heat and power balance that maintains system performance. However, in low or sporadic command queue conditions that can correspond with the use of mobile computing devices, logic 200 may not balance power consumption with heat dissipation as well due to the device spinning and heat being stable below the predetermined threshold.

FIG. 6 displays an example power management scheme 220 that can be carried out by a controller in a mobile data storage environment in accordance with assorted embodiments to more aggressively conserve power, which can be particularly useful in low processing times. While not required, scheme 220 can be triggered in response to a predetermined period of system idleness, such as 1

minute, when the data storage device is powered off by parking the transducing heads and rotation of the data storage media is stopped regardless of the temperature of the device. In yet, scheme 220 can alternatively be continually running individually or in combination with other scheme and logic.

5 Initiation of the power management scheme 220 begins with step 222 receiving at least one read command from a host. Step 224 proceeds to check local or network cache for the requested data. In the event the data is found in cache, the scheme 220 can return the data to the host without alteration of the condition of the rotating data storage device. A failure to locate the requested data in step 224 then
10 conducts decision 226 where a determination if the data storage device is spinning is accomplished. Spinning data storage media results in step 228 executing at least one command from the command queue at the next available command window, such as command window established in step 206 of logic 200. If the media are stationary, step 230 next holds the command while the media are spun to a
15 predetermined speed, such as 9000 rpm, in step 232. Completion of step 232 allows step 228 to subsequently execute the command at the next available command window.

 At the end of the command window where at least one command is executed in step 228, step 234 flushes local cache and parks transducing heads
20 before the data storage device is powered off in step 236. Various embodiments follow a predetermined spinning down profile that allows for efficient spinning up if a new command is received while other embodiments abruptly spin down and power off the data storage device in an effort to maximize power conservation. It is contemplated that a host can set and adjust the degree of power conservation in the
25 power management scheme 220, such as by setting high or low conservation settings that correspond to different spinning down profiles.

 The use of the command queue profile routine 180 of FIG. 4, command logic 200 of FIG. 5, and power management scheme 220 of FIG. 6 can be used individually and concurrently to balance power consumption with temperature
30 control. In some embodiments, the controller of a data storage device intelligently executes the various schemes and logic to adapt to how the mobile computing device is being used. FIG. 7 conveys an example power conservation routine 240 that can be conducted in accordance with various embodiments to intelligently

conduct proactive and reactive mitigation of power consumption in a mobile computing device.

It is contemplated that any number of steps and decisions can be carried out prior to step 242 predicting at least one command queue activity based on a derived profile. For example, routine 180 may be conducted to start or update a derived profile that is utilized in step 242 to predict one or more command queue activities, such as a change in command volume in the queue, increase in command execution, and establishment of a backlog of commands in the queue. A prediction of any kind of command queue activity or system activity, such as high or low processing volumes, can trigger step 244 to adjust the rotational speed of a data storage medium.

As a non-limiting example, step 242 can predict low command queue volumes or slow intake of queue commands prior to step 244 slowing the rotation of the data storage medium by a predetermined interval, such as 500 rpm or 25% of operating speed. The prediction of command queue activity can allow step 244 to proactively save power by slowing the rotational speed of the data storage medium in response to the command queue meeting certain parameters, like number of new or executed commands over a given time. Step 244 can alternatively increase the rotational speed of the data storage medium to allow increased numbers of commands to be executed in the future, which can reduce power consumption compared to gradually executing commands over a longer period of time.

Although use of a derived profile can increase the accuracy of command queue predictions in step 242, a prediction and adjustment of rotational speed can be incorrect. Decision 246 evaluates if a proactive action by a controller in step 244 is correct. A verification that one or more preceding rotational speed adjustments is correct cycles routine 240 to step 242 where command queue activities are continuously, sporadically, and routinely predicted. An incorrect prediction or adjustment to the rotational speed of the data storage medium can correspond with a predetermined time interval, such as 1, 5, 10, 30, and 60 seconds or more, which defines a timeout interval of failed command queue activities.

That is, decision 248 can identify if an incorrect command queue prediction and data storage medium rotational speed adjustment corresponds with an

unwanted delay in the execution or volume of commands in the queue. In the event an incorrect prediction and/or rotational adjustment doesn't result in command execution over the timeout interval, step 250 updates the derived profile to evolve the derived profile to better predict future command queue activities when step 242 is revisited. A command queue delay over the timeout interval causes step 252 to reduce the rotational speed of the data storage medium by a predetermined interval that may be the same, or different than the interval of step 244.

A contemplated, but not required, embodiment of routine 240 involves the prediction of slow or inactivity in the command queue and steps down the rotational speed of the data storage medium in uniform or varying intervals to a low power rotation, such as 500 rpm. The gradual stepping of the rotational speed downward allows a mobile computing device to quickly and seamlessly respond to predicted or actual changes in user and command queue activity by bringing the rotational speed of the data storage medium to an operational status, such as 5600 or 9000 rpm. The power consumed by a mobile computing device executing routine 240 can be optimized by turning the spindle motor off continually or intermittently to reduce the rotational speed of the data storage medium.

The various aspects of routine 240 are not required or limiting as any portion of the routine 240 can be changed, added, and removed at will. For example, a step can be inserted that generates a derived profile or stops rotation of the data storage medium altogether. Through the assorted embodiments described herein, a mobile computing device can predict command queue activity and mitigate power consumption. The ability to selectively respond to predicted command queue activity by decreasing the rotational speed of the data storage medium is complemented by the gradual reduction of rotational speed that enables seamless return to an operating rotational speed.

It will be appreciated that the technology described above can readily be utilized in any number of applications, including computing environments with cooling means. It is to be understood that even though numerous characteristics of various embodiments of the present disclosure have been set forth in the foregoing description, together with details of the structure and function of various embodiments, this detailed description is illustrative only, and changes may be

made in detail, especially in matters of structure and arrangements of parts within the principles of the present technology to the full extent indicated by the broad general meaning of the terms in which the appended claims are expressed. For example, the particular elements may vary depending on the particular application without departing from the spirit and scope of the present disclosure.

CLAIMS:

1. An apparatus comprising a mobile data storage device comprising a rotating data storage medium, a controller connected to a thermal management circuit and a power management circuit, the controller altering rotational speed of the data storage medium in response to a predicted changes in a command queue provided by the thermal management circuit and power management circuit.

2. The apparatus of claim 1, wherein the mobile data storage device is a hard disk drive.

3. The apparatus of claim 1, wherein the mobile data storage device comprises a plurality of data storage media attached to a central spindle.

4. The apparatus of claim 3, wherein the mobile data storage device comprises at least one battery that powers the controller and central spindle.

5. The apparatus of claim 1, wherein the mobile data storage device comprises a cache memory connected to the controller, the cache memory storing the command queue.

6. The apparatus of claim 1, wherein the mobile data storage device is incorporated into a mobile computing device wirelessly connected to a remote host via a network.

7. The apparatus of claim 1, wherein the controller is further connected to a fall protection circuit configured to provide predicted change.

8. The apparatus of claim 1, wherein the data storage medium is positioned adjacent at least one suspended data transducing head.

9. An apparatus comprising a mobile data storage device comprising a rotating data storage medium and a controller, the mobile data storage device comprising a mobile enablement kit configured to recognize the presence of an active cooling feature, the controller altering a rotational speed of the data storage medium in response to a predicted change in a command queue.

10. The apparatus of claim 9, wherein the predicted change corresponds with a derived profile of experienced command queue activity.

11. The apparatus of claim 9, wherein the predicted change corresponds with a reduction in command queue volume.

12. The apparatus of claim 9, wherein the controller reduces the rotational speed of the data storage medium by 25-50%.

13. A method comprising:
connecting a controller to a rotating data storage medium in a mobile data storage device;
measuring temperature of the data storage medium;
checking spinning status of data storage medium;
predicting a change in a command queue; and
altering a rotational speed of the data storage medium in response to the temperature of the data storage medium, spinning status of the data storage medium and predicted change in the command queue.

14. The method of claim 13, wherein the change in the command queue corresponds with a profile of logged command queue activity.

15. The method of claim 13, wherein the rotational speed of the data storage medium is altered by powering a spindle motor off to arrive at a slower rotational speed of the data storage medium.

16. The method of claim 13, wherein the rotational speed of the data storage medium is altered by increasing power to a spindle motor to arrive at an operational rotational speed of the data storage medium.

5 17. The method of claim 13, wherein the altering step comprises reducing the rotational speed of the data storage medium in varying intervals.

18. The method of claim 17, wherein the varying intervals correspond with different rotating speeds.