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(54) **DISPLAY CONFIGURED TO DISPLAY HEALTH STATUS OF A MEMORY DEVICE**

(75) Inventors: **Martin Ragnar Furuhjelm**, Grass Valley, CA (US); **Steffen Markus Hellmold**, Novato, CA (US)

Correspondence Address:
LEFFERT JAY & POLGLAZE, P.A.
P.O. BOX 581009
MINNEAPOLIS, MN 55458-1009 (US)

(73) Assignee: **Lexar Media, Inc.**

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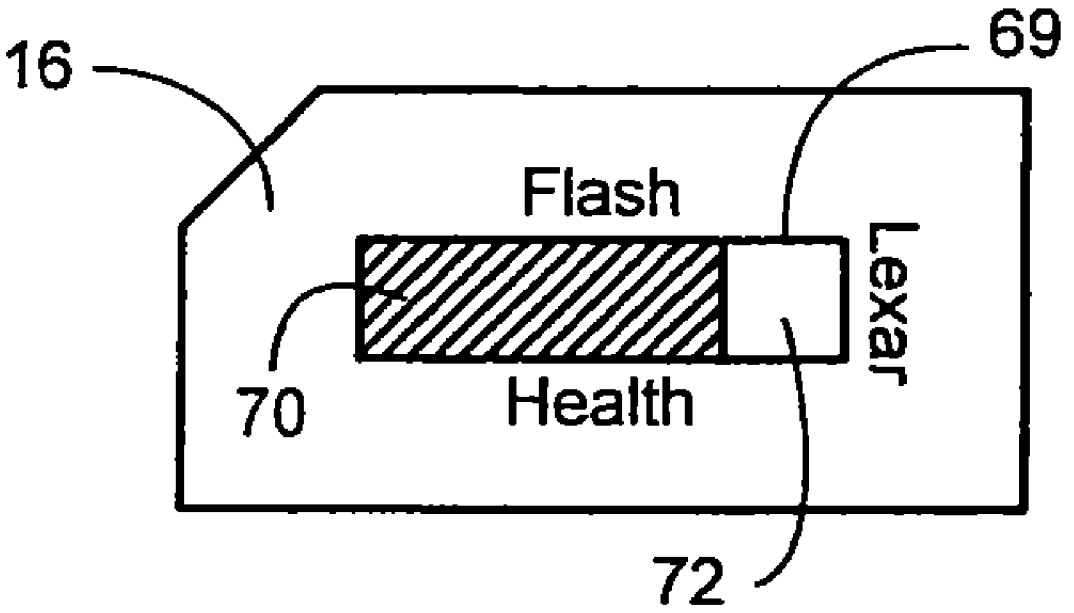
(57) **ABSTRACT**

An apparatus includes a display configured to display a health status of a memory device, where the health status is indicative of an amount of spare memory the memory device has available to replace memory of the memory device that may become defective.



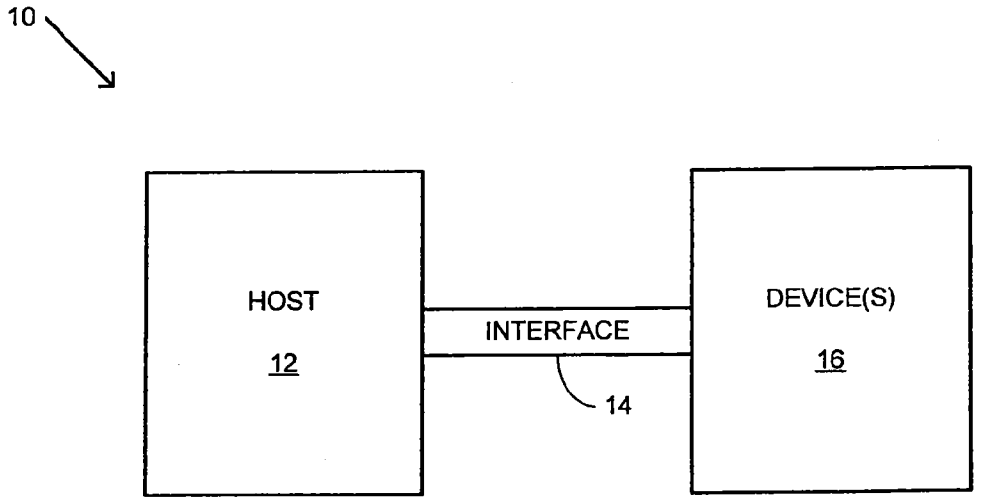

10
HOST
12
INTERFACE
14
DEVICE(S)
16

FIG. 1

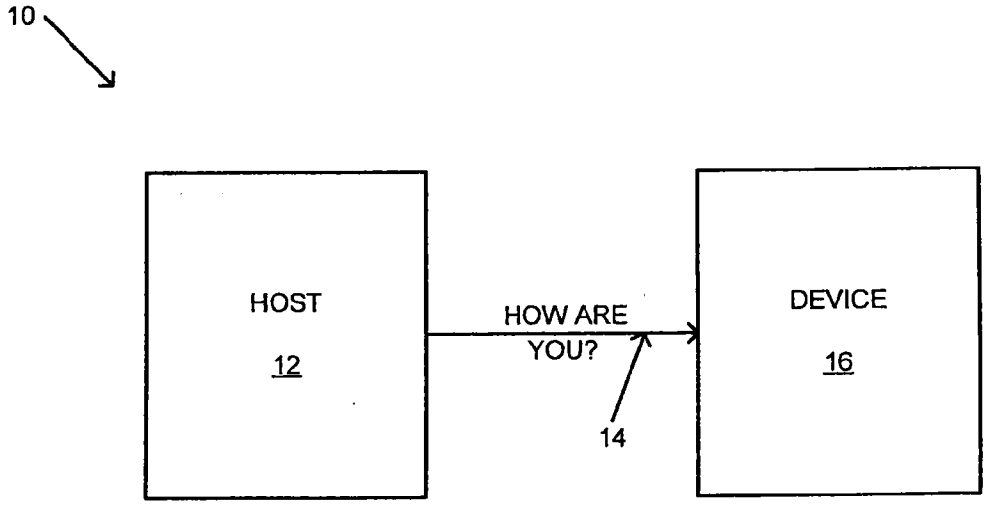

10
HOST
12
HOW ARE
YOU?
14
DEVICE
16

FIG. 2

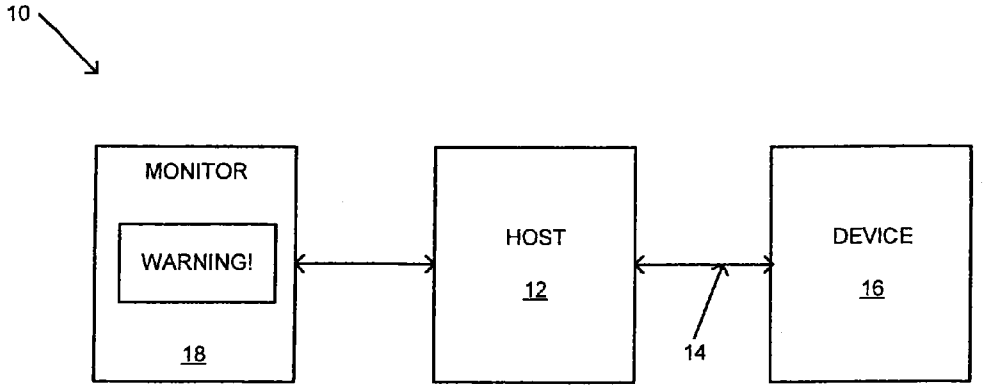

10
MONITOR
WARNING!
18
HOST
12
14
DEVICE
16

FIG. 3

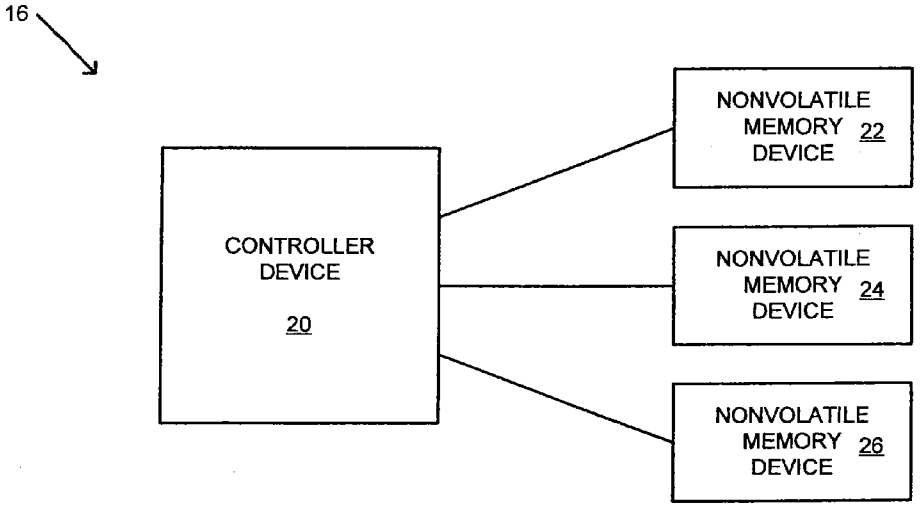

16
CONTROLLER DEVICE
20
NONVOLATILE MEMORY DEVICE 22
NONVOLATILE MEMORY DEVICE 24
NONVOLATILE MEMORY DEVICE 26

FIG. 4

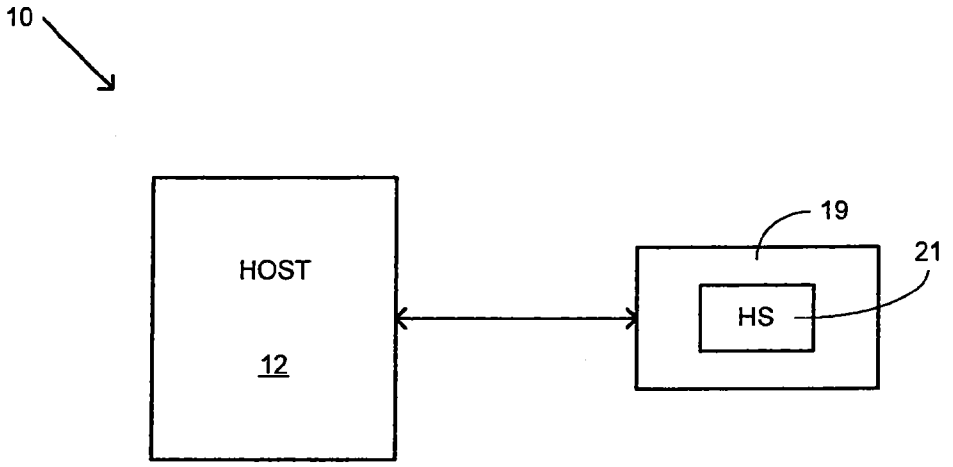


FIG. 4a

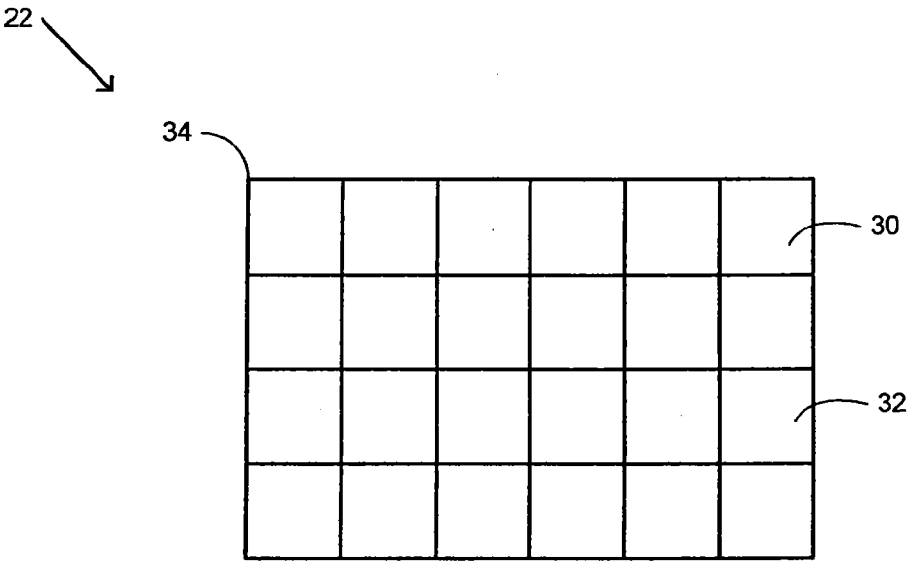


FIG. 5

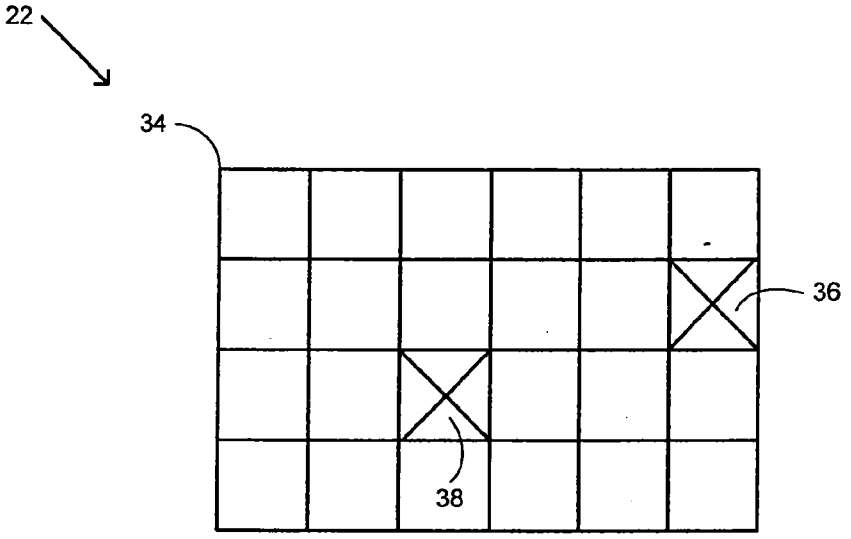


FIG. 6

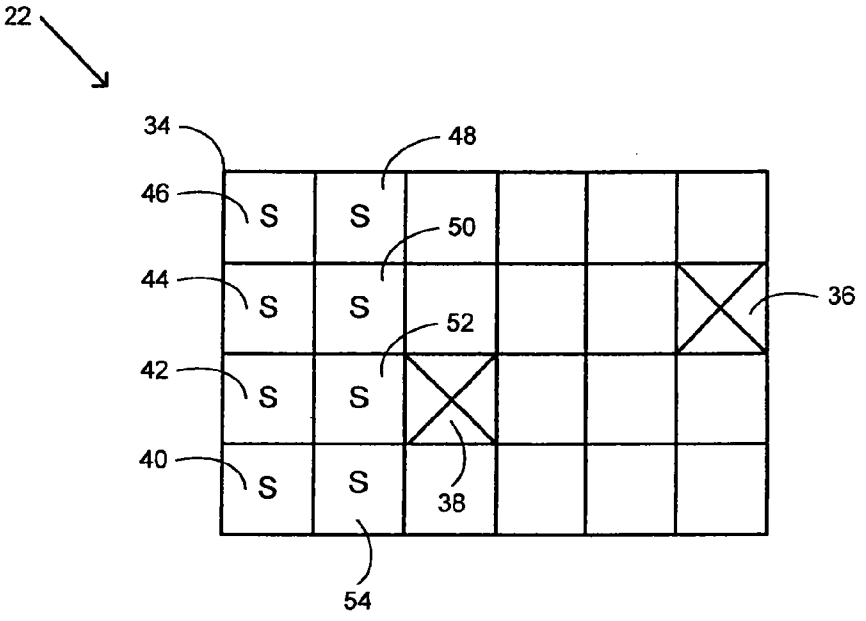


FIG. 7

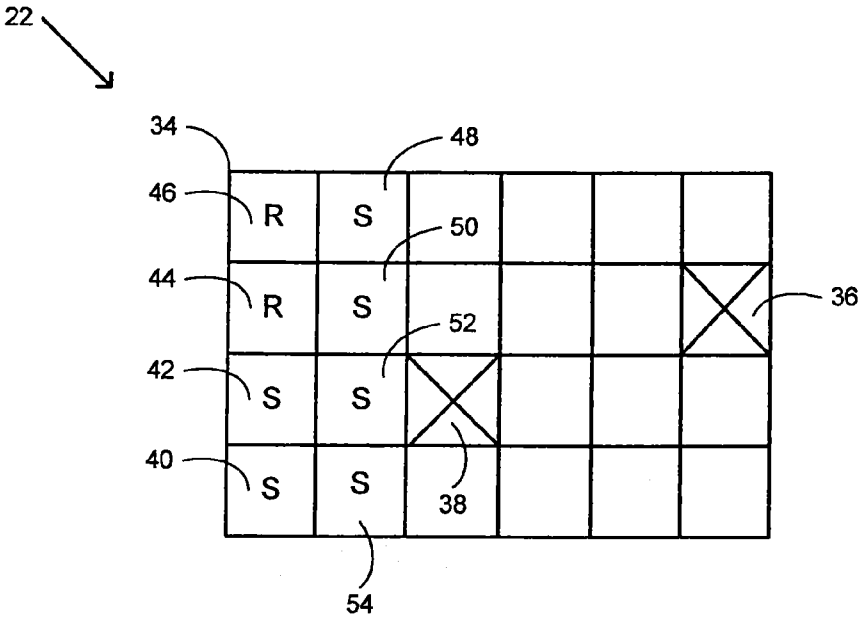

22
34
48
46
R
S
50
44
R
S
52
36
42
S
S
40
S
S
38
54

FIG. 8

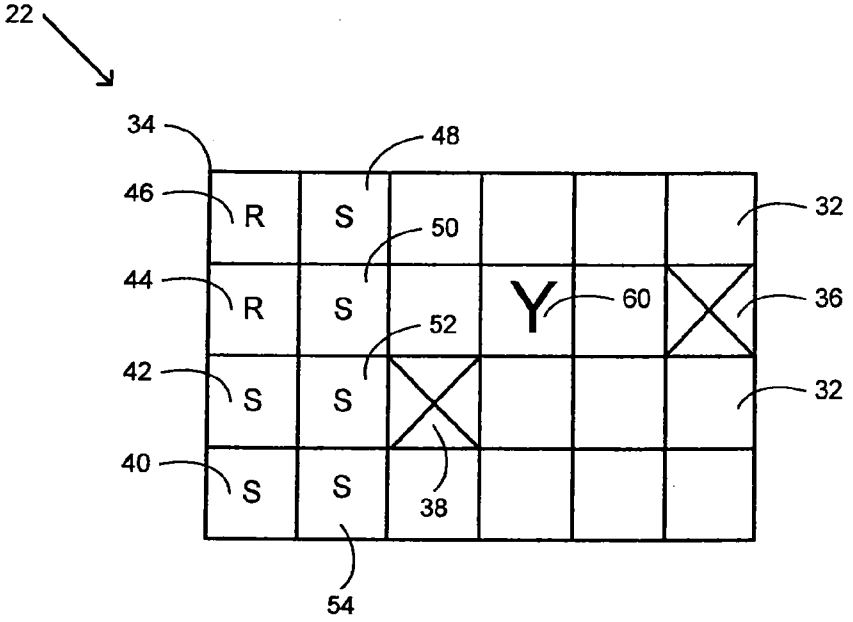

22
34
48
46
R
S
50
32
44
R
S
Y
60
36
52
42
S
S
32
40
S
S
38
54

FIG. 9

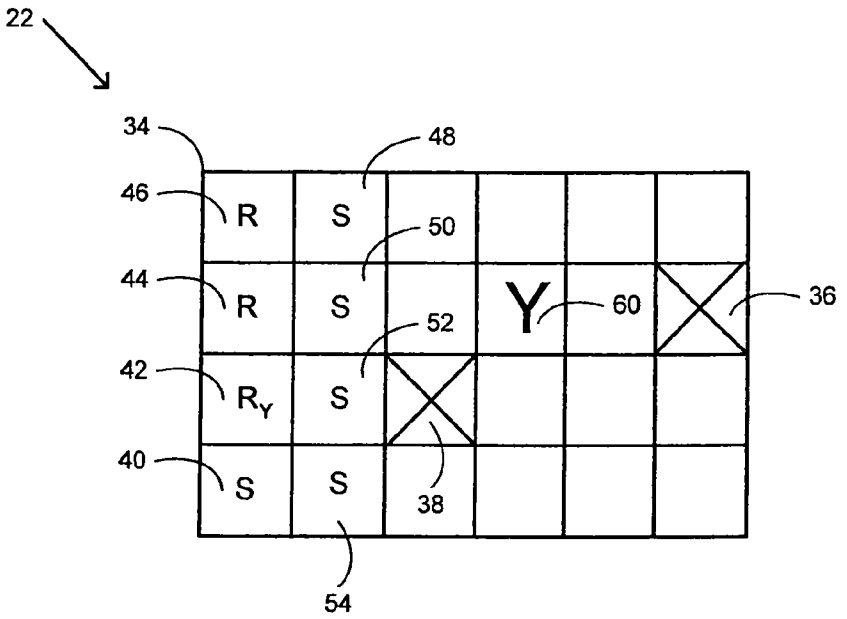

22
34
48
46
R
S
50
44
R
S
Y
60
36
52
42
R_Y
S
40
S
S
38
54

FIG. 10

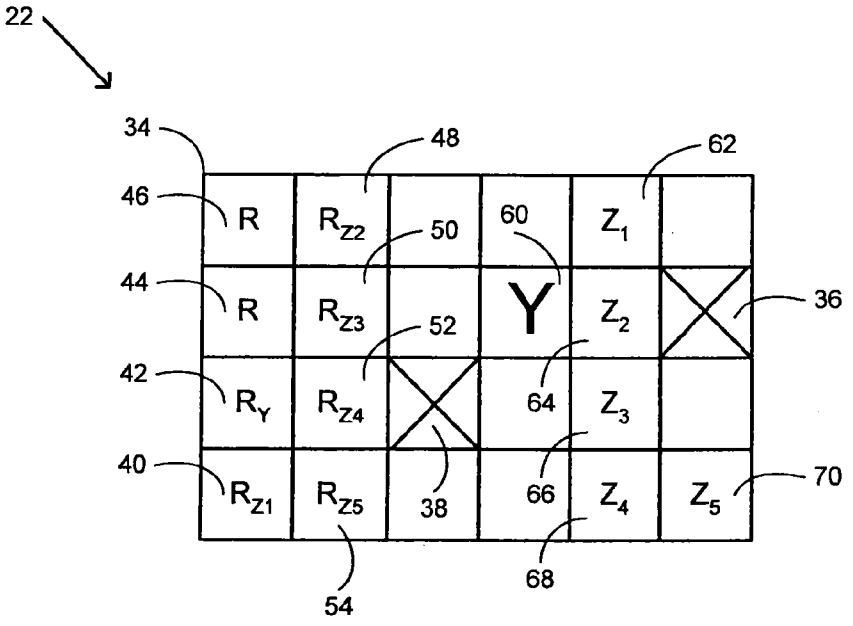

22
34
48
62
46
R
R_{Z2}
50
60
Z_1
44
R
R_{Z3}
Y
Z_2
36
52
42
R_Y
R_{Z4}
64
Z_3
40
R_{Z1}
R_{Z5}
38
66
Z_4
Z_5
70
68
54

FIG. 11

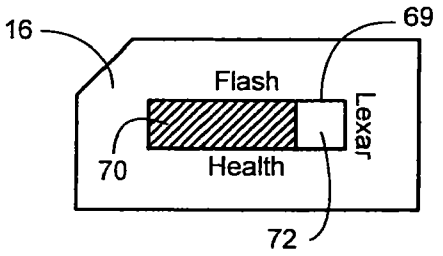


FIG. 12

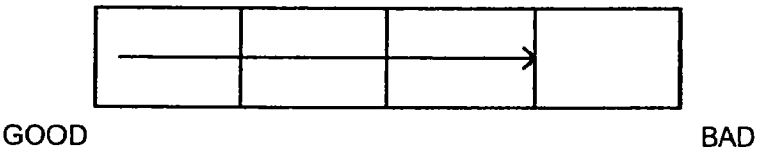


FIG. 13

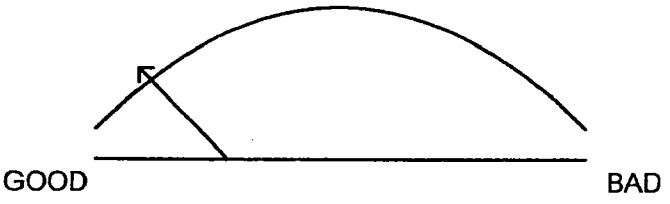


FIG. 14

DISPLAY CONFIGURED TO DISPLAY HEALTH STATUS OF A MEMORY DEVICE

RELATED APPLICATIONS

[0001] This application is a continuation of U.S. application Ser. No. 12/276,699, titled "STATUS OF OVERALL HEALTH OF NONVOLATILE MEMORY," filed Nov. 24, 2008 (allowed), which application is a continuation of U.S. application Ser. No. 10/927,871, titled "STATUS OF OVERALL HEALTH OF NONVOLATILE MEMORY," filed Aug. 27, 2004 and issued on Dec. 9, 2008 as U.S. Pat. No. 7,464,306, both applications commonly assigned and incorporated in their entirety herein by reference.

FIELD

[0002] This invention relates generally to the field of nonvolatile or flash or EEPROM memory and in particular to a method and apparatus for measuring and displaying the health status of such memory.

BACKGROUND

[0003] Nonvolatile memory, such as FLASH memory and EEPROM, has gained notoriety in the recent decade, namely due to its fast write time characteristics and ability to maintain storage of information even when no power is connected thereto. Nonvolatile memory is now employed in a wide number of applications, such as digital film for digital cameras, as a drive (or mass storage) in personal computers (PCs) or other hosts, hand-held electronic devices such as personal data access (PDAs) and the like.

[0004] During manufacturing of nonvolatile memory devices, certain defects within the memory are detected and marked accordingly. Manufacturing defects are inherent in nonvolatile memory devices and other types of defects arise during use of the devices. Other types of defects can and generally result from repeated usage of the device. For example, a nonvolatile memory device is now generally expected to be used or re-written thereto anywhere from thousands to tens of thousands to hundreds of thousands to one million times and thereafter, the device typically becomes unusable due to the number of defective memory locations therein. As nonvolatile memory is utilized, it is written thereto for use in storing information and then it is erased prior to use of the same locations, i.e. re-written. In most applications, nonvolatile memory is organized into blocks and when a write is initiated by a host that is coupled to the memory, generally through a controller device, one or more blocks are written thereto. Prior to re-writing the one or more blocks, the latter need be erased and when a block undergoes anywhere from thousands to tens of thousands to hundreds of thousands to one million or so write and erase operations, it will generally become defective or its ability to store information reliably deteriorates. Thus, the more nonvolatile or flash memory is utilized, the more defects grow.

[0005] Through the use of the controller device coupling nonvolatile memory devices to a host, the defects within the devices are managed by replacing use of the detected defective blocks with blocks from a list of spare blocks. That is, firmware or software code being executed by the controller device causes such a replacement so that when a block, noted to be defective is in some manner, is accessed by a host, such access occurs of a replacement or spare block with the host generally remaining oblivious thereto. Thus, the controller device must maintain a list of spare blocks and a mapping of the defective blocks, if any, to spare blocks in replacement thereof.

[0006] However, currently, while the controller device is aware of the number of defective blocks and the number of spare blocks and the number of blocks being employed for storage, or in essence, status of the health of a nonvolatile memory device, the user of the latter and the host remain ignorant of such information. Additionally, the health status of nonvolatile memory devices is not readily shown or displayed to a host or user thereof.

[0007] Therefore, the need arises for a method and apparatus to measure and display the health status of nonvolatile or flash memory.

IN THE DRAWINGS

[0008] FIG. **1** shows a nonvolatile memory system **10** including a host **12** and a device **16** through an interface **14** in accordance with an embodiment of the present invention.

[0009] FIG. **2** shows the system **10** of FIG. **1** with the host sending an inquiry to the device **16**, through the interface **14**.

[0010] FIG. **3** illustrates the system **10** further including a monitor or display **18** coupled to the host **12**,

[0011] FIG. **4** shows further details of the device **16** in accordance with an embodiment of the present invention.

[0012] FIG. **4**(*a*) shows the system **10** in accordance with another embodiment or the present invention wherein the host **12** is coupled to the display **19** for showing HS at **21** without the need for a controller.

[0013] FIGS. **5-11** show examples of a grid of blocks and for some blocks, status thereof.

[0014] FIGS. **12-14** show examples of different ways in which HS may be displayed.

DETAILED DESCRIPTION

[0015] Referring now to FIG. **1**, a nonvolatile memory system **10** is shown to include a host **12** and a device **16** through an interface **14** in accordance with an embodiment of the present invention. The host **12** may be any number of electronic systems or devices, such a personal computer (PC), a server, a digital camera and the like. The device **16**, while not shown in FIG. **1**, includes a controller device coupled to one or more nonvolatile memory devices. The controller transfers digital information between the host **12** and the nonvolatile memory devices. The nonvolatile memory devices store information transferred by the host upon direction from the controller device and can include any type of nonvolatile memory, such as flash memory, EEPROM memory or the like. The interface **14** can be any of the known interfaces currently being employed and adopted by the industry at large, such as a Universal Serial Bus (USB) interface, a small computer systems interface (SCSI), firewire and the like.

[0016] As noted earlier, there is currently no method and apparatus indicative of the health status of the nonvolatile memory device(s) within the device **16**. Thus, a user of the system **10** and the host **12** remain unaware of the number of defective blocks or usable blocks included within the nonvolatile memory. However, in the embodiment of FIG. **1** and further of those that follow, the host **12** and/or a user of the system **10** are aware of the health of the nonvolatile memory within the device **16**, as will be evident shortly.

[0017] FIG. **2** shows the system **10** of FIG. **1** with the host sending an inquiry to the device **16**, through the interface **14**,

which basically asks the device **16** about its health status, specifically the health of the nonvolatile memory included therein.

[0018] FIG. **3** shows the system **10** further including a monitor or display **18** coupled to the host **12**, which receives a response from the device **16** regarding the health status of the nonvolatile memory included therein and displays the same on the monitor **18**. As an example, the monitor **18** is caused to display a "Warning!" regarding the health of the nonvolatile memory, i.e. the latter may not be usable much longer.

[0019] FIG. **4** shows further details of the device **16** in accordance with an embodiment of the present invention. The device **16** is shown to include a controller device **20** coupled to the nonvolatile memory devices **22-26**. There may be a larger number of memory devices than those shown in FIG. **4**. The devices **22-26** each include nonvolatile memory organized in blocks with each block having one or more sectors for storing sector information received from the host **12**. During manufacturing, the nonvolatile memory of the devices **22-26** include certain defective blocks, which are detected and noted by the controller device **20** to avoid use thereof. As the nonvolatile memory is employed further, other defects develop or grow resulting in the deterioration of the health of the nonvolatile memory.

[0020] While not shown, the controller device **20** is coupled to the host **12** of FIGS. **1-3**, which initiate a read or write operation through the controller device **20**. After the first write operation of any of the locations within the devices **22-26**, any further write operations need to be preceded by an erase operation. Accordingly, the life span of the nonvolatile memory of the devices **22-26** is limited. Generally, such a life expectancy is on the order of anywhere from thousands to tens of thousands to hundreds of thousands to one million write or store operations.

[0021] As earlier noted, each of the nonvolatile memory devices **22-26** includes blocks for storage of sector information from the host. The host addresses or identifies sectors to be stored or written via logical block address and the controller device **20** translates these logical block addresses into physical block addresses or virtual physical block addresses for identifying the blocks within the nonvolatile memory wherein sector information is to be stored or read therefrom.

[0022] FIG. **4**(*a*) shows the system **10** in accordance with another embodiment or the present invention wherein the host **12** is coupled to a display **19** for showing HS at **21** without the need for a controller. The display **19** may be a monitor or a window on a flash or nonvolatile memory card and HS, at **21**, may be displayed in various ways, as will be discussed with respect to additional figures.

[0023] An example of a grid of blocks is shown in FIGS. **5-11** and for some blocks, status thereof. Specifically, in these figures, an example of a twenty four blocks is shown within the device **22**. That is, a group of blocks **34** is shown to include twenty four blocks, such as a block **30** and a block **32** and in FIGS. **6-11**, the status of these blocks is shown to change as defects are noted and grow. FIGS. **5-11** merely shown an example one of the ways in which a method and apparatus of the present invention may be employed, it should be understood that there are many other ways of implementing the various embodiments of the present invention.

[0024] Starting with FIG. **5**, when the device **22** is manufactured, at some point, all of the blocks may be usable, that is a read, write or erase operation may be performed thereupon reliably. However, more typically, even during manufacturing, some blocks are known to be defective, i.e. a read, write or erase operation cannot be performed thereupon reliably. As an example, the group of blocks **34**, in FIG. **6**, is shown to include defective blocks **36** and **38**. Also, during manufacturing or prior to use in operation, some of the blocks of the groups of blocks **34** may be designated as 'spare' blocks, such as the blocks **40-54**, shown in FIG. **7**.

[0025] Next, the defective blocks **36** and **38** are replaced with the replacement blocks **44** and **46**. That is, blocks **44** and **46** are no longer spare blocks and are rather blocks that will be used every time there is a need to store information into the blocks **36** and **38**, respectively.

[0026] In FIG. **6**, there are a total of two defective blocks and assuming there are no defective blocks in the device **24-26**, the total number of defective blocks is two, this value is represented by 'MD'. Thus, 'MD' is the number of manufacturer's defects for all of the nonvolatile memory devices, such as the devices **22-26** within the device **16**. 'SB_{fw}' is the total number of spare blocks, such as the blocks **40-54** of FIG. **7**, initially reserved by the controller device **20**, in FIG. **7**, this value is eight, as each of the blocks **40-54** are reserved as spare blocks. 'SB_{rem}' is the total number of spare blocks remaining at the time of the measurement of the health status of the nonvolatile memory or the devices **22-26**, in FIG. **8**, this value is six, as blocks **40**, **42**, and **48-54** are the remaining total number of spare blocks. Using these values, the following equation results:

$$HS=(SB_{rem}/(SB_{fw}-MD))*100 \quad \text{Equation (1)}$$

where HS is the health status in percentage of the nonvolatile memory of the devices **22-26**. HS is rounded up to the next integer as follows: int(HS+0.5) and reported as the health status of the nonvolatile memory within the devices **22-26** to the host **12** and to a user through, perhaps, the monitor **18** or other display means as will be discussed later.

[0027] In the example of FIGS. **6-8**, HS is equal to 100% because the equation is (6/(8−2))*100 or 6/6 *100. Thus, the health of the nonvolatile memory of the devices **22-26** is 100% or perfect even though two manufacturing defects are noted. The health status of the present invention takes into account the manufacturing defects and is only then concerned with growing defects.

[0028] The controller device **20** of FIG. **4** generally performs the HS measurement pursuant to Equation (1), however, other devices or apparatus may do the same. For example, the nonvolatile memory device **22** or the host **12** may perform such measurement.

[0029] Alternatively, health status can be measured as a ratio in accordance with the following equation:

$$HS=(SB_{rem}/(SB_{fw}-MD)) \quad \text{Equation (2)}$$

[0030] In Equation (2), HS is a value representing a ratio rather than a percentage of growing defects. Thus, whether HS is a percentage or a value representing a ratio, it nevertheless represents the number of growing defects on an ongoing basis, as will become more evident with examples to follow.

[0031] As the device **16** is used, defects grow and the HS of the device **16** will no longer remain 100%, as shown by the example of FIGS. **9-11**. In FIG. **9**, block **60** is noted as being defective and shown accordingly using the letter 'Y'. Thus,

the block **60** is replaced with a spare block, such as the block **42**, as shown in FIG. **10** by the indicator 'Ry'. FIG. **11** shows even further growth of defects of blocks **62-70**, denoted as Z_1-Z_5, respectively. Each of these blocks is replaced by the blocks **40** and **48-54**, respectively.

[0032] According to FIGS. **9** and **10**, SB_{rem} is five, SB_{fw}, is eight and MD is two, thus, HS is (5/(8−2))*100=83%.

[0033] However, the defects grow in FIG. **11** where SB_{rem} is zero, SB_{fw} is eight and MD is two, thus, HS is (0/(8−2)) *100=0% indicating that the information stored in the nonvolatile memory is reliable but should not be used any further. This would perhaps invoke the 'Warning!' message on the monitor **18** in FIG. **3**. In this manner, the HS represents a measure of the health of nonvolatile memory regardless of the number of manufacturing defects. Thus, different manufacturers of nonvolatile memory are on an equal playing field with respect to defect measurement, as only growing defects are accounted therefore with the value of HS.

[0034] In one embodiment of the present invention, HS is displayed to a user of the system **10**. FIGS. **12-14** show examples of such displays. The displays of FIGS. **12-14**, in one embodiment of the present invention, are nonvolatile, i.e. they show the status of the nonvolatile memory even when power is disconnected thereto. In another embodiment of the present invention, the displays of FIGS. **12-14** are Light Emitting Diodes (LEDs) that require power applied thereto to operate. In the latter embodiment, different colors of LEDs can be employed to signify different health status. For example, a single red LED illuminated would indicate poor nonvolatile memory health. In another example, when multiple LEDs are employed, no LEDs being illuminated would indicate good nonvolatile memory health (100%) and as health deteriorates, more LED's would be illuminated, until all LEDs indicate 0%. There may also be a single multicolored LED, or multiple LED's of different colors where green would indicate a "good" status with some defined range (eg 100%) and yellow would indicate some deterioration (eg 50% to 75%) and red would indicate poor (0%).

[0035] In FIG. **12**, the device **16** is shown to include a display **69** with HS being displayed in a bar fashion where the percentage of nonvolatile memory included within the device **16** that is healthy or in good condition for reading, writing and erasing is shown at **70** (the shaded area) and the rest of the display **69** shows the percentage of unhealthy memory locations within the nonvolatile memory of the device **16** at **72**. Thus, if HS is 75%, the area **70** would take up three quarters of the display **69**.

[0036] Similarly, FIGS. **13** and **14** show different ways of displaying the value of HS. In FIG. **13**, the more defective the nonvolatile memory, the more there will be rectangular shapes displayed and in FIG. **14**, the more defective the nonvolatile memory, the further the arrow will point towards 'Bad' similar to a fuel gauge.

[0037] Although the present invention has been described in terms of specific embodiments, it is anticipated that alterations and modifications thereof will no doubt become apparent to those skilled in the art. It is therefore intended that the following claims be interpreted as covering all such alterations and modification as fall within the true spirit and scope of the invention.

What is claimed is:

1. An apparatus, comprising:

a display configured to display a health status of a memory device;

wherein the health status is indicative of an amount of spare memory the memory device has available to replace memory of the memory device that may become defective.

2. The apparatus of claim **1**, wherein the display is a monitor.

3. The apparatus of claim **1**, wherein the memory device can store information when the health status is zero.

4. The apparatus of claim **1**, wherein the display is configured to display a warning when the amount of spare memory the memory device has available to replace memory of the memory device that may become defective is zero.

5. The apparatus of claim **1**, wherein the display is nonvolatile.

6. The apparatus of claim **1**, wherein the display comprises a plurality of different colored LEDs, where each color signifies a different value of the health status.

7. The apparatus of claim **1**, wherein the display comprises a plurality of LEDs, wherein a number of LEDs illuminated indicates a respective value of the health status.

8. The apparatus of claim **1**, wherein the display comprises a single, multi-colored LED, where each color indicates a different value of the health status.

9. The apparatus of claim **1**, wherein the health status is displayed in bar fashion.

10. The apparatus of claim **1**, wherein a value of the health status is displayed using rectangular shapes.

11. The apparatus of claim **1**, wherein the display comprises an indicator that points increasingly toward a particular value of the health status as the health status deteriorates.

12. The apparatus of claim **1**, wherein the health status is a measure of a health of the memory regardless of an amount of memory of the memory device that is defective at a time of manufacture of the memory device.

13. The apparatus of claim **1**, wherein the display is on the memory device.

14. The apparatus of claim **1**, wherein the display is a window on the memory device.

15. The apparatus of claim **1**, wherein the display is coupled to a host.

16. The apparatus of claim **15**, wherein the host measures the health status.

17. The apparatus of claim **1**, wherein the health status is a percentage.

18. The apparatus of claim **1**, wherein the health status is a ratio.

19. The apparatus of claim **1**, wherein a controller coupled to the memory device measures the health status.

20. The apparatus of claim **1**, wherein the memory device measures the health status.

21. The apparatus of claim **1**, wherein the memory device is a memory card.

22. An apparatus, comprising:

a display configured to display a health status of a memory device;

wherein the health status only accounts for a growing number of defects of a memory of the memory device.

23. An apparatus, comprising:

a display configured to display a health status of a memory device;

wherein the health status depends upon a number of memory blocks of the memory device that become defective after the memory device is manufactured.

* * * * *