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(54) ACCESS DEVICE AND MEMORY CONTROLLER

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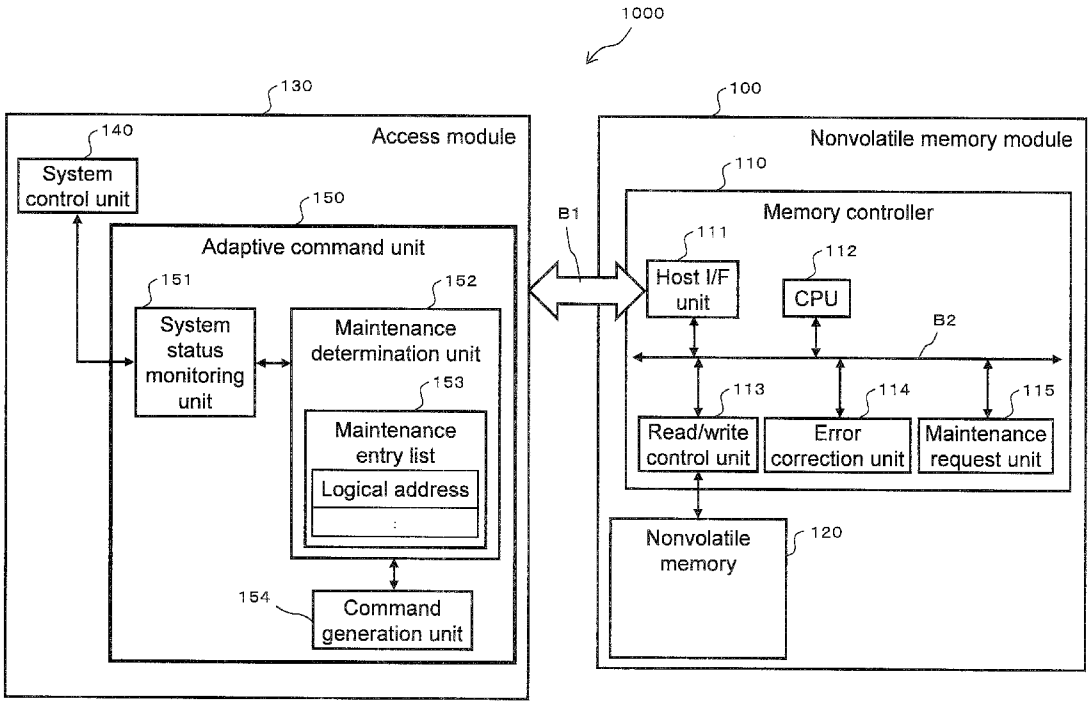
(57) **ABSTRACT**

Refresh to be performed together with normal processing may fail to be performed for a sufficiently long period of time due to the specification requirements. In this case, data loss can occur in an area that has not been refreshed for a sufficiently long period of time. An access module (**130**) receives the status of data stored in a nonvolatile memory (**120**) from a nonvolatile memory module (**100**), and determines whether the data needs maintenance based on the data status, and also determines whether the maintenance is enabled based on the system status of the access module (**130**). In this case, data maintenance is performed without being required to be performed together with normal system processing. This enables the maintenance to be performed with a sufficiently long processing time allocated to the maintenance, and improves the data retention properties.



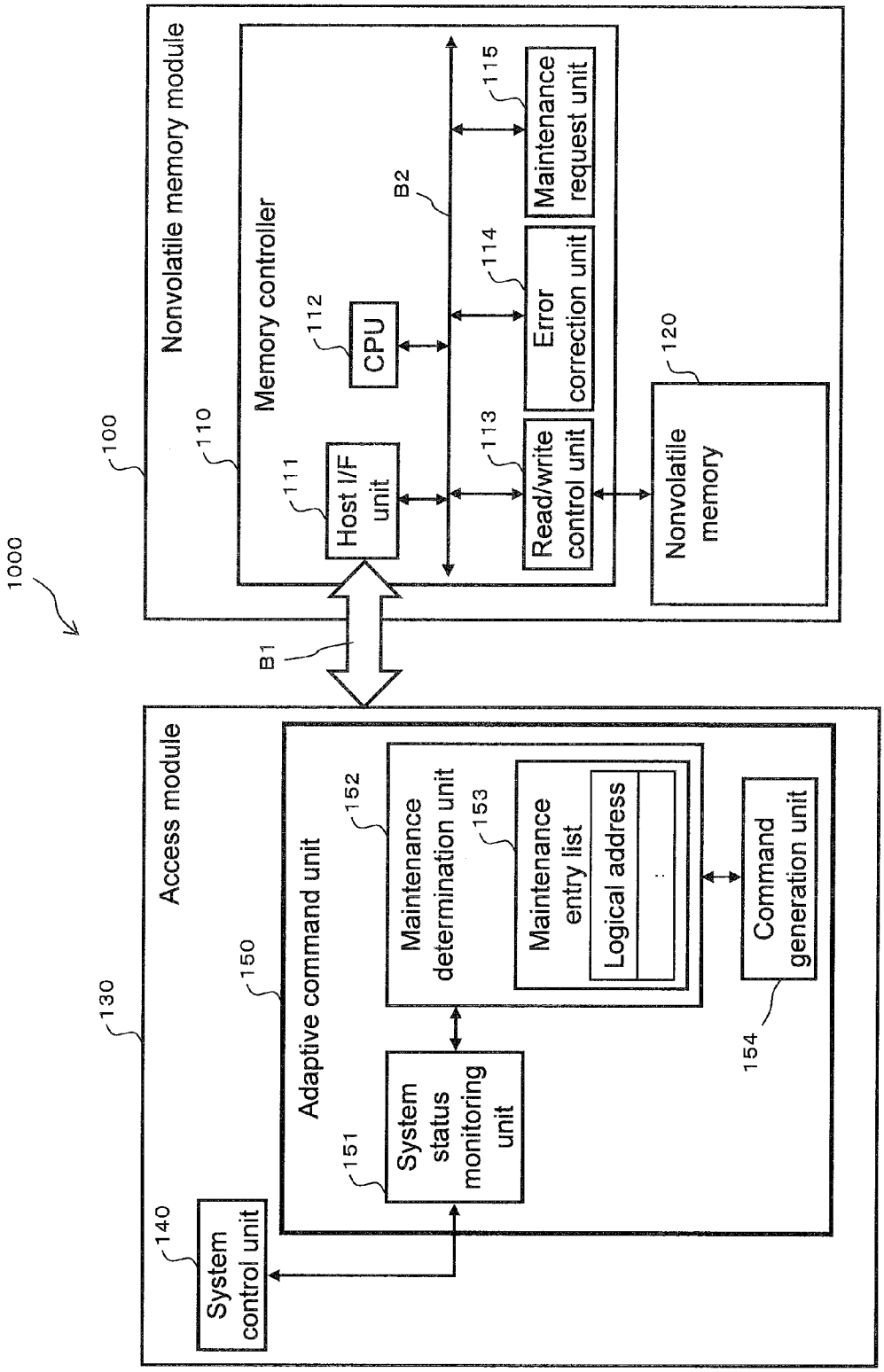

1000
100
Nonvolatile memory module
110
Memory controller
111
Host I/F unit
112
CPU
B2
113
Read/write control unit
114
Error correction unit
115
Maintenance request unit
120
Nonvolatile memory
B1
130
Access module
140
System control unit
150
Adaptive command unit
151
System status monitoring unit
152
Maintenance determination unit
153
Maintenance entry list
Logical address
154
Command generation unit

FIG. 1

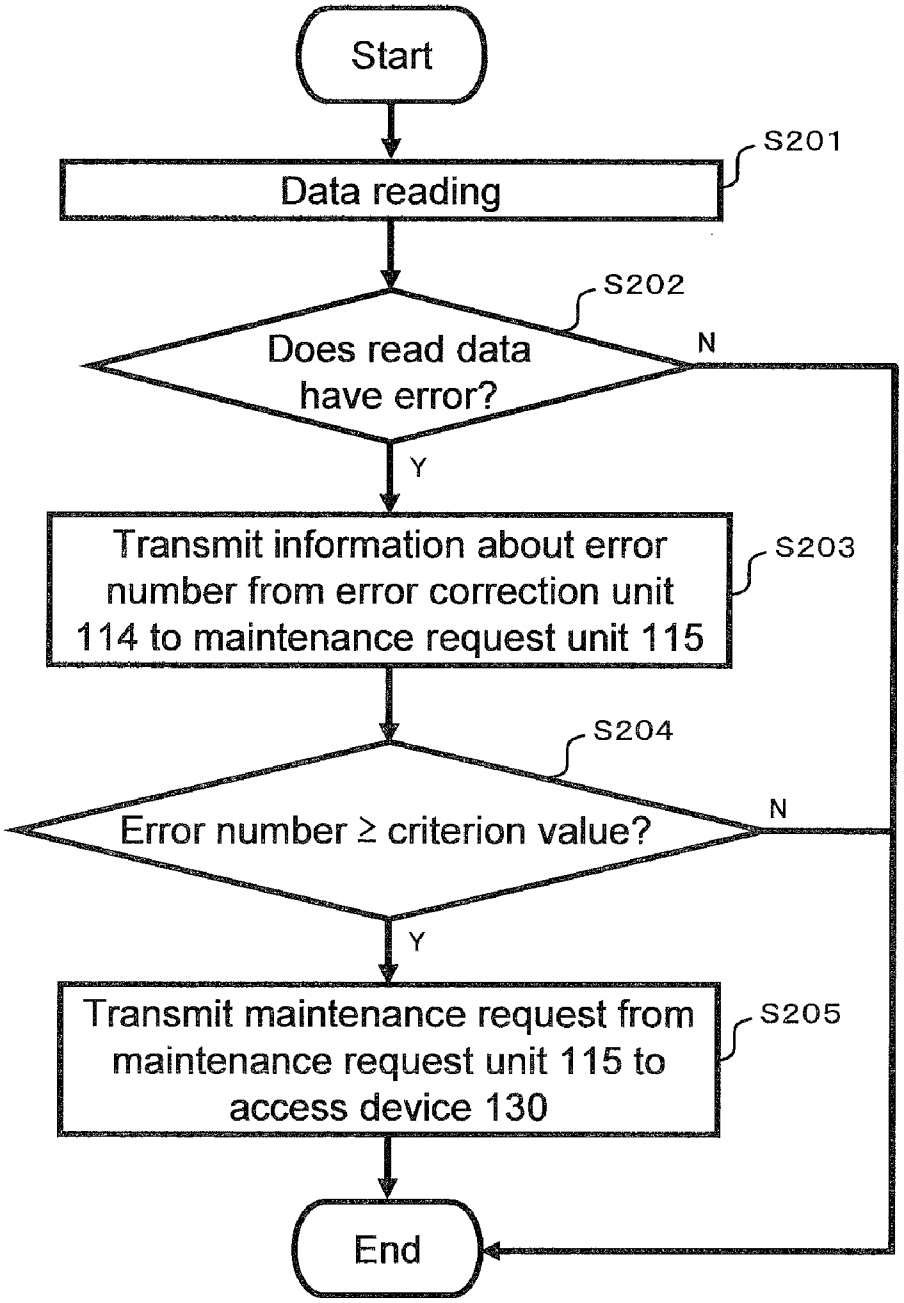

Start
S201
Data reading
S202
Does read data have error?
N
Y
Transmit information about error number from error correction unit 114 to maintenance request unit 115
S203
S204
Error number ≥ criterion value?
N
Y
Transmit maintenance request from maintenance request unit 115 to access device 130
S205
End

FIG. 2

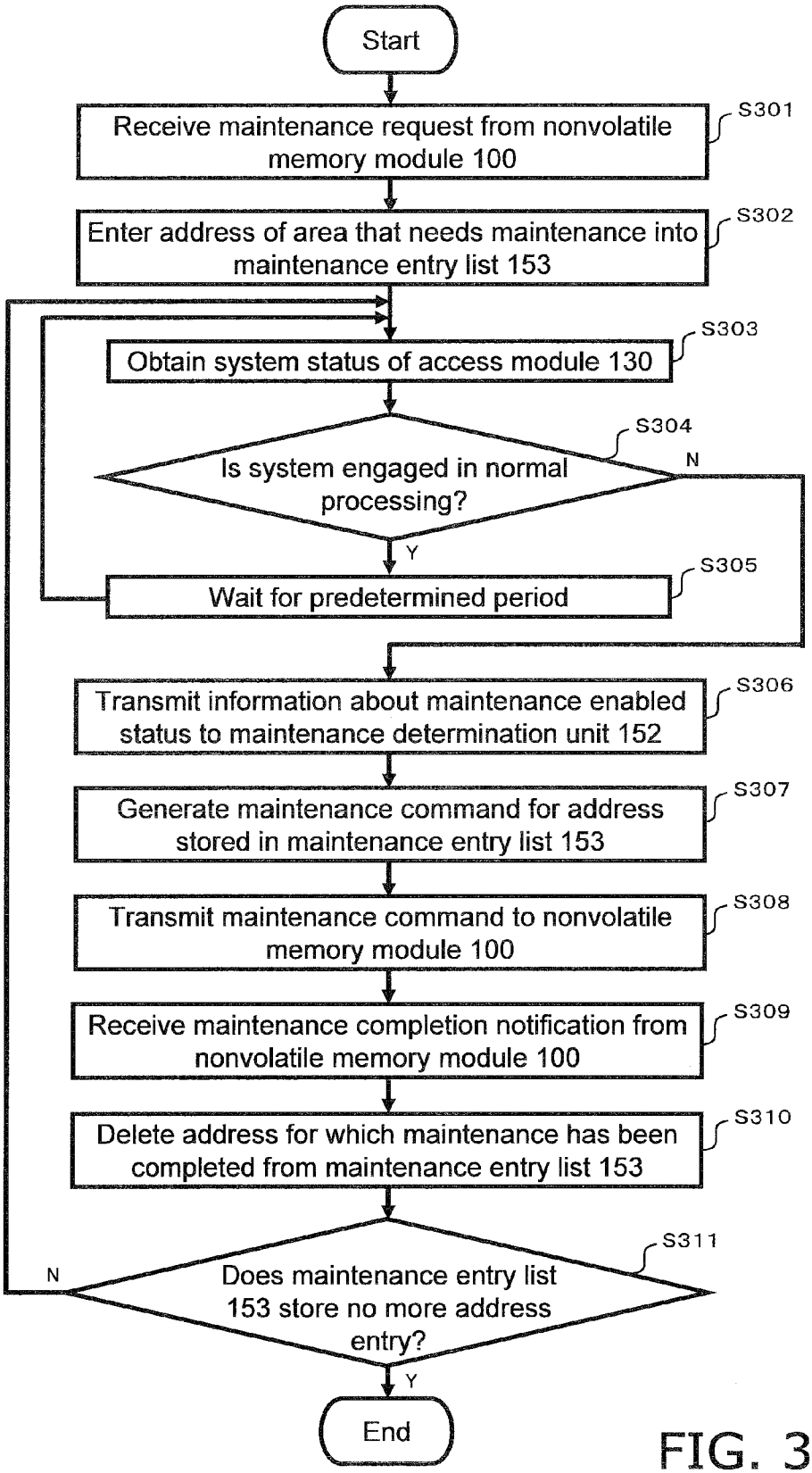

Start
Receive maintenance request from nonvolatile memory module 100
S301
Enter address of area that needs maintenance into maintenance entry list 153
S302
Obtain system status of access module 130
S303
Is system engaged in normal processing?
S304
N
Y
Wait for predetermined period
S305
Transmit information about maintenance enabled status to maintenance determination unit 152
S306
Generate maintenance command for address stored in maintenance entry list 153
S307
Transmit maintenance command to nonvolatile memory module 100
S308
Receive maintenance completion notification from nonvolatile memory module 100
S309
Delete address for which maintenance has been completed from maintenance entry list 153
S310
Does maintenance entry list 153 store no more address entry?
S311
N
Y
End

FIG. 3

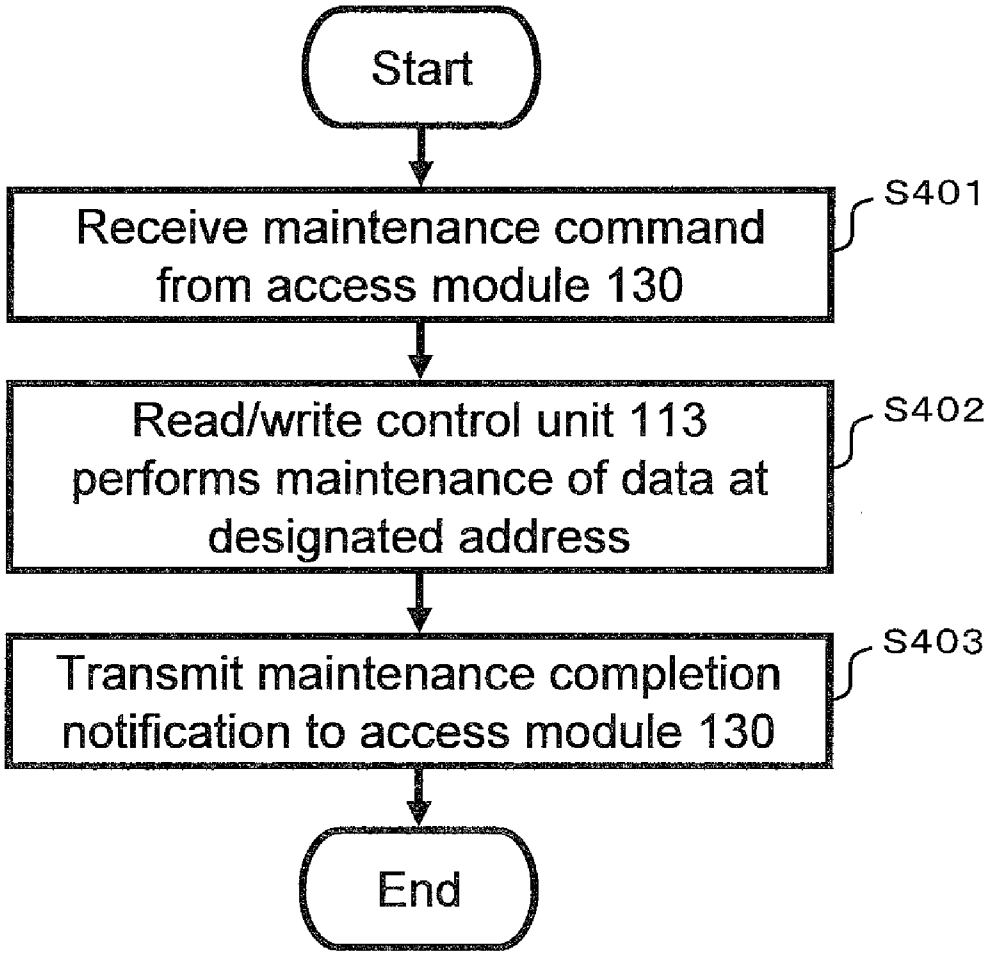

Start
Receive maintenance command from access module 130
S401
Read/write control unit 113 performs maintenance of data at designated address
S402
Transmit maintenance completion notification to access module 130
S403
End

FIG. 4

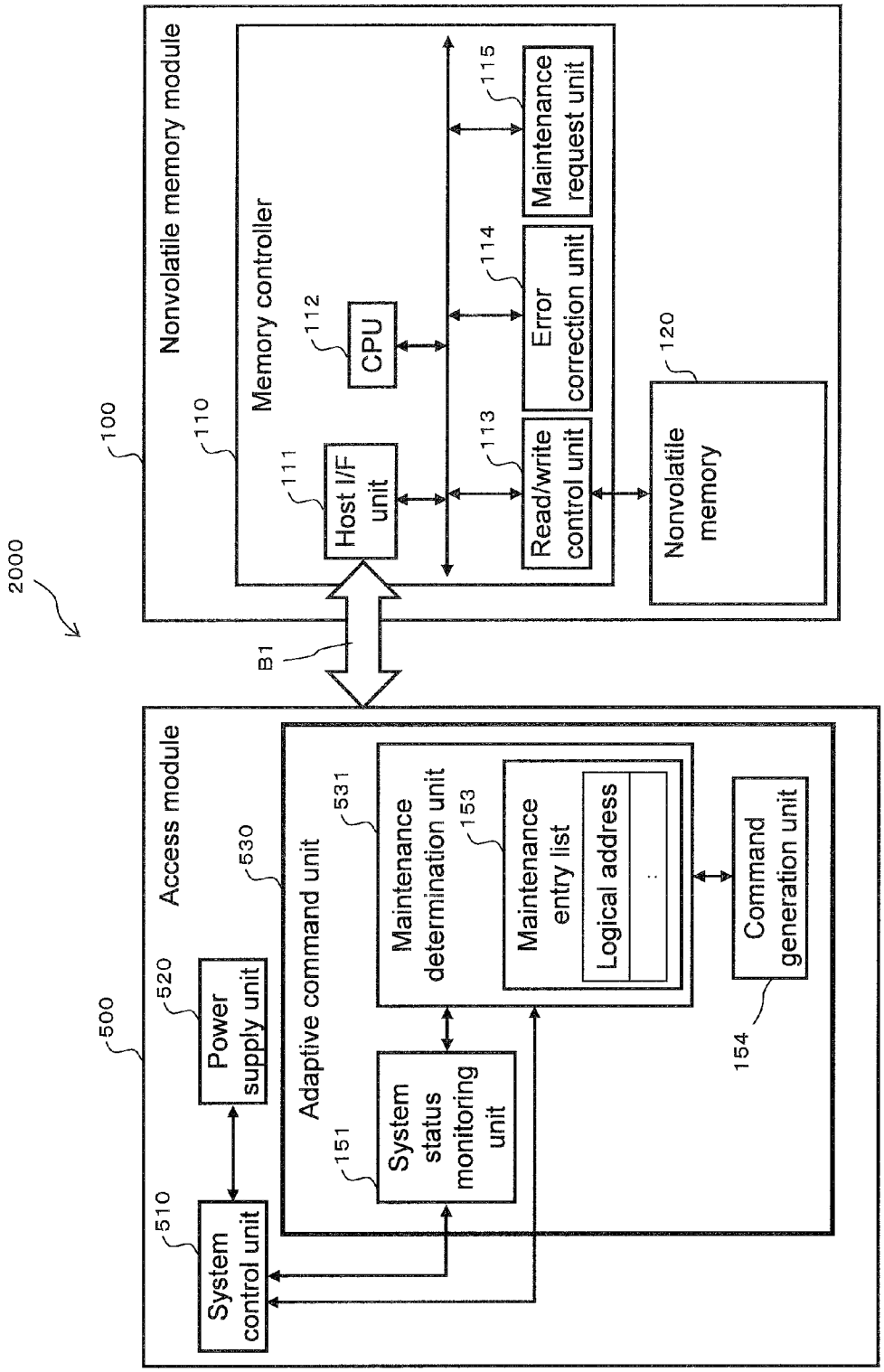

2000
100
Nonvolatile memory module
110
Memory controller
111
Host I/F unit
112
CPU
113
Read/write control unit
114
Error correction unit
115
Maintenance request unit
120
Nonvolatile memory
B1
500
Access module
510
System control unit
520
Power supply unit
530
Adaptive command unit
531
Maintenance determination unit
153
Maintenance entry list
Logical address
151
System status monitoring unit
154
Command generation unit

FIG. 5

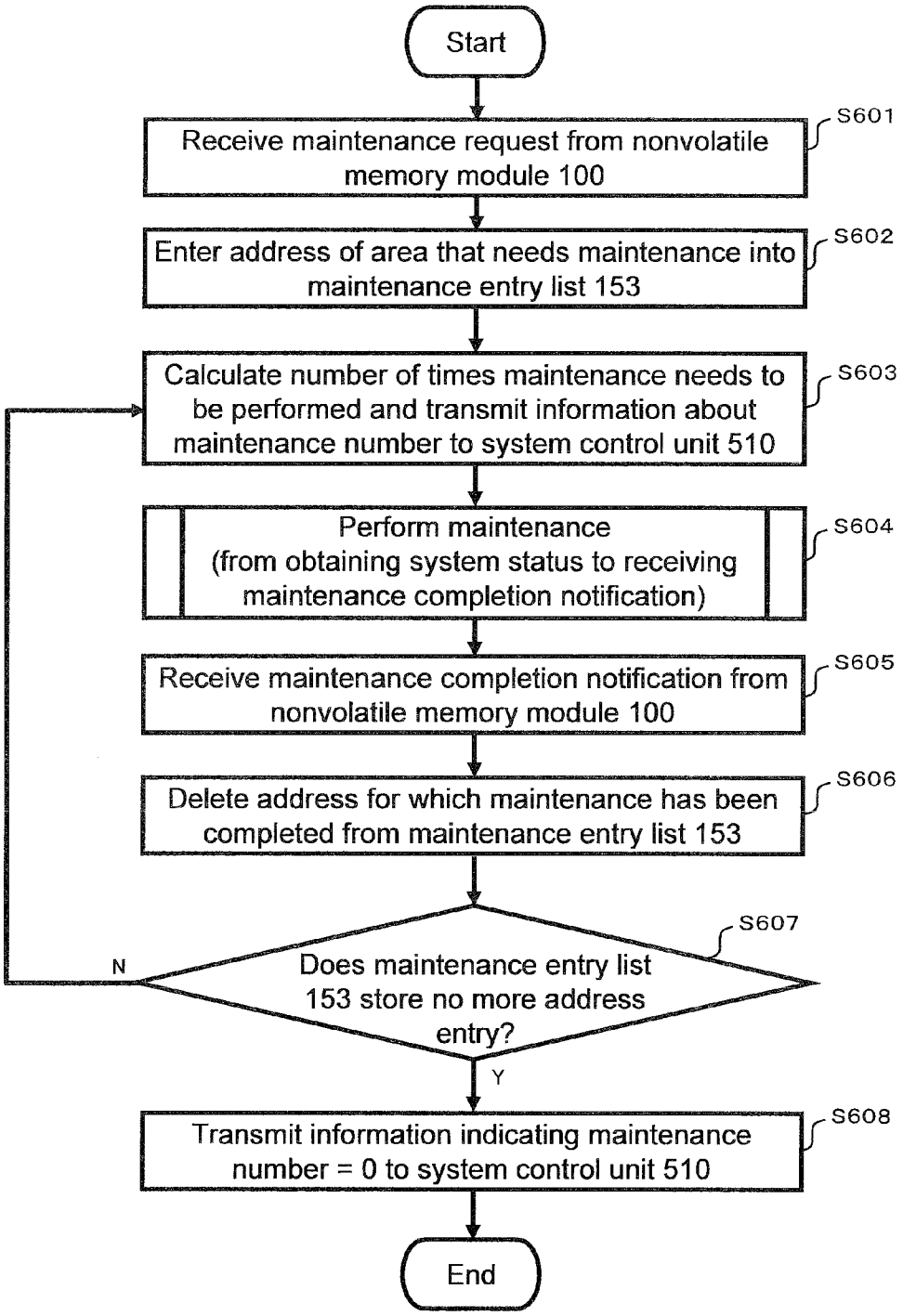

Start
Receive maintenance request from nonvolatile memory module 100
S601
Enter address of area that needs maintenance into maintenance entry list 153
S602
Calculate number of times maintenance needs to be performed and transmit information about maintenance number to system control unit 510
S603
Perform maintenance (from obtaining system status to receiving maintenance completion notification)
S604
Receive maintenance completion notification from nonvolatile memory module 100
S605
Delete address for which maintenance has been completed from maintenance entry list 153
S606
Does maintenance entry list 153 store no more address entry?
S607
N
Y
Transmit information indicating maintenance number = 0 to system control unit 510
S608
End

FIG. 6

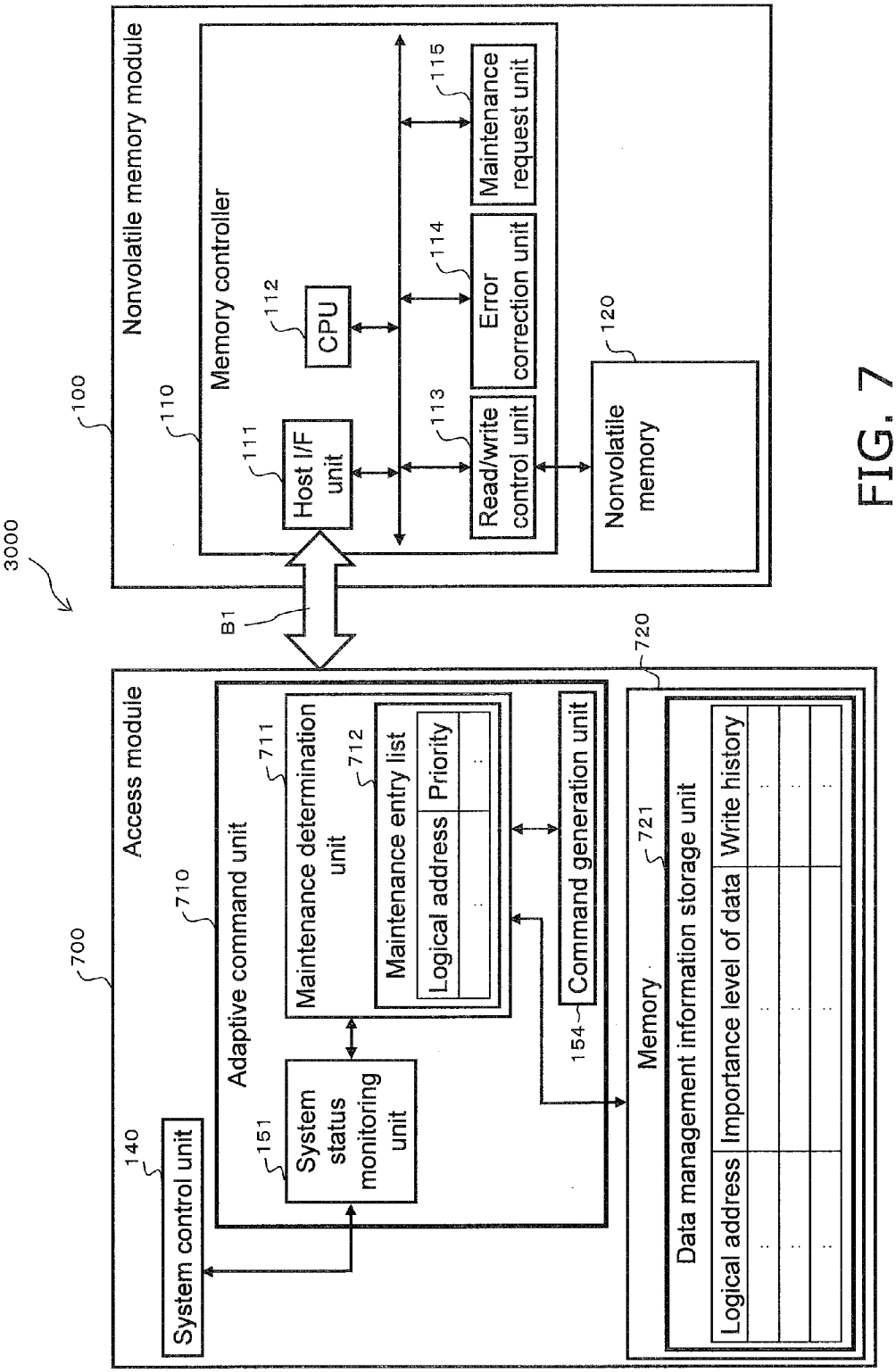

3000
100
Nonvolatile memory module
110
Memory controller
111
Host I/F unit
112
CPU
113
Read/write control unit
114
Error correction unit
115
Maintenance request unit
120
Nonvolatile memory
B1
700
Access module
710
Adaptive command unit
711
Maintenance determination unit
712
Maintenance entry list
Logical address
Priority
151
System status monitoring unit
154
Command generation unit
140
System control unit
720
Memory
721
Data management information storage unit
Logical address
Importance level of data
Write history

FIG. 7

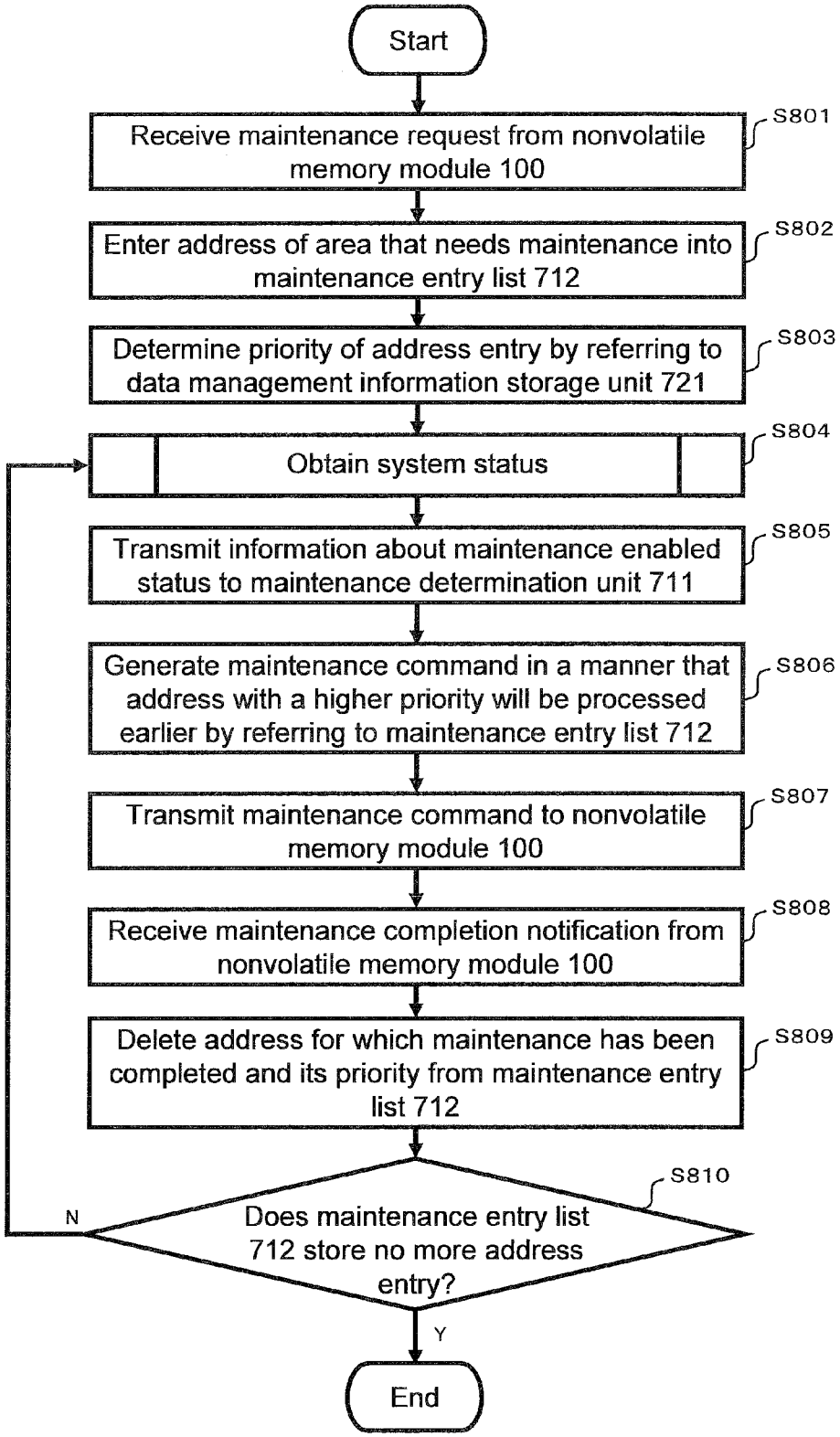

Start
Receive maintenance request from nonvolatile memory module 100
S801
Enter address of area that needs maintenance into maintenance entry list 712
S802
Determine priority of address entry by referring to data management information storage unit 721
S803
Obtain system status
S804
Transmit information about maintenance enabled status to maintenance determination unit 711
S805
Generate maintenance command in a manner that address with a higher priority will be processed earlier by referring to maintenance entry list 712
S806
Transmit maintenance command to nonvolatile memory module 100
S807
Receive maintenance completion notification from nonvolatile memory module 100
S808
Delete address for which maintenance has been completed and its priority from maintenance entry list 712
S809
Does maintenance entry list 712 store no more address entry?
S810
N
Y
End

FIG. 8

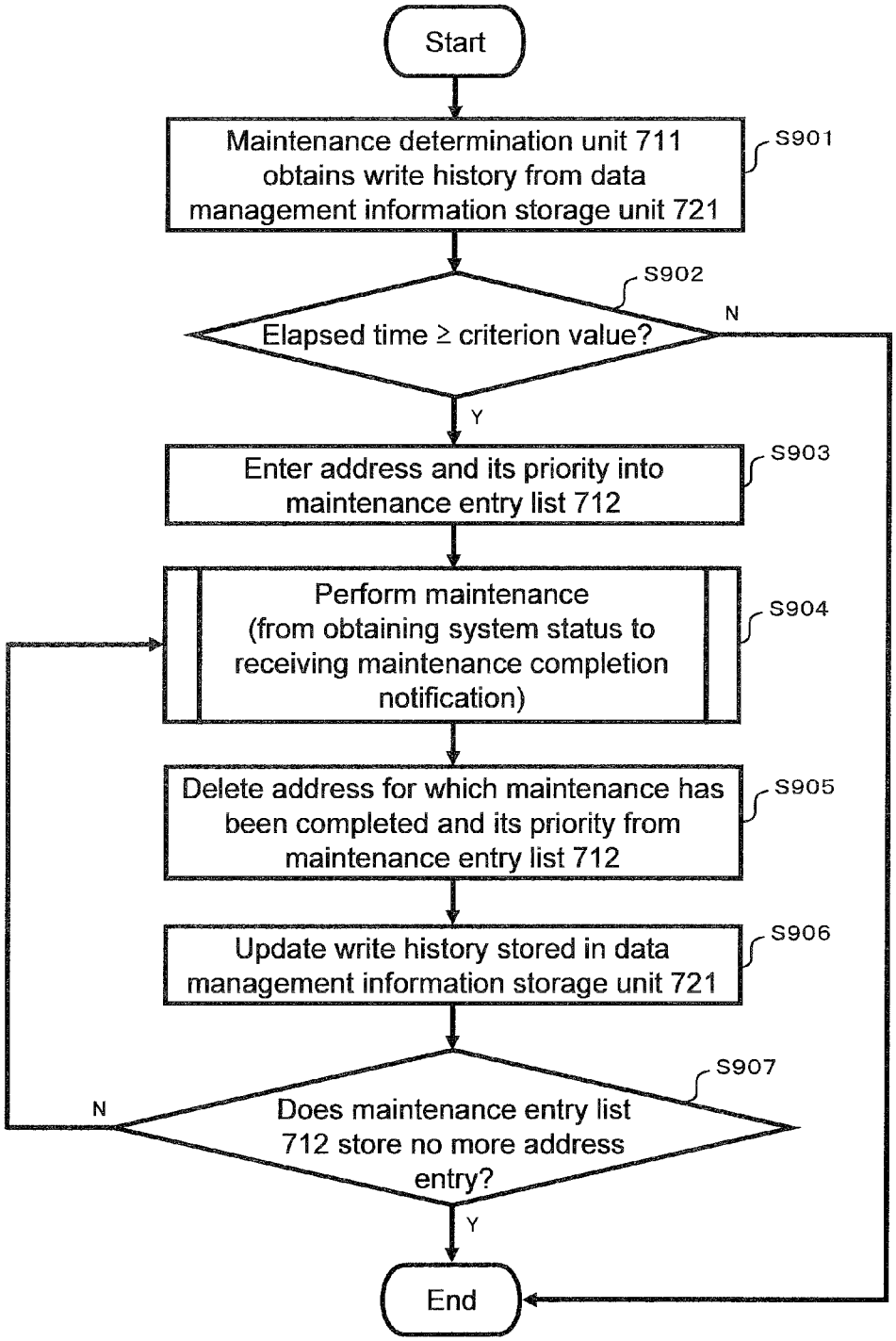

Start
Maintenance determination unit 711 obtains write history from data management information storage unit 721
S901
S902
Elapsed time ≥ criterion value?
N
Y
Enter address and its priority into maintenance entry list 712
S903
Perform maintenance (from obtaining system status to receiving maintenance completion notification)
S904
Delete address for which maintenance has been completed and its priority from maintenance entry list 712
S905
Update write history stored in data management information storage unit 721
S906
S907
Does maintenance entry list 712 store no more address entry?
N
Y
End

FIG. 9

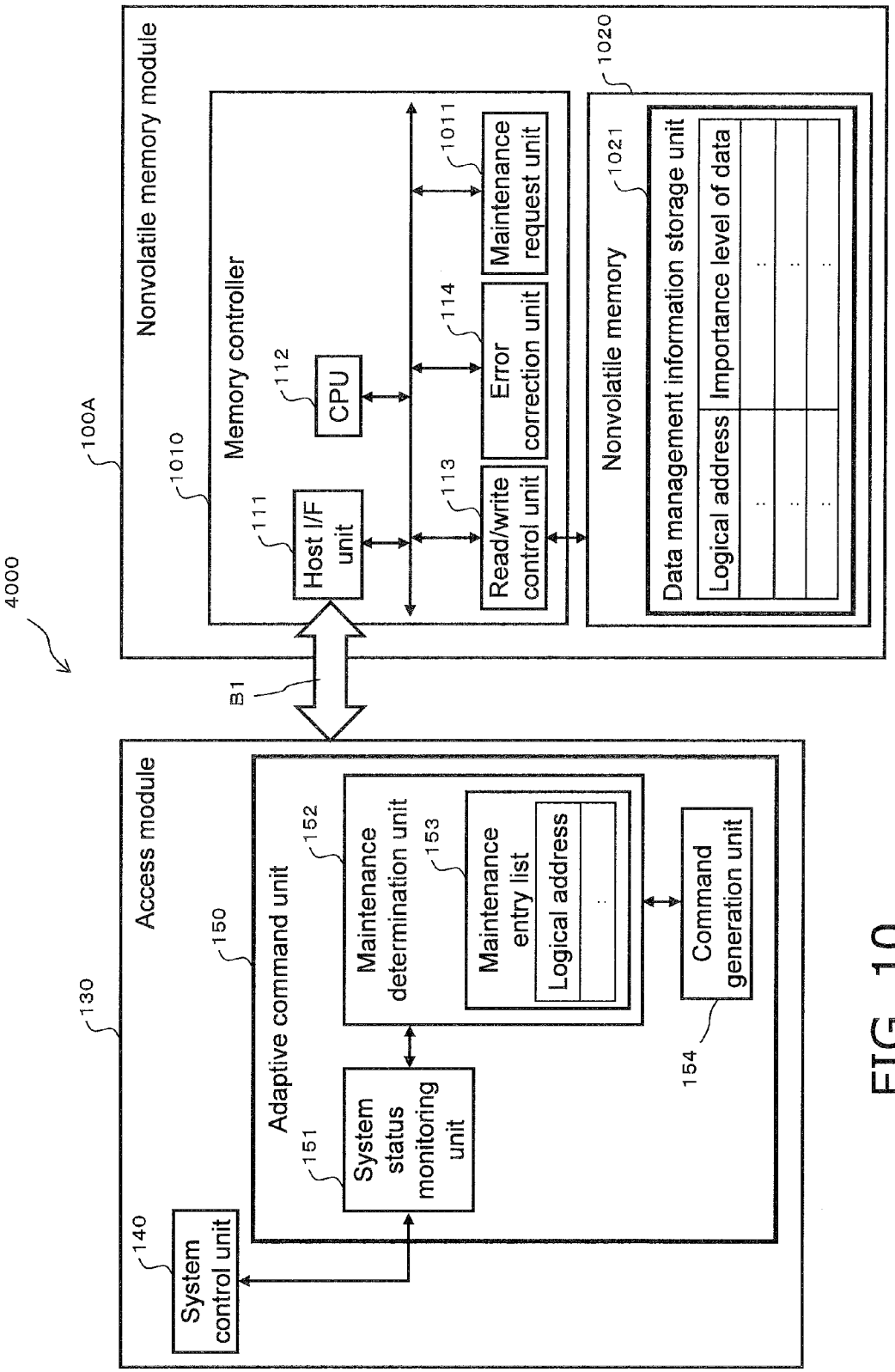

4000
100A
Nonvolatile memory module
1010
Memory controller
111
Host I/F unit
112
CPU
113
Read/write control unit
114
Error correction unit
1011
Maintenance request unit
1020
Nonvolatile memory
1021
Data management information storage unit
Logical address
Importance level of data
B1
130
Access module
140
System control unit
150
Adaptive command unit
151
System status monitoring unit
152
Maintenance determination unit
153
Maintenance entry list
Logical address
154
Command generation unit

FIG. 10

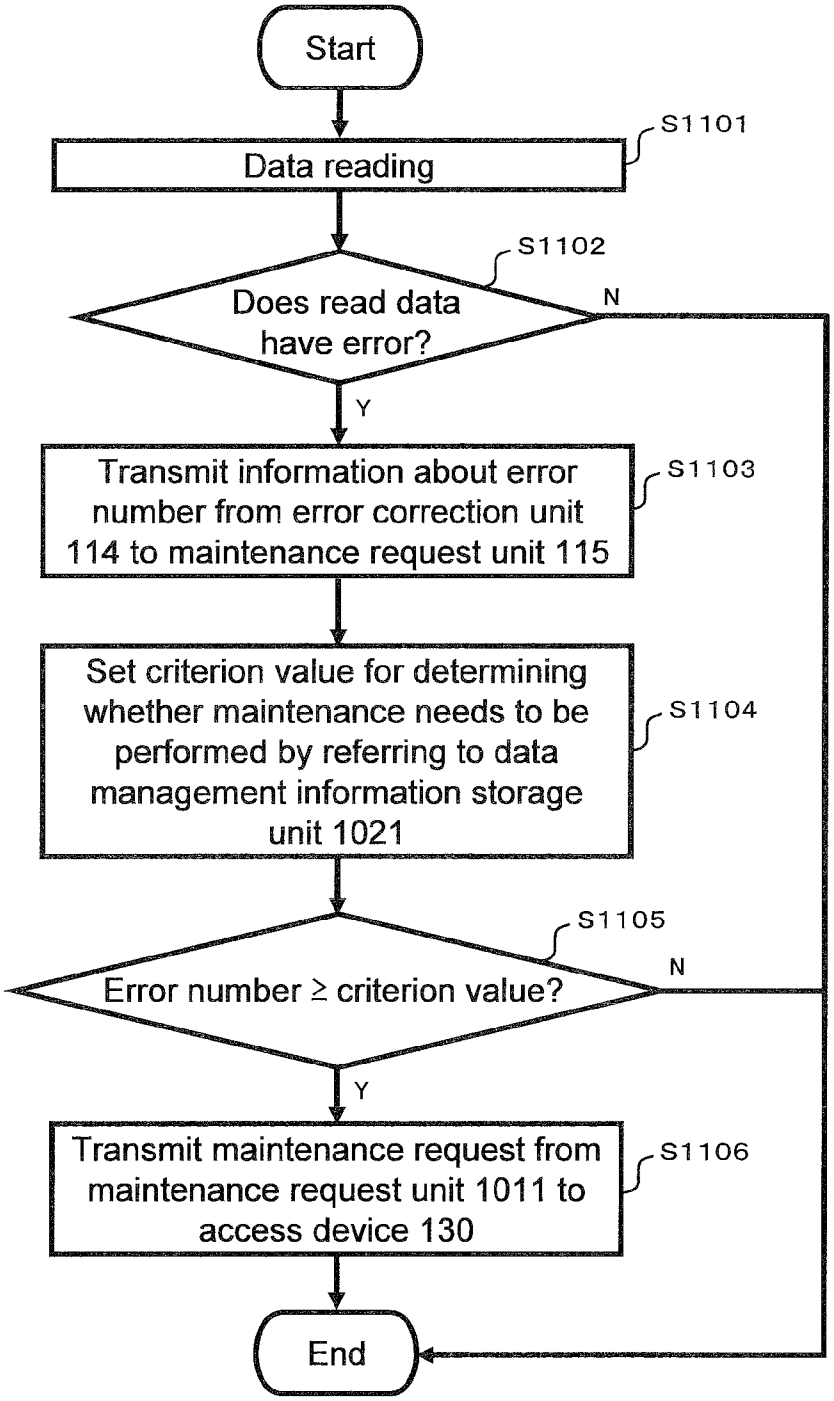

Start
Data reading
S1101
Does read data have error?
S1102
N
Y
Transmit information about error number from error correction unit 114 to maintenance request unit 115
S1103
Set criterion value for determining whether maintenance needs to be performed by referring to data management information storage unit 1021
S1104
Error number ≥ criterion value?
S1105
N
Y
Transmit maintenance request from maintenance request unit 1011 to access device 130
S1106
End

FIG. 11

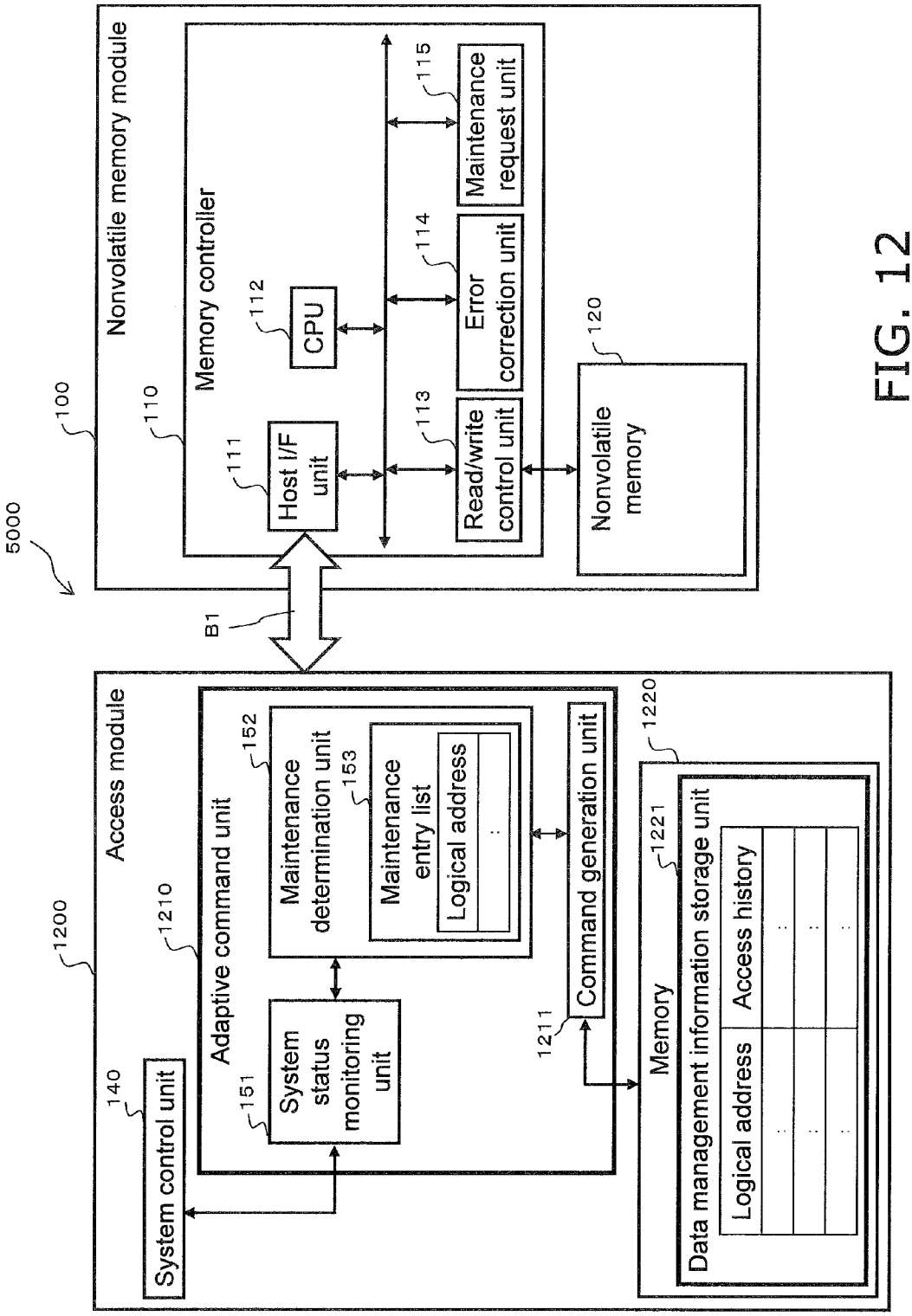

5000
100
Nonvolatile memory module
110
Memory controller
111
Host I/F unit
112
CPU
113
Read/write control unit
114
Error correction unit
115
Maintenance request unit
120
Nonvolatile memory
B1
1200
Access module
1210
Adaptive command unit
151
System status monitoring unit
152
Maintenance determination unit
153
Maintenance entry list
Logical address
140
System control unit
1211
Command generation unit
1220
Memory
1221
Data management information storage unit
Logical address
Access history

FIG. 12

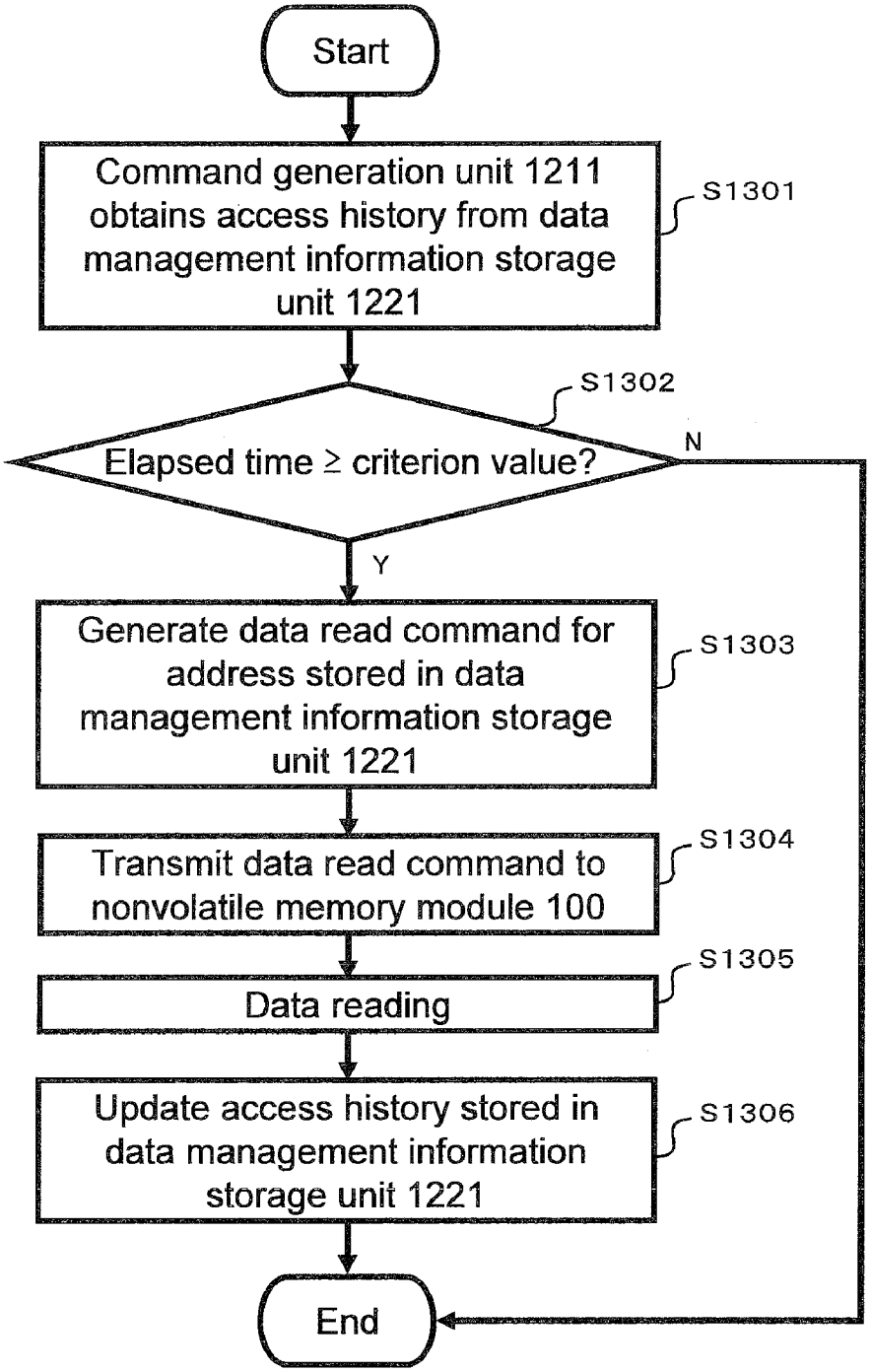

Start
Command generation unit 1211 obtains access history from data management information storage unit 1221
S1301
S1302
Elapsed time ≥ criterion value?
N
Y
Generate data read command for address stored in data management information storage unit 1221
S1303
Transmit data read command to nonvolatile memory module 100
S1304
Data reading
S1305
Update access history stored in data management information storage unit 1221
S1306
End

FIG. 13

ACCESS DEVICE AND MEMORY CONTROLLER

TECHNICAL FIELD

[0001] The present invention relates to an access device that rewrites data to a nonvolatile memory device, a memory controller that controls a nonvolatile memory, a nonvolatile memory device including the nonvolatile memory and the memory controller, and a nonvolatile memory system including the access device and the nonvolatile memory device.

BACKGROUND ART

[0002] Nonvolatile memory devices (nonvolatile memory modules) that include a rewritable nonvolatile memory have attracted widespread popularity and are used mainly in semiconductor memory cards. Although the nonvolatile memory modules are more expensive than optical discs and tape media, they are compact, lightweight, and earthquake-resistant, and can be handled easily. These advantages have increased the popularity of the nonvolatile memory modules as recording media for portable devices, such as digital still cameras and mobile telephones. While expanding the range of applications, the nonvolatile memory modules are now used not only in the above consumer devices but also in professional moving image recorders used at broadcasting stations.

[0003] Such a nonvolatile memory module includes a flash memory as a nonvolatile main memory and a memory controller for controlling the flash memory. The memory controller controls reading from and writing to the flash memory in accordance with a read command and a write command transmitted from an access device (access module), such as a digital still camera or a mobile telephone.

[0004] The flash memory requires a relatively long time to write or erase data in its memory cell array, which is a recording unit defined for the flash memory. To shorten the time required for data writing or data erasure, the flash memory is formed in a manner that data stored in a plurality of memory cells can be erased at a time or data can be written into a plurality of memory cells at a time. More specifically, the flash memory consists of a plurality of physical blocks (units for erasure), each of which includes a plurality of pages (units for writing). Data is erased from the flash memory in units of physical blocks, whereas data is written to the flash memory in units of pages.

[0005] To satisfy the recent demand for larger capacity and lower cost, flash memories that can store 2-bit or more information in a single memory cell, which can be multivalued NAND flash memories, have recently become major flash memories. However, the data retention properties of such multivalued NAND flash memories are poorer than the data retention properties of conventional binary NAND flash memories. As the flash memories tend toward even larger capacities, the flash memories will be more strongly required to achieve the data integrity of their memory cells.

[0006] To enhance the data integrity of nonvolatile memories, nonvolatile memory modules may conventionally use error correcting codes (ECCs) to detect and correct erroneous data. However, while data read from a nonvolatile memory can be corrected using an ECC, data that has not been read and has been stored in a memory cell for a long period of time can accumulate errors. Such data can accumulate so many errors that cannot be corrected using an ECC. Also, only a specific memory cell in a memory cell array can be read frequently. In this case, the threshold voltage for other memory cells of the same array can change, and the read disturb can occur in the memory cell array.

[0007] To overcome these problems, the nonvolatile memory needs processing to retain data, or maintenance, which can be, for example, data refreshing (data rewriting) performed regularly. With a technique described in Patent Literature 1, the number of errors occurring in data is determined when the data is read from a nonvolatile memory. When the number of errors exceeds a criterion value, the data stored in the nonvolatile memory is to be refreshed. The refresh is then performed together with the processing performed when the nonvolatile memory module is powered on or when the memory nonvolatile module is initialized. In this manner, the conventional technique maintains the integrity of data recorded on the nonvolatile memory to or above a sufficiently high level, while also preventing the data reading speed and the data writing speed from being lowered by such refresh processing.

CITATION LIST

Patent Literature

[0008] Patent Literature 1: Japanese Unexamined Patent Publication No. 2008-90778

SUMMARY

Technical Problem

[0009] With the technique described in Patent Literature 1, the refresh is performed together with the normal processing performed when, for example, the module is powered on or initialized. When a large amount of data needs to be refreshed in the memory area of the nonvolatile memory, the processing time for the refresh may be long. The long refreshing time can disable the specification requirements to be satisfied. If the refresh time is shortened to satisfy the specification requirements, the refresh may be insufficient. Data loss can occur in an area that has not been refreshed for a sufficiently long period of time. Also, the poorer data retention properties of multivalued flash memories may further increase the risk of such data loss.

[0010] Moreover, the data maintenance, such as the refresh, requires a certain amount of power consumption. Portable devices in particular are preferably required to consider the level of their batteries when maintenance is performed. However, the conventional technique fails to consider the device conditions including the battery level when maintenance is performed.

[0011] To solve the above problem, it is an object of the present invention to provide an access device, a nonvolatile memory device, a memory controller used in a nonvolatile memory device, and a nonvolatile memory system that improve their data retention properties and expand the range of their applications to various devices including portable devices.

Solution to Problem

[0012] A first aspect of the present invention provides an access device that accesses a nonvolatile memory device including a nonvolatile memory. The access device includes an adaptive command unit.

[0013] The adaptive command unit determines whether data stored in the nonvolatile memory needs maintenance based on a data retention status of the nonvolatile memory obtained from the nonvolatile memory device, and determines whether maintenance is to be performed based on whether the access device is in a system status in which maintenance is enabled and based on whether the data stored in the nonvolatile memory needs maintenance, and generates a maintenance command to the nonvolatile memory device when determining that the maintenance is to be performed.

[0014] In this access device, the adaptive command unit determines whether maintenance is enabled based on the system status of the access device, and generates a maintenance command to the nonvolatile memory device when determining that the maintenance is to be performed. This enables data maintenance to be performed in accordance with the system status of a nonvolatile memory system including, for example, the access device and the nonvolatile memory system, without requiring the maintenance to be performed together with normal processing of the system.

[0015] This enables the maintenance to be performed with a sufficiently long processing time allocated to the maintenance, and improves the data retention properties of the nonvolatile memory device.

[0016] A second aspect of the present invention provides the access device of the first aspect of the present invention in which the adaptive command unit includes a system status monitoring unit, a maintenance determination unit, and a command generation unit.

[0017] The system status monitoring unit monitors the system status of the access device. The maintenance determination unit determines whether the maintenance is to be performed based on a monitoring result obtained by the system status monitoring unit and based on whether the data stored in the nonvolatile memory needs maintenance. The command generation unit generates a maintenance command to the nonvolatile memory device in accordance with a determination result obtained by the maintenance determination unit.

[0018] A third aspect of the present invention provides the access device of the second aspect of the present invention in which the system status monitoring unit monitors a processing status of the access device, and provides information indicating that maintenance is enabled when determining that the access device is not engaged in normal processing. The maintenance determination unit determines that the maintenance is to be performed when determining that the data stored in the nonvolatile memory needs maintenance and further receiving from the system status monitoring unit the information indicating that maintenance is enabled. The command generation unit generates a maintenance command to the nonvolatile memory device when the maintenance determination unit determines that the maintenance is to be performed.

[0019] In this access device, the adaptive command unit determines whether maintenance is enabled based on the system status of the access device, and generates a maintenance command to the nonvolatile memory device when determining that the maintenance needs to be performed. This enables data maintenance to be performed in accordance with the system status of a nonvolatile memory system including, for example, the access device and the nonvolatile memory system, without requiring the maintenance to be performed together with normal processing of the system.

[0020] This enables the maintenance to be performed with a sufficiently long processing time allocated to the maintenance, and improves the data retention properties of the nonvolatile memory device.

[0021] The normal processing refers to the processing that involves at least a predetermined amount of communication performed between the access device and the nonvolatile memory device, and specifically includes initialization of the nonvolatile memory device, data reading, and data writing. The access device performs maintenance of the nonvolatile memory device while the access device is not engaged in normal processing. This enables the maintenance to be performed without lowering the processing performance of the nonvolatile memory system including the access device and the nonvolatile memory device.

[0022] A fourth aspect of the present invention provides the access device of the first aspect of the present invention in which the maintenance determination unit stores at least one address of the nonvolatile memory that needs maintenance, and selects an address for which the maintenance is to be performed from the at least one address when receiving from the system status monitoring unit information indicating that maintenance is enabled. The command generation unit generates a maintenance command for performing maintenance for the address of the nonvolatile memory device selected by the maintenance determination unit.

[0023] A fifth aspect of the present invention provides the access device of the first aspect of the present invention further including a system control unit that executes system control of the access device. The maintenance determination unit stores at least one address of the nonvolatile memory that needs maintenance, and provides information about the at least one address of the nonvolatile memory to the system control unit.

[0024] A sixth aspect of the present invention provides the access device of the fifth aspect of the present invention further including a power supply unit that supplies power to the access device. The system control unit determines a minimum battery level to be reserved by the power supply unit based on the information about the at least one address of the nonvolatile memory, and controls the power supply unit and the access device in a manner to reserve the determined minimum battery level.

[0025] This access device determines whether maintenance is enabled while monitoring the system management status including the battery level. This reduces the risk of, for example, the battery level reaching zero and forcing the system to shut down during the maintenance processing.

[0026] A seventh aspect of the present invention provides the access device of the fourth aspect of the present invention further including a data management information storage unit storing data management information for managing data stored in the nonvolatile memory. The maintenance determination unit changes an order in which maintenance is to be performed for the at least one address in accordance with a status of data stored in the nonvolatile memory by referring to the information stored in the data management information storage unit.

[0027] This access device changes the processing order of the maintenance in accordance with the data status of the nonvolatile memory. This enables maintenance to be performed for memory areas of the nonvolatile memory sequen-

tially in the order of the need for such maintenance. As a result, the access device improves the data retention properties.

[0028] An eighth aspect of the present invention provides the access device of the fourth aspect of the present invention further including a data management information storage unit storing data management information for managing data stored in the nonvolatile memory. The maintenance determination unit voluntarily determines and stores an address for which maintenance needs to be performed in accordance with a status of data stored in the nonvolatile memory by referring to the information stored in the data management information storage unit without receiving information about the status of data stored in the nonvolatile memory from the nonvolatile memory device.

[0029] This access device voluntarily determines and stores an address for which maintenance needs to be performed in accordance with the data status of the nonvolatile memory that the access device manages without receiving information about the data status of the nonvolatile memory from the nonvolatile memory device. In this case, the access device can control the maintenance to be performed. For example, the access device can solely determine an address for which maintenance is to be performed among predetermined addresses of the nonvolatile memory by managing the write history of the predetermined addresses of the nonvolatile memory. This improves the data retention properties of the nonvolatile memory.

[0030] A ninth aspect of the present invention provides the access device of one of the first to eighth aspects of the present invention in which the maintenance includes refresh and/or wear leveling of the nonvolatile memory.

[0031] A tenth aspect of the present invention provides a memory controller used in a nonvolatile memory device that reads and/or writes data in accordance with a command provided from an access device for reading data from and writing data to a nonvolatile memory included in the nonvolatile memory device. The memory controller includes an error correction unit and a maintenance request unit.

[0032] The error correction unit determines the number of errors included in data read from the nonvolatile memory, and corrects an error included in the read data. The maintenance request unit generates a maintenance request indicating that the nonvolatile memory needs maintenance to the access device when the number of errors determined by the error correction unit is greater than or equal to a criterion value.

[0033] The maintenance request unit dynamically changes the criterion value used to determine whether to generate a maintenance request in accordance with a status of data stored in the nonvolatile memory. The maintenance includes refresh and/or wear leveling of the nonvolatile memory.

[0034] An eleventh aspect of the present invention provides a nonvolatile memory device for reading and/or writing data in accordance with a command provided from an access device. The nonvolatile memory device includes a nonvolatile memory storing data, and the memory controller of the tenth aspect of the present invention.

[0035] A twelfth aspect of the present invention provides a nonvolatile memory system including a nonvolatile memory device having a nonvolatile memory and a memory controller for reading data from and writing data to the nonvolatile memory and an access device that communicates with the nonvolatile memory device having the nonvolatile memory. The nonvolatile memory system includes the nonvolatile memory device of the eleventh aspect of the present invention, and the access device of one of the first to ninth aspects of the present invention.

Advantageous Effects

[0036] The present invention enables an access device to receive the status of a nonvolatile memory from a nonvolatile memory device and enables data maintenance to be performed in accordance with the status of the nonvolatile memory system, without requiring the data maintenance to be performed together with normal processing of the system. The invention thus enables the maintenance to be performed with a sufficiently long processing time allocated to the maintenance, and improves the data retention properties. The invention also enables the system management status, such as the battery level, to be controlled in a manner that the maintenance will be completed in a reliable manner.

[0037] The invention thus enables data maintenance in, for example, portable devices to be performed in a reliable manner.

BRIEF DESCRIPTION OF DRAWINGS

[0038] FIG. **1** is a schematic diagram showing the structure of a nonvolatile memory system **1000** according to a first embodiment of the present invention.

[0039] FIG. **2** is a flowchart showing data maintenance request generation performed by a nonvolatile memory module **100**.

[0040] FIG. **3** is a flowchart showing data maintenance command generation performed by an adaptive command unit **150**.

[0041] FIG. **4** is a flowchart showing data maintenance performed by the nonvolatile memory module **100**.

[0042] FIG. **5** is a schematic diagram showing the structure of a nonvolatile memory system **2000** according to a second embodiment of the present invention.

[0043] FIG. **6** is a flowchart showing system control notification and data maintenance command generation performed by an adaptive command unit **530**.

[0044] FIG. **7** is a schematic diagram showing the structure of a nonvolatile memory system **3000** according to a third embodiment of the present invention.

[0045] FIG. **8** is a flowchart showing address prioritizing and data maintenance command generation performed by an adaptive command unit **710**.

[0046] FIG. **9** is a flowchart showing voluntary data maintenance command generation performed by an adaptive command unit **710**.

[0047] FIG. **10** is a schematic diagram showing the structure of a nonvolatile memory system **4000** according to a fourth embodiment of the present invention.

[0048] FIG. **11** is a flowchart showing maintenance need determination and maintenance request generation performed by a nonvolatile memory module **100**A.

[0049] FIG. **12** is a schematic diagram showing the structure of a nonvolatile memory system **5000** according to a fifth embodiment of the present invention.

[0050] FIG. **13** is a flowchart showing data read command generation performed by a command generation unit **1211**.

REFERENCE SIGNS LIST

[0051] **1000**, **2000**, **3000**, **4000**, **5000** nonvolatile memory system

[0052] **100**, **100**A nonvolatile memory module (nonvolatile memory system)
[0053] **110**, **1010** memory controller
[0054] **111** host I/F unit
[0055] **112** CPU
[0056] **113** read/write control unit
[0057] **114** error correction unit
[0058] **115**, **1011** maintenance request unit
[0059] **120**, **1020** nonvolatile memory
[0060] **130**, **500**, **700**, **1200** access module (access device)
[0061] **140** system control unit
[0062] **150**, **530**, **710**, **1210** adaptive command unit
[0063] **151** system status monitoring unit
[0064] **152**, **531**, **711** maintenance determination unit
[0065] **153**, **712** maintenance entry list
[0066] **154**, **1211** command generation unit
[0067] **520** power supply unit
[0068] **720**, **1220** memory
[0069] **721**, **1021**, **1221** data management information storage unit

DESCRIPTION OF EMBODIMENTS

[0070] Embodiments of the present invention will now be described with reference to the drawings. In each of the embodiments, the components or processing parts given the same reference numerals as in the preceding embodiments will not be described.

First Embodiment

1.1 Structure of Nonvolatile Memory System

[0071] FIG. **1** is a block diagram of a nonvolatile memory system **1000** according to a first embodiment of the present invention.

[0072] As shown in FIG. **1**, the nonvolatile memory system **1000** of the present embodiment includes a nonvolatile memory module (nonvolatile memory device) **100** and an access module (access device) **130**. The nonvolatile memory module **100** and the access module **130** are connected to each other with a bus B**1**, via which bidirectional data communication can be performed between the modules.

[0073] The nonvolatile memory module **100** includes a memory controller **110** and a nonvolatile memory **120**.

[0074] The access module **130** transmits a command for reading and writing user data (hereafter referred simply as "data"), a logical address, and data to the nonvolatile memory **120** via the bus B**1** and the memory controller **110** included in the nonvolatile memory module **100**.

1.1.1 Internal Structure of Memory Controller **110**

[0075] The internal structure of the memory controller **110** will now be described.

[0076] The memory controller **110** controls the nonvolatile memory module **100**. The memory controller **110** includes a host interface unit (host I/F unit) **111**, a CPU **112**, a read/write control unit **113**, an error correction unit **114**, and a maintenance request unit **115**. These functional units of the memory controller **110** are connected to each other via an internal bus B**2** as shown in FIG. **1**. The functional units of the memory controller **110** may not necessarily be connected to each other via a bus, but some or all of the functional units may be directly connected to each other.

[0077] The host I/F unit **111** receives a data read command, a data write command, or data transmitted from the access module **130** to the nonvolatile memory module **100**. Also, the host I/F unit **111** transmits data or the like transmitted from the nonvolatile memory module **100** to the access module **130**.

[0078] The CPU **112** controls the overall operation of the memory controller **110** using a RAM (not shown) as a workplace or a ROM (not shown) storing programs.

[0079] The read/write control unit **113** controls reading of data from and writing of data to the nonvolatile memory **120**.

[0080] The error correction unit **114** calculates an ECC for data that is written to the nonvolatile memory **120**. For data that is read from the nonvolatile memory **120**, the error correction unit **114** performs error detection and error correction of the data and also determines the number of errors in the data using an ECC. The functions of the error correction unit **114** may be implemented by the CPU **112** performing software processing.

[0081] The maintenance request unit **115** determines whether an area (in units of blocks) in the nonvolatile memory **120** from which data has been read needs maintenance based on the number of errors determined by the error correction unit **114**. When determining that the area needs maintenance, the maintenance request unit **115** transmits a maintenance request to the access module **130**.

[0082] The maintenance request includes a logical address of a block that needs maintenance. The maintenance request is transmitted to the access module **130** via the host I/F unit **111**.

1.1.2 Internal Structure of Access Module **130**

[0083] The internal structure of the access module **130** will now be described.

[0084] The access module **130** includes a system control unit **140** and an adaptive command unit **150**.

[0085] The system control unit **140** controls the overall operation of the access module **130** including control associated with the processing caused by commands including a read command and a write command or management of the other system status.

[0086] The internal structure of the adaptive command unit **150** will now be described.

[0087] The adaptive command unit **150** includes a system status monitoring unit **151**, a maintenance determination unit **152**, and a command generation unit **154**.

[0088] The system status monitoring unit **151** monitors the system status of the access module **130** (whether the access module is engaged in data transfer for example), and transmits information about the system status to the maintenance determination unit **152**.

[0089] The maintenance determination unit **152** stores a logical address included in each maintenance request transmitted from the maintenance request unit **115** in a maintenance entry list **153**. When determining that the access module **130** is not engaged in normal processing (initialization, data reading, or data writing) performed with the nonvolatile memory module **100** based on the information about the system status transmitted from the system status monitoring unit **151**, the maintenance determination unit **152** determines that the system is enabled to perform maintenance, or in other words the system is in maintenance-enabled status.

[0090] In this case, the command generation unit **154** included in the adaptive command unit **150** generates a main-

tenance command for causing maintenance for data retention, such as refresh, to be performed for an address stored in the maintenance entry list **153**. The adaptive command unit **150** then transmits the maintenance command generated by the command generation unit **154** to the nonvolatile memory module **100**.

[0091] The maintenance command includes a logical address of a block that needs maintenance (hereafter referred to as a "maintenance-needed block") stored in the maintenance entry list **153**. The maintenance command is transmitted to the nonvolatile memory module **100** via the host I/F unit **111**.

1.2 Operation of Nonvolatile Memory System

[0092] A data maintenance cycle used in the nonvolatile memory system **1000** with the above-described structure will now be described with reference to the flowcharts shown in FIGS. **2** to **4**.

[0093] FIG. **2** shows a data maintenance request generation cycle used in the nonvolatile memory module **100**. FIG. **3** shows a data maintenance command generation cycle used in the adaptive command unit **150** included in the access module **130**. FIG. **4** shows a data maintenance cycle used in the nonvolatile memory module **100**.

[0094] For ease of explanation, only the operational procedure associated with data maintenance according to the present embodiment will be described.

1.2.1 Data Maintenance Request Generation Cycle

S**201**:

[0095] In the nonvolatile memory system **1000**, as shown in FIG. **2**, the access module **130** transmits, to the nonvolatile memory module **100**, a command for reading valid data including an address (logical address) of data to be read, and then the read/write control unit **113** reads data from a designated address in the nonvolatile memory **120** (a physical address corresponding to the logical address designated by the access module **130**) and an ECC associated with the data, and transmits the data and the ECC to the error correction unit **114**.

[0096] The error correction unit **114** determines whether the read data has an error, and determines the number of errors in the data. When detecting an error in the data, the error correction unit **114** corrects the erroneous data. After completing the error correction, the CPU **112** transmits the data from the error correction unit **114** to the access module **130**, and completes the data reading process (S**201**).

S**202**, S**203**:

[0097] When the data reading process is completed in the nonvolatile memory system **1000**, the read data is then subjected to determination as to whether the data needs maintenance.

[0098] The error correction unit **114** first determines whether the data has an error (S**202**). When detecting an error, the error correction unit **114** transmits information about the number of errors in the data to the maintenance request unit **115** (S**203**). When detecting no error, the error correction unit **114** ends the determination as to whether the data needs maintenance.

S**204**, S**205**:

[0099] The maintenance request unit **115** determines whether the read area needs maintenance based on the received information about the number of errors in the data. More specifically, the maintenance need determination is performed based on whether the number of errors is greater than or equal to a criterion value (S**204**). When the number of errors is greater than or equal to the criterion value, the maintenance request unit **115** transmits a maintenance request to the access module **130** (S**205**), and ends the maintenance need determination. When the number of errors is smaller than the criterion value, the maintenance request unit **115** determines that the data needs no maintenance, and ends the maintenance need determination.

1.2.2 Data Maintenance Command Generation Cycle

[0100] The procedure performed by the access module **130** when receiving a maintenance request from the nonvolatile memory module **100** until generating a maintenance command will now be described with reference to FIG. **3**.

S**301**, S**302**:

[0101] When the access module **130** receives a maintenance request from the nonvolatile memory module **100** (S**301**), the maintenance determination unit **152** enters, into the maintenance entry list **153**, a logical address of a block that needs maintenance (maintenance-needed block) included in the maintenance request (S**302**). It is preferable that the maintenance request transmitted from the nonvolatile memory module **100** to the access module **130** includes information for identifying the maintenance-needed block and information about the processing time for the maintenance that will be required by the nonvolatile memory module **100**. The information for identifying the maintenance-needed block may be, for example, a logical address of the maintenance-needed block, or a logical address of the start of the maintenance-needed block and the size of the block, or a logical address of the start of the maintenance-needed block and a logical address of the end of the maintenance-needed block.

S**303** to S**305**:

[0102] When detecting an address stored in the maintenance entry list **153**, the system status monitoring unit **151** obtains the system status of the nonvolatile memory system **1000** from the system control unit **140** (S**303**), and determines whether the system is engaged in normal processing (S**304**).

[0103] When determining that the system is engaged in normal processing, the system status monitoring unit **151** waits for a predetermined period of time (S**305**), and again obtains the system status (S**303**).

S**306** to S**308**:

[0104] When determining that the system is not engaged in normal processing, the system status monitoring unit **151** transmits information indicating that the system is in maintenance-enabled status to the maintenance determination unit **152** (S**306**). The maintenance determination unit **152** then instructs the command generation unit **154** to generate a maintenance command using the address of the maintenance-needed block stored in the maintenance entry list **153**. The command generation unit **154** generates and outputs a maintenance command as instructed by the maintenance determination unit **152** (S**307**).

[0105] The adaptive command unit **150** transmits the maintenance command generated by the command generation unit **154** to the nonvolatile memory module **100** (S**308**).

S**309** to S**311**:

[0106] Subsequently, the access module **130** receives a maintenance completion notification from the nonvolatile memory module **100** (S**309**). The maintenance determination unit **152** then deletes the address for which maintenance has been completed from the maintenance entry list **153** (S**310**).

[0107] The maintenance determination unit **152** determines whether the maintenance entry list **153** stores another address entry (S**311**). When detecting no address entry, the maintenance determination unit **152** determines that all maintenance has been completed, and ends the data maintenance command generation cycle. When the maintenance entry list **153** stores an address entry, the processing returns to the step in which the system status is obtained (S**303**).

1.2.3 Data Maintenance Cycle

[0108] The procedure performed by the nonvolatile memory module **100** when receiving a maintenance command from the access module **130** until completing the maintenance will now be described with reference to FIG. **4**.

S**401** to S**403**:

[0109] When the nonvolatile memory module **100** receives a maintenance command from the access module **130** (S**401**), the read/write control unit **113** performs maintenance, such as refresh, of data stored at a designated address (logical address) of the nonvolatile memory **120** included in the maintenance command (S**402**). More specifically, the read/write control unit **113** first converts the designated address (logical address) of the nonvolatile memory **120** included in the maintenance command to a physical address of the nonvolatile memory **120** through logical to physical address conversion. The read/write control unit **113** then performs maintenance, such as refresh, of data stored at the physical address of the nonvolatile memory **120** obtained through the logical to physical address conversion.

[0110] After completing the maintenance, the nonvolatile memory module **100** transmits a maintenance completion notification to the access module **130** (S**403**), and ends the maintenance cycle.

[0111] The maintenance completion notification contains a logical address of a block included in the nonvolatile memory **120** for which maintenance has been completed.

[0112] In the nonvolatile memory system **1000** of the present embodiment, the criterion value for the number of errors, which is used to determine whether maintenance needs to be performed, is set based on the threshold number of errors that can be corrected by the system, and the criterion value also considers the effect of its setting on the data retention period and the processing speed.

[0113] As described above, the nonvolatile memory system **1000** of the present embodiment enables the maintenance to be performed with a sufficiently long processing time allocated to the maintenance, without requiring the maintenance to be performed together with normal processing of the system, and reduces the risk of data loss and improves the data retention properties.

[0114] The number of errors may be defined in units of bits or may be defined in units of symbols each of which consists of a plurality of bits.

[0115] The system status monitoring unit **151** may obtain the system status. Alternatively, the information about the system status may be provided from the system control unit **140** to the adaptive command unit **150**.

[0116] The maintenance request may include a plurality of logical addresses of a plurality of blocks instead of including only a single address of a single block. In this case, information indicating whether an area that needs maintenance consists of a single block or consists of a plurality of blocks may also be entered into the maintenance entry list **153** when the corresponding address is entered into the maintenance entry list **153**.

[0117] A single maintenance command may be generated for a plurality of addresses of a plurality of blocks in the nonvolatile memory system **1000**, instead of being generated for a single block address.

[0118] The maintenance may be performed for a plurality of logical blocks at a time, instead of being performed for a single block address at a time.

[0119] When the nonvolatile memory system **1000** includes a plurality of nonvolatile memory modules **100** to which the access module **130** is connected, the maintenance determination unit **152** may include a plurality of maintenance entry lists **153** corresponding in one-to-one to the plurality of nonvolatile memory modules **100**. In this case, for example, the plurality of nonvolatile memory modules **100** may be given unique IDs (identifiers). The maintenance determination unit **152** may then manage the maintenance entry lists **153** using the IDs (identifiers) of the nonvolatile memory modules **100**. This enables the single access module **130** to manage the plurality of nonvolatile memory modules **100**.

Second Embodiment

2.1 Structure of Nonvolatile Memory System

[0120] FIG. **5** is a block diagram of a nonvolatile memory system **2000** according to a second embodiment of the present invention.

[0121] As shown in FIG. **5**, the nonvolatile memory system **2000** includes a nonvolatile memory module (nonvolatile memory device) **100** and an access module (access device) **500**. The nonvolatile memory module **100** and the access module **500** are connected to each other with a bus B**1**, via which bidirectional data communication can be performed between the modules.

[0122] In the present embodiment, the components that are the same as the components in the first embodiment are given the same reference numerals as in FIG. **1**, and will not be described.

[0123] The nonvolatile memory module **100** has the same structure as in the first embodiment. The access module **500** includes a system control unit **510**, a power supply unit **520**, and an adaptive command unit **530**.

[0124] The power supply unit **520** supplies power not only to the access module **500** but also to the nonvolatile memory module **100**.

[0125] The system control unit **510** controls the overall operation of the access module **500** including control associated with the processing caused by commands including a

read command and a write command, management of the power supply of the power supply unit **520**, and management of the other system status.

[0126] The part of the adaptive command unit **530** different from the adaptive command unit in the first embodiment will now be described.

[0127] The adaptive command unit **530** includes a maintenance determination unit **531**.

[0128] In addition to the functions of the maintenance determination unit **152** of the first embodiment, the maintenance determination unit **531** further determines the number of times maintenance needs to be performed based on the number of addresses stored in the maintenance entry list **153** when the maintenance entry list **153** is updated, and transmits information about the number of times maintenance needs to be performed to the system control unit **510**.

2.2 Operation of Nonvolatile Memory System

[0129] A data maintenance cycle used in the nonvolatile memory system **2000** with the above-described structure will now be described with reference to the flowchart shown in FIG. **6**.

[0130] FIG. **6** shows a data maintenance command generation cycle used in the adaptive command unit **530** included in the access module **500**. For simplification, the processing part that is the same as the processing of the first embodiment will not be described.

2.2.1 Data Maintenance Request Generation Cycle

S**601**, S**602**:

[0131] In the nonvolatile memory system **2000**, as shown in FIG. **6**, the access module **500** first receives a maintenance request from the nonvolatile memory module **100** (S**601**). The maintenance determination unit **531** then enters a logical address of a maintenance-needed block into the maintenance entry list **153** (S**602**).

S**603**:

[0132] The maintenance determination unit **531** determines the number of times maintenance needs to be performed based on the number of addresses stored in the maintenance entry list **153**, and transmits information about the determined number of times to the system control unit **510** (S**603**).

[0133] The system control unit **510** then determines a minimum battery level that will be required for the maintenance processing corresponding to the determined number of times based on the transmitted information about the number of times maintenance needs to be performed, and manages the power supply unit **520** as well as the entire system to reserve the required battery level.

S**604**:

[0134] The maintenance is then performed (S**604**). The processing in step S**604** is the same as the processing in steps S**303** to S**308** in FIG. **3** described in the first embodiment.

S**605** to S**608**:

[0135] When the maintenance is completed and the access module **500** receives a maintenance completion notification from the nonvolatile memory module **100** (S**605**), the maintenance determination unit **531** deletes the address for which the maintenance has been completed from the maintenance entry list **153** (S**606**).

[0136] The maintenance determination unit **531** determines whether the maintenance entry list **153** stores another address entry (S**607**). When detecting no address entry, the maintenance determination unit **531** determines that all maintenance has been completed, and transmits information indicating that the number of times maintenance needs to be performed is zero to the system control unit **510** (S**608**).

[0137] When receiving the information indicating that the number of times maintenance needs to be performed is zero, the system control unit **510** releases the system limitations including the reserved battery level. No more maintenance needs to be performed in this state. The system control unit **510** may control the nonvolatile memory system **2000**, which has been operating in, for example, the power saving mode to reserve the required battery level, to operate in the normal mode (mode that is not the power saving mode).

[0138] When the maintenance entry list **153** stores an address entry in step S**607**, the processing returns to the step in which information about the number of times maintenance needs to be performed is transmitted (S**603**).

[0139] As described above, the nonvolatile memory system **2000** of the present embodiment executes the system control in accordance with the maintenance status, and executes the system control in a manner that all the needed maintenance processing will be completed in a reliable manner by, for example, reserving the required battery level in advance. As a result, the nonvolatile memory system **2000** enhances the data retention properties.

[0140] The number of times the maintenance needs to be performed, which is determined by the maintenance determination unit **531**, may be simply equal to the number of address entries stored in the list, or may be determined as the number of times the maintenance is to be performed when a single maintenance command is generated for a plurality of block addresses.

[0141] The required battery level to be reserved, which is determined by the system control unit **510**, may be calculated based on the type of the nonvolatile memory used in the nonvolatile memory module **100** connected to the access module **500** or based on the block length setting of the nonvolatile memory. Alternatively, the system control unit **510** may calculate and store information about the power consumption required per maintenance in advance, and may determine the required battery level based on the information about the power consumption required per maintenance.

[0142] The system control unit **510** may use a different condition for switching the system mode to the power saving mode to reserve the required battery level. More specifically, the system control unit **510** may use, for example, the condition for switching to the power saving mode when the battery level decreases to or below X2% (X2>X12), instead of using the condition for switching to the power saving mode when the battery level decreases to or below X1%. The use of such a condition provides a larger margin against the possibility that the battery level will reach zero. This enables the maintenance to be performed in a more reliable manner (reduces the risk of the battery level reaching zero and forcing the system to shut down during the maintenance processing). Additionally, when the access module **500** includes a display

unit, the system control unit **510** may change the battery level display on the display unit in a manner to urge the user to supply power to the module.

[0143] Additionally, the system control unit **510** may control all the needed maintenance processing to be completed with priority over normal processing of the system when determining that the battery level decreases and approaches the required battery level.

Third Embodiment

3.1 Structure of Nonvolatile Memory System

[0144] FIG. **7** is a block diagram of a nonvolatile memory system **3000** according to a third embodiment of the present invention.

[0145] As shown in FIG. **7**, the nonvolatile memory system **3000** of the present embodiment includes a nonvolatile memory module (nonvolatile memory device) **100** and an access module (access device) **700**. The nonvolatile memory module **100** and the access module **700** are connected to each other with a bus B**1**, via which bidirectional data communication can be performed between the modules.

[0146] In the present embodiment, the components that are the same as the components in the first embodiment are given the same reference numerals as in FIG. **1**, and will not be described.

[0147] The nonvolatile memory module **100** has the same structure as in the first embodiment.

[0148] The access module **700** includes a system control unit **140**, an adaptive command unit **710**, and a memory **720**.

[0149] The memory **720** includes a data management information storage unit **721**.

[0150] The data management information storage unit **721** may store, together with the addresses, the importance levels of data stored in the nonvolatile memory **120** and the write history of data in the nonvolatile memory **120** (information about the time at which the data has been written). The information stored in the data management information storage unit **721** is updated when the access module **700** writes data to the nonvolatile memory **120**.

[0151] The part of the adaptive command unit **710** different from the adaptive command unit in the first embodiment will be described.

[0152] The adaptive command unit **710** includes a maintenance determination unit **711**.

[0153] In addition to the functions of the maintenance determination unit **152** of the first embodiment, the maintenance determination unit **711** further enters the priorities for the plurality of addresses stored in the maintenance entry list **712**. The priorities added to the addresses are used when the maintenance is performed for each of the addresses. The addresses having higher priorities are processed earlier. The adaptive command unit **710** prioritizes the addresses by referring to information about the importance levels of data stored in the data management information storage unit **721**. The adaptive command unit **710** generates a maintenance command in a manner that the addresses (logical addresses) are processed sequentially from an address having a higher priority in the maintenance entry list **712**.

3.2. Operation of Nonvolatile Memory System

[0154] A data maintenance cycle used in the nonvolatile memory system **3000** with the above-described structure will now be described with reference to the flowchart shown in FIG. **8**.

3.2.1 Data Maintenance Cycle **1**

[0155] FIG. **8** shows a data maintenance command generation cycle used in the adaptive command unit **710** included in the access module **700**. For simplification, the processing part that is the same as the processing of the first embodiment will not be described. The data management information storage unit **721** stores information about, for example, the importance levels of data entered when the data is written to the nonvolatile memory **120**.

S**801** to S**803**:

[0156] In the nonvolatile memory system **3000**, as shown in FIG. **8**, the access module **700** first receives a maintenance request from the nonvolatile memory module (S**801**). The maintenance determination unit **711** then enters a logical address of a block that needs maintenance (maintenance-needed block) into the maintenance entry list **712** (S**802**). When entering the address, the maintenance determination unit **711** refers to information about, for example, the importance level of the data stored in the data management information storage unit **721**, and adds a priority with which maintenance is to be performed to the address entry (S**803**).

[0157] For example, the maintenance determination unit **711** may obtain the importance level of data corresponding to the address entry from the data management information storage unit **721**. When the obtained importance level is high, the maintenance determination unit **711** may add a high priority to the address entry.

S**804**:

[0158] Subsequently, the system status is obtained (S**804**). The processing in step S**804** is the same as the processing in steps S**303** to S**305** in FIG. **3** described in the first embodiment.

S**805** to S**807**:

[0159] When the system status is other than the status in which normal processing is performed, the system status monitoring unit **151** transmits information indicating that the system is enabled to perform maintenance, or in maintenance-enabled status, to the maintenance determination unit **711** (S**805**). The maintenance determination unit **711** then instructs the command generation unit **154** to generate a maintenance command for an address of a maintenance-needed block having a higher priority stored in the maintenance entry list **712**. The command generation unit **154** generates and outputs a maintenance command as instructed by the maintenance determination unit **711** (S**806**). The adaptive command unit **710** then transmits the maintenance command generated by the command generation unit **154** to the nonvolatile memory module **100** (S**807**).

S**808** to S**810**:

[0160] When the access module **700** receives a maintenance completion notification from the nonvolatile memory module **100** (S**808**), the maintenance determination unit **711** deletes the address for which the maintenance has been completed and its priority from the maintenance entry list **712** (S**809**).

[0161] The maintenance determination unit **711** determines whether the maintenance entry list **712** stores another address entry (S**810**). When detecting no address entry, the maintenance determination unit **711** determines that all maintenance has been completed, and ends the data maintenance command generation cycle. When the maintenance entry list

712 stores an address entry, the processing returns to the step in which the system status is obtained (S804).

3.2.1 Data Maintenance Cycle 2

[0162] Another data maintenance cycle used in the nonvolatile memory system 3000 of the present embodiment will now be described with reference to a flowchart shown in FIG. 9. For simplification, the processing part that is the same as the processing for the data maintenance cycle described above in the present embodiment will not be described.

S901:

[0163] In the nonvolatile memory system 3000, as shown in FIG. 9, the maintenance determination unit 711 first obtains the write history stored in the data management information storage unit 721 (information about the time at which data has been previously written to the address) (S901).

S902, S903:

[0164] The maintenance determination unit 711 calculates the elapsed time from when the data has been written previously based on the write history, and determines whether the elapsed time is greater than or equal to a criterion value for determining the data retention (S902). When determining that the elapsed time is greater than or equal to the criterion value, the maintenance determination unit 711 enters the address and its priority into the maintenance entry list 712 (S903).

[0165] The criterion value is set based on the data retention properties of the nonvolatile memory 120. The nonvolatile memory module 100 and the access module 700 exchange their device information including the data retention properties with each other when, for example, the system is initialized. As a result, the access module 700 obtains and stores the set criterion value in advance.

S904 to S907:

[0166] Subsequently, the maintenance is performed in the nonvolatile memory system 3000. The access module 700 receives a maintenance completion notification from the nonvolatile memory module 100 (S904). The maintenance determination unit 711 then deletes the address for which the maintenance has been completed and its priority from the maintenance entry list 712 (S905), and further updates the write history stored in the data management information storage unit 721 (S906).

[0167] The maintenance determination unit 711 determines whether the maintenance entry list 712 stores another address entry (S907). When detecting no address entry, the maintenance determination unit 711 determines that all maintenance has been completed, and ends the data maintenance command generation cycle. When the maintenance entry list 712 stores an address entry, the processing returns to the step in which the system status is obtained (S904).

[0168] In the nonvolatile memory system 3000 of the present embodiment described above, the access module 700 manages the logical addresses of important data, and prioritizes the addresses in a manner that more important data will be processed earlier. This enables important data to be retained in a more reliable manner.

[0169] In the nonvolatile memory system 3000, the access module 700 further manages the write history of data for each logical address, and voluntarily performs maintenance of data that has been left unread for a long period of time after the data has been written, without receiving a maintenance request from the nonvolatile memory module 100. This reduces the risk of data loss occurring in an area of the nonvolatile memory 120 from which data has not been read for a long period of time.

[0170] The importance level of data may be indicated by using a flag set for only important data, or by using one of a plurality of importance levels set for important data.

[0171] The importance level of data may be set for each address of a single block, or may be set for a plurality of logical addresses of a plurality of blocks.

[0172] The priorities with which maintenance is to be performed may not be stored in the maintenance entry list 712, but the information about the priorities stored in the data management information storage unit 721 may be referred to every time when maintenance is performed.

[0173] The importance level of data and the write history may not necessarily be stored for all data, but may be stored only for specific types of data or for data written in specific areas.

Fourth Embodiment

4.1 Structure of Nonvolatile Memory System

[0174] FIG. 10 is a block diagram of a nonvolatile memory system 4000 according to a fourth embodiment of the present invention.

[0175] As shown in FIG. 10, the nonvolatile memory system 4000 of the present embodiment includes a nonvolatile memory module (nonvolatile memory device) 100A and an access module (access device) 130. The nonvolatile memory module 100A and the access module 130 are connected to each other with a bus B1, via which bidirectional data communication can be performed between the modules.

[0176] In the present embodiment, the components that are the same as the components in the first embodiment are given the same reference numerals as in FIG. 1, and will not be described.

[0177] The access module 130 has the same structure as in the first embodiment.

[0178] The nonvolatile memory module 100A includes a memory controller 1010 and a nonvolatile memory 1020.

[0179] The nonvolatile memory 1020 includes a data management information storage unit 1021 in the same manner as the memory 720 described in the third embodiment.

[0180] The data management information storage unit 1021 stores, together with the addresses, the priorities of data stored in the nonvolatile memory 120 and other information. The information stored in the data management information storage unit 1021 is written together with data when the access module 130 writes the data to the nonvolatile memory 120.

[0181] The part of the memory controller 1010 different from the memory controller in the first embodiment will now be described.

[0182] The memory controller 1010 includes a maintenance request unit 1011.

[0183] In addition to the functions of the maintenance request unit 115 of the first embodiment, the maintenance request unit 1011 further refers to information about the importance level of data stored in the data management information storage unit 1021 when determining whether the read data needs maintenance, and dynamically changes the crite-

rion of determination as to whether the data needs maintenance based on the information about the importance level of data.

4.2 Operation of Nonvolatile Memory System

[0184] A data maintenance request generation cycle used in the nonvolatile memory system **4000** with the above-described structure will now be described with reference to the flowchart shown in FIG. **11**.

4.2.1 Data Maintenance Request Generation cycle

[0185] FIG. **11** shows a data maintenance request generation cycle used in the nonvolatile memory module **100**A. For simplification, the processing part that is the same as the processing of the above embodiments will not be described.

S**1101** to S**1103**:

[0186] In the nonvolatile memory system **4000**, as shown in FIG. **11**, the processing from the reading of data (S**1101**) to the notification of the number of data errors (S**1103**) is the same as in the first embodiment.

S**1104**:

[0187] The maintenance request unit **1011** receives information about the number of errors from the error correction unit **114**, and then obtains the importance level of data that has been read by referring to the data management information storage unit **1021** and sets the criterion value used to determine whether the data needs maintenance in accordance with the obtained importance level (S**1104**).

S**1105**, S**1106**:

[0188] Subsequently, the maintenance request unit **1011** determines whether maintenance needs to be performed based on whether the number of errors is greater than or equal to the criterion value (S**1105**). When the number of errors is greater than or equal to the criterion value, the maintenance request unit **1011** transmits a maintenance request to the access module **130** (S**1106**), and ends the determination as to whether maintenance needs to be performed. When the number of errors is below the criterion value, the maintenance request unit **1011** determines that no maintenance needs to be performed, and ends the maintenance need determination.

[0189] As described above, the nonvolatile memory system **4000** of the present embodiment dynamically changes the criterion value used to determine whether maintenance needs to be performed based on the importance level of data. This enables a maintenance request to be generated in a manner to provide a sufficient margin only for important data against the possibility that the number of its errors will reach the threshold number of errors that can be corrected by the system, and thus improves the data retention properties in an efficient manner.

[0190] In the nonvolatile memory system **4000**, the nonvolatile memory **1020** stores management information including the information about the importance level of data to enable the management information to be shared between different access modules. This prevents loss of important data and enables the important data to be retained in a more reliable manner. The access module **130** stores the latest data management information into the nonvolatile memory **1020** when, for example, the system is powered off. The access module **130** reads the data management information from the nonvolatile memory **120** when the system is initialized.

[0191] The importance level of data may be indicated by using a flag set for only important data, or by using one of a plurality of importance levels set for importance data.

[0192] The importance level of data may be set for each address of a single block, or may be set for a plurality of logical addresses of a plurality of blocks.

[0193] The criterion value used to determine whether maintenance needs to be performed may be set using binary information either indicating that the data is important or that the data is not important, or alternatively may be set using one of a plurality of criterion values determined in accordance with the priorities of data. It is preferable that the criterion value is set to prevent maintenance from being performed even for important data when unnecessary.

[0194] The importance level of data may not be stored for all data, but may be stored only for specific types of data or for data written in specific areas.

Fifth Embodiment

5.1 Structure of Nonvolatile Memory System

[0195] FIG. **12** is a block diagram of a nonvolatile memory system **5000** according to a fifth embodiment of the present invention.

[0196] As shown in FIG. **12**, the nonvolatile memory system **5000** of the present embodiment includes a nonvolatile memory module (nonvolatile memory device) **100** and an access module (access device) **1200**. The nonvolatile memory module **100** and the access module **1200** are connected to each other with a bus B**1**, via which bidirectional data communication can be performed between the modules.

[0197] In the present embodiment, the components that are the same as the components in the first embodiment are given the same reference numerals as in FIG. **1**, and will not be described.

[0198] The nonvolatile memory module **100** has the same structure as in the first embodiment.

[0199] The access module **1200** includes an adaptive command unit **1210** and a memory **1220**.

[0200] The memory **1220** includes a data management information storage unit **1221**.

[0201] The data management information storage unit **1221** stores, together with the addresses, the access history of the nonvolatile memory **120** (information about the time at which data has been read from or written to the memory) and other information. The information stored in the data management information storage unit **1221** is updated when the access module **1200** reads the data from or writes the data to the nonvolatile memory **120**.

[0202] The part of the adaptive command unit **1210** different from the adaptive command unit in the first embodiment will now be described.

[0203] The adaptive command unit **1210** includes a command generation unit **1211**.

[0204] In addition to the functions of the command generation unit **154** of the first embodiment, the command generation unit **1211** further performs the processing described below. The command generation unit **1211** refers to the access history stored in the data management information storage unit **1221**, and detects an area from which or to which no data has been read or written for a long period of time, and generates a command for reading data from the detected area (area from which or to which no data has been read or written for a long period of time). This command causes the nonvola-

tile memory module **100** to perform the data maintenance request generation cycle shown in FIG. **2** to determine whether the area that has not been accessed for a long period of time includes an area that needs maintenance.

5.2 Operation of Nonvolatile Memory System

[0205] A data read cycle used in the nonvolatile memory system **5000** with the above-described structure will now be described with reference to the flowchart shown in FIG. **13**.

5.2.1 Data Read Cycle

[0206] FIG. **13** shows a data read command generation cycle used in the command generation unit **1211** included in the access module **1200**.

S**1301**:

[0207] In the nonvolatile memory system **5000**, as shown in FIG. **13**, the command generation unit **1211** first obtains the access history stored in the data management information storage unit **1221** (information about the time at which data has been previously written or read at the address) (S**1301**).

S**1302**, S**1303**:

[0208] The command generation unit **1211** calculates the elapsed time from when the data has been written or read previously based on the access history, and determines whether the elapsed time is greater than or equal to a criterion value for determining the data retention (S**1302**). When determining that the elapsed time is greater than or equal to the criterion value, the command generation unit **1211** generates a data read command for reading data from the address (S**1303**), and transmits the generated data read command to the nonvolatile memory module **100** (S**1304**).

[0209] The criterion value is set based on the data retention properties of the nonvolatile memory **120**. The nonvolatile memory module **100** and the access module **1200** exchange their device information including the data retention properties with each other when, for example, the system is initialized. As a result, the access module **1200** obtains and stores the set criterion value in advance.

S**1305** to S**1306**:

[0210] In the nonvolatile memory system **5000**, the data reading process is performed subsequently (S**1305**). When the data reading process is completed, the command generation unit **1211** updates the access history of the address from which the data has been read in the address data management information storage unit **1221** (S**1306**).

[0211] In the nonvolatile memory system **5000** of the present embodiment described above, the access module **1200** manages the access history of data in the nonvolatile memory **120** for each logical address. When detecting an area that has not been accessed for a long period of time, the access module **1200** generates a read command for the detected area (a read command for reading data from the detected area). The nonvolatile memory system **5000** determines whether the nonvolatile memory module **100** includes an area that has not been accessed for a long period of time and that needs maintenance. This reduces the risk of data loss occurring in such an area that has not been accessed for a long period of time.

[0212] In the nonvolatile memory system **5000**, the access history may not necessarily be stored for all data, but may be stored only for specific types of data or for data in specific areas.

[0213] In the nonvolatile memory system **5000**, the single data read command may be generated for reading data from a single address of a single block, or for reading data from a plurality of logical addresses of a plurality of blocks.

Other Embodiments

[0214] Each block of the nonvolatile memory system, the nonvolatile memory module, and the access module described in the above embodiments may be formed using a single chip with a semiconductor device, such as LSI (large-scale integration), or some or all of the blocks of the nonvolatile memory system, the nonvolatile memory module, and the access module may be formed using a single chip.

[0215] Although LSI is used as the semiconductor device technology, the technology may be IC (integrated circuit), system LSI, super LSI, or ultra LSI depending on the degree of integration of the circuit.

[0216] The circuit integration technology employed should not be limited to LSI, but the circuit integration may be achieved using a dedicated circuit or a general-purpose processor. A field programmable gate array (FPGA), which is an LSI circuit programmable after manufactured, or a reconfigurable processor, which is an LSI circuit in which internal circuit cells are reconfigurable or more specifically the internal circuit cells can be reconnected or reset, may be used.

[0217] Further, if any circuit integration technology that can replace LSI emerges as an advancement of the semiconductor technology or as a derivative of the semiconductor technology, the technology may be used to integrate the functional blocks. Biotechnology is potentially applicable.

[0218] The processes described in the above embodiments may be implemented using either hardware or software, or may be implemented using both software and hardware.

[0219] The specific structures described in the above embodiment are mere examples of the present invention, and may be changed and modified variously without departing from the scope and spirit of the invention.

INDUSTRIAL APPLICABILITY

[0220] The nonvolatile memory system of the present invention prevents data loss that can occur in a nonvolatile memory whose data retention period can be shortened by the trend toward multivalued flash memories.

[0221] The present invention is applicable not only to a semiconductor memory card, but also to, for example, a still image recording/playback apparatus, a moving image recording/playback apparatus, and a portable information terminal including a nonvolatile memory.

1. An access device that accesses a nonvolatile memory device including a nonvolatile memory, the access device comprising:

an adaptive command unit that determines whether data stored in the nonvolatile memory needs maintenance based on a data retention status of the nonvolatile memory obtained from the nonvolatile memory device, and determines whether maintenance is to be performed based on whether the access device is in a system status in which maintenance is enabled and based on whether the data stored in the nonvolatile memory needs main-

tenance, and generates a maintenance command to the nonvolatile memory device when determining that the maintenance is to be performed.

2. The access device according to claim **1**, wherein

the adaptive command unit includes

a system status monitoring unit that monitors the system status of the access device,

a maintenance determination unit that determines whether the maintenance is to be performed based on a monitoring result obtained by the system status monitoring unit and based on whether the data stored in the nonvolatile memory needs maintenance, and

a command generation unit that generates a maintenance command to the nonvolatile memory device in accordance with a determination result obtained by the maintenance determination unit.

3. The access device according to claim **2**, wherein

the system status monitoring unit monitors a processing status of the access device, and provides information indicating that maintenance is enabled when determining that the access device is not engaged in normal processing,

the maintenance determination unit determines that the maintenance is to be performed when determining that the data stored in the nonvolatile memory needs maintenance and further receiving from the system status monitoring unit the information indicating that maintenance is enabled, and

the command generation unit generates a maintenance command to the nonvolatile memory device when the maintenance determination unit determines that the maintenance is to be performed.

4. The access device according to claim **2**, wherein

the maintenance determination unit stores at least one address of the nonvolatile memory that needs maintenance, and selects an address for which the maintenance is to be performed from the at least one address when receiving from the system status monitoring unit information indicating that maintenance is enabled, and

the command generation unit generates a maintenance command for performing maintenance for the address of the nonvolatile memory device selected by the maintenance determination unit.

5. The access device according to claim **2**, further comprising:

a system control unit that executes system control of the access device,

wherein the maintenance determination unit stores at least one address of the nonvolatile memory that needs maintenance, and provides information about the at least one address of the nonvolatile memory to the system control unit.

6. The access device according to claim **5**, further comprising:

a power supply unit that supplies power to the access device,

wherein the system control unit determines a minimum battery level to be reserved by the power supply unit based on the information about the at least one address of the nonvolatile memory, and controls the power supply unit and the access device in a manner to reserve the determined minimum battery level.

7. The access device according to claim **4**, further comprising:

a data management information storage unit storing data management information for managing data stored in the nonvolatile memory,

wherein the maintenance determination unit changes an order in which maintenance is to be performed for the at least one address in accordance with a status of data stored in the nonvolatile memory by referring to the information stored in the data management information storage unit.

8. The access device according to claim **4**, further comprising:

a data management information storage unit storing data management information for managing data stored in the nonvolatile memory,

wherein the maintenance determination unit voluntarily determines and stores an address for which maintenance needs to be performed in accordance with a status of data stored in the nonvolatile memory by referring to the information stored in the data management information storage unit without receiving information about the status of data stored in the nonvolatile memory from the nonvolatile memory device.

9. The access device according to claim **1**, wherein

the maintenance includes refresh and/or wear leveling of the nonvolatile memory.

10. A memory controller used in a nonvolatile memory device that reads and/or writes data in accordance with a command provided from an access device for reading data from and writing data to a nonvolatile memory included in the nonvolatile memory device, the memory controller comprising:

an error correction unit that determines the number of errors included in data read from the nonvolatile memory, and corrects an error included in the read data; and

a maintenance request unit that generates a maintenance request indicating that the nonvolatile memory needs maintenance to the access device when the number of errors determined by the error correction unit is greater than or equal to a criterion value,

wherein the maintenance request unit dynamically changes the criterion value used to determine whether to generate a maintenance request in accordance with a status of data stored in the nonvolatile memory, and

the maintenance includes refresh and/or wear leveling of the nonvolatile memory.

11. A nonvolatile memory device for reading and/or writing data in accordance with a command provided from an access device, the nonvolatile memory device comprising:

a nonvolatile memory storing data; and

the memory controller according to claim **10**.

12. A nonvolatile memory system including a nonvolatile memory device having a nonvolatile memory and a memory controller for reading data from and writing data to the nonvolatile memory and an access device that communicates with the nonvolatile memory device having the nonvolatile memory, the nonvolatile memory system comprising:

the nonvolatile memory device according to claim **11**; and

an access device that accesses a nonvolatile memory device including a nonvolatile memory, the access device comprising:

an adaptive command unit that determines whether data stored in the nonvolatile memory needs maintenance based on a data retention status of the nonvolatile

memory obtained from the nonvolatile memory device, and determines whether maintenance is to be performed based on whether the access device is in a system status in which maintenance is enabled and based on whether the data stored in the nonvolatile memory needs maintenance, and generates a maintenance command to the nonvolatile memory device when determining that the maintenance is to be performed.

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