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(54) **MEMORY DEVICE**

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(51) **Int. Cl.**
G11C 29/00 (2006.01)

(52) **U.S. Cl.** **714/763**; **714/799**

(58) **Field of Classification Search** **714/763**,
714/799

See application file for complete search history.

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(57) **ABSTRACT**

An exemplary memory device has at least one memory chip that stores data and error correcting information. An error detecting circuit in the memory chip performs a calculation on the data and error correcting information to obtain error detection information indicating the locations of bit errors in the data. The uncorrected data and the error detection information are output from the memory chip. The uncorrected data and error detection information may also be output from the memory device, or the memory device may include a memory controller chip with an error correcting circuit that uses the error detection information to correct the bit errors and outputs corrected data from the memory device.

14 Claims, 12 Drawing Sheets

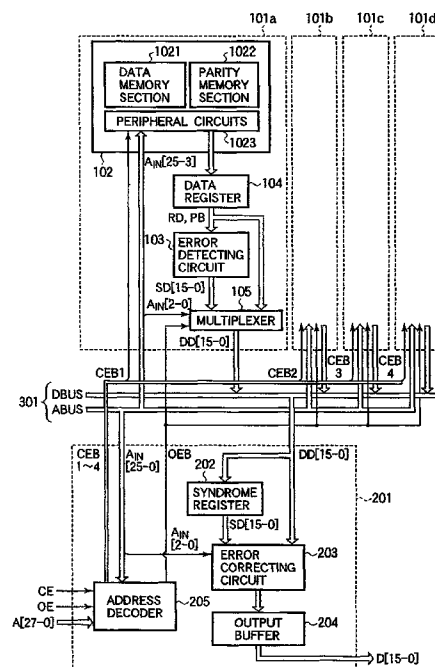


FIG.2

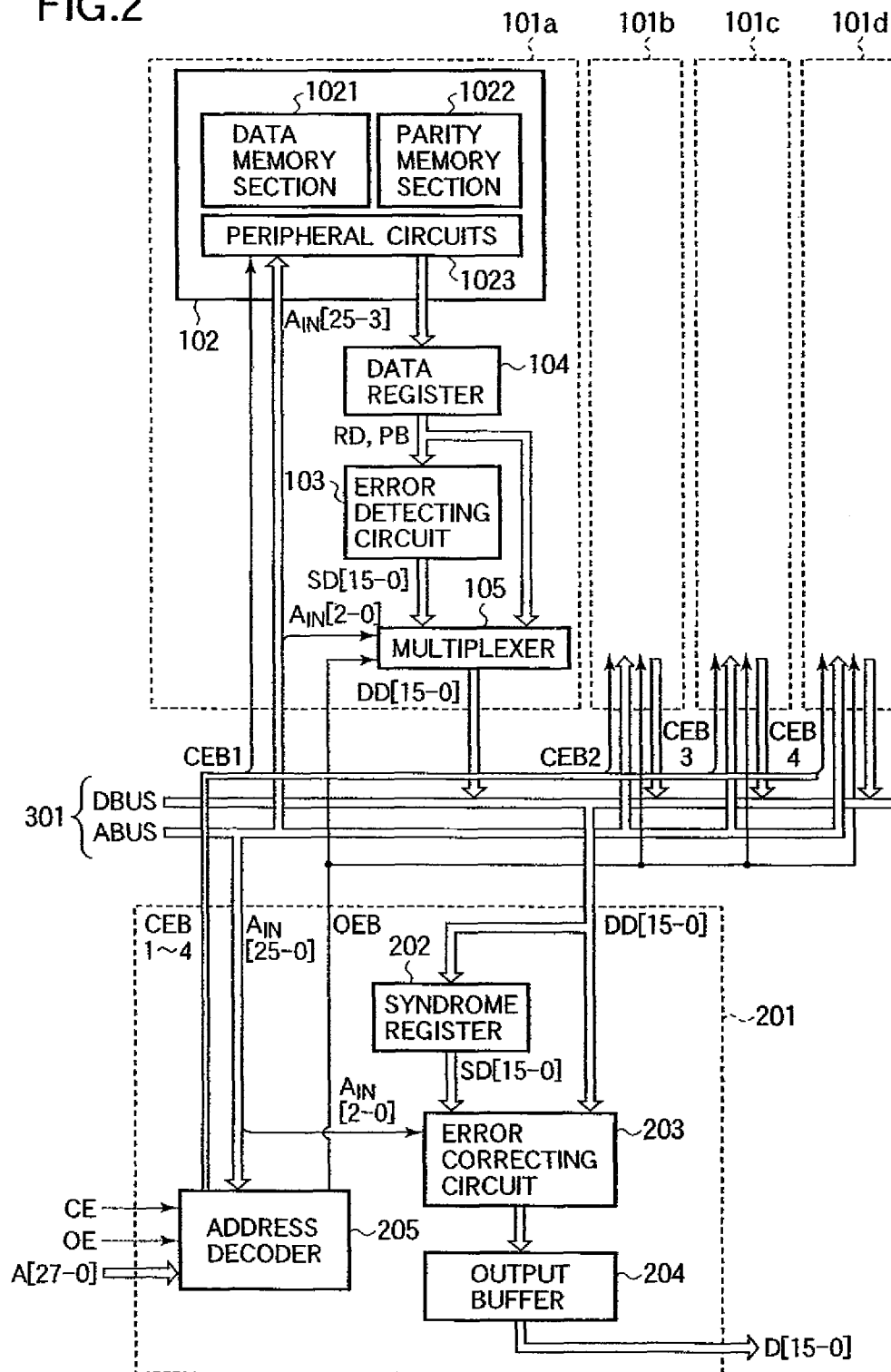


FIG.3

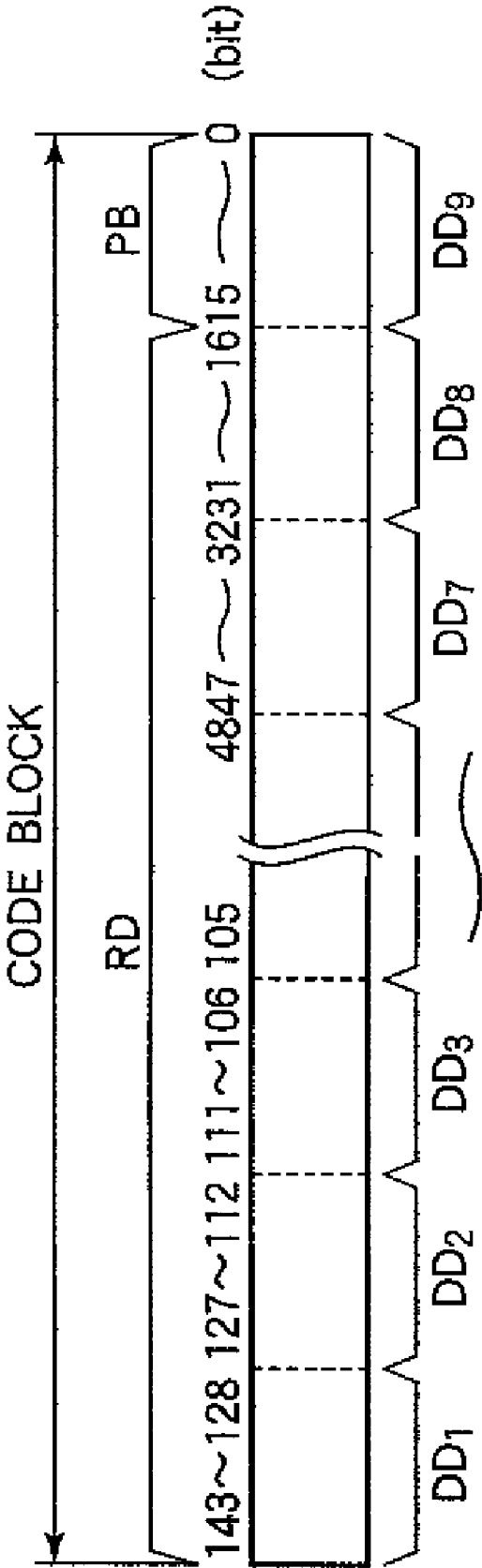


FIG. 4

$$H = \begin{bmatrix} \alpha^{143} & \alpha^{142} & \alpha^{141} & \alpha^{140} & \alpha^{139} & \dots & \alpha^4 & \alpha^3 & \alpha^2 & \alpha & 1 \\ \alpha^{179} & \alpha^{171} & \alpha^{168} & \alpha^{165} & \alpha^{162} & \dots & \alpha^{12} & \alpha^9 & \alpha^6 & \alpha^3 & 1 \end{bmatrix}$$

FIG.5A

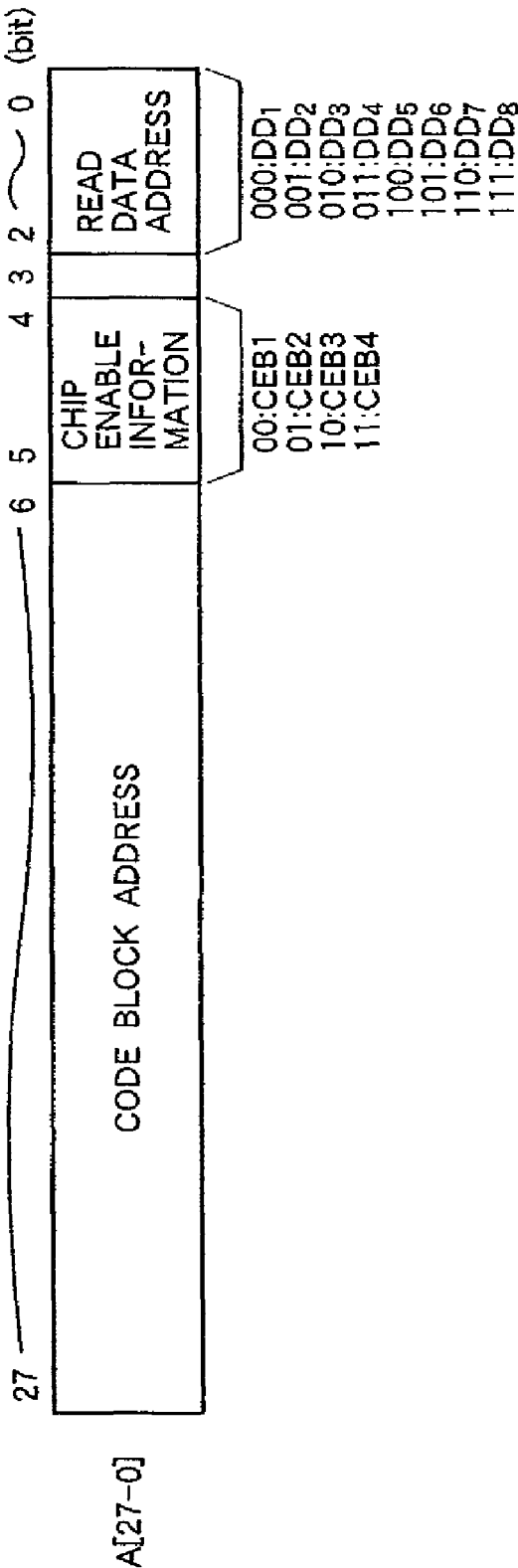


FIG.5B

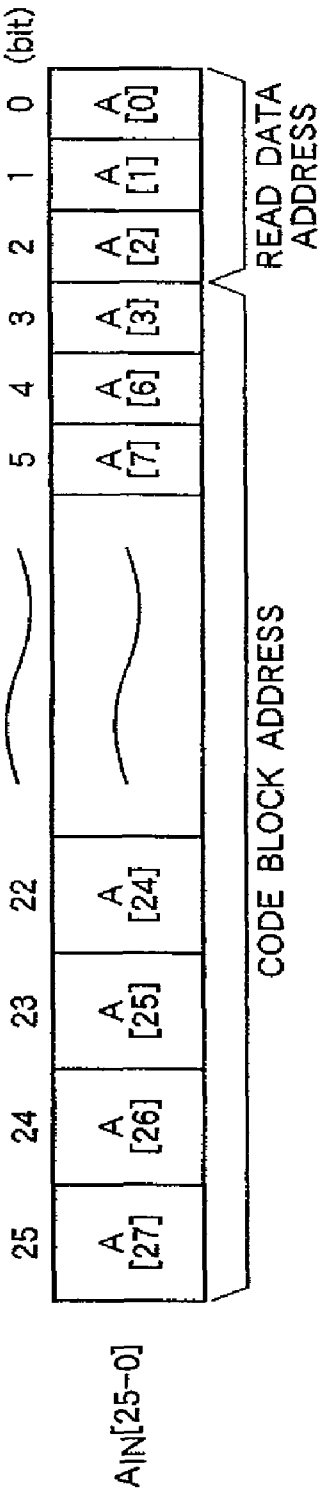


FIG. 6

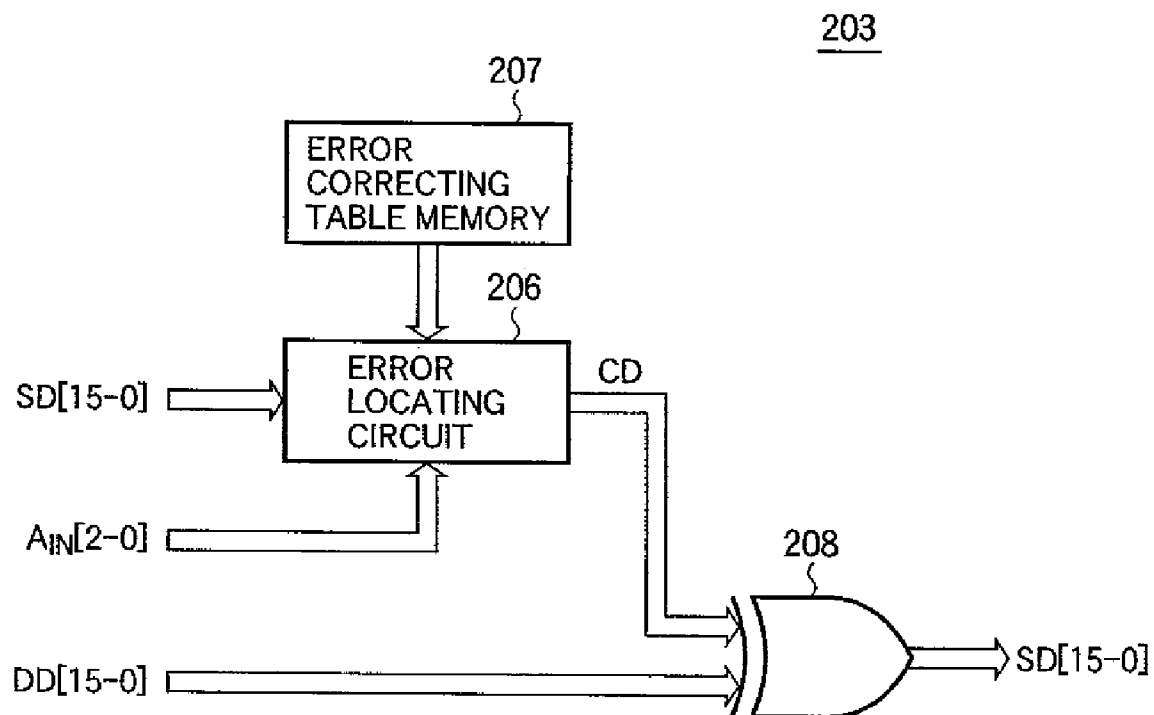


FIG. 7

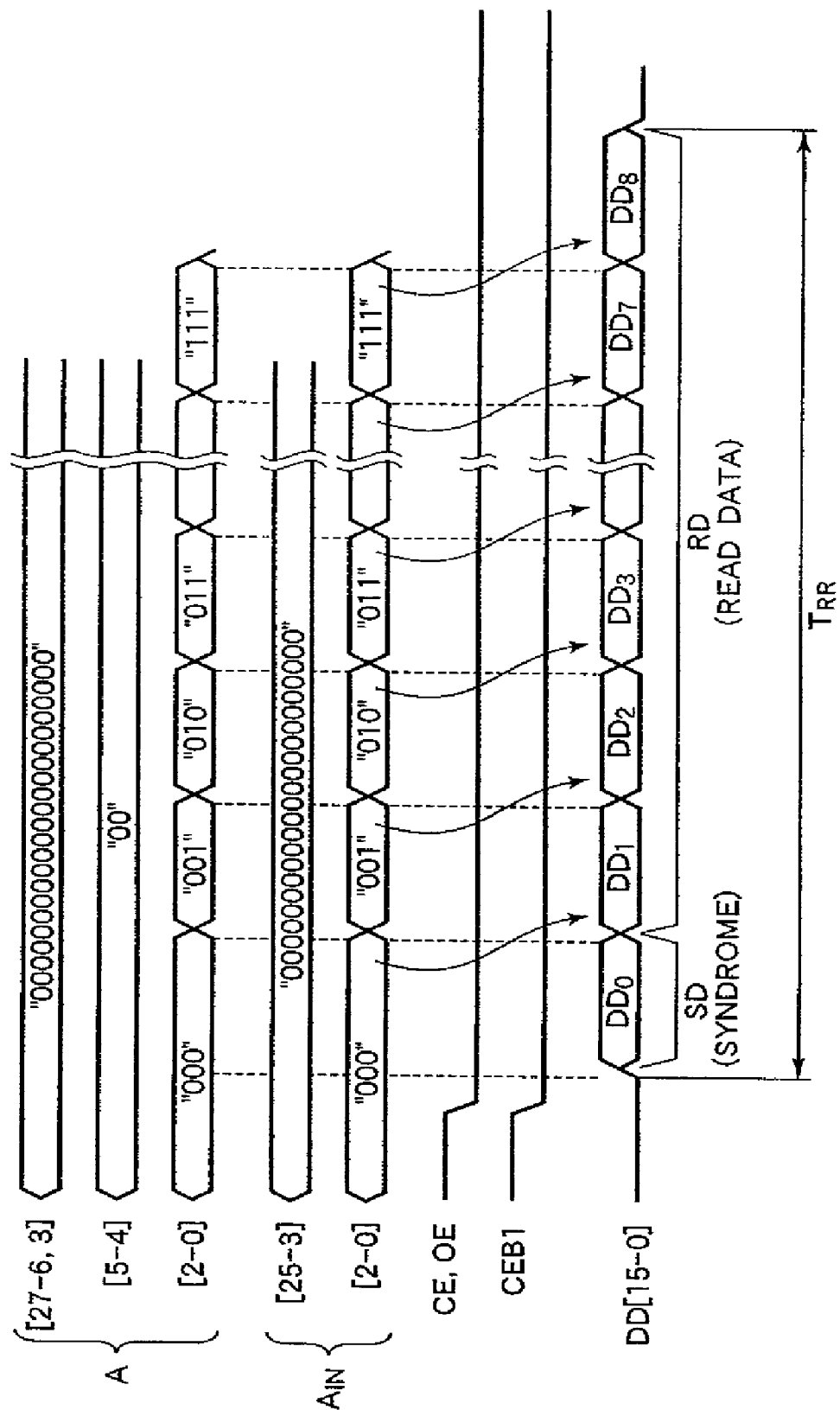


FIG.8

$$H=\begin{bmatrix} \alpha^{192} & \alpha^{186} & \alpha^{143} & \alpha^{142} & \alpha^{140} & \alpha^{139} & \alpha^{138} & \alpha^{136} & \alpha^{135} & \cdots & \alpha^4 & \alpha^3 & \alpha^2 & \alpha & 1 \\ \alpha^{66} & \alpha^{48} & \alpha^{174} & \alpha^{171} & \alpha^{165} & \alpha^{162} & \alpha^{159} & \alpha^{153} & \alpha^{150} & \cdots & \alpha^{12} & \alpha^9 & \alpha^6 & \alpha^3 & 1 \end{bmatrix}$$

FIG. 9

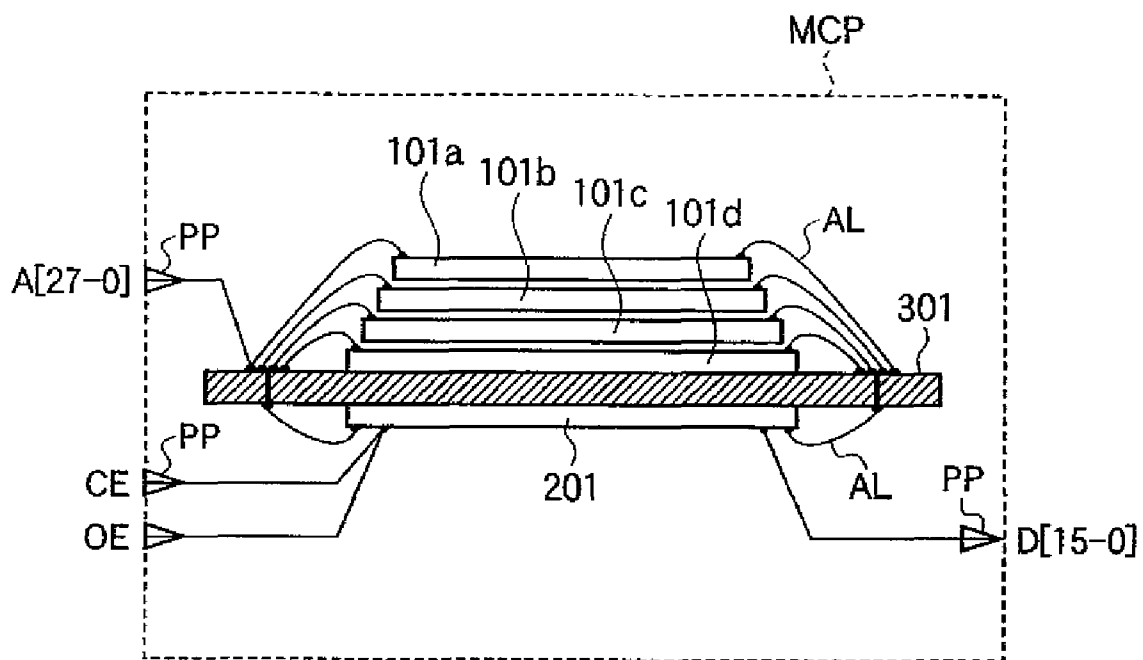


FIG.10

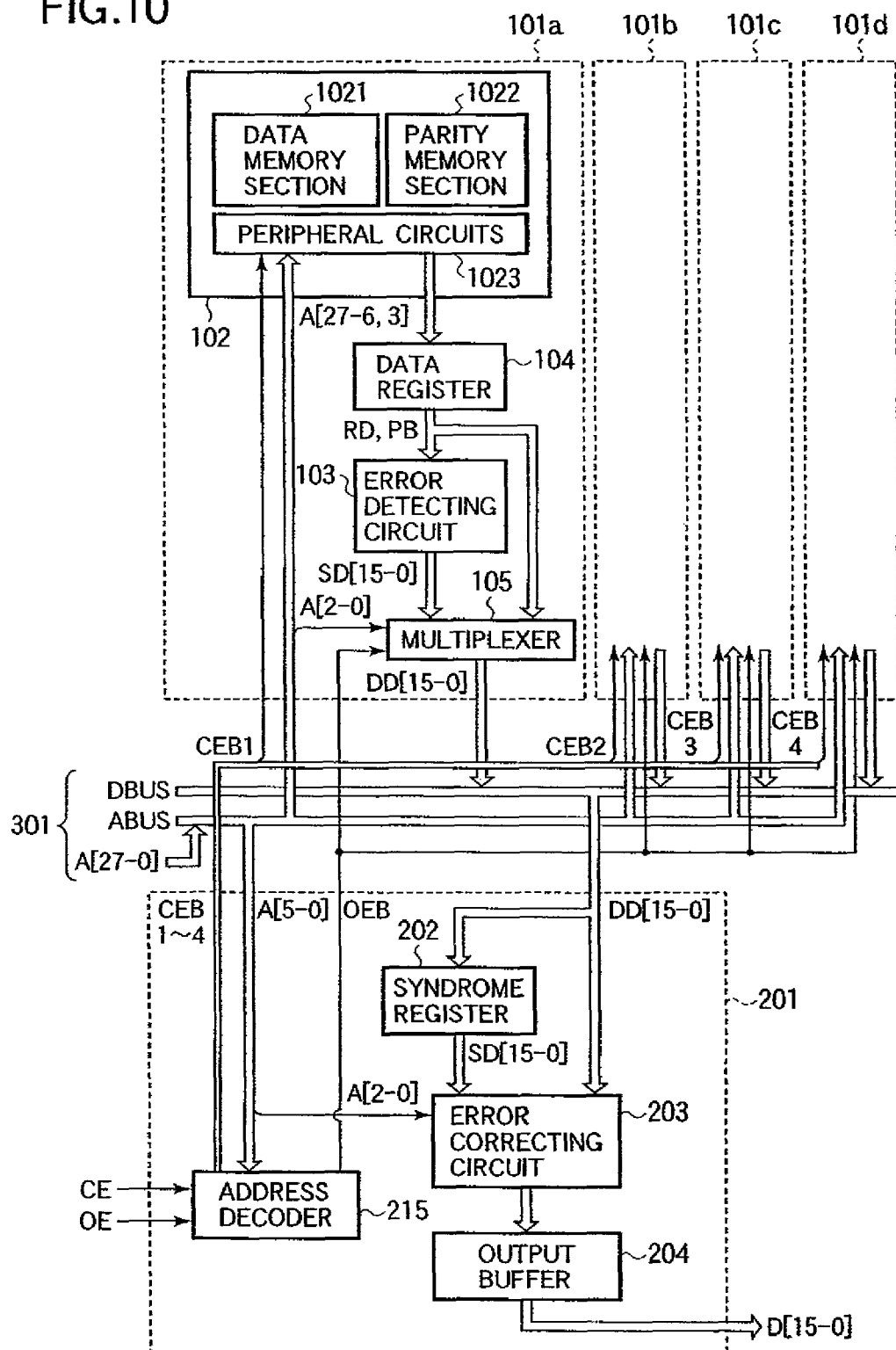


FIG.11

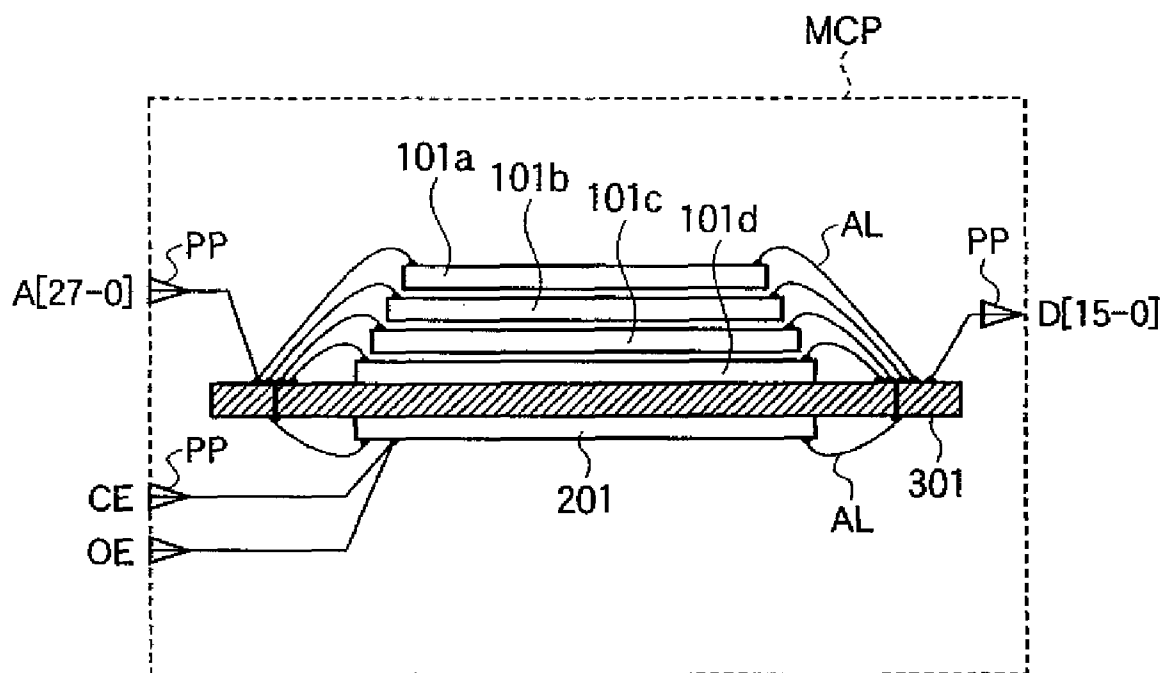
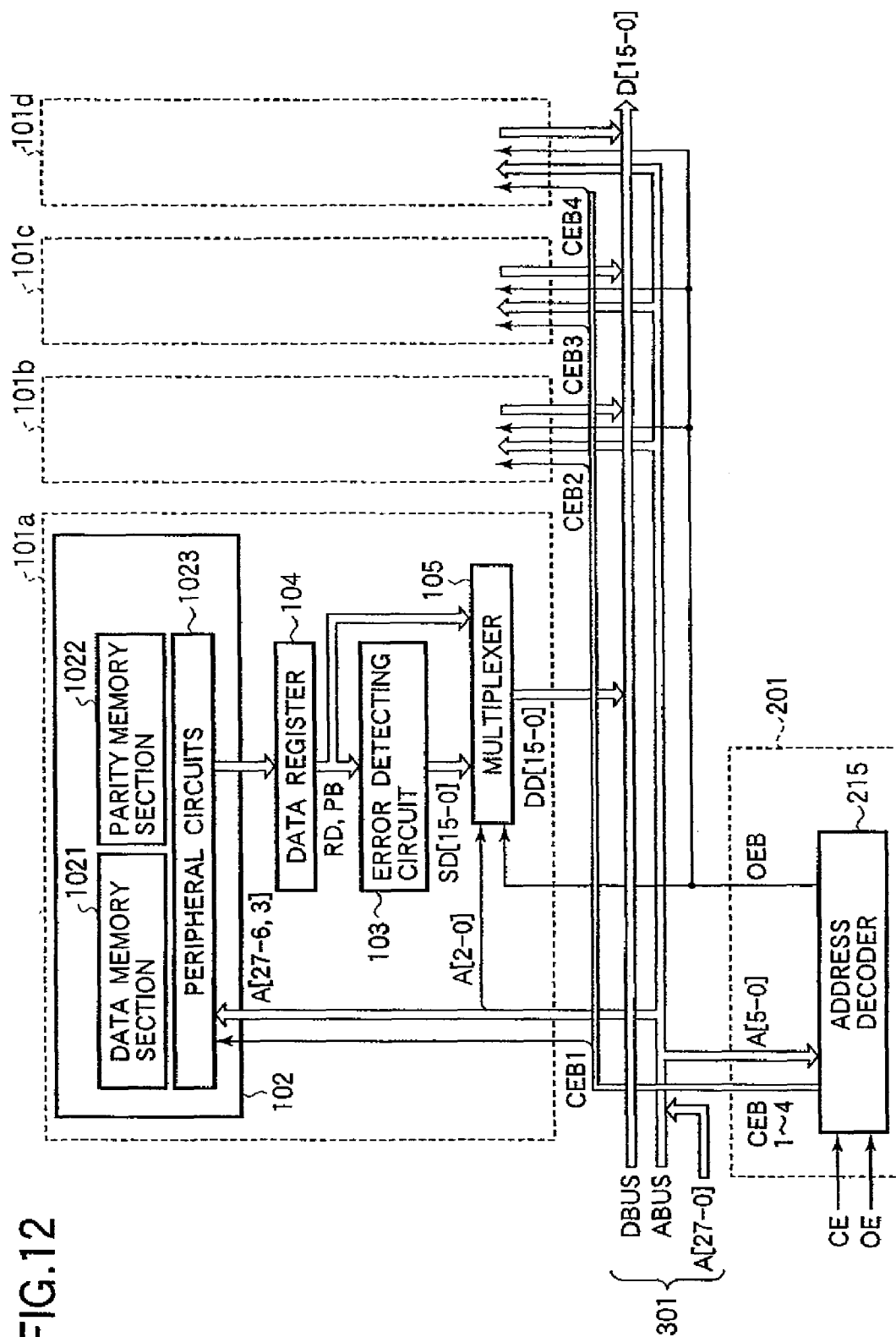


FIG. 12



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MEMORY DEVICE

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is based on and claims priority under 35 U.S.C. §119 from Japanese Patent Application No. 2009-039455, filed Feb. 23, 2009, the disclosure of which is incorporated by reference herein.

RELATED ART

1. Field of the Invention

The present disclosure relates to a semiconductor memory device, more particularly to a semiconductor memory device capable of detecting and correcting data errors.

2. Brief Discussion of Related Art

In the years since memory devices including one or more semiconductor integrated circuit (IC) memory chips and a controller IC chip to control the reading and writing of data in the memory chips were first proposed, such devices have come into widespread use as file systems for personal computers and other electronic devices. To assure the integrity of the data stored in the memory chips, memory chips with encoding and decoding circuits that detect and correct data errors are often used, as described in Japanese Patent Application Publication No. 11-143787. The controller IC chip has similar encoding and decoding circuits that assure integrity of data communication with external devices.

A problem with this configuration is that the encoding and decoding circuits in the memory chips occupy space. In a device with many memory chips, much space is used up by these circuits, increasing the size and cost of the device.

INTRODUCTION TO THE INVENTION

An exemplary objective of the disclosure is to decrease the size and cost of a memory device including one or more memory chips and having facilities for detecting data errors.

A further exemplary objective of the disclosure is to decrease the size and cost of a memory device including one or more memory chips and a memory controller chip and having facilities for detecting and correcting data errors.

The disclosure accordingly provides a novel memory device including at least one memory chip having a memory array for storing data and error correcting information. The memory chip also includes an error detecting circuit for performing a calculation, such as a syndrome calculation, on the data and error correcting information to obtain error detection information indicating the locations of bit errors in the data. A first output circuit outputs uncorrected data and corresponding error detection information from the memory chip.

The uncorrected data and error detection information may also be output from the memory device itself.

Alternatively, the memory device may include a memory controller chip that receives the uncorrected data and error detection information from the memory chip(s). The memory controller chip has an error correcting circuit that uses the error detection information to correct the errors in the uncorrected data and a second output circuit that outputs the corrected data from the memory device.

Placing only the error detecting circuit, instead of both the error detecting circuit and the error correcting circuit, in each memory chip reduces the memory chip size and cost.

When the memory device includes a memory controller chip, placing only the error correcting circuit, instead of both

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the error detecting circuit and the error correcting circuit, in the memory controller chip reduces the size and cost of the memory controller chip.

The data and error correcting information stored in the memory array in each memory chip may be organized into code blocks with a specified read latency time per code block. The first output circuit then outputs both the uncorrected data and the error detection information within the specified read latency time. Performing the error detection calculation in the memory chip(s) within the read latency time enables corrected data to be obtained quickly.

The error correcting information may be structured so that when all '1' bits of data are stored in the memory array, the error correcting bits are also all '1'. This simplifies testing of the memory device.

BRIEF DESCRIPTION OF THE DRAWINGS

Exemplary embodiments of the present disclosure will be described in detail based on the following figures, wherein:

FIG. 1 is a side view of a multiple chip package incorporating an exemplary novel memory device;

FIG. 2 is a functional block diagram of the novel memory device in FIG. 1;

FIG. 3 illustrates the bit and word structure of a code block in the exemplary novel memory device;

FIG. 4 illustrates an exemplary parity checking matrix;

FIG. 5A illustrates the external address signal structure in the exemplary novel memory device;

FIG. 5B illustrates the internal address signal structure in the exemplary novel memory device;

FIG. 6 is a schematic block diagram illustrating the internal structure of the error correcting circuit in FIG. 2;

FIG. 7 is a timing diagram illustrating read access to one code block of data;

FIG. 8 illustrates another exemplary parity checking matrix;

FIG. 9 is a side view of a multiple chip package incorporating another novel memory device;

FIG. 10 is a functional block diagram of the novel memory device in FIG. 9;

FIG. 11 is a side view of a multiple chip package incorporating yet another novel memory device; and

FIG. 12 is a functional block diagram of the novel memory device in FIG. 11.

DETAILED DESCRIPTION

The exemplary embodiments of the present disclosure are described and illustrated below to encompass a semiconductor device and, specifically, a semiconductor memory device capable of detecting and correcting data errors. Of course, it will be apparent to those of ordinary skill in the art that the preferred embodiments discussed below are exemplary in nature and may be reconfigured without departing from the scope and spirit of the present invention. However, for clarity and precision, the exemplary embodiments as discussed below may include optional steps, methods, and features that one of ordinary skill should recognize as not being a requisite to fall within the scope of the present invention.

Referring to the side view in FIG. 1, one embodiment is a novel memory device housed in a multiple chip package (MCP) indicated schematically by a dotted line. The memory device includes four memory chips **101a**, **101b**, **101c**, **101d** mounted one atop another on a substrate **301**, and a single memory controller chip **201** mounted below the substrate **301**. The memory chips **101a**, **101b**, **101c**, **101d** and the

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memory controller chip **201** are electrically connected by metal wires AL to wiring traces (not shown) on the two major surfaces of the substrate **301**. The memory controller chip **201** is electrically connected to the memory chips **101a**, **101b**, **101c**, **101d** by these wiring traces and by metal vias that pass through the substrate **301**. The memory controller chip **201** is also connected to the external package pins PP of the multiple chip package for input of external address signals A[27-0], an external chip enable signal CE, and an external output enable signal OE, and input and output of data signals D[15-0].

Referring to the block diagram in FIG. 2, each of the memory chips **101a**, **101b**, **101c**, **101d** includes a memory array **102**, an error detecting circuit **103**, a data register **104**, and a multiplexer **105** (the first output circuit), as shown for memory chip **101a**. The memory chips **101a**, **101b**, **101c**, **101d** are connected to an address bus ABUS, a data bus DBUS, and a control bus on the substrate **301**. The control bus includes signal lines for four internal chip enable signals CEB1, CEB2, CEB3, CEB4, which are supplied to memory chips **101a**, **101b**, **101c**, **101d**, respectively.

The memory array **102** includes a data memory section **1021** that stores, for example, two gigabits of data, a parity memory section **1022** that stores, for example, 256 megabits of error correcting information referred to as parity bits, and peripheral circuits **1023** that perform read and write access by reading data from and writing data to the data memory section **1021** and parity memory section **1022** at an address indicated by address bits A_{2N}[25-3]. The internal chip enable signals are active at the '0' logic level. Data in the memory array **102** in memory chip **101a** are accessed when CEB1 is active, data in the memory array **102** in memory chip **101b** are accessed when CEB2 is active, data in the memory array **102** in memory chip **101c** are accessed when CEB3 is active, and data in the memory array **102** in memory chip **101d** are accessed when CEB4 is active. In read access, 128 data bits RD and 16 corresponding parity bits PB are read simultaneously from the data memory section **1021** and parity memory section **1022** and stored in the data register **104**.

The data register **104** concatenates the 16 parity bits PB with the 128 read data bits RD and supplies the resulting block of 144 bits (RD+PB) to the error detecting circuit **103** as a code block. The code block consists of nine 16-bit data words DD₁ to DD₉ as shown in FIG. 3. The parity bits are located in the last data word DD₉. The 128 read data bits RD in data words DD₁ to DD₈ are also supplied to the multiplexer **105**.

The error detecting circuit **103** executes a syndrome calculation on the received code block to generate syndrome data SD[15-0] indicating the locations of erroneous bits. If, for example, a Bose-Chaudhuri-Hocquenghem (BCH) code with the generator polynomial

$$P(x)=x^8+x^4+x^3+x^2+x^1$$

is used and the parity bits are generated using the parity checking matrix H shown in FIG. 4, in which α is a primitive root of unity in a Galois field, the error detecting circuit **103** executes a well known calculation based on the polynomial P(x) and the matrix H. The resulting syndrome data can pinpoint the position of up to two bit errors in the code block. The syndrome data SD[15-0] are supplied to the multiplexer **105** as indicated in FIG. 2.

The multiplexer **105** receives an internal output enable signal OEB from the memory controller chip **201**. The internal output enable signal OEB is also active at the '0' logic level. When the internal output enable signal OEB and the corresponding internal chip enable signal CEB1, CEB2, CEB3, or CEB4 are both active, the multiplexer **105** outputs

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nine data words, one at a time, on the data bus DBUS. The first data word DD₀ includes the syndrome data SD[15-0]. The next eight data words DD₁ to DD₈ include the read data RD in the order indicated in FIG. 3, as listed in Table 1.

TABLE 1

Read data words	
DD ₁	code block bits 143-128
DD ₂	code block bits 127-112
DD ₃	code block bits 111-96
DD ₄	code block bits 95-80
DD ₅	code block bits 79-64
DD ₆	code block bits 63-48
DD ₇	code block bits 47-32
DD ₈	code block bits 31-16

These eight data words are selected by internal read data address signals A_{2N}[2-0], which the multiplexer **105** receives from the address bus ABUS.

As shown in FIG. 2, the memory controller chip **201** includes a syndrome register **202**, an error correcting circuit **203**, an output buffer **204** (the second output circuit), and an address decoder **205**. The memory controller chip **201** has output pads for output of the four internal chip enable signals CEB1-CEB4, the internal output enable signal OEB, twenty-six internal address signals A_{2N}[25-0], and sixteen read data signals D[15-0], and for input of the external chip enable signal CE, the external output enable signal OE, the twenty-eight external address signals A[27-0], and sixteen internal read data signals DD[15-0].

The syndrome register **202** stores the first word DD₀ of data output on the data bus DBUS on the substrate **301** during read access, containing the syndrome data SD[15-0], and supplies the syndrome data SD[15-0] to the error correcting circuit **203**.

The address decoder **205** generates the internal output enable signal OEB from the external chip enable signal CE and external output enable signal OE received at the MCP package pins PP. The internal output enable signal OEB is active ('0') when CE and OE are both active, and is inactive ('1') at other times. The internal output enable signal OEB is supplied to all four memory chips **101a**, **101b**, **101c**, **101d**.

While the external output enable signal OE is active, the address decoder **205** also generates the internal chip enable signals CEB1-CEB4 and the internal address signals A_{2N}[25-0] from the external address signals A[27-0], and supplies these signals to the memory chips **101a**, **101b**, **101c**, **101d**.

More specifically, as indicated in FIG. 5A, the address decoder **205** generates the internal chip enable signals CEB1-CEB4 from the fourth and fifth external address signals A[4] and A[5], more compactly denoted A[5, 4]. When, for example, A[5, 4] is '00' (meaning that A[5] is '0' and A[4] is '0'), internal chip enable signal CEB1 is activated (driven to the '0' logic level) and supplied through the substrate **301** to enable memory chip **101a**. Similarly when A[5, 4] is '01', internal chip enable signal CEB2 is activated and supplied through the substrate **301** to enable memory chip **101b**; when A[5, 4] is '10', internal chip enable signal CEB3 is activated and supplied through the substrate **301** to enable memory chip **101c**; and when A[5, 4] is '11', internal chip enable signal CEB4 is activated and supplied through the substrate **301** to enable memory chip **101d**.

The address decoder **205** uses the other external address signals A[27-6] and A[3-0] to generate the internal address signals A_{2N}[25-0]. The twenty-two most significant external address bits A[27-6] become the twenty-two most significant

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internal address signals $A_{IN}[25-4]$ and the four least significant external address bits $A[3-0]$ become the four least significant internal address bits $A_{IN}[3-0]$. The three least significant internal and external address bits $A_{IN}[2-0]$ and $A[2-0]$ form a read data address that selects one of the eight data words DD_1 - DD_8 in Table 1, as indicated in FIGS. 5A and 5B. The other address signals $A_{IN}[25-3]$, or $A[27-6]$ and $A[3]$, form a code block address. The internal address signals $A_{IN}[25-0]$ are supplied to the memory chips **101a** to **101d** via the address bus ABUS on the substrate **301**.

The address decoder **205** supplies the internal read data address signals $A_{IN}[2-0]$ to the error correcting circuit **203**.

Referring to the schematic block diagram in FIG. 6, the error correcting circuit **203** includes an error locating circuit **206**, an error correcting table memory **207**, and an exclusive logical OR circuit **208**. The exclusive logical OR circuit **208** includes sixteen parallel one-bit exclusive logical OR gates (EX-OR gates).

The error correcting table memory **207** stores error position information indicating, for each possible bit pattern of the sixteen syndrome data bits $SD[15-0]$, the corresponding positions of errors in the 144-bit code block (RD+PB).

The error locating circuit **206** receives the syndrome data $SD[15-0]$, reads the corresponding error position information from the error correcting table memory **207**, and generates 144 bits of corrective data QD in which a '1' bit indicates the position of an error and a '0' bit indicates a position that is error-free. The error locating circuit **206** then uses the internal read data address signals $A_{IN}[2-0]$ to select the sixteen QD bits corresponding to the sixteen bits of read data $DD[15-0]$ in one of data words DD_1 to DD_8 . For example, if internal address signals $A_{IN}[2-0]$ indicate data word DD_2 , consisting of bits **127-112** in the 144-bit code block (RD+PB), the error locating circuit **206** selects bits **127-112** of the corrective data QD. The sixteen selected bits of corrective data are output to the exclusive logical OR circuit **208** as a corrective data word CD.

The exclusive logical OR circuit **208** also receives the sixteen-bit word of read data $DD[15-0]$ currently output on the data bus DBUS, performs a bit-wise exclusive OR operation on the read data word $DD[15-0]$ and the corrective data word CD, and outputs the resulting word of corrected data $D[15-0]$ to the output buffer **204**. If the read data word $DD[15-0]$ is error-free, then all bits of the corrective word CD are '0' and the corrected data word $D[15-0]$ is identical to the read data word $DD[15-0]$. If there is an error in the read data word $DD[15-0]$, the corresponding bit in the corrective data word CD is set to '1', so the exclusive OR operation inverts the erroneous data bit, thereby correcting the error.

Read access to the 128 bits of read data RD stored at addresses '0000000' to '0000008' (in hexadecimal address notation) is illustrated in FIG. 7. The external address signals $A[27-0]$ are originally all zero (hexadecimal '0000000'). In binary notation, the code block address $A[27-6, 3]$ consisting of address signals $A[27-6]$ and $A[3]$ is '000000000000000000000000', the memory chip address $A[5, 4]$ is '00', indicating memory chip **101a**, and the read data address $A[2-0]$ is '000', selecting read data word DD_1 , as indicated at the top of FIG. 7. From $A[27-6, 3]$ and $A[2-0]$, the address decoder **205** generates a corresponding internal code block address $A_{IN}[25-3]$ and read data address $A_{IN}[2-0]$, all bits of which are likewise '0'. Since the memory chip address signals $A[5, 4]$ are '00', when the external chip enable signal CE and output enable signal OE are activated by being driven to the low ('1') logic level, the address decoder **205** activates internal chip enable signal CEB1 by driving it also to the low ('0') logic level.

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In memory chip **101a**, the 144-bit code block stored at the address '000000000000000000000000' given by internal address signals $A_{IN}[25-3]$, including 128 data bits (RD) and 16 parity bits (PB), is read from the memory array **102** into the data register **104**. The error detecting circuit **103** performs a syndrome calculation on the 144 bits in the data register **104** and sends the resulting word of syndrome data $SD[15-0]$ to the multiplexer **105**. The multiplexer **105** outputs the syndrome data $SD[15-0]$ on the data bus DBUS as read data $DD[15-0]$, more specifically as data word DD_0 , as shown at the bottom of FIG. 7. This data word DD_0 is received by the memory controller chip **201** and stored in the syndrome register **202**. The error correcting circuit **203** generates corrective data QD from the syndrome data $SD[15-0]$ in word DD_0 .

Next, while the external and internal read data address signals $A[2-0]$ and $A_{IN}[2-0]$ are still '000', the multiplexer **105** takes the first read data word DD_1 , consisting of read data bits **143-128** as shown in FIG. 3, from the data register **104** and places it on the data bus DBUS as read data $DD[15-0]$. In the memory controller chip **201**, the error correcting circuit **203** receives this word DD_1 from the data bus DBUS, corrects it as described above, and outputs the corrected data $D[15-0]$ to the output buffer **204**. The output buffer **204** outputs the corrected data $D[15-0]$ to the package pins of the multiple chip package.

When the multiplexer **105** in memory chip **101a** places the first read data word DD_1 on the data bus DBUS, data address signals $A[2-0]$ and $A_{IN}[2-0]$ change from '000' to '001', causing the multiplexer **105** to take the second read data word DD_2 (bits **127-112**) from the data register **104**. After the first data word DD_1 has been corrected by the error correcting circuit **203** and sent to the output buffer **204**, the multiplexer **105** places the second data word DD_2 on the data bus DBUS. The error correcting circuit **203** in the memory controller chip **201** receives this word DD_2 , corrects it as described above, and outputs the corrected data $D[15-0]$ to the output buffer **204**, replacing the corrected data of the first read data word DD_1 . The output buffer **204** outputs the corrected data to the package pins.

While the data in the second read data word DD_2 are being corrected and output, data address signals $A[2-0]$ and $A_{IN}[2-0]$ change to '010', and the third read data word DD_3 (bits **111-96**) is accessed in the same way, being taken from the data register **104** by the multiplexer **105** in memory chip **101a**, then output on the data bus DBUS, received by the error correcting circuit **203** in the memory controller chip **201**, corrected, sent to the output buffer **204**, and output from the memory device.

Access continues in this way as the read data address signals $A[2-0]$ change successively from '011' to '111', causing successive output of the corrected data $D[15-0]$ for data words DD_4 to DD_8 (bits **95-16** of the read data RD). At the conclusion of this operation, 128 bits of corrected data have been output from the 144-bit code block stored at hexadecimal address '0000000' in memory chip **101a**. The total time during which the syndrome data and read data are being transferred from the memory chip to the memory controller chip **201** is within the read latency time T_{RR} specified for the memory chips.

The data stored in other code blocks in memory chip **101a** and the data stored in the other memory chips **101b**, **101c**, **101d** are accessed similarly.

An advantage of this novel memory device is that while each memory chip **101a**, **101b**, **101c**, **101d** has an error detecting circuit **103**, only the memory controller chip **201** has an error correcting circuit **203**. Compared with conventional memory devices in which each memory chip has both

an error detecting circuit and an error correcting circuit, a significant amount of space is saved by placing an error correcting circuit **203** only in the memory controller chip **201**. The amount of space saved increases as the number of memory chips in the memory device increases. This saving in space is achieved without any loss of performance because the syndrome calculation, which requires access to all 144 bits of data in a code block, is carried out in the memory chips, where all 144 bits are available at once in the data register **104**.

Another advantage of the novel memory device is that since the error detecting circuits **103** and the error correcting circuit **203** are in separate chips, each of these chips can be smaller than would be possible if both the error detecting circuit and error correcting circuit were placed in the same chip.

In a variation of the embodiment described above, the parity checking matrix H in FIG. 4 is replaced by the parity checking matrix H shown in FIG. 8. The code blocks are generated by using this checking matrix H and the generator polynomial P(x) given above:

$$P(x)=x^8+x^4-x^3+x^2+x^1$$

An advantage of the parity checking matrix H in FIG. 8 is that if all 128 bits of read data RD in a code block have the '1' logic level, then all 16 bits of parity data PB in the same code block also have the '1' logic level. Conversely, if all 128 bits of read data RD in a code block have the '0' logic level, then all 16 bits of parity data PB in the same code block also have the '0' logic level. This greatly simplifies the pre-shipment inspection of the memory device. A pre-shipment inspection is carried out by writing a test pattern, such as a pattern in which all bits in both the data memory section **1021** and the parity memory section **1022** are '1' (or all bits are '0'), or a checkerboard pattern of '1' and '0' bits, into the memory device, and then reading the written data. With the parity checking matrix in FIG. 8, in the initial or erased state, for example, in which all bits are '1', the device can be tested simply by reading all of its data; it is not necessary to derive the parity bit values for 128 bits of all '1' data and then write these parity bit values separately into the parity memory section **1022** in advance.

Referring to FIGS. 9 and 10, in another variation of the embodiment described above, the external address signals A[27-0] are supplied directly from the package pins PP of the multiple chip package MCP to the address bus ABUS on the substrate **301**, instead of being supplied to the address bus through the address decoder in the memory controller chip **201**. The peripheral circuits **1023** in the memory chips **101a** to **101d** take twenty-six address signals A[27-6, 3] from the address bus ABUS. The multiplexer **105** in the memory chips **101a** to **101d** and the error correcting circuit **203** in the memory controller chip **201** take three address signals A[2-0] from the address bus ABUS. These circuits operate as described above. The address decoder **215** in the memory controller chip **201** receives the external chip enable signal CE and external output enable signal OE, takes address signals A[5-0] from the address bus, and generates the internal chip enable signals CEB1-CEB4 and the internal output enable signal OEB as described above.

Compared with the memory device shown in FIGS. 1 and 2, the memory device in FIGS. 9 and 10 permits higher speed read access because address signals A[27-6, 3] reach the memory arrays **102** directly from the package pins PP, without undergoing a propagation delay in the address decoder. In FIG. 7, the read cycle and accordingly the read latency time T_{RR} can be shortened.

In another variation of the embodiment described above, the number of memory chips is altered from four to some other number. The embodiment(s) can be practiced in any memory device having one memory controller chip and at least one memory chip mounted on the same substrate.

The memory controller chip and the memory chip(s) do not have to be mounted on opposite sides or the substrate. Memory chips may be distributed on both sides of the substrate. Alternatively, the memory controller chip and all the memory chips may be mounted on the same side of the substrate.

The disclosure is not limited to the use of a BCH error correcting code. For example, a Hamming code may be used instead.

The disclosure is not limited to 144-bit code blocks with 128 data bits and 16 parity bits. The code blocks may have other numbers of data bits and parity bits.

The error correcting circuit **203** and the other parts of the memory controller chip **201** do not have to be located on the same chip. The error correcting circuit **203** may be located on a separate chip, or in a separate package.

This last variation is illustrated in FIGS. 11 and 12. As in FIGS. 9 and 10, the external address signals A[27-0] are supplied from the package pins PP directly to the address bus ABUS on the substrate **301**. The four memory chips **101a** to **101d** have the same configuration as in FIG. 10. The memory controller chip **201** consists only of an address decoder **215** similar to the address decoder **215** in FIG. 10, which generates the internal chip enable signals CEB1-CEB4 and the internal output enable signal OEB. The data bus DBUS is connected directly to the package pins PP. The data D[15-0] output from the memory device are accordingly the uncorrected read data and the syndrome data placed on the data bus DBUS by the multiplexer **105** in each memory chip. An external device (not shown) receives both the syndrome data and the uncorrected read data from the package pins, and uses the syndrome data to correct the read data. The external device should have a syndrome register and an error correcting circuit.

Following from the above description and disclosure summaries, it should be apparent to those of ordinary skill in the art that, while the methods and apparatuses herein described constitute exemplary embodiments of the present disclosure, the invention contained herein is not limited to this precise embodiment and that changes may be made to such embodiments without departing from the scope of the invention as defined by the claims. Additionally, it is to be understood that the invention is defined by the claims and it is not intended that any limitations or elements describing the exemplary embodiments set forth herein are to be incorporated into the interpretation of any claim element unless such limitation or element is explicitly stated. Likewise, it is to be understood that it is not necessary to meet any or all of the identified advantages or objects of the disclosure in order to fall within the scope of any claims, since the invention is defined by the claims and since inherent and/or unforeseen advantages of the present invention may exist even though they may not have been explicitly discussed herein.

What is claimed is:

1. A memory device including at least one memory chip having a memory array for storing data and error correcting information, wherein the memory chip includes:

an error detecting circuit for performing a calculation on the stored data and the stored error correcting information to obtain error detection information indicating locations of bit errors in the stored data; and

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a first output circuit that outputs, from the memory chip, uncorrected data read from the memory array and corresponding error detection information calculated by the error detecting circuit, indicating the locations of bit errors in the uncorrected data.

2. The memory device of claim 1, wherein the data and the error correcting information stored in the memory array are organized into code blocks, a read latency time is specified for the data in each code block, and the first output circuit outputs both the uncorrected data and the error detection information of each code block within the specified read latency time.

3. The memory device of claim 1, wherein if the data stored in the memory array are all '1' bits, the error correcting information stored in the memory array is also all '1' bits.

4. The memory device of claim 1, wherein the error detecting circuit performs a syndrome calculation to generate the error detection information.

5. The memory device of claim 1, wherein the first output circuit is a multiplexer that multiplexes the error detection information with the uncorrected data.

6. The memory device of claim 1, wherein the uncorrected data and the error detection information are output from the memory device.

7. The memory device of claim 6, further including a package with package pins from which the uncorrected data and the error detection information are output.

8. The memory device of claim 7, further including a substrate on which the at least one memory chip is mounted, the substrate having a data bus to which the first output circuit of the at least one memory chip and the package pins of the package are electrically connected.

9. The memory device of claim 8, wherein the package is a multiple chip package.

10. The memory device of claim 1, further including a memory controller chip that receives the uncorrected data and

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the error detection information from the at least one memory chip, the memory controller chip having:

an error correcting circuit for correcting the errors in the uncorrected data by using the error detection information to generate corrected data; and

a second output circuit for output of the corrected data from the memory device.

11. The memory device of claim 10, wherein the error correcting circuit includes:

an error correcting table memory storing error location patterns corresponding to the error detection information;

an error locating circuit for reading an error location pattern stored in the error correcting table memory, corresponding to the error detection information received from the first output circuit; and

a logic circuit for performing a bit-wise exclusive logical operation on the error location pattern read by the error locating circuit and the uncorrected data received from the first output circuit.

12. The memory device of claim 10, further including a substrate on which the memory controller chip and the at least one memory chip are mounted, the substrate having a data bus to which the first output circuit of the at least one memory chip and the error correcting circuit of the memory controller chip are electrically connected.

13. The memory device of claim 12, further including a package with package pins from which the corrected data are output, the package pins being electrically connected to the second output circuit.

14. The memory device of claim 13, wherein the package is a multiple chip package.

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