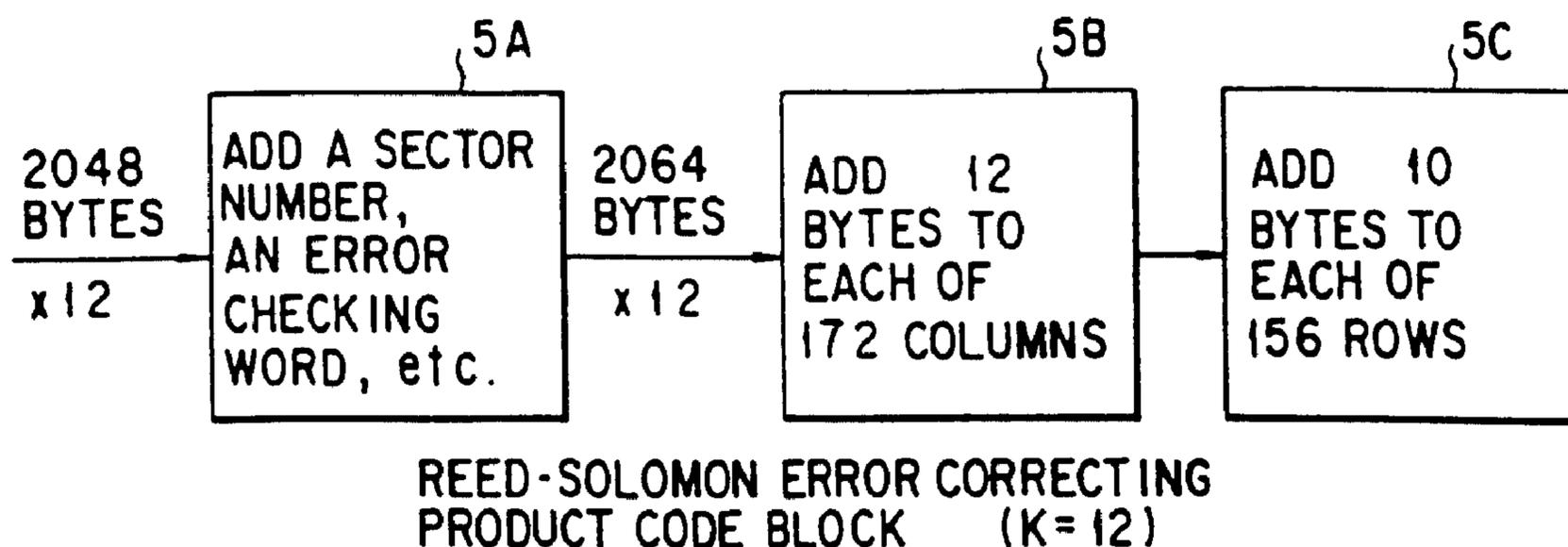


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(54) **METHODES DE TRAITEMENT DE DONNEES PERMETTANT DE GENERER UN BLOC DE CODE PRODUIT AUTOCORRECTEUR ET D'ENREGISTRER CES DONNEES SUR SUPPORT, ET DISPOSITIF DE TRAITEMENT DE DONNEES ASSOCIE**

(54) **METHOD AND APPARATUS FOR GENERATING, RECORDING AND TRANSMITTING AN ERROR PRODUCT CODE BLOCK HAVING AN IMPROVED CHECK CODE ARRANGEMENT**



(57) There is provided a method of processing data for generating an error correction product code block devised so as to maintain the current level of redundancy after the error correcting ability is modified as a result of advancement of semiconductor and data recording/transmission technologies. Unlike any known technique of configuring a Reed-Solomon error correcting product code block of $(M+PO) \times (N+PI)$ bytes for an information data of $(M \times N)$ bytes, an error correcting product code block data structure is obtained by configuring a $(K \times (M+1) \times (N+P))$ -byte Reed-Solomon error correcting product code block for $(K \times M \times N)$ -byte data, making K variable to consequently make the entire size of the Reed-Solomon error correcting product code block variable. At the same time, the error correcting ability varies in proportion to the value of K without increasing redundancy.

Abstract

There is provided a method of processing data for generating an error correction product code block devised so as to maintain the current level of redundancy after the error correcting ability is modified as a result of advancement of semiconductor and data recording/transmission technologies. Unlike any known technique of configuring a Reed-Solomon error correcting product code block of $(M+P_0) \times (N+P_1)$ bytes for an information data of $(M \times N)$ bytes, an error correcting product code block data structure is obtained by configuring a $(K \times (M+1) \times (N+P))$ -byte Reed-Solomon error correcting product code block for $(K \times M \times N)$ -byte data, making K variable to consequently make the entire size of the Reed-Solomon error correcting product code block variable. At the same time, the error correcting ability varies in proportion to the value of K without increasing redundancy.

METHOD AND APPARATUS FOR GENERATING, RECORDING AND
TRANSMITTING AN ERROR PRODUCT CODE BLOCK HAVING AN
IMPROVED CHECK CODE ARRANGEMENT

BACKGROUND OF THE INVENTION

5 Field of the Invention

This invention relates to a method of configuring an error correcting product code block adapted for use for digital data recording/transmission and, more particularly, it relates to a method of processing data for generating an error correcting product code block
10 devised so as not to change the level of redundancy after the error correcting ability is modified. The present invention also relates to a method of processing data for recording such data on a recording medium as well as to an apparatus for processing such data.
15

2. Description of the Related Art

In a system for recording digital data by using byte unit, which is equal to eight bits, data are processed by configuring Reed-Solomon error correcting product code
20 blocks. More specifically, after arranging data of (MxN) bytes in M rows x N columns, a P₀-byte error correcting check word is added to the N-byte information section of each column and then a P₁-byte error correcting check word is added to the N-byte information section of each
25 row to produce a Reed-Solomon error correcting product code block comprising (M+P₀) rows x (N+P₁) columns. Then, random errors and burst errors can be efficiently corrected on the data reproducing side or the data receiving side by means of the Reed-Solomon error
30 correcting product code blocks that are recorded and transmitted.

A Reed-Solomon error correcting product code block as described above operates efficiently when the redundancy is large or the ratio of the redundant section
35 of the error correcting check word (P₁xM+P₀xN+P₁xP₀) to

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the entire code word $(M+P_0) \times (N+P_1)$ is small. On the other hand, its error correcting ability is raised for both random errors and burst errors when large values are used for P_1 and P_0 .

5 It is known that, when different Reed-Solomon error correcting product code blocks having a same level of redundancy are compared, those having small M , N , P_1 and P_0 are poorly adapted for error correcting because the probability of occurrence of error correction rises with
10 such code blocks.

On the other hand, while it is also known that the error correcting ability of a Reed-Solomon error correcting product code block is raised by increasing the values of M and N because the values of P_1 and P_0 are
15 also increased accordingly, if the redundancy is held to a same level, such high error correcting ability cannot be realized without satisfying requirements as will be described below.

Firstly, in terms of code word length that allows a
20 Reed-Solomon code word to be configured, $M+P_0$ and $N+P_1$ have to be equal to or less than 255 bytes.

Secondly, there is a hardware cost restriction to be observed. Specifically, it is expressed typically in terms of the cost of the operational circuit and that of
25 the memory for storing the entire code word or $(M+P_0) \times (N+P_1)$ bytes. Since the cost of a memory can change with the development of semiconductor technology, it is highly desirable to make the above described parameters of M , N , P_1 and P_0 of Reed-Solomon error
30 correcting product code block variable as a function of the advancement of semiconductor technology and, particularly, the reduction in the cost of a memory.

This is because a same error in a physical length or a time length is translated into a larger burst of error
35 bytes as the density in which data are recorded on a medium or the rate at which data are transmitted through a transmission path is raised in accordance with the

advancement of semiconductor technology, so that a higher error correcting ability becomes necessary.

Conventionally, however, a Reed-Solomon error correcting product code block having $(M+P_0) \times (N+P_1)$ bytes is configured for a given data of $(M \times N)$ bytes so that
5 redundancy is automatically set as a function of the entire size of the product code block. In other words, any attempt for maintaining a given level of error correcting ability is accompanied by a problem of
10 invariable block size.

However, as a higher recording density and a higher transmission rate are expected with the advancement of semiconductor technology in the future, a much higher level of error correcting ability will be required for an
15 error correcting product code block of a given size. This in turn requires the use of a large error correcting check word, which entails an enhanced level of redundancy if conventional technology is used.

SUMMARY OF THE INVENTION

20 The present invention provides a method of processing data for generating an error correcting product code block devised so as to maintain the current level of redundancy after the error correcting ability is improved as a result of advancement of semiconductor and
25 data recording/transmission technologies. The present invention also provides a method of processing data for recording such data on a recording medium as well as to an apparatus for processing such data.

30 According to the invention, there is provided a method of processing data by generating an error correcting product code block, comprising:

first, processing digital data on a byte by byte basis to configure an information data block of a plurality of information data blocks of $(M \times N)$ bytes of M
35 rows \times N columns, permitting data to exist on the byte by byte basis in the information data block and

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permitting the data in each row to exist sequentially from a 0th to a (N-1)-th column according to a sequence of data transmission and sequentially from a 0th to a (M-1)-th row according to the sequence of data

5 transmission;

second, providing a matrix block of (KxM) rows x N columns by using K of the information data blocks arranged sequentially according to the sequence of data transmission;

10 third, adding a first error correcting check word of K bytes to each column of (KxM) bytes of the matrix block to turn each of the N columns into a Reed-Solomon code word C2 of (Kx(M+1)) bytes, the error correcting check word of K bytes existing on a byte by byte basis at
15 a position corresponding to every M bytes of information data; and

fourth, adding a second error correcting check word of P bytes to each row of N bytes to turn each of the (Kx(M+1)) rows into a Reed-Solomon code word C1 of (N+P)
20 bytes, wherein:

the error correcting product code block is a Reed-Solomon error correcting product code block of (Kx(M+1)x(N+P)) bytes having an information section of K of the information data blocks of (KxMxN) bytes, and

25 a sum of (MxN) bytes of an information data block and an average number of bytes of a check word added thereto are held to a constant value of (M+1)x(N+P) bytes.

30 With the above method, the sum of (MxN) bytes of an information data block and the average number of bytes of a check word added thereto is held to a constant value of (M+1)x(N+P) that is not dependent on the number of information data blocks, or K, of the error correcting product code block and hence the level of redundancy of
35 the (M+1)x(N+P) bytes is maintained invariable.

According to the invention, there is also provided a recording medium comprising an error correcting product

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code block recorded thereon wherein data is processed and the error correcting product block code is generated by a method comprising:

first, processing digital data on a byte by byte basis to configure an information data block of a plurality of information data blocks of $(M \times N)$ bytes of M rows \times N columns, permitting data to exist on a byte by byte basis in the information data block and permitting the data in each row to exist sequentially from a 0.^{sup}.th to a $(N-1)$ -th column according to a sequence of data transmission and sequentially from a 0.^{sup}.th to a $(M-1)$ -th row according to the sequence of data transmission;

second, producing a matrix block of $(K \times M)$ rows \times N columns by using K of the information data blocks arranged sequentially according to the sequence of data transmission;

third, adding a first error correcting check word of K bytes to each column of $(K \times M)$ bytes of the matrix block to turn each of the N columns into a Reed-Solomon code word C_2 of $(K \times (M+1))$ bytes, the error correcting check word of K bytes existing on a byte by byte basis at a position corresponding to every M bytes of information data; and

fourth, adding a second error correcting check word of P bytes to each row of N bytes to turn each of the $(K \times (M+1))$ rows into a Reed-Solomon code word C_1 of $(N+P)$ bytes, wherein:

the error correcting product code block is a Reed-Solomon error correcting product code block of $(K \times (M+1) \times (N+P))$ bytes having an information section of K of the information data blocks of $(K \times M \times N)$ bytes, and a sum of $(M \times N)$ bytes of an information data block and an average number of bytes of a check word added thereto are held to a constant value of $(M+1) \times (N \times P)$ bytes.

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In a further aspect, the present invention provides a data processing apparatus comprising:

means for processing digital data on a byte by byte basis to configure an information data block of a plurality of information data blocks by $(M \times N)$ bytes of M rows \times N columns;

means for arranging the digital data on a byte by byte basis in the information data block and arranging the digital data in each row sequentially from a 0.^{sup}.th to a $(N-1)$ -th column according to a sequence of data transmission and sequentially from a 0.^{sup}.th to a $(M-1)$ -th row according to the sequence of data transmission;

means for arranging a matrix block of $(K \times M)$ rows \times columns by using K of the information data blocks arranged sequentially according to the sequence of data transmission;

means for adding a first error correcting check word of K bytes to each column of $(K \times M)$ bytes of the matrix block to turn each of the N rows into a Reed-Solomon code word C_2 of $(K \times (M+1))$ bytes; and

means for adding a second error correcting check word of P bytes to each row of N bytes to turn each of the $(K \times (M+1))$ rows into a Reed-Solomon code word C_1 of $(N+P)$ bytes, wherein:

the error correcting product code block is a Reed-Solomon error correcting product code block of $(K \times (M+1) \times (N+P))$ bytes having an information section of K of the information data blocks of $(K \times M \times N)$ bytes, and a sum of $(M \times N)$ bytes of an information data block and an average number of bytes of a check word added thereto being held to a constant value of $(M+1) \times (N+P)$ bytes.

In a further aspect, the present invention provides a recording medium comprising an error correcting product code block recorded thereon, the error correcting product code block being configured by:

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processing digital data on a byte by byte basis to configure an information data block of a plurality of information data blocks by $(M \times N)$ bytes of M rows \times N columns;

5 permitting the digital data to exist on a byte by byte basis in the information data block and permitting the digital data in each row to exist sequentially from a 0.^{sup}.th to a $(N-1)$ th column according to a sequence of data transmission and sequentially from a 0.^{sup}.th to a
10 $(M-1)$ -th row according to the sequence of data transmission;

 permitting a matrix block of $(K \times M)$ rows \times N columns to exist, the matrix block including K of the information data blocks arranged sequentially according to the
15 sequence of data transmission;

 adding a first error correcting check word of K bytes to each column of $(K \times M)$ bytes of the matrix block to turn each of the N columns into a Reed-Solomon code word C_2 of $(K \times (M+1))$ bytes, the first error correcting
20 check word of K bytes existing on the byte by byte basis at a position corresponding to every M bytes of information data;

 adding a second error correcting check word of P bytes to each row of N bytes to turn each of the
25 $(K \times (M+1))$ rows into a Reed-Solomon code word C_1 of $(N+P)$ bytes, wherein:

 the error correcting product code block is a Reed-Solomon error correcting product code block of
 $(K \times (M+1) \times (N+P))$ bytes having an information section of K
30 of the information data blocks of $(K \times M \times N)$ bytes,

 a sum of $(M \times N)$ bytes of an information data block and an average number of bytes of a check word added thereto are held to a constant value of $(M+b-1) \times (N+P)$ bytes.

35 In a still further aspect, the present invention provides a transmission apparatus for transmitting data, comprising:

means for permitting an information data block of a plurality of information data blocks to comprise $(M \times N)$ bytes of M rows \times N columns;

means for permitting the data to exist on a byte by byte basis in the information data block and permitting the data in each row to exist sequentially from a 0.sub.th to a $(N-1)$ -th column according to a sequence of data transmission and sequentially from a 0.sup.th to a $(M-1)$ -th row according to the sequence of data transmission;

means for permitting a matrix block of $(K \times M)$ rows \times N columns to exist, the matrix block including K of the information data blocks arranged sequentially according to the sequence of data transmission;

means for adding a first error correcting check word of K bytes to each column of $(K \times M)$ bytes of the matrix block to turn each of the N columns into a Reed-Solomon code word C_2 of $(K \times (M+1))$ bytes, the first error correcting check word of K bytes existing on the byte by byte basis at a position corresponding to every M bytes of information data;

means for adding a second error correcting check word of P bytes to each row of N bytes to turn each of the $(K \times (M+1))$ rows into a Reed-Solomon code word C_1 of $(N+P)$ bytes, wherein:

the error correcting product code block is a Reed-Solomon error correcting product code block of $(K \times (M+1) \times (N+P))$ bytes having an information section of K of the information data blocks of $(K \times M \times N)$ bytes, and a sum of $(M \times N)$ bytes of an information data block and an average number of bytes of a check word added thereto are held to a constant value of $(M+1) \times (N+P)$ bytes.

In a still further aspect, the present invention provides a method of processing data by generating an error correcting product code block, comprising:

processing digital data on a byte by byte basis to
configure an information data block of a plurality of
information data blocks of $(M \times N)$ bytes of M rows \times N
columns, permitting data to exist on the byte by byte
5 basis in the information data block and permitting the
data in each row to exist sequentially from a 0-th to a
 $(N-1)$ -th column according to a sequence of data
transmission and sequentially from 0th to a $(M-1)$ -
th row according to the sequence of data transmission;
10 providing a matrix block of $(K \times M)$ rows \times N columns
by using K of the information data blocks arranged
sequentially according to the sequence of data
transmission;

adding a first error correcting check word of K
15 bytes to each column of $(K \times M)$ bytes of the matrix block
to turn each of the N columns into a Reed-Solomon code
word C_2 of $(K \times (M+1))$ bytes, the error correcting check
word of K bytes existing on a byte by byte basis at a
position corresponding to every M bytes of information
20 data; and

adding a second error correcting check word of P
bytes to each row of N bytes to turn each of the
 $(K \times (M+1))$ rows into a Reed-Solomon code word C_1 of $(N+P)$
bytes wherein:

25 the error correcting product code block is a Reed-
Solomon error correcting product code block of
 $(K \times (M+1) \times (N+P))$ bytes having an information section of K
of the information data blocks of $(K \times M \times N)$ bytes, and
a sum of $(M \times N)$ bytes of an information data block
30 and an average number of bytes of a check word added
thereto are held to a constant value of $(M+1) \times (N+P)$
bytes.

In a still further aspect, the present invention
provides a method of processing data to record the data
35 in a recording medium by generating an error correcting
product code, comprising:

processing digital data on a byte by byte basis to
configure an information data block of a plurality of
information data blocks of $(M \times N)$ bytes of M rows \times N
columns, permitting data to exist on a byte by byte
5 basis in the information data block and permitting the
data in each row to exist sequentially from a 0.^{sup}.th
to a $(N-1)$ -th column according to a sequence of data
transmission and sequentially from a 0.^{sup}.th to the
 $(M-1)$ -th row according to the sequence of data
10 transmission;

producing a matrix block of $(K \times M)$ rows \times N columns
by using K of the information data blocks arranged
sequentially according to the sequence of data
transmission;

15 adding a first error correcting check word of K
bytes to each column of $(K \times M)$ bytes of the matrix block
to turn each of the N columns into a Reed-Solomon code
word C_2 of $(K \times (M+1))$ bytes, the error correcting check
word of K bytes existing on a byte by byte basis at a
20 position corresponding to every M bytes of information
data; and

adding a second error correcting check word of P
bytes to each row of N bytes to turn each of the
 $(K \times (M+1))$ rows into a Reed-Solomon code word C_1 of $(N+P)$
25 bytes, wherein:

the error correcting product code block is a Reed-
Solomon error correcting product code block of
 $(K \times (M+1) \times (N+P))$ bytes having an information section of K
of the information data blocks of $(K \times M \times N)$ bytes, and
30 a sum of $(M \times N)$ bytes of an information data block
and an average number of bytes of a check word added
thereto are held to a constant value of $(M+1) \times (N \times P)$
bytes.

In a further aspect, the present invention provides
35 an optical disk reproducing apparatus being constructed
and arranged to reproduce data from an optical disk
having an error correcting product code block recorded

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thereon, and the optical disk reproducing apparatus being constructed and arranged to execute error correction processing with respect to the reproduced data, the optical disk reproducing apparatus comprising:

5 means for processing digital data on a byte by byte basis to configure an information data block of $(M \times N)$ bytes of M rows \times N columns;

means for permitting data to exist on the byte by byte basis in the information data block and permitting
10 the data in each row to exist sequentially from a 0^{th} to a $(N-1)$ -th column according to a sequence of data transmission and sequentially from a 0^{th} to a $(M-1)$ -th row according to the sequence of data transmission;

means for permitting a matrix block of $(K \times K)$ rows \times
15 N columns to exist, the matrix block including K of the information data blocks arranged sequentially according to the sequence of data transmission;

means for adding a first error correcting check word of K bytes to each column of $(K \times K)$ bytes of the matrix
20 block to turn each of the N columns into a Reed-Solomon code word $C2$ of $(K \times (M+1))$ bytes, the error correcting check word of K bytes existing on a byte by byte basis at a position corresponding to every M bytes of information data; and

25 means for adding a second error correcting check word of P bytes to each row of N bytes to turn each of the $(K \times (M+1))$ rows into a Reed-Solomon code word $C1$ of $(N+P)$ bytes, wherein:

the error correcting product code block is a Reed-
30 Solomon error correcting product code block of $(K \times (M+1) \times (N+P))$ bytes having an information section of K of the information data blocks of $(K \times M \times N)$ bytes, and
a sum of $(M \times N)$ bytes of an information data block and an average number of bytes of a check word added
35 thereto are held to a constant value of $(M+1) \times (N+P)$ bytes.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated in and constitute a part of the specification, illustrate presently preferred embodiments of the invention and, together with the general description given above and the detailed description of the preferred embodiments given below, serve to explain the principles of the invention.

FIG. 1 is an illustration showing the configuration of a known Reed-Solomon error correcting product code block;

FIG. 2 is a block diagram showing the procedure of generating a Reed-Solomon error correcting product code block according to an embodiment of the invention;

FIG. 3 is an illustration showing the configuration of a Reed-Solomon error correcting product code block generated by the procedure of FIG. 2;

FIG. 4 is an illustration showing the configuration of sectors of a Reed-Solomon error correcting product code block generated by a method according to the invention;

FIG. 5 is a block diagram showing the procedure of generating a Reed-Solomon error correcting product code block according to another embodiment of the invention;

FIG. 6 is an illustration showing the configuration of a Reed-Solomon error correcting product code block generated by the procedure of FIG. 5;

FIG. 7 is a block diagram showing the procedure of generating a Reed-Solomon error correcting product code block according to still another embodiment of the invention; and

FIG. 8 is an illustration showing the configuration of a Reed-Solomon error correcting product code block generated by the procedure of FIG. 7.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

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Now, the present invention will be described by referring to the accompanying drawings that illustrate preferred embodiments of the invention.

FIG. 1 is an illustration showing the configuration of a known Reed-Solomon error correcting product code block. With this known format, as described earlier, a Reed-Solomon error correcting product code block of $(M+P_0) \times (N+P_1)$ bytes is configured for an information data of $(M \times N)$ bytes, therefore, the level of redundancy and the size of the entire block are closely tied to each other, so that the size of the block cannot be arbitrarily changed without modifying the error correcting ability. In other words, the level of redundancy is inevitably and undesirably raised if a large error correcting check word is used.

Contrary to this, according to the invention, a Reed-Solomon error correcting product code block is configured in a manner as illustrated in FIG. 2.

In a first embodiment, which will be described hereinafter, values of $K=16$, $M=12$, $N=172$ and $P=10$ are selected for recording a data of 2,048 bytes in a sector of a recording medium, which may preferably be an optical disc.

In this embodiment, $P=10$ bytes is selected for code word C_1 and $K=16$ bytes is selected for code word C_2 as the number of bytes of an error correcting check word in view of the fact that 1) an even number is more efficient than an odd number for the same error correcting ability, 2) that a required level of burst error correcting ability cannot be maintained for $K=16$ rows if $P=8$ bytes or less because of a rise in the probability of error correction, and 3) that a relationship of $K > P$ is required to raise the level of burst error correcting ability for a same level of redundancy. Additionally, values of $M=12$ and $N=172$ are selected in view of the fact that the size of a sector has to be slightly larger than 2,048 bytes because a sector number and an error detecting word have

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to be added to recorded data of 2,048 bytes for each sector.

FIG. 2 is a block diagram showing the procedure of generating a Reed-Solomon error correcting product code block by using a unit of 16 sectors. FIG. 3 is an illustration showing the row configuration of a Reed-Solomon error correcting product code block in a sector.

Referring to block A through C of FIG. 2, in the first step, a digital data is processed on byte by byte basis to form an information data block with $(M \times N)$ bytes of $M (=12)$ rows \times $N (=172)$ columns and data are arranged on a byte by byte basis in the information data block, while data are arranged sequentially in each row from the 0th to the $(N-1)$ -th column according to the sequence of data transmission and sequentially from the 0th to the $(M-1)$ -th row according to the sequence of data transmission.

Then, in the second step, a matrix block of $(K \times M)$ rows \times N columns is arranged by using $K (=16)$ information data blocks, each having a configuration as described above.

Subsequently, in the third step, an error correcting check word of $K (=16)$ bytes is added to each column of $(K \times M)$ bytes of the matrix block to turn each of N columns into a Reed-Solomon code word $C2$ of $(K \times (M+1))$ bytes.

Finally, in the fourth step, an error correcting check word of $P (=10)$ bytes is added to each row of N bytes to turn each of the $(K \times (M+1))$ rows into a Reed-Solomon code word $C1$ of $(N+P)$ bytes.

The entire error correcting product code block is a Reed-Solomon error correcting product code block of $(K \times (M+1) \times (N+P))$ bytes having an information section of K information data blocks of $(K \times M \times N)$ bytes. The sum of $(M \times N)$ bytes of an information data block and the average number of bytes of a check word added thereto is held to a constant value of $(M+1) \times (N+P)$ bytes.

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This embodiment will be described further by referring to FIGS. 2, 3 and 4.

Data to be recorded is taken in 2,048 bytes at a time for a sector, to which a sector number and an error detecting word (16 bytes) are added to the sector to make the total number of bytes equal to 2,064. (See block A of FIG. 2.) As shown in FIG. 4, a total of 16 bytes is used for a sector number (ID; sector identification), an ID error correcting word (IEC), a system reservation code (RSV) and an error detecting code (EDC).

The 2,064 bytes are assigned to a sector of a Reed-Solomon error correcting product code block and stored in a storage area of M rows x N columns = 12 rows x 172 columns = 2,064 bytes obtained by subtracting the storage area for an error correcting check word from the overall storage area of a sector of $(M+1)$ rows x $(N+P)$ columns = 13 rows x 182 columns.

In this way, the data is sequentially stored into $K=16$ sectors of memory.

After storing data of 192 rows x 172 columns in $K=16$ sectors, each of the 172 columns are processed to produce a Reed-Solomon code word $C2$ of $(192+16)$ bytes to fill the 16 void rows, each of which is arranged every 12 rows (as indicated by X in FIG. 3). (See block B of FIG. 2.)

The relationship between the 16 rows to be filled with Reed-Solomon code words and the degree of the Reed-Solomon code word $C2$ is determined in advance such that the positions of the 16 rows and the degree show a one-to-one correspondence or the former correspond to a lower degree side of the 15th down to the 0th.

After filling the 16 void rows (X), an error correcting check word of 10 bytes is added to each row of the matrix of 208 rows x 172 columns to form a $(172+10)$ -byte Reed-Solomon code word $C1$ for each of the 208 rows. Thus, a Reed-Solomon error correcting product code block is formed as shown in FIG. 3 by using a unit of 16 sectors. (See block C of FIG. 2.)

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The block has a size of 208 rows x 182 columns = 37,856 bytes that can be optimally stored with a generous margin in a memory device that is currently commercially available at low cost.

5 The redundancy of a Reed-Solomon error correcting product code block realized by using a unit of 16 sectors is equal to $(208 \times 182 - 192 \times 172) / (208 \times 182) = 12.76\%$ while a correctable burst error has a maximum length that can be obtained on the basis of the number of rows
10 corresponding to the number of error correcting check words C2, or 16 rows x 182 columns = 2,912 bytes.

As a correctable burst error has a maximum length that can be obtained on the basis of the number of rows corresponding to the number of error correcting check
15 words C2, the error correcting ability can be improved by increasing the number of rows and that of error correcting check words C2 of a Reed-Solomon error correcting product code block.

Thus, the level of redundancy can be maintained to a
20 constant level with the above described method of the present invention because the information data is always allocated to the sectors in a manner as illustrated in FIG. 4.

Situations where the number of rows and that of
25 error correcting check words have to be increased for a Reed-Solomon error correcting product code block may include those in which the error correcting ability has to be raised and those in which the recording density per given length of the tracks of an optical disk as a
30 result of advancement of the semiconductor and data recording/transmission technologies has increased. If such is the case, the number of error correcting check words C2 can be increased by increasing the number of rows of the block. For reproducing the stored
35 information, the stored pieces of information are sequentially picked up along the rows of the block and, with the above described method of the present

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invention, a same level of redundancy can be maintained if the stored Reed-Solomon error correcting product code block is taken up for error correction.

While a figure of $K=16$ is used in the above
5 description, it may be needless to say that $K=12$ may be selected depending on the memory size. Then, a less costly memory device may be used for the purpose of the invention since the size of block is 28,392 byte which can be stored in 256 Kbit capacity.

10 FIG. 5 is a block diagram showing the procedure of generating a Reed-Solomon error correcting product code block according to a second embodiment of the invention. Note that $K=12$ in this embodiment. Blocks 5A, 5B and 5C of FIG. 5 correspond to blocks A, B and C in FIG. 2
15 respectively.

FIG. 6 is an illustration showing the configuration of a Reed-Solomon error correcting product code block generated by the procedure of FIG. 5.

FIG. 7 is a block diagram showing the procedure of
20 generating a Reed-Solomon error correcting product code block according to a third embodiment of the invention. FIG. 8 is an illustration showing the configuration of a Reed-Solomon error correcting product code block generated by the procedure of FIG. 7.

25 As shown, data to be recorded is taken in by 2,048 bytes at a time for a sector, to which a sector number and an error detecting word (16 bytes) are added for the sector to make the total number of bytes equal to 2,064. (See block 7A of FIG. 7.) The 2,064 bytes are assigned to
30 a sector of a Reed-Solomon error correcting product code block and stored in the storage area of M rows x N columns = 12 rows x 172 columns = 2,064 bytes obtained by subtracting the storage area for an error correcting check word from the overall storage area of a sector of
35 $(M+1)$ rows x $(N+P)$ columns = 13 rows x 182 columns.

In this way, the data is sequentially stored into $K=18$ sectors of memory.

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After storing data of 216 rows x 172 columns in K=18 sectors, each of the 172 columns are processed to produce a Reed-Solomon code word C2 of (216+18) bytes to fill the 18 void rows, each of which is arranged for every 12 rows (as indicated by X in FIG. 8). (See block 7B of FIG. 7.)

After filling the 18 void rows (X), an error correcting check word of 10 bytes is added to each row of the matrix of 234 rows x 172 columns to form a (172+10)-byte Reed-Solomon code word C1 for each of the 234 columns. Thus, a Reed-Solomon error correcting product code block is formed as shown in FIG. 8 by using a unit of 18 sectors. (See block 7C of FIG. 7.) This embodiment can raise the error correcting ability relative to the preceding embodiments, although the level of redundancy remains same.

As described above in detail, there is provided a method of processing data for generating an error correcting product code block devised so as to maintain the current level of redundancy after the error correcting ability is improved as a result of advancement of the technologies of semiconductor and data recording/transmission.

Additional advantages and modifications will readily occur to those skilled in the art. Therefore, the invention in its broader aspects is not limited to the specific details, representative devices, and illustrated examples shown and described herein. Accordingly, various modifications may be made without departing from the spirit or scope of the general inventive concept as defined by the appended claims and their equivalents.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A method of processing data by generating an error correcting product code block, comprising:
 - first, processing digital data on a byte by byte basis to configure an information data block of a plurality of information data blocks of $(M \times N)$ bytes of M rows \times N columns, permitting data to exist on the byte by byte basis in the information data block and permitting the data in each row to exist sequentially from a 0th to a $(N-1)$ -th column according to a sequence of data transmission and sequentially from a 0th to a $(M-1)$ -th row according to the sequence of data transmission;
 - second, providing a matrix block of $(K \times M)$ rows \times N columns by using K of the information data blocks arranged sequentially according to the sequence of data transmission;
 - third, adding a first error correcting check word of K bytes to each column of $(K \times M)$ bytes of the matrix block to turn each of the N columns into a Reed-Solomon code word $C2$ of $(K \times (M+1))$ bytes, the error correcting check word of K bytes existing on a byte by byte basis at a position corresponding to every M bytes of information data; and
 - fourth, adding a second error correcting check word of P bytes to each row of N bytes to turn each of the $(K \times (M+1))$ rows into a Reed-Solomon code word $C1$ of $(N+P)$ bytes, wherein:
 - the error correcting product code block is a Reed-Solomon error correcting product code block of $(K \times (M+1) \times (N+P))$ bytes having an information section of K of the information data blocks of $(K \times M \times N)$ bytes, and
 - a sum of $(M \times N)$ bytes of an information data block and an average number of bytes of a check word added

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thereto are held to a constant value of $(M+1) \times (N+P)$ bytes.

2. A method of processing data according to claim 1, wherein:

5 each of the information data blocks contains data to be recorded on a sector of a recording medium, and each of the information data blocks comprises:
a sector identification,
an ID error correcting word,
10 a system reservation code, and
an error detecting code.

3. A method of processing data according to claim 2, wherein:

the sector identification includes four bytes,
15 the ID error correcting word includes two bytes,
the system reservation word includes six bytes, and
the error detecting code includes 4 bytes.

4. A method of processing data to record the data in a recording medium by generating an error correcting
20 product code, comprising:

first, processing digital data on a byte by byte basis to configure an information data block of a plurality of information data blocks of $(M \times N)$ bytes of M rows \times N columns, permitting data to exist on a byte by
25 byte basis in the information data block and permitting the data in each row to exist sequentially from a 0th to a $(N-1)$ -th column according to a sequence of data transmission and sequentially from a 0th to a $(M-1)$ -th row according to the sequence of data transmission;
30 second, producing a matrix block of $(K \times M)$ rows \times N columns by using K of the information data blocks arranged sequentially according to the sequence of data transmission;

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third, adding a first error correcting check word of K bytes to each column of $(K \times M)$ bytes of the matrix block to turn each of the N columns into a Reed-Solomon code word C2 of $(K \times (M+1))$ bytes, the error correcting check word of K bytes existing on a byte by byte basis at a position corresponding to every M bytes of information data; and

fourth, adding a second error correcting check word of P bytes to each row of N bytes to turn each of the $(K \times (M+1))$ rows into a Reed-Solomon code word C1 of $(N+P)$ bytes, wherein:

the error correcting product code block is a Reed-Solomon error correcting product code block of $(K \times (M+1) \times (N+P))$ bytes having an information section of K of the information data blocks of $(K \times M \times N)$ bytes, and

a sum of $(M \times N)$ bytes of an information data block and an average number of bytes of a check word added thereto are held to a constant value of $(M+1) \times (N \times P)$ bytes.

5. A method of processing data according to any one of claims 1 and 2 wherein, in the adding of the first error correcting check word, the first error correcting check word of K bytes is added to a tail end of each column of $(K \times M)$ bytes for form the Reed-Solomon code word C2 of $(K \times (M+1))$ bytes for each of the N rows, and

subsequently the first error correcting check word of K bytes is redistributed on the byte by byte basis to a position of every M bytes of the information data.

6. A method of processing data according to any one of claims 1 and 4, wherein:

in the adding of the first error correcting check word, the Reed Solomon error correcting code word C2 of $(K \times (M+1))$ bytes is formed by arranging a one byte position in every M bytes for each of the K bytes of the

first error correcting check word to be added to each column of (KxM) bytes.

7. A method of processing data according to any one of claims 1 and 4, wherein:

5 a value of $M \times N$ is at least 2,054 and less than 2,064,

the K is an even number having a value being at least 12, the P is an even number having a value being at least 10,

10 a value of $K \times (M+1)$ is at most 255, and

a value of $N+P$ is at most 255.

8. A method of processing data according to any one of claims 1 and 4, wherein $M=12$, $N=172$, $K=16$ and $P=10$.

9. A method of processing data according to any one
15 of claims 1 and 4, wherein $M=12$, $N=172$, $K=12$ and $P=10$.

10. A method of processing data according to any one of claims 1 and 4, wherein $M=12$, $N=172$, $K=18$ and $P=10$.

11. A recording medium comprising an error
correcting product code block recorded thereon wherein
20 data is processed and the error correcting product block code is generated by a method comprising:

first, processing digital data on a byte by byte basis to configure an information data block of a plurality of information data blocks of (MxN) bytes of M
25 rows x N columns, permitting data to exist on a byte by byte basis in the information data block and permitting the data in each row to exist sequentially from a 0.^{sup}.th to a (N-1)-th column according to a sequence of data transmission and sequentially from a 0.^{sup}.th to a
30 (M-1)-th row according to the sequence of data transmission;

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second, producing a matrix block of $(K \times M)$ rows \times N columns by using K of the information data blocks arranged sequentially according to the sequence of data transmission;

5 third, adding a first error correcting check word of K bytes to each column of $(K \times M)$ bytes of the matrix block to turn each of the N columns into a Reed-Solomon code word $C2$ of $(K \times (M+1))$ bytes, the error correcting check word of K bytes existing on a byte by byte basis at a
10 position corresponding to every M bytes of information data; and

fourth, adding a second error correcting check word of P bytes to each row of N bytes to turn each of the $(K \times (M+1))$ rows into a Reed-Solomon code word $C1$ of $(N+P)$
15 bytes, wherein:

the error correcting product code block is a Reed-Solomon error correcting product code block of $(K \times (M+1) \times (N+P))$ bytes having an information section of K of the information data blocks of $(K \times M \times N)$ bytes, and
20 a sum of $(M \times N)$ bytes of an information data block and an average number of bytes of a check word added thereto are held to a constant value of $(M+1) \times (N \times P)$ bytes.

12. A recording medium comprising an information
25 data block of $(M \times N)$ bytes of an error correcting product code block being correspondingly recorded in a sector, wherein data is processed and the error correcting product code is generated by a method comprising:

first, processing digital data on a byte by byte
30 basis to configure an information data block of a plurality of information data blocks of $(M \times N)$ bytes of M rows \times N columns, permitting data to exist on a byte by byte basis in the information data block and permitting the data in each row to exist sequentially from a
35 0.^{sup}.th to a $(N-1)$ -th column according to a sequence of data transmission and sequentially from a 0.^{sup}.th to a

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(M-1)-th row according to the sequence of data transmission;

second, producing a matrix block of $(K \times M)$ rows x N columns by using K of the information data blocks
 5 arranged sequentially according to the sequence of data transmission;

third, adding a first error correcting check word of K bytes to each column of $(K \times M)$ bytes of the matrix block to turn each of the N columns into a Reed-Solomon
 10 code word C2 of $(K \times (M+1))$ bytes, the error correcting check word of K bytes existing on a byte by byte basis at a position corresponding to every M bytes of information data; and

fourth, adding a second error correcting check word
 15 of P bytes to each row of N bytes to turn each of the $(K \times (M+1))$ rows into a Reed-Solomon code word C1 of $(N+P)$ bytes, wherein:

the error correcting product code block is a Reed-Solomon error correcting product code block of
 20 $(K \times (M+1) \times (N+P))$ bytes having an information section of K of the information data blocks of $(K \times M \times N)$ bytes, and
 a sum of $(M \times N)$ bytes of an information data block and an average number of bytes of a check word added thereto are held to a constant value of $(M+1) \times (N \times P)$
 25 bytes.

13. A method of processing data according to claim 4, wherein:

each of the information data blocks contains data to be recorded on a sector of the recording medium, and
 30 each of the information data blocks comprises:
 a sector identification,
 an ID error correcting word,
 a system reservation code, and
 an error detecting code.

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14. A method of processing data according to claim 13, wherein:

5 the sector identification includes four bytes,
the ID error correcting word includes two bytes,
the system reservation word includes six bytes, and
the error detecting code includes 4 bytes.

15. A data processing apparatus comprising:

10 means for processing digital data on a byte by byte basis to configure an information data block of a plurality of information data blocks by $(M \times N)$ bytes of M rows \times N columns;

15 means for arranging the digital data on a byte by byte basis in the information data block and arranging the digital data in each row sequentially from a 0.^{sup}.th to a $(N-1)$ -th column according to a sequence of data transmission and sequentially from a 0.^{sup}.th to a $(M-1)$ -th row according to the sequence of data transmission;

20 means for arranging a matrix block of $(K \times M)$ rows \times columns by using K of the information data blocks arranged sequentially according to the sequence of data transmission;

25 means for adding a first error correcting check word of K bytes to each column of $(K \times M)$ bytes of the matrix block to turn each of the N rows into a Reed-Solomon code word C_2 of $(K \times (M+1))$ bytes; and

30 means for adding a second error correcting check word of P bytes to each row of N bytes to turn each of the $(K \times (M+1))$ rows into a Reed-Solomon code word C_1 of $(N+P)$ bytes, wherein:

35 the error correcting product code block is a Reed-Solomon error correcting product code block of $(K \times (M+1) \times (N+P))$ bytes having an information section of K of the information data blocks of $(K \times M \times N)$ bytes, and a sum of $(M \times N)$ bytes of an information data block and an average number of bytes of a check word added

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thereto being held to a constant value of $(M+1) \times (N+P)$ bytes.

16. A data processing apparatus according to claim 15, wherein the means for processing an error correcting product code block is arranged in a telecommunications apparatus, a data recording apparatus for recording data onto a disk or an error correction processing apparatus.

17. A recording medium comprising an error correcting product code block recorded thereon, the error correcting product code block being configured by:

processing digital data on a byte by byte basis to configure an information data block of a plurality of information data blocks by $(M \times N)$ bytes of M rows \times N columns;

15 permitting the digital data to exist on a byte by byte basis in the information data block and permitting the digital data in each row to exist sequentially from a 0.^{sup}.th to a $(N-1)$ th column according to a sequence of data transmission and sequentially from a 0.^{sup}.th to a
20 $(M-1)$ -th row according to the sequence of data transmission;

permitting a matrix block of $(K \times M)$ rows \times N columns to exist, the matrix block including K of the information data blocks arranged sequentially according to the
25 sequence of data transmission;

adding a first error correcting check word of K bytes to each column of $(K \times M)$ bytes of the matrix block to turn each of the N columns into a Reed-Solomon code word C_2 of $(K \times (M+1))$ bytes, the first error correcting
30 check word of K bytes existing on the byte by byte basis at a position corresponding to every M bytes of information data;

adding a second error correcting check word of P bytes to each row of N bytes to turn each of the

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($K \times (M+1)$) rows into a Reed-Solomon code word C_1 of $(N+P)$ bytes, wherein:

the error correcting product code block is a Reed-Solomon error correcting product code block of
 5 ($K \times (M+1) \times (N+P)$) bytes having an information section of K of the information data blocks of $(K \times M \times N)$ bytes,
 a sum of $(M \times N)$ bytes of an information data block and an average number of bytes of a check word added thereto are held to a constant value of $(M+1) \times (N+P)$
 10 bytes.

18. A transmission apparatus for transmitting data, comprising:

means for permitting an information data block of a plurality of information data blocks to comprise $(M \times N)$
 15 bytes of M rows \times N columns;

means for permitting the data to exist on a byte by byte basis in the information data block and permitting the data in each row to exist sequentially from a 0.sub.th to a $(N-1)$ -th column according to a sequence of
 20 data transmission and sequentially from a 0.sup.th to a $(M-1)$ -th row according to the sequence of data transmission;

means for permitting a matrix block of $(K \times M)$ rows \times N columns to exist, the matrix block including K of the
 25 information data blocks arranged sequentially according to the sequence of data transmission;

means for adding a first error correcting check word of K bytes to each column of $(K \times M)$ bytes of the matrix block to turn each of the N columns into a Reed-Solomon
 30 code word C_2 of $(K \times (M+1))$ bytes, the first error correcting check word of K bytes existing on the byte by byte basis at a position corresponding to every M bytes of information data;

means for adding a second error correcting check
 35 word of P bytes to each row of N bytes to turn each of

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the $(K \times (M+1))$ rows into a Reed-Solomon code word $C1$ of $(N+P)$ bytes, wherein:

the error correcting product code block is a Reed-Solomon error correcting product code block of $(K \times (M+1) \times (N+P))$ bytes having an information section of K of the information data blocks of $(K \times M \times N)$ bytes, and a sum of $(M \times N)$ bytes of an information data block and an average number of bytes of a check word added thereto are held to a constant value of $(M+1) \times (N+P)$ bytes.

19. A method of processing data by generating an error correcting product code block, comprising:

processing digital data on a byte by byte basis to configure an information data block of a plurality of information data blocks of $(M \times N)$ bytes of M rows \times N columns, permitting data to exist on the byte by byte basis in the information data block and permitting the data in each row to exist sequentially from a 0-th to a $(N-1)$ -th column according to a sequence of data transmission and sequentially from 0^{sup}.th to a $(M-1)$ -th row according to the sequence of data transmission;

providing a matrix block of $(K \times M)$ rows \times N columns by using K of the information data blocks arranged sequentially according to the sequence of data transmission;

adding a first error correcting check word of K bytes to each column of $(K \times M)$ bytes of the matrix block to turn each of the N columns into a Reed-Solomon code word $C2$ of $(K \times (M+1))$ bytes, the error correcting check word of K bytes existing on a byte by byte basis at a position corresponding to every M bytes of information data; and

adding a second error correcting check word of P bytes to each row of N bytes to turn each of the $(K \times (M+1))$ rows into a Reed-Solomon code word $C1$ of $(N+P)$ bytes wherein:

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the error correcting product code block is a Reed-Solomon error correcting product code block of $(K \times (M+1) \times (N+P))$ bytes having an information section of K of the information data blocks of $(K \times M \times N)$ bytes, and
 5 a sum of $(M \times N)$ bytes of an information data block and an average number of bytes of a check word added thereto are held to a constant value of $(M+1) \times (N+P)$ bytes.

20. A method of processing data to record the data
 10 in a recording medium by generating an error correcting product code, comprising:

processing digital data on a byte by byte basis to configure an information data block of a plurality of information data blocks of $(M \times N)$ bytes of M rows \times N
 15 columns, permitting data to exist on a byte by byte basis in the information data block and permitting the data in each row to exist sequentially from a 0.^{sup}.th to a $(N-1)$ -th column according to a sequence of data transmission and sequentially from a 0.^{sup}.th to the
 20 $(M-1)$ -th row according to the sequence of data transmission;

producing a matrix block of $(K \times M)$ rows \times N columns by using K of the information data blocks arranged sequentially according to the sequence of data
 25 transmission;

adding a first error correcting check word of K bytes to each column of $(K \times M)$ bytes of the matrix block to turn each of the N columns into a Reed-Solomon code word C_2 of $(K \times (M+1))$ bytes, the error correcting check
 30 word of K bytes existing on a byte by byte basis at a position corresponding to every M bytes of information data; and

adding a second error correcting check word of P bytes to each row of N bytes to turn each of the
 35 $(K \times (M+1))$ rows into a Reed-Solomon code word C_1 of $(N+P)$ bytes, wherein:

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the error correcting product code block is a Reed-Solomon error correcting product code block of $(K \times (M+1) \times (N+P))$ bytes having an information section of K of the information data blocks of $(K \times M \times N)$ bytes, and
5 a sum of $(M \times N)$ bytes of an information data block and an average number of bytes of a check word added thereto are held to a constant value of $(M+1) \times (N \times P)$ bytes.

21. A method of processing data according to claim
10 19, wherein:

each of the information data blocks contains data to be recorded on a sector of a recording medium, and each of the information data blocks comprises:
a sector identification,
15 an ID error correcting word,
a system reservation code, and
an error detecting code.

22. A method of processing data according to claim
20 21, wherein:

the sector identification includes four bytes,
the ID error correcting word includes two bytes,
the system reservation word includes six bytes, and
the error detecting code includes 4 bytes.

23. A method of processing data according to claim
25 20, wherein:

each of the information data blocks contains data to be recorded on a sector of a recording medium, and each of the information data blocks comprises:
a sector identification,
30 an ID error correcting word,
a system reservation code, and
an error detecting code.

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24. A method of processing data according to claim 23, wherein:

the sector identification includes four bytes,
the ID error correcting word includes two bytes,
5 the system reservation word includes six bytes, and
the error detecting code includes 4 bytes.

25. An optical disk reproducing apparatus being constructed and arranged to reproduce data from an optical disk having an error correcting product code
10 block recorded thereon, and the optical disk reproducing apparatus being constructed and arranged to execute error correction processing with respect to the reproduced data, the optical disk reproducing apparatus comprising:

means for processing digital data on a byte by byte
15 basis to configure an information data block of (MxN) bytes of M rows x N columns;

means for permitting data to exist on the byte by byte basis in the information data block and permitting the data in each row to exist sequentially from a 0th to a
20 (N-1)-th column according to a sequence of data transmission and sequentially from a 0th to a (M-1)-th row according to the sequence of data transmission;

means for permitting a matrix block of (KxM) rows x N columns to exist, the matrix block including K of the
25 information data blocks arranged sequentially according to the sequence of data transmission;

means for adding a first error correcting check word of K bytes to each column of (KxM) bytes of the matrix block to turn each of the N columns into a Reed-Solomon
30 code word C2 of (Kx(M+1)) bytes, the error correcting check word of K bytes existing on a byte by byte basis at a position corresponding to every M bytes of information data; and

means for adding a second error correcting check
35 word of P bytes to each row of N bytes to turn each of

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the $(K \times (M+1))$ rows into a Reed-Solomon code word C_1 of $(N+P)$ bytes, wherein:

the error correcting product code block is a Reed-Solomon error correcting product code block of $(K \times (M+1) \times (N+P))$ bytes having an information section of K of the information data blocks of $(K \times M \times N)$ bytes, and a sum of $(M \times N)$ bytes of an information data block and an average number of bytes of a check word added thereto are held to a constant value of $(M+1) \times (N+P)$ bytes.

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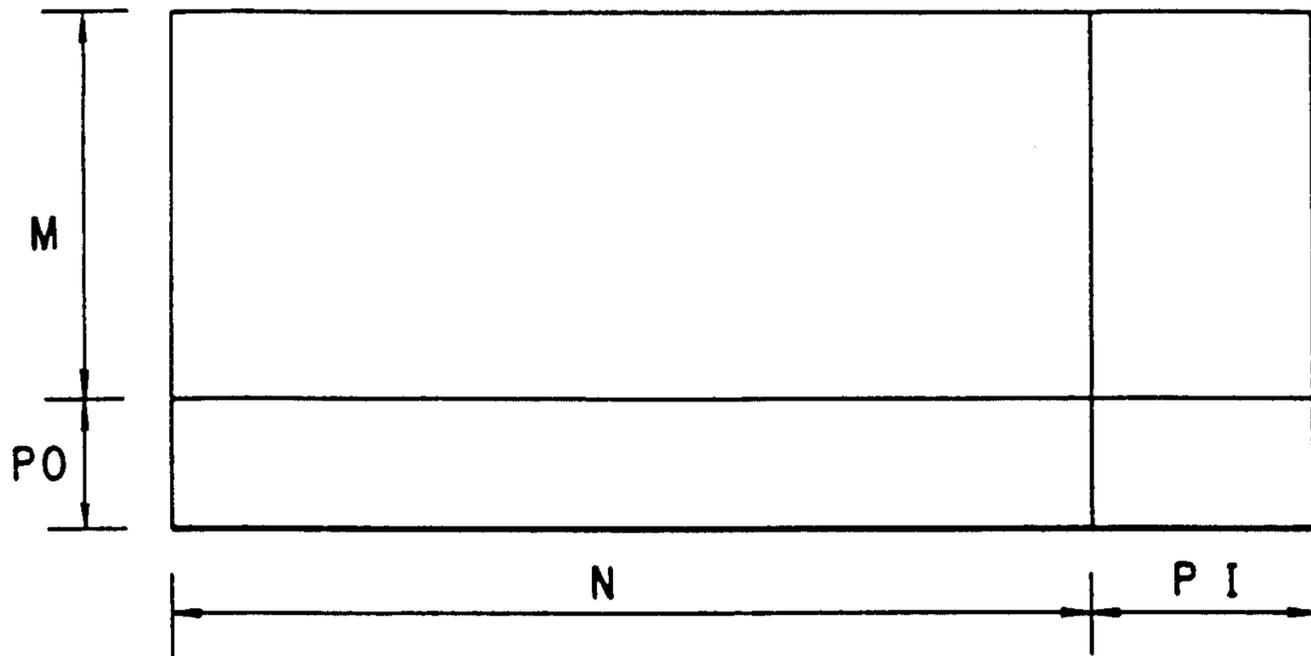


FIG. 1

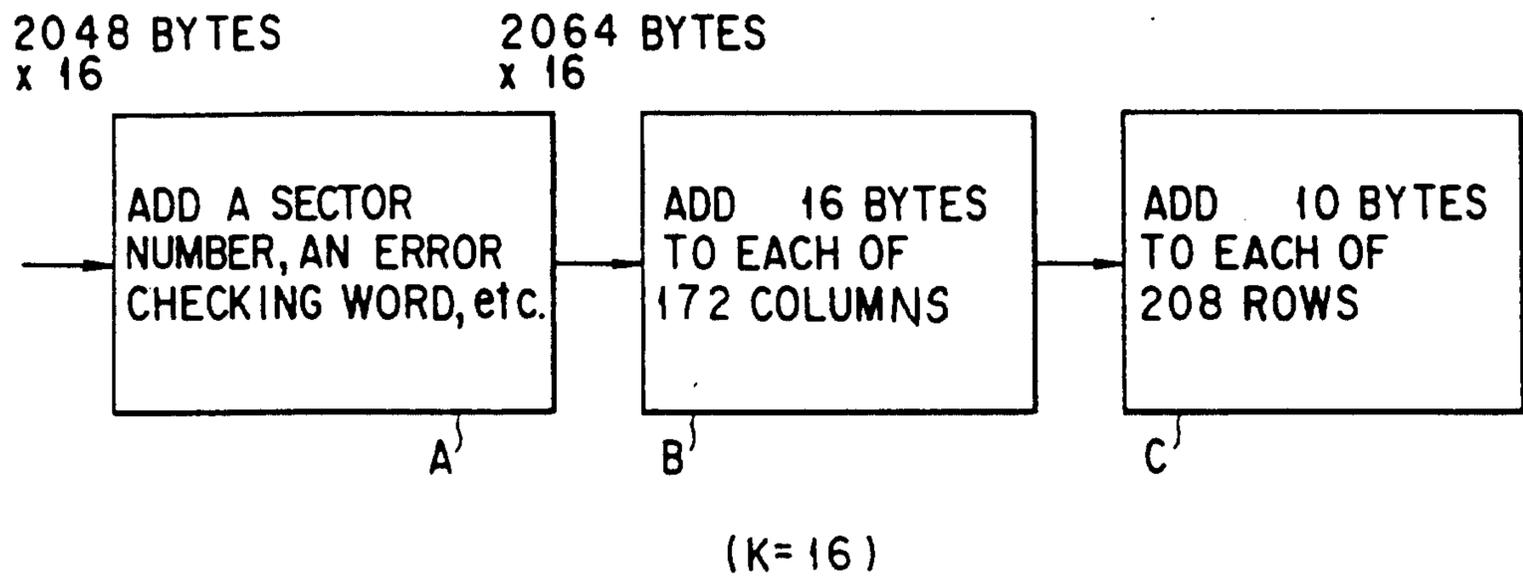


FIG. 2

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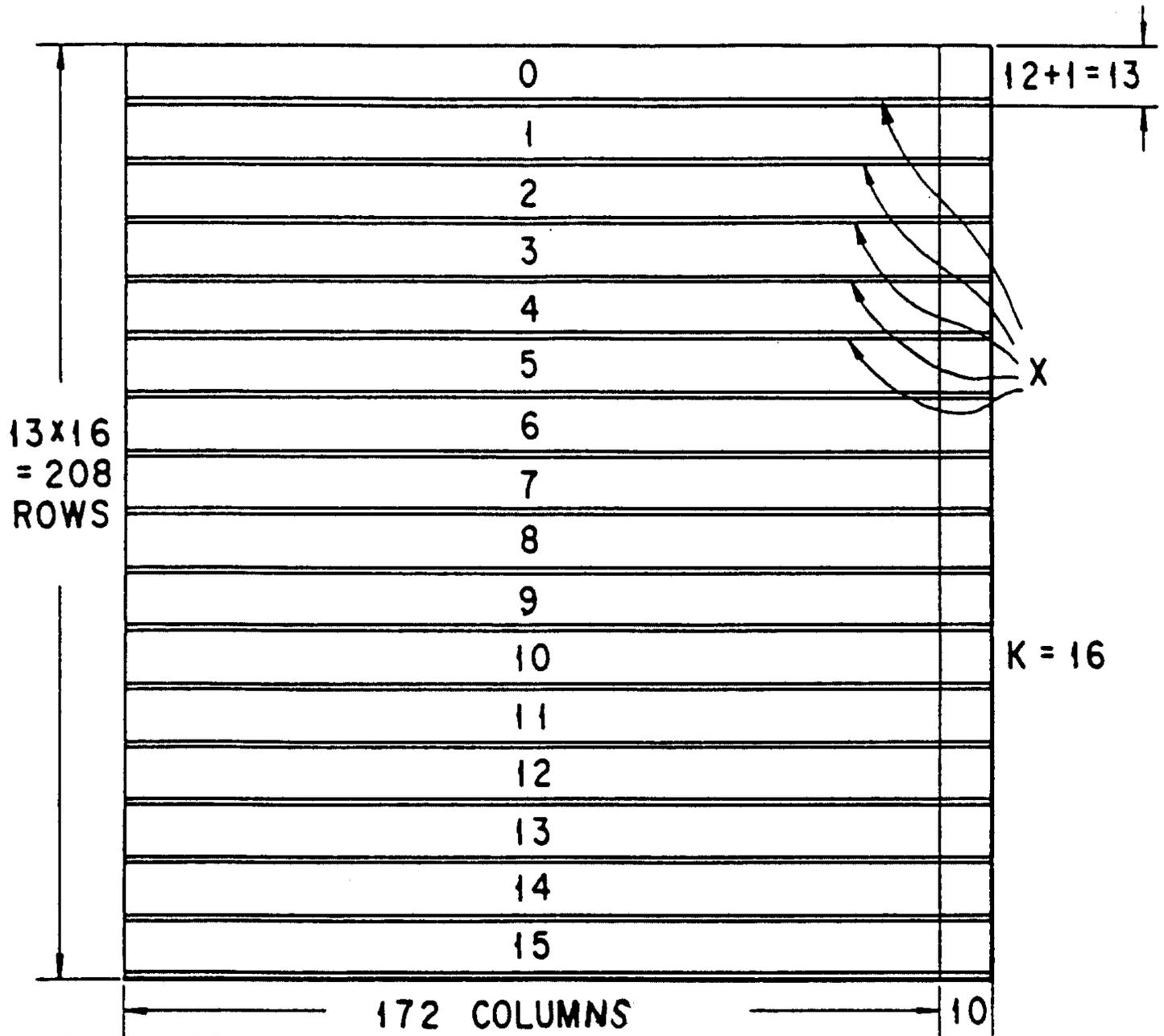


FIG. 3

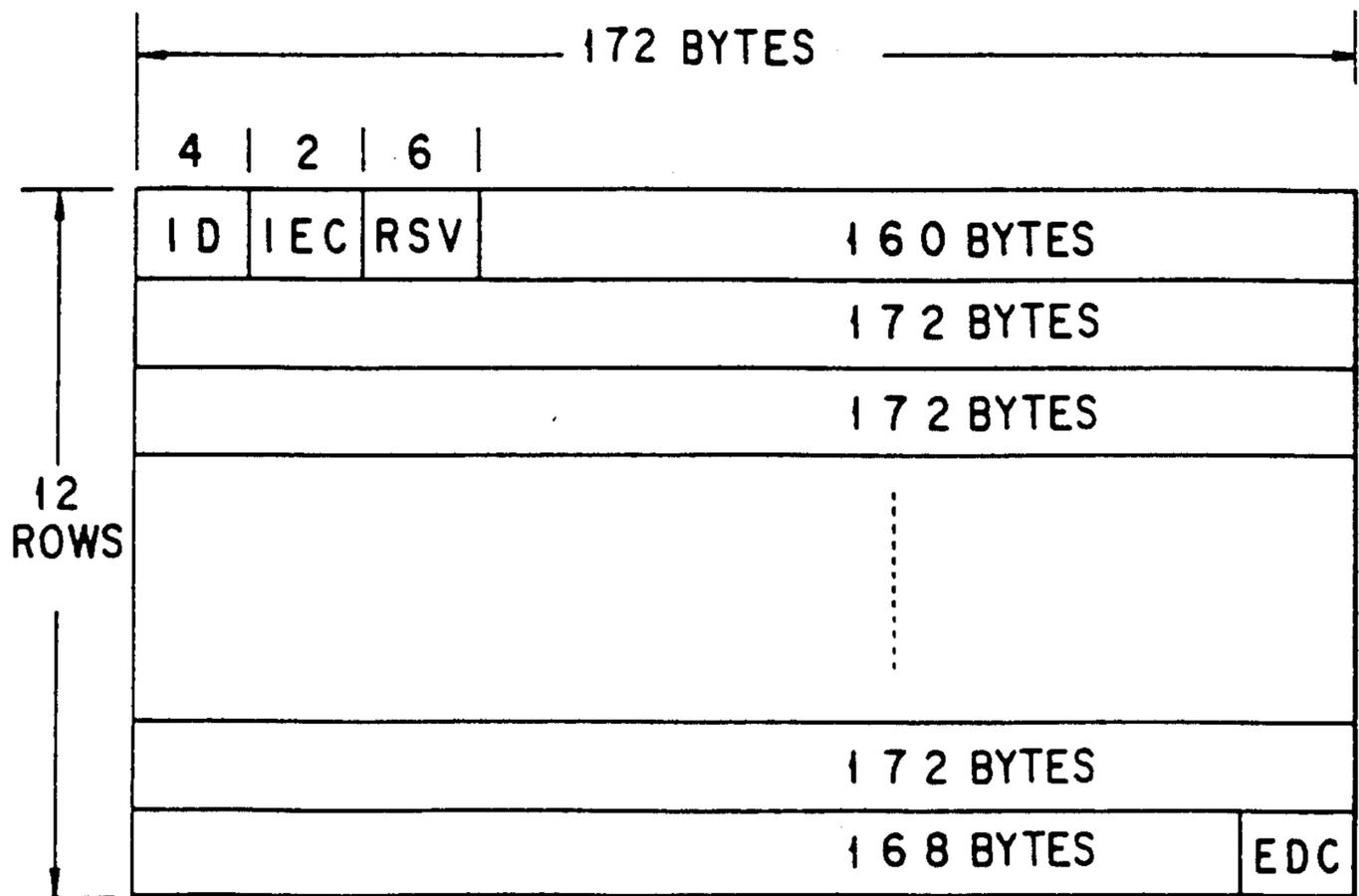


FIG. 4

SECTOR CONFIGURATION

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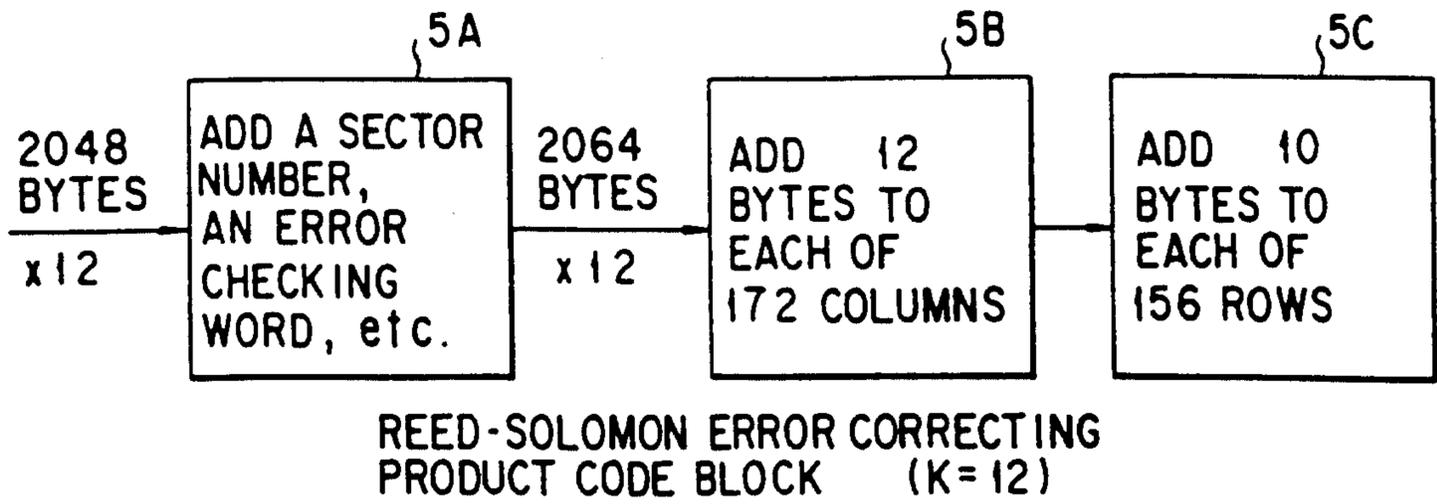


FIG. 5

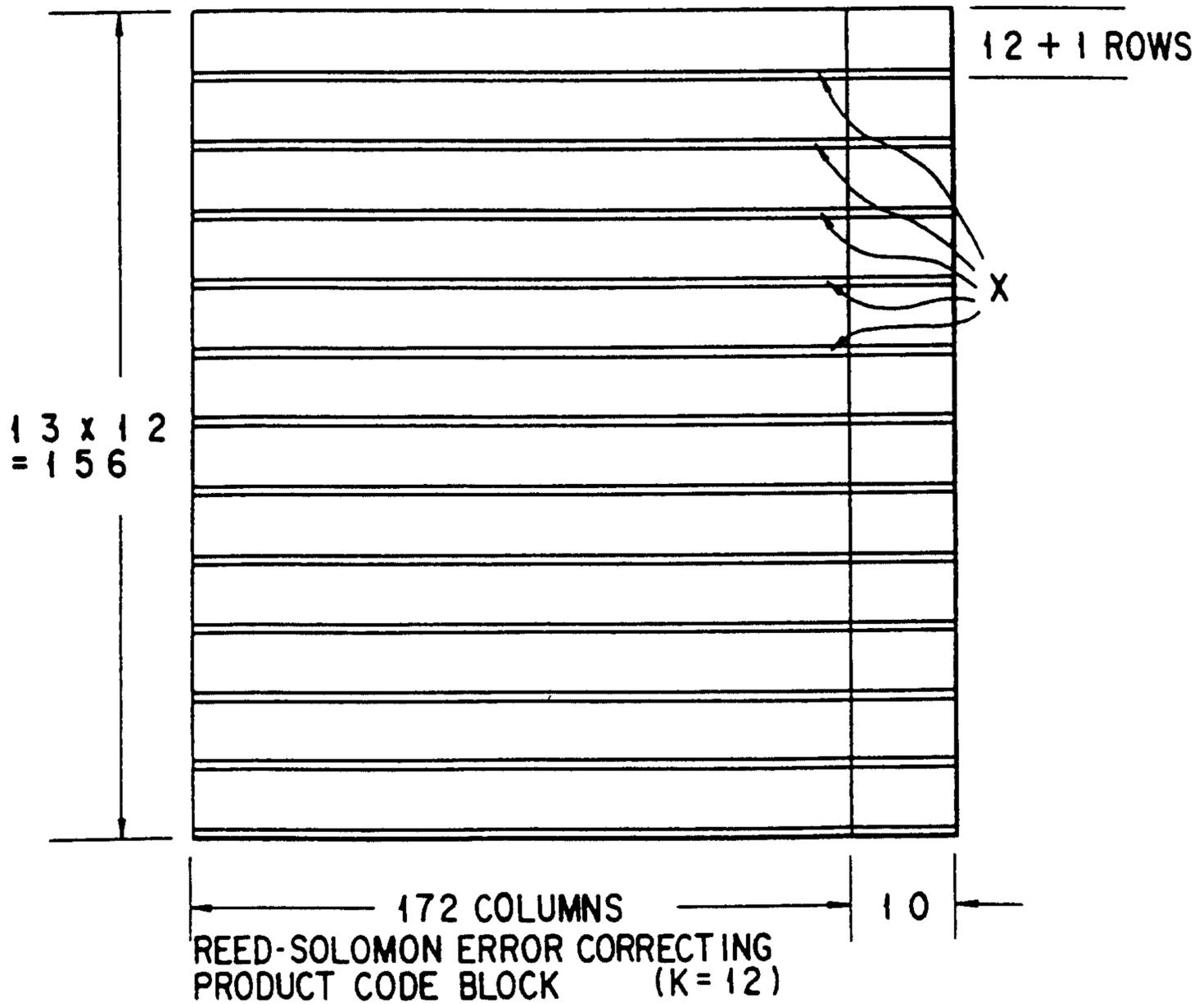


FIG. 6

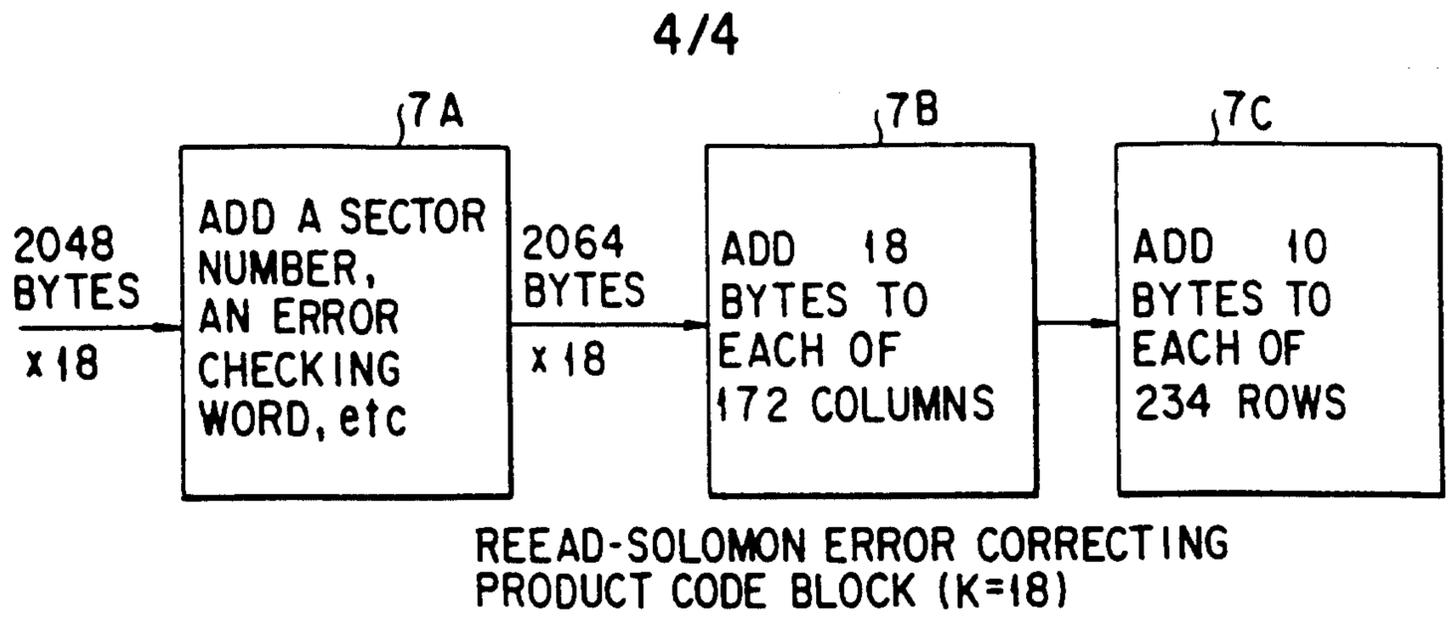


FIG. 7

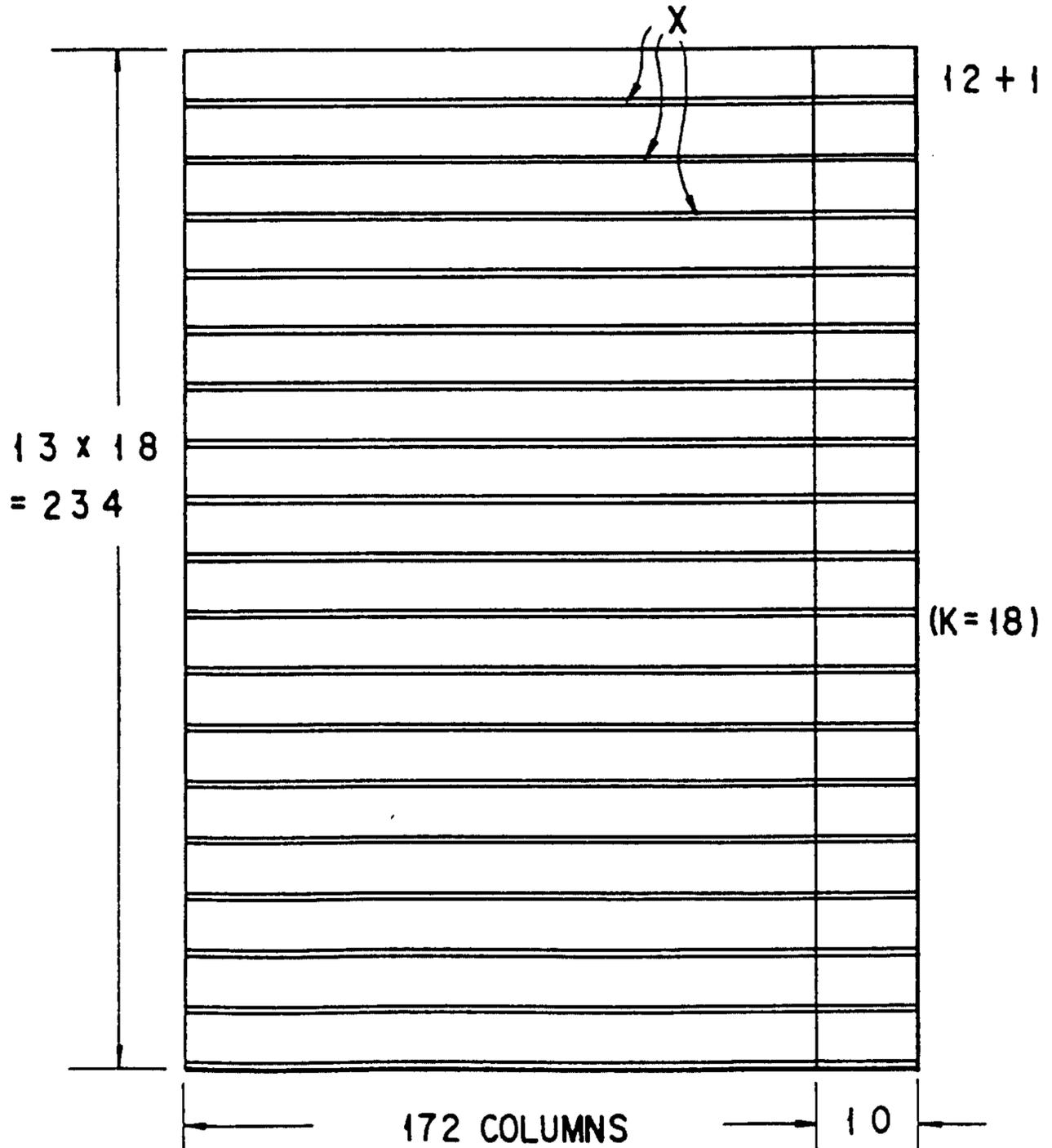
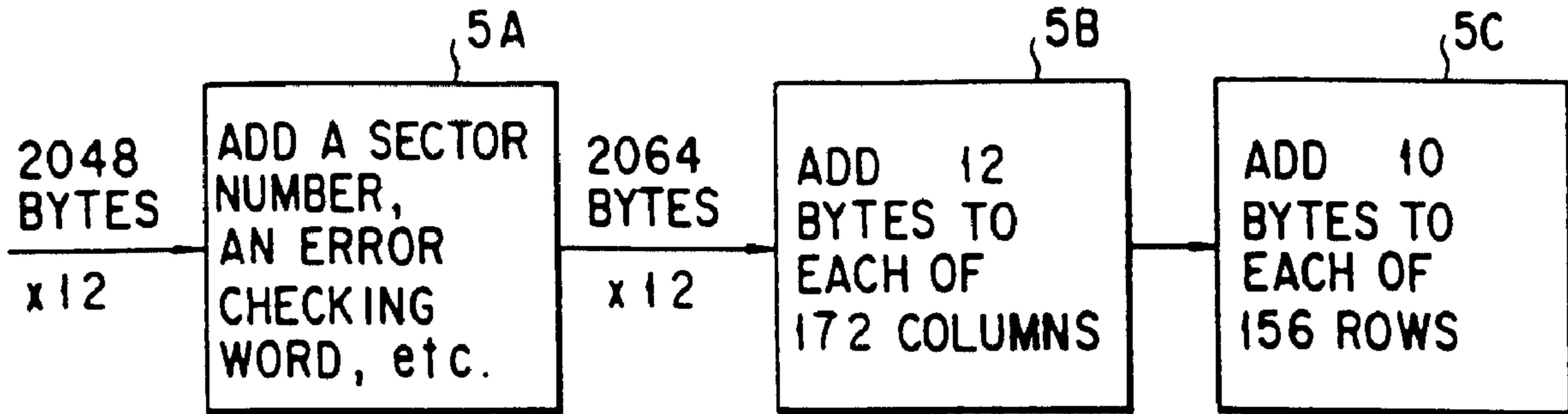


FIG. 8 REED-SOLOMON ERROR CORRECTING PRODUCT CODE BLOCK



REED-SOLOMON ERROR CORRECTING
PRODUCT CODE BLOCK (K=12)