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(71) Applicant *(for all designated States except US)*: **INTERNATIONAL BUSINESS MACHINES CORPORATION** [US/US]; New Orchard Road, Armonk, New York 10504 (US).

(71) Applicant *(for MG only)*: **IBM UNITED KINGDOM LIMITED** [GB/GB]; PO Box 41, Portsmouth Hampshire PO6 3AU (GB).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: **SEGER, Paul** [US/US]; 5145 West Paseo del Barranco, Tucson, Arizona 85745 (US). **ELEFTHERIOU, Evangelos** [GR/CH]; Bellariastrasse 53, CH-8038 Zurich (CH). **JAQUETTE, Glen, Alan** [US/US]; 5270 North Rocky Ridge Place, Tucson, Arizona 85750 (US). **CIDECIYAN, Roy, Daron** [CH/CH]; Loostrasse 15, CH-8803 Rueschlikon (CH).

(74) Agent: **WILLIAMS, Julian, David**; IBM United Kingdom Limited, Intellectual Property Law, Hursley Park, Winchester Hampshire SO21 2JN (GB).

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(54) **Title:** METHOD AND APPARATUS FOR PROVIDING ERROR CORRECTION CAPABILITY TO LONGITUDINAL POSITION DATA

(57) **Abstract:** A method and apparatus for providing error correction capability to longitudinal position data are disclosed. Initially, data are encoded via a set of even LPOS words and a set of odd LPOS words . The encoded data are then decoded by generating a set of syndrome bits for each of the LPOS words. A determination is then made as to whether or not there is an error within one of the LPOS words based on its corresponding syndrome bits.

METHOD AND APPARATUS FOR PROVIDING ERROR CORRECTION CAPABILITY TO LONGITUDINAL POSITION DATA

BACKGROUND OF THE INVENTION

1. Technical Field

The present invention relates to tape storage systems in general. More particularly, the present invention relates to a method and apparatus for providing longitudinal position (LPOS) data in a tape storage system. Still more particularly, the present invention relates to a method and apparatus for providing error correction capability to LPOS words in a tape storage system.

2. Description of Related Art

Tape storage systems remain to be the most efficient and cost-effective means for providing data backup because no other storage technology offers the same low cost and high capacity combined advantage. In addition, tape storage systems have been proven to be very reliable.

By combining the advantages of linear multi-channel bi-directional tape formats in common usage, Linear Tape-Open (LTO) technology has been developed to maximize capacity and performance of tape storage systems. LTO tapes use a tape format that has longitudinally pre-written servo tracks. The servo tracks provide a timing-based track-following position error scheme. The servo tracks contain a repeated pattern of recorded flux transitions that occur in grouped bursts of 5, 5, 4 and 4 transitions. The timing between the sets of five-bursts and between sets of four-bursts provides the position information for track following. Additionally, the individual transitions within the five-bursts are phase-shifted in a manner that encodes longitudinal position information (LPOS) into the servo tracks.

The LPOS information are used to keep track of the longitudinal position of data records written onto or read from a tape, and are used to locate those data records when the reading or writing process temporarily stops. By detecting the phase-encoded LPOS information, a tape storage system is able to determine the tape position relative to landmarks

lengthwise down a tape. The LPOS locations of data files on tape are also stored in the volume control data for use to locate the data files during a later tape cartridge load for reading, or for write-appending new files onto the end of the last file written to the tape. The LPOS data are used as the primary positional information for the tape storage servo control system to determine the starting and stopping of a tape, and to back-hitch the tape in order to position the read-write heads at the beginning of a data record at the required velocity and track position that allows the start of a new data transfer operation.

LPOS data typically cannot tolerate any errors. But if a tape drive is reduced to a single channel because other servo heads have been smeared or shorted, a single bit error on that channel can cause a *Stop Write* condition. Thus, LPOS data have to able to tolerate some level of errors such that the good servo head can continue to operate after an occurrence of an error.

One known solution to the above-mentioned problem is to append Reed-Solomon parity symbols to an LPOS word, but it would increase the length of the LPOS word, and it would cause problems in synchronizing to the LPOS word since Reed- Solomon words are not base-14 as required by the LPOS format in order to allow for synchronization. Another solution is to add a base-14 checksum, but again it would increase the length of the LPOS word, and it only provides error detection but not error correction.

Consequently, it would be desirable to provide an improved method and apparatus for providing error correction capability to LPOS words.

SUMMARY OF THE INVENTION

In accordance with a preferred embodiment of the present invention, data are initially encoded via a set of even LPOS words and a set of odd LPOS words. The encoded data are then decoded by generating a set of syndrome bits for each of the LPOS words. A determination is then made as to whether or not there is an error within one of the LPOS words based on its corresponding syndrome bits.

All features and advantages of the present invention will become apparent in the following detailed written description.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention itself, as well as a preferred mode of use, further objects, and advantages thereof, will best be understood by reference to the following detailed description of an illustrative embodiment when read in conjunction with the accompanying drawings, wherein:

Figure **1** is a block diagram of a tape library system in which a preferred embodiment of the present invention can be incorporated;

Figure **2** is a block diagram of a tape drive in which a preferred embodiment of the present invention can be incorporated;

Figure **3** illustrates a recording format on a magnetic tape, in accordance with a preferred embodiment of the present invention; and

Figure **4** is a high-level logic flow diagram of a method for providing error correction capability to longitudinal position words within a tape storage system, in accordance with a preferred embodiment of the present invention.

DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT

Referring now to the drawings, and specifically to Figure **1**, there is depicted a tape library system in which a preferred embodiment of the present invention can be incorporated. As shown, a tape library system **10** includes tape drives **11-12**, a loader **15**, and a library of tape cassettes (or cartridges) **14**. Loader **15** can fetch any one of tape cassettes **14** and loads it into one of tape drives **11-12**.

With reference now to Figure **2**, there is depicted a tape drive, such as tape drive **11** from Figure **1**, in which a preferred embodiment of the present invention can be incorporated. As shown, a tape drive **11** includes a tape read/write head **23**, takeup reels **24-25** and takeup reel motors **26-27**. A magnetic tape **22** is spooled on takeup reels **24-25**, and is routed over tape read/write head **23**. Tape read/write head **23** reads data from and writes data to magnetic tape **22**. Takeup reel motors **26-27** control the positioning of magnetic tape **22** over tape read/write head **23** via takeup reels **24-25**, respectively.

In addition, a controller **30** provides control signals to motor drivers **28-29**. Motor drivers **28-29**, in turn, provide drive signals to takeup reel motors **26-27**, respectively. Position encoders **31-32** commutates takeup reel motors **26-27**, respectively. longitudinal position (LPOS) information are used to cause controller **30** to move magnetic tape **22** over the entire length of magnetic tape **22**, to rewind from the end of magnetic tape **22** to the beginning of magnetic tape **22** and unspool, unthread, etc.

Referring now to Figure **3**, there is illustrated a recording format on a magnetic tape, such as magnetic tape **22** from Figure **2**, in accordance with a preferred embodiment of the present invention. As shown, magnetic tape **22** includes servo bands **0-4** to enable an accurate positioning of a tape read/write head over a data track, and to ensure that the tape read/write head does not stray onto an adjacent data track. Servo bands **0-4** are written on magnetic tape **22** at time of manufacture. Each of servo bands **0-4** is located at a specific distance from a tape reference edge **33**. Within each of servo bands **0-4** are servo stripes, groups of which make up servo bursts. Four servo bursts make up a servo frame. For example, in servo band **0**, a servo frame includes servo bursts **34-35**. First two servo bursts **34** contain five flux transitions, and second two servo bursts **35** contain four flux transitions.

In the prior art, an LPOS word includes one sync mark and seven 14-ary symbols (written in a forward tape motion direction), as follows:

Sy,L0,L1,L2,L3,L4,L5,Tx

where Sy is the word sync mark
L0 is the least significant symbol in longitudinal position
L1 is the next most significant symbol in longitudinal position
L2 is the next most significant symbol in longitudinal position
L3 is the next most significant symbol in longitudinal position
L4 is the next most significant symbol in longitudinal position
L5 is the next most significant symbol in longitudinal

position
Tx is a symbol of tape manufacturer information

LPOS word symbols are constructed from a set of bit sequences listed in Table **I**. The most significant bit within each LPOS word symbol is encoded into a servo subframe first. An LPOS word contains 36 bits and has a length of 36 servo frames.

Table **I**

symbol	**bit sequence**
Sy	10000000
D	0001
C	0010
B	0011
A	0100
9	0101
8	0110
7	0111
6	1001
5	1010
4	1011
3	1100
2	1101
1	1110
0	1111

In accordance with a preferred embodiment of the present invention, LPOS information is initially represented by an even LPOS word and an odd LPOS word (or vice versa), followed by a group of LPOS words that are made up of a combination of even or odd LPOS words. Each of even and odd LPOS words includes one sync mark and seven 14-ary symbols (written in a forward tape motion direction), as follows:

even LPOS word: Sy,L0,L1,L2,L3,X,Y,Tx
odd LPOS word: Sy,L0,L1,L4,L5,X,Y,Tx

where Sy is the word sync mark
L0 is the least significant symbol in longitudinal position
L1 is the next most significant symbol in longitudinal osition
L2 is the next most significant symbol in longitudinal position
L3 is the next most significant symbol in longitudinal

position
L4 is the next most significant symbol in longitudinal position
L5 is the next most significant symbol in longitudinal position
Tx is a symbol of tape manufacturer information
X, Y are 8 bits of (d=0, k=3) runlength-limited (RLL) constrained error correction code that are encoded as the following 8 bits: a, b, c, 1, d, e, f, 1, *where* a, b, c, d, e, and f are six parity bits associated with a shortened extended Hamming code (generating a Hamming distance of 4, which is capable of correcting any one-bit error and detecting any two-bit error) over:

- even LPOS word: L0, L1, L2, L3, and Tx *where* L0 is 0, 2, ..., 12
- odd LPOS word: L0, L1, L4, L5, and Tx *where* L0 is 1, 3, ..., 13

The two 1's RLL constrain the X,Y bit sequence so that no false Sy is seen.

Mappings for the 14-ary symbols in an even LPOS word (*i.e.*, L0 L1 L2 L3 X Y Tx) and mappings for the 14-ary symbols in an odd LPOS word (*i.e.*, L0 L1 L4 L5 X Y Tx) are as follows:

L0 bits:	u_1 u_2 u_3 u_4
L1 bits:	u_5 u_6 u_7 u_8
L2 or L4 bits:	u_9 u_{10} u_{11} u_{12}
L3 or L5 bits:	u_{13} u_{14} u_{15} u_{16}
X bits:	a b c 1
Y bits:	d e f 1
Tx bits:	u_{17} u_{18} u_{19} u_{20}

LPOS word symbols are constructed from the bit sequences shown in Table **I**, and for each of L0 - L5 and Tx bits, each of u_i ... u_j corresponds to a bit in the bit sequence in Table **I**. For example, if L0 = 5, then the bit sequence for L0, according to Table **I**, should be 1010, which means $u_1 = 1$, $u_2 = 0$, $u_3 = 1$, $u_4 = 0$. As another example, if L2 = 8, then the bit sequence for L1, according to Table **I**, should be 0110, which means $u_9 = 0$, $u_{10} = 1$, $u_{11} = 1$, $u_{12} = 0$.

An encoder is used to compute the parity bits a, b, c, d, e and f as a function of $u_1 \ldots u_{20}$. Within the encoder, the following computations are performed:

$$a = u_1 \oplus u_5 \oplus u_6 \oplus u_9 \oplus u_{11} \oplus u_{14} \oplus u_{15} \oplus u_{16} \oplus u_{18} \oplus u_{20}$$
$$b = u_1 \oplus u_2 \oplus u_7 \oplus u_{10} \oplus u_{11} \oplus u_{12} \oplus u_{15} \oplus u_{16} \oplus u_{17} \oplus u_{19}$$
$$c = u_2 \oplus u_3 \oplus u_6 \oplus u_8 \oplus u_{11} \oplus u_{12} \oplus u_{13} \oplus u_{17} \oplus u_{18} \oplus u_{20}$$
$$d = u_3 \oplus u_4 \oplus u_7 \oplus u_9 \oplus u_{12} \oplus u_{13} \oplus u_{14} \oplus u_{16} \oplus u_{18} \oplus u_{19}$$
$$e = u_4 \oplus u_5 \oplus u_8 \oplus u_{10} \oplus u_{13} \oplus u_{14} \oplus u_{15} \oplus u_{17} \oplus u_{19} \oplus u_{20}$$
$$f = u_1 \oplus u_2 \oplus u_3 \oplus u_4 \oplus u_5 \oplus u_6 \oplus u_7 \oplus u_8 \oplus u_9 \oplus u_{10}$$

where $\oplus$ stands for an exclusive OR operation (*i.e.*, modulo 2 addition). Preferably, a total of 54 exclusive OR logic gates are required to implement the encoder, and a total of nine exclusive OR gates are used to compute each of the parity bits a - f.

The values of $u_1 \ldots u_{20}$ for forming parity bits a - f are based on a 6 × 26 parity check matrix $\mathbf{H} = [h_1\ h_2\ h_3 \ldots h_{20}\ h_{21}\ h_{22}\ h_{23}\ h_{24}\ h_{25}\ h_{26}]$, where h_i is the i^{th} column vector of matrix $\mathbf{H}$ given by:

$$H = \begin{bmatrix} 10001100101001110101100000 \\ 11000010011100111010010000 \\ 01100101001110001101001000 \\ 00110010100111010110000100 \\ 00011001010011101011000010 \\ 11111111111000000000000001 \end{bmatrix}$$

A decoder is used to compute six syndrome bits $s_1 \ldots s_6$. The decoder then determines whether or not there is an error in an LPOS word based on the values of the computed syndrome bits. Within the decoder, the following computations are performed:

$$s_1 = a' \oplus u'_1 \oplus u'_5 \oplus u'_6 \oplus u'_9 \oplus u'_{11} \oplus u'_{14} \oplus u'_{15} \oplus u'_{16} \oplus u'_{18} \oplus u'_{20}$$
$$s_2 = b' \oplus u'_1 \oplus u'_2 \oplus u'_7 \oplus u'_{10} \oplus u'_{11} \oplus u'_{12} \oplus u'_{15} \oplus u'_{16} \oplus u'_{17} \oplus u'_{19}$$
$$s_3 = c' \oplus u'_2 \oplus u'_3 \oplus u'_6 \oplus u'_8 \oplus u'_{11} \oplus u'_{12} \oplus u'_{13} \oplus u'_{17} \oplus u'_{18} \oplus u'_{20}$$
$$s_4 = d' \oplus u'_3 \oplus u'_4 \oplus u'_7 \oplus u'_9 \oplus u'_{12} \oplus u'_{13} \oplus u'_{14} \oplus u'_{16} \oplus u'_{18} \oplus u'_{19}$$
$$s_5 = e' \oplus u'_4 \oplus u'_5 \oplus u'_8 \oplus u'_{10} \oplus u'_{13} \oplus u'_{14} \oplus u'_{15} \oplus u'_{17} \oplus u'_{19} \oplus u'_{20}$$
$$s_6 = f' \oplus u'_1 \oplus u'_2 \oplus u'_3 \oplus u'_4 \oplus u'_5 \oplus u'_6 \oplus u'_7 \oplus u'_8 \oplus u'_9 \oplus u'_{10}$$

where $\oplus$ stands for an exclusive OR operation. Preferably, a total of 60 exclusive OR logic gates are required to compute syndrome bits, and a total of 10 exclusive OR logic gates are used to compute each syndrome bit. The prime notation denotes a received bit (*e.g.*, a' is the received bit a, b' is the received bit b, u'_1 is the received bit u_1, u'_2 is the received bit u_2, etc.), which can be potentially in error. The decoder considers three separate cases and makes a decision in each of the three cases as follows.

Case 1: $s_1 + s_2 + s_3 + s_4 + s_5 + s_6 = 0$ or 1
In case 1, if all the received 4-bit data nibbles are valid 14-ary nibbles, nothing is done (*i.e.*, no error is corrected in bits u'_1 ... u'_{20}). In the present example, $u_1 = u'_1$, ..., $u_{20} = u'_{20}$ are declared by the decoder, where u_1 ... u_{20} are the decoder's data estimates. However, if al least one of the received 4-bit nibbles is not valid, an error detection flag is raised.

Case 2: $s_1 + s_2 + s_3 + s_4 + s_5 + s_6 = 2$ or 4 or 5 or 6
In case 2, an error detection flag is raised.

Case 3: $s_1 + s_2 + s_3 + s_4 + s_5 + s_6 = 3$
In case 3, depending on the values of the syndrome bits, a particular single bit among bits u'_1 ... u'_{20} is "flipped." Specifically, if the syndrome vector in column form is equal to the i^{th} column vector of the parity check matrix **H**, i = 1, 2, ..., 20, then the i^{th} bit u'_i is "flipped." In other words, if $[s_1\ s_2\ s_3\ s_4\ s_5\ s_6]^t = h_i$, *where* i = 1, 2, ..., 20, then the i^{th} bit u'_i is "flipped," where *t* denotes the transpose operation. The decoder then concludes $u_i = u'_i \tilde{}\ 1$, and $u_j = u'_j$ if j is not equal to i. If all the data nibbles with the data estimate after error correction u_i, where i = 1, 2, ..., 20, are valid 14-ary nibbles, the decoding is complete. However, if one of the data nibbles after error correction is not a valid 14-ary nibble, an error detection flag is raised.

For each new LPOS word sequence, a tape drive needs to first read two LPOS words consecutively in order to fully land a seek position since L0, L1, L2, L3, L4, and L5 are required. But after the first two LPOS words (*i.e.*, L2 through L5) are known and can be updated, only one LPOS word is then required for subsequent updates.

With reference now to Figure **4**, there is depicted a high-level logic flow diagram of a method for providing error correction capability to longitudinal position words within a tape storage system, in accordance with a preferred embodiment of the present invention. Starting at block **40**, data are initially encoded via a set of even LPOS words and a set of odd LPOS words, as shown in block **41**. The encoded data can be decoded by generating a set of syndrome bits for each of the LPOS words, as depicted in block **42**. Then, a determination is made as to whether or not there is an error in an LPOS word based on its corresponding syndrome bits. If the sum of the syndrome bits equals 0 or 1, then there is no error in the LPOS word, as shown in block **43**. If the sum of the syndrome bits equals 3, then there is an error in one of the bits of the LPOS word, as depicted in block **44**. If the sum of the syndrome bits equals 2, 4, 5 or 6, then there is more than one error in the bits of the LPOS word, as shown in block **45**.

As has been described, the present invention provides an improved method and apparatus for providing error correction capability to LPOS words. The method of the present invention allows a single-bit error to be corrected and a double-bit error to be detected without increasing the LPOS word length. The particular (n,k) = (26,20) extended shortened Hamming code that was designed can correct all single errors and detect all double errors. In addition, the method of the present invention can detect 20.77% of all possible triple errors (three errors at any position) and 96.55% of all quadruple errors (four errors at any position).

It is also important to note that although the present invention has been described in the context of hardware, those skilled in the art will appreciate that the mechanisms of the present invention are capable of being distributed as a program product in a variety of forms, and that the present invention applies equally regardless of the particular type of signal bearing media utilized to actually carry out the distribution. Examples of signal bearing media include, without limitation, recordable type media such as floppy disks or compact discs and transmission type media such as analog or digital communications links.

While the invention has been particularly shown and described with reference to a preferred embodiment, it will be understood by those

skilled in the art that various changes in form and detail may be made therein without departing from the spirit and scope of the invention.

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CLAIMS

1. A method for providing error correction capability to longitudinal position (LPOS) words in a tape storage system, said method comprising:

encoding data via a plurality of even LPOS words and a plurality of odd LPOS words;

decoding said encoded data by

generating a plurality of syndrome bits for each of said LPOS words; and

determining whether or not there is an error within one of said LPOS words based on its corresponding syndrome bits.

2. The method of Claim 1, wherein one of said even LPOS words includes Sy,L0,L1,L2,L3,X,Y,Tx,
and one of said odd LPOS words includes
Sy,L0,L1,L4,L5,X,Y,Tx

where Sy is a word sync mark
L0 is the least significant symbol in longitudinal position
L1 is the next most significant symbol in longitudinal position
L2 is the next most significant symbol in longitudinal position
L3 is the next most significant symbol in longitudinal position
L4 is the next most significant symbol in longitudinal position
L5 is the next most significant symbol in longitudinal position
Tx is a symbol of tape manufacturer information
X, Y are runlength-limited (RLL) constrained error correction code that are encoded as the following 8 bits: a, b, c, 1, d, e, f, 1, *where* a, b, c, d, e, and f are six parity bits associated with a shortened extended Hamming code.

3. The method of Claim 1, wherein said method further includes concluding there is no error in said one LPOS word if a syndrome bit sum of said one LPOS word equals 0 or 1.

4. The method of Claim 1, wherein said method further includes concluding there is a one-bit error in said one LPOS word if a syndrome bit sum of said one LPOS word equals 3.

5. The method of Claim 1, wherein said method further includes concluding there is more than one bit error in said one LPOS word if a syndrome bit sum of said one LPOS word equals 2, 4, 5 or 6.

6. A tape storage system having error correction capability for longitudinal position (LPOS) words, said tape storage system comprising:

means for encoding data via a plurality of even LPOS words and a plurality of odd LPOS words;

means for decoding said encoded data, wherein said decoding means includes

means for generating a plurality of syndrome bits for each of said LPOS words; and

means for determining whether or not there is an error within one of said LPOS words based on its corresponding syndrome bits.

7. The tape storage system of Claim 6, wherein one of said even LPOS words includes

Sy,L0,L1,L2,L3,X,Y,Tx,

and one of said odd LPOS words includes

Sy,L0,L1,L4,L5,X,Y,Tx

where Sy is a word sync mark

L0 is the least significant symbol in longitudinal position

L1 is the next most significant symbol in longitudinal position

L2 is the next most significant symbol in longitudinal position

L3 is the next most significant symbol in longitudinal position

L4 is the next most significant symbol in longitudinal position

L5 is the next most significant symbol in longitudinal position

Tx is a symbol of tape manufacturer information

X, Y are runlength-limited (RLL) constrained error correction code that are encoded as the following 8 bits: a, b, c, 1, d, e, f, 1, *where* a, b, c, d, e, and f are six parity bits associated with a shortened extended Hamming code.

8. The tape storage system of Claim 6, wherein said tape storage system further includes means for concluding there is no error in said one LPOS word if a syndrome bit sum of said one LPOS word equals 0 or 1.

9. The tape storage system of Claim 6, wherein said tape storage system further includes means for concluding there is a one-bit error in said one LPOS word if a syndrome bit sum of said one LPOS word equals 3.

10. The tape storage system of Claim 6, wherein said tape storage system further includes means for concluding there is more than one bit error in said one LPOS word if a syndrome bit sum of said one LPOS word equals 2, 4, 5 or 6.

11. A computer program product residing in a computer usable medium for providing error correction capability to longitudinal position (LPOS) words in a tape storage system, said computer program product comprising:

program code means for encoding data via a plurality of even LPOS words and a plurality of odd LPOS words;

program code means for decoding said encoded data by

generating a plurality of syndrome bits for each of said LPOS words; and

determining whether or not there is an error within one of said LPOS words based on its corresponding syndrome bits. generating a plurality of syndrome bits for each of said LPOS words.

12. The computer program product of Claim 11, wherein one of said even LPOS words includes

Sy,L0,L1,L2,L3,X,Y,Tx,

and one of said odd LPOS words includes

Sy,L0,L1,L4,L5,X,Y,Tx

where Sy is a word sync mark

L0 is the least significant symbol in longitudinal position

L1 is the next most significant symbol in longitudinal position

L2 is the next most significant symbol in longitudinal position

L3 is the next most significant symbol in longitudinal position

L4 is the next most significant symbol in longitudinal position

L5 is the next most significant symbol in longitudinal position

Tx is a symbol of tape manufacturer information

X, Y are runlength-limited (RLL) constrained error correction code that are encoded as the following 8 bits: a, b, c, 1, d, e, f, 1, *where* a, b, c, d, e, and f are six parity bits associated with a shortened extended Hamming code.

13. The computer program product of Claim 11, wherein said computer program product further includes program code means for concluding there is no error in said one LPOS word if a syndrome bit sum of said one LPOS word equals 0 or 1.

14. The computer program product of Claim 11, wherein said computer program product further includes program code means for concluding there is a one-bit error in said one LPOS word if a syndrome bit sum of said one LPOS word equals 3.

15. The computer program product of Claim 11, wherein said computer program product further includes program code means for concluding there is more than one bit error in said one LPOS word if a syndrome bit sum of said one LPOS word equals 2, 4, 5 or 6.

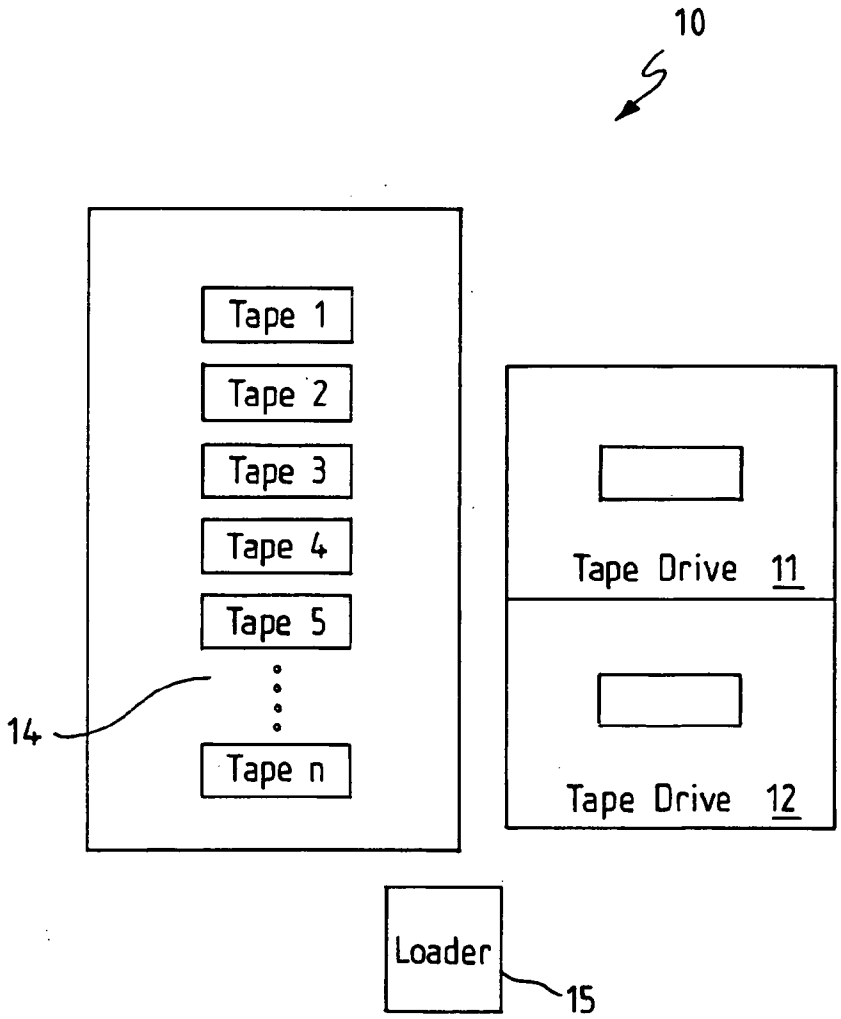
10
Tape 1
Tape 2
Tape 3
Tape 4
Tape 5
Tape n
14
Tape Drive 11
Tape Drive 12
Loader
15

FIG. 1

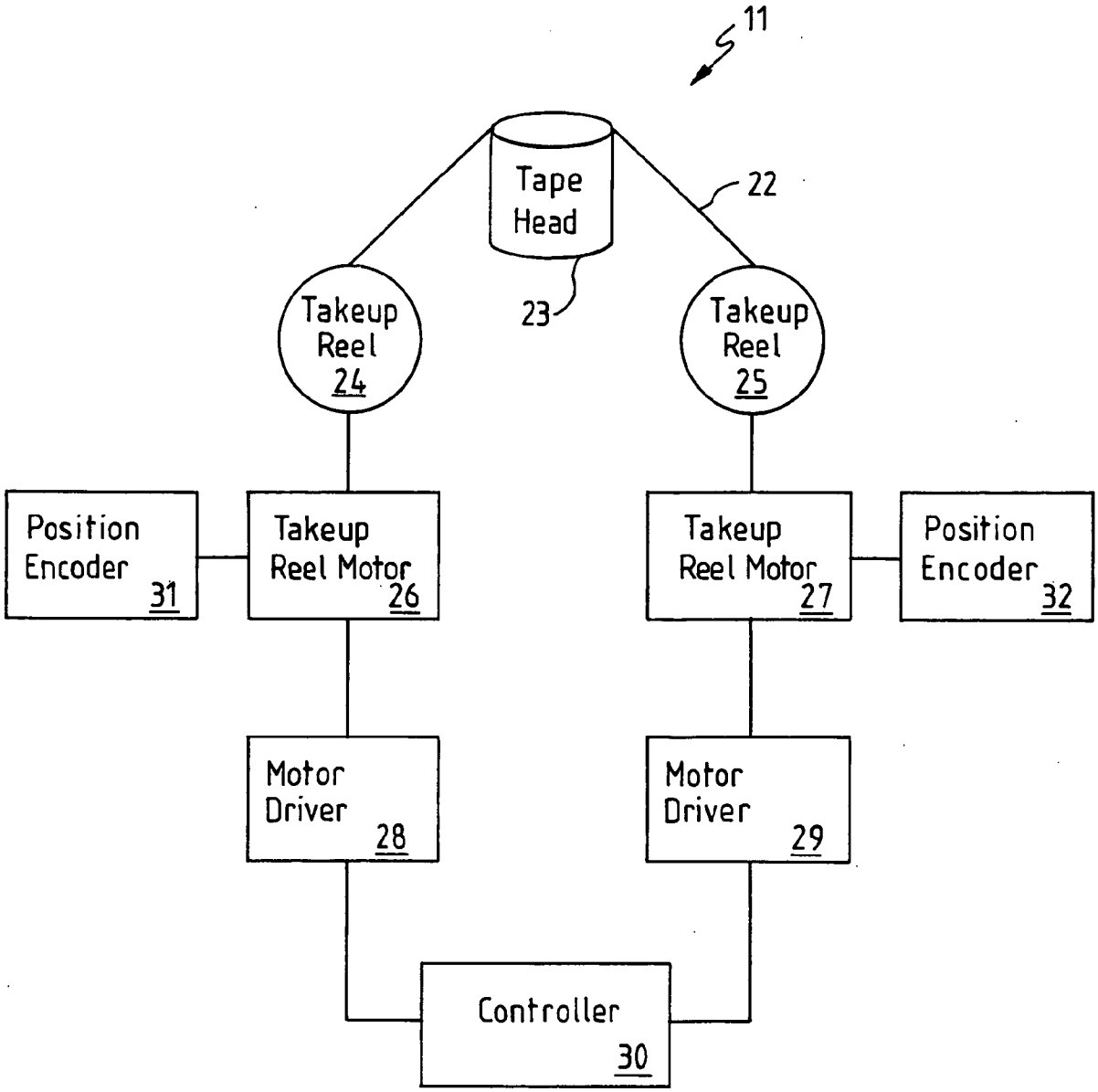
11
Tape Head
22
23
Takeup Reel 24
Takeup Reel 25
Position Encoder 31
Takeup Reel Motor 26
Takeup Reel Motor 27
Position Encoder 32
Motor Driver 28
Motor Driver 29
Controller 30

FIG. 2

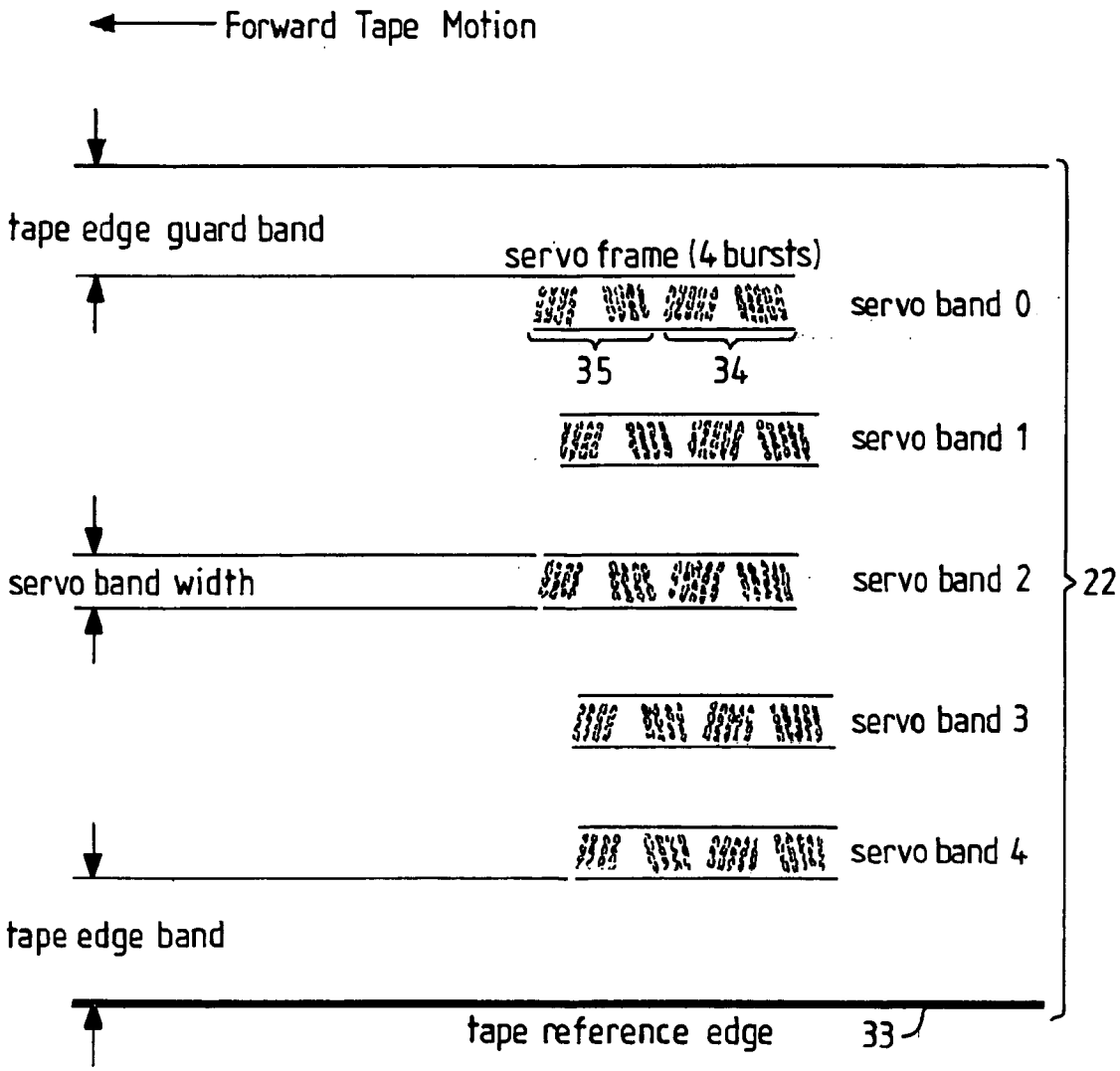
Forward Tape Motion
tape edge guard band
servo frame (4 bursts)
servo band 0
35
34
servo band 1
servo band width
servo band 2
22
servo band 3
servo band 4
tape edge band
tape reference edge
33

FIG. 3

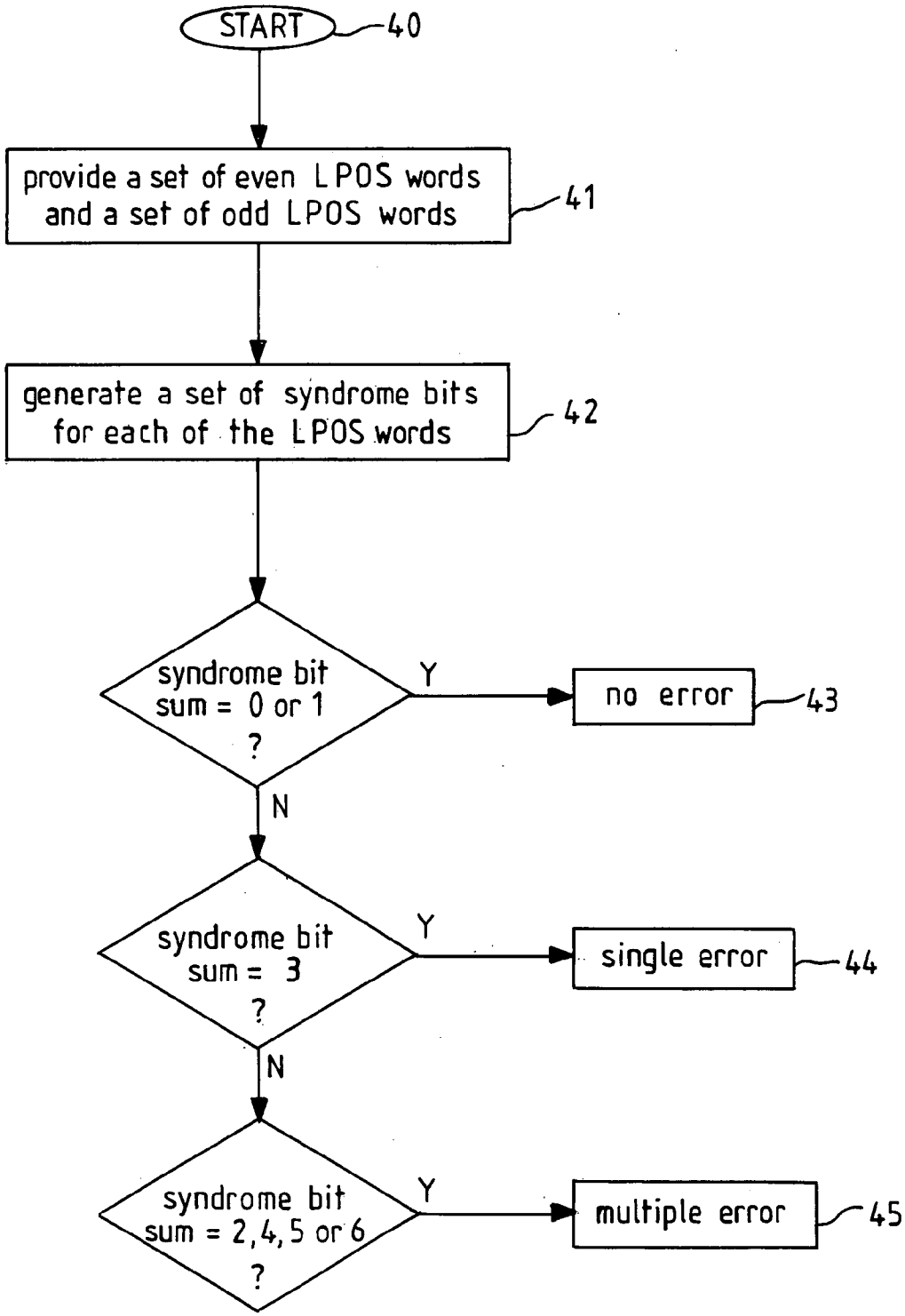
START
40
provide a set of even LPOS words and a set of odd LPOS words
41
generate a set of syndrome bits for each of the LPOS words
42
syndrome bit sum = 0 or 1 ?
Y
no error
43
N
syndrome bit sum = 3 ?
Y
single error
44
N
syndrome bit sum = 2,4,5 or 6 ?
Y
multiple error
45

FIG. 4

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2006/063457

A. CLASSIFICATION OF SUBJECT MATTER
INV. G11B20/18

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G11B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, PAJ, WPI Data, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	ECMA: "ECMA-319: Data Interchange on 12,7 mm 384-Track Magnetic Tape Cartridges ? Ultrium-1 Format" INTERNET ARTICLE, [Online] June 2001 (2001-06), XP002395655 Retrieved from the Internet: URL:http://www.ecma-international.org/publications/files/ECMA-ST/Ecma-319.pdf> [retrieved on 2006-08-22] page 52 - page 54 -----	1-15
Y	G.W. BROCK, C,H, KALTHOFF: "Detecting erroneous servo in record storage apparatus" IBM TECHNICAL DISCLOSURE BULLETIN, vol. 21, no. 3, August 1978 (1978-08), XP002395656 the whole document -----	1-15

-/--

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
22 August 2006	13/09/2006

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Rydyger, K

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2006/063457

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	SONY: "Digital Audio Technology" 2001, FOCAL PRESS , OXFORD, GB , XP002395658 page 122 - page 127 -----	1-15
A	US 5 696 774 A (INOUE ET AL) 9 December 1997 (1997-12-09) figure 12 figure 25 -----	1-15
A	G.A. JAQUETTE: "LTO: a better format for midrange tape" IBM J. RES. & DEV, [Online] vol. 47, no. 4, July 2003 (2003-07), XP002395659 Retrieved from the Internet: URL:http://www.research.ibm.com/journal/rd/474/jaquette.pdf> [retrieved on 2006-08-22] the whole document -----	1-15

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2006/063457

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5696774 A	09-12-1997	GB 2295946 A	12-06-1996