(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
7 August 2003 (07.08.2003)

PCT

(10) International Publication Number
WO 03/065374 A1

(51) International Patent Classification[7]: G11B 27/36, 20/12, G06F 3/06

(21) International Application Number: PCT/GB03/00178

(22) International Filing Date: 17 January 2003 (17.01.2003)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
10/058,101 29 January 2002 (29.01.2002) US

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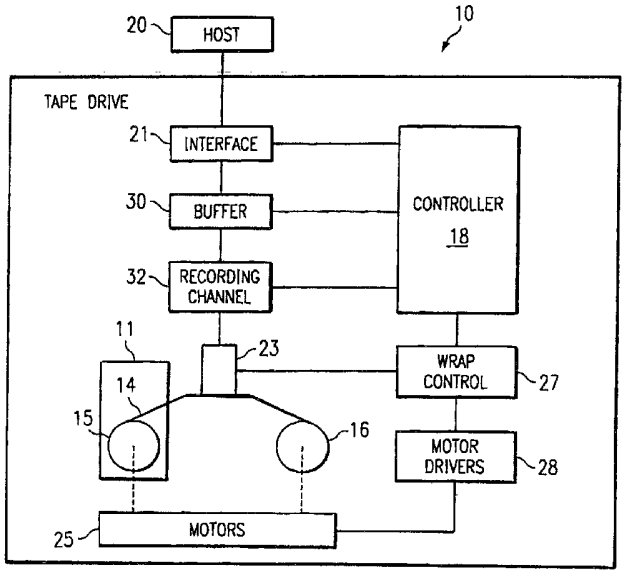
(81) Designated States (national): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SD, SE, SG, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States (regional): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PT, SE, SI, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

[Continued on next page]

(54) Title: WRITING SYNCHRONIZED DATA TO MAGNETIC TAPE



(57) Abstract: Synchronized data is written to magnetic tape while reducing the number of backhitches. A controller detects a pattern of synchronizing events for received data records to be written to tape; writes each transaction of data records to the magnetic tape; accumulates the synchronized transactions in a buffer; and subsequently recursively writes the accumulated transactions of data records from the buffer to the magnetic tape in a sequence. A single backhitch may be employed to place the recursively written accumulated data records following the preceding data, maximizing performance and capacity.

WO 03/065374 A1

Published:
— *with international search report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

WRITING SYNCHRONIZED DATA TO MAGNETIC TAPE

FIELD OF THE INVENTION

This invention relates to storage of data to magnetic tape, and, more particularly, to storage of synchronized data, so that the entity sending the data is able to erase its data, knowing that a copy physically exists on magnetic tape.

BACKGROUND OF THE INVENTION

Magnetic tape provides a means for physically storing data which may be archived or which may be stored in storage shelves of automated data storage libraries and accessed when required. Data stored in this manner has an aspect of permanence which allows copies of the data stored in memory or disk at a host system to be erased, knowing that a copy exists on magnetic tape. The available storage space at the host system is relatively expensive, and there is a desire to release the storage space as soon as possible. Hence, data is typically transferred through an intermediate staging buffer, such as a hard disk, to the tape drive, and there is also a desire to release and overwrite the staging buffer as soon as possible.

Thus, it is often desirable to "synchronize" the data.

"Synchronized data" is defined as data or other information which is subject to a "synchronizing event" or similar command requiring the tape drive to not return "Command Complete" to a write type of command, or an indication that the command has been or will be successfully executed, until it has actually committed the data to media, specifically, the magnetic tape. As the result, if power is lost, the data can be recovered from the tape, whereas it may not be recoverable from a volatile DRAM storage of the tape drive buffer.

One example of a synchronizing event is a Write Filemark command with the Immediate bit set to "0". This means that the drive is not to respond immediately, but instead is to respond when the command has completed, meaning that any data sent as part of the command is written out to tape. A specialized case of a Write Filemark command is where the number of Filemarks field is also set to "0", meaning that the Write Filemark command has no data of its own, and all data which precedes the command must be written to tape before a command complete is sent. Hence,

this command is often referred to as a "Synchronize" command, as is known to those of skill in the art.

Another example of a synchronizing event is a host selectable write mode known to those of skill in the art as "non-buffered writes", where an implicit synchronize must be performed after each record is written from the host. "Command Complete" is not returned for any write command until the data is successfully written on media.

Herein, writing any data record, group of records, or other mark, is defined as a "transaction", and writing such data record, etc., as the result of a synchronizing event is defined as a "synchronized transaction".

A difficulty with respect to magnetic tape is that the data is recorded sequentially without long gaps between data sets, whereas synchronized transactions are stored in separate bursts for each synchronizing event, with a noticeable time period before writing the next transaction. This requires that the tape drive "backhitch" after writing the synchronized transaction in order to write the next transaction closely following the preceding transaction. Tape is written or read while it is moved longitudinally at a constant speed. Hence, a backhitch requires that the tape be stopped, reversed to beyond the end of the previous transaction, stopped again, and accelerated up to speed in the original direction by the time that the end of the previous transaction is reached. As is understood by those of skill in the art, the backhitch process consumes a considerable amount of time, and, if a large number of small synchronized transactions are to be stored, the throughput of the tape drive is reduced dramatically. As an example, backhitch times can vary from about half a second to over three seconds.

It would be desirable to write synchronized data as transactions to magnetic tape while reducing the number of backhitches for writing the synchronized transactions.

SUMMARY OF THE INVENTION

In one aspect of the present invention, a recording system for a magnetic tape drive comprises at least one buffer for storing data in the form of transactions to be written to magnetic tape, at least one recording channel coupled to the buffer for operating at least one

read/write head for writing transactions from the buffer to the magnetic tape, and a controller.

The controller detects a synchronizing event for a received transaction stored in the buffer; writes the detected synchronized transaction from the buffer to the magnetic tape; continues to move the tape longitudinally, leaving large gaps or writing separator signals to the magnetic tape following the written synchronized transaction, continuing until a subsequently received transaction is written to the magnetic tape following the separator signals; and repeats the detection of a synchronized received transaction, writing the detected synchronized transaction, moving the tape, and writing the separator signals, for each succeeding detected synchronized received transaction, such that the tape is moved longitudinally during the repeated writing without stopping. Thus, there is no backhitch, the tape drive continues to write the transactions without stopping.

In another embodiment, the recording system is as above, and the controller detects a pattern of synchronized transactions to be written to the magnetic tape; writes each detected synchronized transaction of the detected pattern from the buffer to the magnetic tape; upon writing each synchronized transaction from the buffer to the magnetic tape, accumulates the synchronized transaction in the buffer; and subsequently recursively writes the accumulated transactions from the buffer to the magnetic tape in a sequence. The recursive writing may require a backhitch to place the recursively written accumulated transactions following the preceding data, but the prior art may have required significantly more backhitches to write the same data.

In still another embodiment, where the magnetic tape comprises a plurality of wraps, such as in an LTO system, as is known to those of skill in the art, the controller, writes at least some of the synchronized transactions of the detected pattern on at least one of the plurality of wraps that is separate from any wrap of the recursive writing. Thus, a good working copy is fixed on the tape before the final set of transactions are recursively written. The working copy is written without stopping, leaving larger than normal gaps between formatted entities, and may comprise multiple copies or special constructs. The recursively written copy is written to conform to normal density gaps and standard format.

In a further embodiment, the controller separately writes each synchronized transaction from the buffer to the magnetic tape, and

identifies each separately written synchronized transaction, for example by means of an access point. The controller additionally identifies the recursively written transactions as the most current copy thereof, superseding the identified separately written synchronized transactions.

In an alternative embodiment, the controller writes each synchronized transaction of the detected pattern from the buffer to the magnetic tape by rewriting all the accumulated transactions of the detected pattern in a sequence, and appending the synchronized transaction to the sequence of rewritten accumulated transactions, identifying rewritten and appended written synchronized transactions as the most current copy thereof, for example by means of an incremented write pass or access point. The controller additionally identifies the recursively written transactions as the most current copy thereof, superseding the identified rewritten and appended written synchronized transactions.

Thus, the present invention writes synchronized data to magnetic tape while reducing the number of backhitches for the synchronized data.

Embodiments of the invention will now be described, by way of example only, with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram of a magnetic tape drive with a magnetic tape cartridge which tape drive may implement the present invention;

FIG. **2** is a diagrammatic illustration of synchronized data written on a magnetic tape employing the prior art methodology with backhitches;

FIG. **3** is a diagrammatic illustration of synchronized data written on magnetic tape employing one embodiment of the present invention;

FIG. **4** is a diagrammatic illustration of synchronized data written on magnetic tape employing an alternative embodiment of the present invention;

FIG. **5** is a diagrammatic illustration of synchronized data written on magnetic tape having a plurality of wraps, and employing separate accumulating backhitchless wraps for storing a work copy in accordance with an embodiment of the present invention;

FIG. **6** is a flow chart depicting an embodiment of the method of the present invention for backhitchless writing of synchronized data;

FIG. **7** is a flow chart depicting an embodiment of the method of the present invention for accumulating synchronized data for recursively writing the data;

FIG. **8** is a flow chart depicting an embodiment of the method of the present invention for writing the accumulated synchronized data of FIG. **7**;

FIG. **9** is a flow chart depicting an embodiment of the method of the present invention for writing the accumulated synchronized data of FIG. **8**;

FIG. **10** is a flow chart depicting an alternative embodiment of the method of the present invention for writing the accumulated synchronized data of FIG. **8**; and

FIG. **11** is a flow chart depicting an embodiment of the method of the present invention for recursively writing the accumulated synchronized data of FIG. **7**.

DETAILED DESCRIPTION OF THE INVENTION

Referring to FIG. **1**, a tape drive **10** is illustrated which may implement embodiments of the present invention. The tape drive provides a means for reading and writing information with respect to a magnetic tape cartridge **11**. A cartridge and associated tape drive are illustrated, such as those adhering to the Linear Tape Open (LTO) format. An example of a single reel tape drive is the IBM 3580 Ultrium magnetic tape drive based on LTO technology. A further example of a single reel tape drive and cartridge is such as that discussed in U.S. Patent No. 5,432,652, Comeaux et al., issued July 11, 1995. Another example of a single reel tape drive is the IBM 3590 Magstar magnetic tape drive and associated magnetic tape cartridge. An example of a dual reel cartridge is the IBM 3570 magnetic tape cartridge and associated drive.

As is understood by those of skill in the art, a magnetic tape cartridge **11** comprises a length of magnetic tape **14** wound on one or two reels **15**, **16**. Also as is understood by those of skill in the art, a tape drive **10** comprises one or more controllers **18** of a recording system for operating the tape drive in accordance with commands received from a host system **20** received at an interface **21**. The tape drive may comprise a

standalone unit or comprise a part of a tape library or other subsystem. The tape drive **10** may be coupled to the host system **20** directly, through a library, or over a network, and employ the Small Computer Systems Interface (SCSI), Fibre Channel Interface, etc.

The magnetic tape cartridge **11** may be inserted in the tape drive **10**, and loaded by the tape drive so that one or more read and/or write heads **23** of the recording system reads and/or writes information with respect to the magnetic tape **14** as the tape is moved longitudinally by one or more motors **25**. The magnetic tape comprises a plurality of parallel tracks, or groups of tracks. In some formats, such as the LTO format, above, the tracks are arranged in a serpentine back and forth pattern of separate wraps, as is known to those of skill in the art. Also as known to those of skill in the art, the recording system comprises a wrap control system **27** to electronically switch to another set of read and/or write heads, and/or to seek and move the read and/or write heads **23** laterally of the magnetic tape, to position the heads at a desired wrap or wraps, and, in some embodiments, to track follow the desired wrap or wraps. The wrap control system may also control the operation of the motors **25** through motor drivers **28**, both in response to instructions by the controller **18**.

Controller **18** also provides the data flow and formatting of data to be read from and written to the magnetic tape, employing a buffer **30** and a recording channel **32**, as is known to those of skill in the art.

As discussed above, magnetic tape provides a means for physically storing data which may be archived or which may be stored in storage shelves of automated data storage libraries and accessed when required. Tape drives often employ a "read after write" process to insure that the data is written correctly to provide an aspect of permanence. This permanence allows copies of the data stored in memory or disk at the host system **20** to be erased, knowing that a correct copy exists on magnetic tape.

The available storage space at the host system is relatively expensive, and there is a desire to release the storage space as soon as possible. Hence, data is typically transferred through an intermediate staging buffer, such as a hard disk, to the tape drive, and there is also a desire to release and overwrite the staging buffer as soon as possible. In the instant example, the staging buffer, if any, is considered to comprise part of the host system **20**.

In order to release the staging buffer, it is necessary to have an assurance that the data has actually been recorded on the magnetic tape **14**, and is not just in a volatile DRAM storage, such as buffer **30**, and may be lost if power to the buffer or to the drive is lost. Thus, it is often desirable to "synchronize" the data, requiring the tape drive to not return "Command Complete" to a write type of command, or an indication that the command has been or will be successfully executed, until it has actually committed the data to media, specifically, the magnetic tape **14**. Once the data has been written to the magnetic tape, if power is lost, the data can be recovered from the tape, whereas it may not be recoverable from a volatile DRAM storage of the tape drive buffer.

Various examples of synchronizing events which have the effect of synchronizing the data are known to those of skill in the art. One example of a synchronizing event is a Write Filemark command with the Immediate bit set to "0". This means that the drive is not to respond immediately, but instead is to respond when the command has completed, meaning that any data sent as part of the command is written out to tape. A specialized case of a Write Filemark command is where the number of Filemarks field is also set to "0", meaning that the Write Filemark command has no data of its own, and the only meaning of the command is that all data which precedes the command must be written to tape before a command complete is sent. Another example is a host selected non-buffered write mode implicitly requiring a synchronize for each record.

Referring to FIG. **2**, data is typically recorded on magnetic tape sequentially with only short gaps between data sets, for example between data sets **31** and **32**, **32** and **33**, etc. These gaps may be written with an Interblock Gap (IBG) pattern, or may comprise a Data Set Separator (DSS) pattern **40**, as is known to those of skill in the art. The gap may comprise an actual unrecorded portion and a portion that is recorded. For example, the LTO format DSS comprises a tone pattern between data sets. As discussed above, the tape is written or read while motors **25** of FIG. **1** move the tape longitudinally. Data typically comprises a string of records arranged in data sets, each with a DSS, which are written with nominal spacing. Only occasionally, typically when the buffer is empty, is the tape stopped.

However, if the data is synchronized, it must be immediately written to tape from the buffer, and only after the synchronized transaction has been written to tape is the transaction erased from the buffer and overwritten, such that it cannot be the subject of a continuous data flow.

Hence, synchronized transactions instead must be written immediately in separate bursts for each synchronization event. As the result, after one data set is written for a synchronized transaction, in the prior art of FIG. **2**, to insure that the data sets are closely spaced, the controller **18** of FIG. **1** typically operates the servo system and motor drivers to stop the tape after the data set. Some finite distance and finite time is required to stop the tape, and the tape is then "backhitched", reversed to beyond the end of the previous data set, stopped again, and accelerated up to speed in the original direction by the time that the end of the first data set is reached, so that the DSS and the next data set may be written. As is understood by those of skill in the art, the backhitch process consumes a considerable amount of time.

Thus, if a large number of synchronized transactions are to be stored, the throughput of the tape drive is reduced dramatically. As an example, backhitch times can vary from about half a second to over three seconds each.

In the example of FIG. **2**, records **50-53** are synchronized. Typically, a transaction will comprise hundreds of records, but only transactions of one record each are illustrated for descriptive purposes herein. If a transaction comprised of a record, or group of records, ends in the middle of a data set, then an End Marker (EM) is written to signal that the remainder of that data set is empty. Typically, each synchronized transaction is formatted as separate data set, and is illustrated in FIG. **2** as data records **50-53** in data sets **31-34**. Thus, the prior art process requires that the tape drive **10** backhitch (shown by arrow **71**) after writing data set **31** (to synchronize transaction record **50**), to be positioned to write data set **32** with a minimum amount of DSS pattern in between; to backhitch **72** after writing data set **32** to synchronize transaction record **51**, and write data set **33**; etc. The process continues until all of the synchronized data has been written.

FIGS. **1** and **3** illustrate embodiments of the present invention for reducing the number of backhitches for the synchronized data.

In one embodiment, the recording system for a magnetic tape drive, e.g., magnetic tape drive **10** of FIG. **1**, comprises at least one buffer **30** for storing data in the form of data transactions to be written to magnetic tape **14**, at least one recording channel **32** coupled to the buffer for operating at least one read/write head **23** for writing transactions from the buffer to the magnetic tape, and at least one controller **18**.

In one embodiment, the controller **18** detects a synchronized received transaction, e.g., transaction record **50** of FIG. **3**, stored in the buffer **30**; writes the detected synchronized transaction record **50**, with EM **60**, from the buffer to the magnetic tape as data set **80**; leaves an elongated gap, comprising an unrecorded gap and/or written separator signals **90** (e.g., DSS) to the magnetic tape following the written synchronized transaction record **50** (data set **80**), continuing the gap with or without separator signals **90** until a subsequently received synchronized transaction **51** (data set **81**) is written to the magnetic tape following the separator signals; and repeats the detection of a synchronized received transaction (e.g., record **51**), writing the detected synchronized transaction (as data set **81**), and writing the gap of separator signals (e.g., separator signals **91**), etc., for each succeeding detected synchronized received transaction, such that the tape is moved longitudinally during the repeated writing without stopping. Thus, there is no backhitch, the tape drive continues to write the synchronized transactions without stopping.

To complete the example of FIG. **3** for the four illustrated synchronized transaction records **50-53**, the next synchronized received transaction **52** is detected, and is written as data set **82**, and the gap separator signals (e.g., separator signals **92**) are typically written for some or all of the distance until the next detected synchronized received transaction **53** is written as data set **83**, etc.

Thus, no backhitch is required, saving considerable processing time for completing the process for writing all of the synchronized data.

In another embodiment of the present invention, also illustrated by FIGS. **1** and **3**, space on the magnetic tape is saved by recursively writing the synchronized data. To preserve the synchronized transactions **50-53** in the event that power is lost, the data sets **80-83** are considered as work copies of the transactions. Once the transactions have been recursively written, the work copies may be overwritten.

First, the controller **18** detects a pattern of synchronized transactions to be written to the magnetic tape **14**. A pattern may comprise a predetermined number of consecutive synchronized transactions of less than a certain length. As one example, a pattern may comprise two consecutive synchronized transactions, each having a length less than that of a data set. As discussed above, the typical synchronized transaction

is written to tape, and then the transaction is erased from the host system with the assurance that the transaction has been written and will not be lost as the result of a power loss.

The controller **18** writes each detected synchronized transaction, illustrated as a record **50-53**, of the detected pattern from the buffer to the magnetic tape **14**, e.g., as data sets **80-83**, above. Previous synchronized transactions of the detected pattern may be excluded, having already been written in the manner discussed above before the pattern is detected. Thus, in FIG. **3**, the previous synchronized transactions may comprise the previous data **99**. Upon writing each synchronized transaction of the detected pattern from the buffer to the magnetic tape, the controller accumulates the synchronized transaction in the buffer **30**; and subsequently recursively writes the accumulated transactions from the buffer to the magnetic tape in a sequence, e.g., illustrated as data sets **100, 101**. The recursive writing may comprise a backhitch to place the recursively written accumulated transactions following the preceding data **99**, and with the nominal gap.

Thus, the synchronized transactions **50-53** have been immediately written to the magnetic tape **14**, and preserved against a power loss at the buffer **30**, as work copies in data sets **80-83**, while also being accumulated in buffer **30**, and then recursively written to immediately follow the preceding data **99** in data sets **100,101**, saving space. Once the transactions have been recursively written, the work copies **80-83** may be overwritten.

The point at which the accumulated synchronized data is recursively written may comprise the termination of the pattern of synchronously written transactions, may comprise a predetermined threshold, such as the limit of capacity of the buffer **30** to accumulate data records, or may comprise the limit of capacity of the work space for the work copies **80-83** and their separation signals **90-92**.

In the embodiment of FIG. **3**, the controller separately writes each synchronized transaction **50-53** from the buffer to the magnetic tape, in the example as data sets **80-83**, and identifies each separately written synchronized transaction, for example, by means of an access point **110-113**. Access points are a means under the LTO format for designating the beginning of a current data record or records. The controller additionally identifies the recursively written transactions as the most

current copy thereof, employing a new access point **115**, superseding the identified separately written synchronized transactions of the data sets **80-83**. Alternatively or additionally, the write pass indication **"WP"** for each data set may be incremented to indicate that the recursively written transactions are each the most recent copy, superseding the identified separately written synchronized transactions of the data sets **80-83**. Both access points and write pass procedures are within the LTO format, as is known to those of skill in the art. As the result, should power be lost before the work copies **80-83** are overwritten, examination of the access points and/or write pass indicators will allow a correct recovery to be made.

An alternative embodiment of the present invention is illustrated in FIG. **4**, wherein the controller writes each synchronized transaction **50-53** of the detected pattern of synchronizing events from the buffer to the magnetic tape by writing data sets of transactions, and, for any partial data set that was not filled upon writing a transaction, rewriting the partial data set and appending the next synchronized transaction that is being written. The partial data set is obtained from the data accumulated in the buffer **30** of FIG. **1**. Thus, a transaction of one or more records, shown as record **50**, is written separately as data set **120**, followed by an End Marker **300** as comprising a partial data set. Then, the DSS **130** is written, and the transaction is accumulated in buffer **30**. The subsequent transaction **51** is appended to the accumulated transaction **50** in data set **121** which is written, causing transaction **50** (or the last part of transaction **50** if it includes previous data sets) to be rewritten and the appended transaction **51** to be written to tape, so that there is a concentration of the transactions. As data set **121** is also a partial data set, End Marker **301** is written, and the data set **121** is followed by DSS **131**, and transaction **51** is accumulated in the buffer. The process continues as the subsequent transaction **52** is appended to the accumulated transactions **50** and **51** of the partial data set, and the rewritten accumulated transactions **50**, **51** and the synchronized transaction **52** are written as data sets **122** and **123**, etc. Once a data set has been filled, it is again rewritten, such as data set **122**, and, after that filled data set is written, it is no longer rewirrten as a work copy.

The rewritten and appended written synchronized transaction is identified as the most current copy thereof, for example by means of an incremented write pass **"WP"** for the data set, as discussed above.

Subsequently, upon recursively writing the data sets, the controller additionally identifies the recursively written transactions as the most current copies thereof, for example by further incrementing the write pass "**WP**" for the data sets, superseding the written and/or identified rewritten and appended written synchronized transactions.

For example, the write pass indicator of data set **141** for transaction **50**, when rewritten for the first time, is incremented to "**WP1**", and the write pass indicator for data set **122** in which transaction **50** is rewritten a second time, is incremented to "**WP2**". The controller then recursively writes the transactions **50-53** as data sets **145** and **146**. The controller additionally identifies the recursively written transactions as the most current copy thereof, incrementing the write pass for the data set **145** containing transaction **50** an additional time to "**WP3**", and incrementing the write pass for the data set **146** containing part of the rewritten transaction **52** to "**WP1**". Again, as the result, should power be lost before the work copies **120-123** are overwritten, examination of the write pass indicators will allow a correct recovery to be made.

Alternatively, FIG. **4** represents a further alternative embodiment of separately writing each of the synchronized transactions discussed above, in that the write pass indicator need not be updated. Instead, the active copy of the transaction is indicated by an access point **140-142**. Thus, transaction **50** is indicated by access point **140**, transaction **51** is indicated by access point **141**, etc. The controller recursively writes the transactions **50-53** as data sets **145** and **146**, and additionally identifies the recursively written transactions as the most current copy thereof, employing an access point **148**, superseding the identified separately written synchronized transactions of the data sets **120-123**.

Referring to FIG. **5**, in still another embodiment, where the magnetic tape comprises a plurality of wraps, such as in an LTO system as discussed above, the controller **18** of FIG. **1** writes the work copies of at least some of the synchronized transactions of the detected pattern on at least one of the plurality of wraps that is separate from the wrap to which it will be recursively written. Thus, a good working copy is fixed on the tape before the final set of transactions in the example, are recursively written.

Specifically, in the example, the pattern of synchronously written transactions is detected after data sets **150** and **151** have been written on

standard wrap **160** in the direction of arrow **161**. The controller operates the wrap control system **27** of FIG. **1** to electronically switch read/write heads, or to conduct a seek and reposition the tape head **23** to a set of work copy wraps, such as accumulating backhitchless wraps **180** and **181**.

In one embodiment, the controller **18** designates a plurality of wraps of the magnetic tape **14** as work copy wraps **180**, **181**, and, upon detecting a pattern of synchronizing events, determines whether access to the work copy wraps requires a seek, or may be conducted electronically, switching to a different set of read/write heads. If a seek is required in which the head is moved laterally of the wraps, the controller **18** selects a work copy wrap having the quickest seek. As an example, the quickest seek may be to the closest available work copy wrap.

In another embodiment, once a work copy wrap has been selected, the controller **18** determines the present longitudinal position of the read write head along the tape, and determines the writable space of the selected work copy wrap in each longitudinal direction from that present longitudinal position. The controller then operates the motors **25**, the wrap control **27** and the read/write head to begin write the synchronized transactions in the longitudinal direction of the selected work copy wrap having the greatest writable space.

In the example, the work copies **170-171** are then written on the accumulating backhitchless wraps **180** and **181**, first in the direction of arrow **185**, and then in the direction of arrow **186**. In the example, the work copies are written in the manner of separately writing the synchronized transactions by appending, and employing the access points, while ignoring the rewritten data records, all as illustrated in FIG. **4**. The reversal of direction between that of arrow **185** to that of arrow **186** provides a reduced distance for the backhitch process, and, accomplishes one reversal of the backhitch. The reversal point for switching direction of writing the work copies from the direction of arrow **185** to that of arrow **186** may comprise the point at which the buffer **30** of FIG. **1** is about half full of accumulated synchronized transactions. Various algorithms may be employed to determine the reversal point for switching the direction of writing the work copies. The goal of any such algorithm is to reach the original append point (to recursively write the transactions) when the buffer is full of accumulated synchronized transactions.

The controller operates the wrap control system **27** of FIG. **1** to access the tape head **23** to the standard wrap and the synchronized

transactions are then recursively written from the buffer to the standard wrap **160** immediately after the preceding data **151** in the direction of arrow **161**, shown as data sets **190**. The work copies **170-171** may then be overwritten.

Embodiments of the method of the present invention are illustrated in FIGS. **6-11**.

Referring to FIGS. **1**, **3**, **4** and **6**, in step **200**, data is received at interface **21** and, in step **201**, is stored in buffer **30**. Step **203** detects whether the data is accompanied by or followed by a synchronizing event, such that the transaction is to be synchronized. If not, the data is written to the magnetic tape **14** employing a normal algorithm in step **205**, for example, writing the data at a time selected by the tape drive, typically to maximize streaming, which may entail delaying the start of writing, in sequence, each data set separated from the previous data set by a DSS.

Upon detection of a synchronizing event at step **203**, step **204** kicks off a check at connector **206** to detect a pattern of synchronizing events as will be discussed, and proceeds at step **207**. In step **207**, the synchronized transaction is written to tape, either as part of the pattern as will be discussed, or as a single transaction. Step **208** determines whether the end of data for the transaction has been reached and, if not, cycles back to step **207** to continue writing the data. Once the end of data for the transaction is sensed and the data has been written to tape in steps **207** and **208**, in step **210**, the controller **18** signals command complete. Thus, the host system **20** may release the staging buffer or other source of the data. As an example, in FIG. **3**, the detected synchronized data record or records **50**, with EM **60**, is written from the buffer to the magnetic tape as data set **80**, and in FIG. **4** as data set **120**.

In step **211**, the controller **18** leaves a gap and/or writes separator signals (e.g., DSS) to the magnetic tape following the written synchronized data record **50** (in FIG. **3** separator signals **90** following data set **80**, in FIG. **4** separator signals **130** following data set **120**), continuing the gap and/or separator signals **90**, **130** until, as determined by step **212** and steps **203** and **205** or **207** cause a subsequently received transaction **51** (data set **81** in FIG. **3**, data set **121** in FIG. **4**) to be written to the magnetic tape following the separator signals. The process of FIG. **6** thus repeats the detection of synchronized received transactions

(e.g., illustrated as record **51**), writing the detected synchronized transactions (as data set **81**, **121**), and writing the gaps and/or separator signals (e.g., separator signals **91**, **131**), etc., for each succeeding detected synchronized received transaction, such that the tape is moved longitudinally during the repeated writing without stopping. Thus, there is no backhitch, and the tape drive continues to write the transactions without stopping.

Connector **206** leads to FIG. **7**. Referring to FIGS. **1**, **3**, **4** and **7**, space on the magnetic tape is saved by recursively writing the synchronized data. To preserve the transactions **50-53** in the event that power is lost, the data sets **80-83** are considered as work copies of the transactions. Once the transactions have been recursively written, the work copies may be overwritten.

First, in step **220**, the controller **18** detects a pattern of synchronizing events for transactions to be written to the magnetic tape **14**. As discussed above, a pattern may comprise a predetermined number of consecutive synchronizing events for transactions of less than a certain length. The pattern may not appear as a sequence of synchronize commands or explicit write mode, but may appear implicitly as a sequence of emptied buffer events. If there is no such pattern, the controller, in step **221**, returns for the next command.

Upon detecting a pattern of synchronizing events in step **220**, the controller **18**, in step **223**, separately and completely writes each detected synchronized transaction **50-53** of the detected pattern from the buffer to the magnetic tape **14**, in the manner of the process of FIG. **6**, with the gaps and/or separator signals following the data sets. As discussed above, the early synchronized transactions of the detected pattern may be excluded, having already been written in the manner discussed above before the pattern is detected. Thus, in FIG. **3**, and in FIG. **4**, the early synchronized transactions may comprise the previous data **99**.

In step **225**, upon writing each synchronized transaction from the buffer to the magnetic tape, the controller accumulates the synchronized transaction in the buffer **30**, providing a command complete in step **226**.

Step **230** determines whether the accumulated transactions have reached a predetermined threshold. As discussed above, examples of predetermined threshold may comprise the limit of capacity of the buffer **30** to accumulate transactions, or may comprise the limit of capacity of

the work space for the work copies **80-83** and their separation signals **90-92**. If the threshold has not been reached, step **231** determines whether the pattern of synchronizing events has ended. If the pattern is continuing, the process cycles back to step **223** to write the next synchronized transaction.

Upon either the accumulated transaction threshold being reached in step **230**, or upon reaching the end of the pattern of synchronizing events in step **231**, in step **233**, the controller recursively writes the accumulated transactions from the buffer to the magnetic tape in a sequence, e.g., illustrated as data sets **100**, **101** in FIG. **3** or as data sets **145** and **146** of FIG. **4**, and identifies the recursively written copies as the most current, e.g., employing the access point **115** of FIG. **3**, the write pass indicators of FIG. **4**, or the access point **148** of FIG. **4**. The recursive writing may comprise a backhitch to place the recursively written accumulated transactions following the preceding data **99**.

Since the data has been recursively written to tape, the work copies are no longer required, and the copies in the buffer are no longer required. Hence, in step **235**, the accumulated transactions are released to allow this section of the buffer to be overwritten, as is known to those of skill in the art. In step **236**, the controller returns to other processing, such as step **200** of FIG. **6**.

Specific embodiments of step **223** of FIG. **7** are illustrated in FIGS. **8-10**, beginning at step **240**.

Referring to FIGS. **5** and **8**, in step **245**, the controller determines whether the magnetic tape comprises a plurality of wraps, such as in an LTO system as discussed above, and whether the work copies are to be written to at least one of the plurality of wraps that is separate from a wrap of the recursive writing. If not, the process proceeds to step **247**.

If step **245** determines that accumulating backhitchless wraps, e.g., wraps **180** and **181** of FIG. **5**, are to be utilized for work copies, in step **250**, as discussed above, the controller operates the wrap control system **27** of FIG. **1** to determine whether access to the work copy wraps requires a seek. If not, the wrap control system, in step **251**, electronically switches to a different set of read/write heads. If, in step **250**, a seek is required, the controller **18**, in step **252**, determines the work copy wrap which can be reached by the quickest seek. As discussed above, this may

be the closest adjacent available work copy wrap. Then, in step **253**, the controller operates the wrap control to conduct the seek and move the head laterally to the selected work copy wrap.

Once the work copy wrap has been selected, the controller, in step **255**, as discussed above, determines the writable space of the work copy wrap in each longitudinal direction from the present longitudinal position of the read/write head, and determines the direction having the greatest writable space. In step **256**, the controller determines whether the direction having the greatest writable space is the current direction, and, if so, no change of direction is made. If, however, step **256** determines that the tape direction must be switched, the controller, in step **257**, operates the motors **25** to switch the direction of tape motion. In the steps following step **247**, the work copies **170-171** are then written on the accumulating backhitchless wraps **180** and **181**, first in the direction of arrow **185**, and then in the direction of arrow **186**, as discussed above with respect to FIG. **8**.

Step **247** determines whether the work copies are to be written separately or appended to rewritten copies.

If the work copies are to be written separately, connector **260** leads to FIG. **9**, and to step **261**. In step **261**, the work copy of each synchronized transaction, e.g., of transactions **50-53**, of the pattern is written separately from the buffer to the magnetic tape, either as illustrated in FIG. **3**, as data sets **80-83**, or as illustrated in FIG. **4** as data sets **120-123**, each as discussed above. In step **262**, each separately written transaction is identified with an access point. For example, in FIG. **3**, each separately written synchronized transaction **50-53** is identified by means of an access point **110-113**, and, in FIG. **4** each separately written synchronized transaction **50-53** is identified by means of an access point **140-142**, and the rewrites of the accumulated data records are ignored and the write pass indicator is not updated, as discussed above. Instead, the active record is indicated by an access point **140-142**. In step **265**, the process returns to step **225** of FIG. **7**.

If step **247** of FIG. **8** determines that the work copies are to be written as appended to rewritten accumulated synchronized transactions, connector **270** leads to FIG. **10**, and to step **271**.

Step **271** determines whether there is an existing accumulated synchronized transactions of the detected synchronizing event pattern that has only partially filled a data set. If not, the present transaction starts a new data set, and is written in step **273**. As an example, the transaction appears as record or records **50** in partial data set **120** of FIG. **4**, followed by DSS **130**. The process proceeds to step **275** and returns to step **225** of FIG. **7**, where the transaction is accumulated to the buffer, and the process ultimately cycles back to step **271** of FIG. **10** with the next synchronized transaction. Although steps **223** and **225** are shown sequentially, both must happen, either simultaneously or in either order.

Step **271** then determines that there is now an existing partial data set with at least one accumulated synchronized transaction, and, in step **278**, rewrites the accumulated transaction(s) of the data set, incrementing the write pass indicator for the data set in step **280**, and appending the present synchronized transaction to the rewritten accumulated transactions in step **283**. Thus, in FIG. **4**, the subsequent transaction **51** is appended to the accumulated transaction **50** and the rewritten accumulated transaction **50** and the new synchronized transaction are written as data set **121**, followed by DSS **131**, and step **275** returns to step **225** of FIG. **7** and transaction **51** is accumulated in the buffer, etc., as discussed above.

The rewritten and appended written synchronized data set is identified as the most current copy thereof in step **280** by means of an incremented write pass **"WP"**, as discussed above.

Specific embodiments of step **233** of FIG. **7** are illustrated in FIG. **11**, beginning at step **290**. Step **291** is similar to step **245** of FIG. **8**, and determines whether the work copies have been written to at least one of a plurality of wraps that is separate from any wrap of the recursive writing. If not, the process proceeds to step **293**.

If step **291** determines that accumulating backhitchless wraps, e.g., wraps **180** and **181** of FIG. **5**, have been utilized, in step **295**, as discussed above, the controller operates the wrap control system **27** of FIG. **1** to access the tape head **23** to the standard wrap, either by electronic switching or a seek as above, and the process continues at step **293**. In step **293**, the wrap control system operates to position the tape head at the end of the previous data at the speed required to write, and the process returns in step **299** to step **233** of FIG. **7** to recursively write the accumulated synchronized transactions from the buffer to the standard wrap

160 immediately after the preceding data 151 in the direction of arrow 161, shown as data sets 190. The work copies 170-171 may then be overwritten. Also in step 293, the write pass indicators or access points are updated.

As discussed above, in step 233 of FIG. 7, the controller additionally identifies the recursively written transactions as the most current copy thereof, employing in the separately written embodiment of FIG. 3, the access point 115 superseding the identified separately written synchronized data records of the data sets 80-83; in the separately written embodiment of FIG. 4 the access point 148 superseding the identified separately written synchronized data records of the data sets 121-123; and in the rewriting embodiment of FIG. 4, the incrementing the write passes an additional time to, e.g., to "WP3" for data set 145, etc., superseding the identified separately written synchronized transactions of the data sets 121-123.

Again, as the result, should power be lost before the work copies are overwritten, examination of the access points and/or of the write pass indicators will allow a correct recovery to be made.

Those of skill in the art understand that changes may be made in accordance with specific formats in which the invention may be implemented, and in accordance with alternative locations of the work copies of synchronized data records. Further, those of skill in the art understand that various tape drives, and tape cartridges may be employed, having differing specific component arrangements than that illustrated herein.

While the preferred embodiments of the present invention have been illustrated in detail, it should be apparent that modifications and adaptations to those embodiments may occur to one skilled in the art without departing from the scope of the present invention as set forth in the following claims.

CLAIMS

1. A recording system for a magnetic tape drive, said magnetic tape drive having at least one motor for moving a magnetic tape longitudinally, having at least one read/write head for reading from and for writing to said magnetic tape while said magnetic tape is moved longitudinally by said at least one motor, and having an interface for receiving data to be written to said magnetic tape, said recording system comprising:

at least one buffer coupled to said interface for storing data to be written to said magnetic tape, said data in the form of transactions;

at least one recording channel coupled to said at least one buffer and coupled to said at least one read/write head for operating said at least one read/write head for writing transactions from said at least one buffer to said magnetic tape; and

a controller coupled to and operating said at least one buffer, said at least one motor, and said at least one recording channel, said controller:

detects a pattern of synchronizing events for writing said transactions to said magnetic tape as synchronized transactions, said synchronized transactions stored in said at least one buffer;

writes each said detected synchronized transaction of said detected pattern from said at least one buffer to said magnetic tape;

upon writing each said synchronized transaction from said at least one buffer to said magnetic tape, accumulates said synchronized transaction in said at least one buffer; and

subsequently recursively writes said accumulated transactions from said at least one buffer to said magnetic tape in a sequence.

2. The recording system of Claim 1, wherein said controller, in writing each said stored synchronized transaction to said magnetic tape, additionally writes separator signals between said synchronized transactions written to said magnetic tape, while operating said at least one motor to continue to move said tape longitudinally during said writing without stopping.

3. The recording system of Claim 1, wherein said magnetic tape comprises a plurality of wraps, and wherein said controller, in writing each said stored synchronized transaction of said detected pattern from said at least one buffer to said magnetic tape, writes at least some of said synchronized transactions on at least one of said plurality of wraps that is separate from a wrap of said recursive writing.

4. The recording system of Claim 1 or Claim 2, wherein said controller, in subsequently recursively writing said accumulated transactions, additionally identifies said recursively written transactions as the most current copy thereof.

5. The recording system of Claim 4, wherein said controller, in subsequently recursively writing said accumulated transactions to said magnetic tape, additionally, upon said accumulated transactions reaching a predetermined threshold, finalizes a sequence of said accumulated transactions and recursively writes said finalized sequence of accumulated transactions, and subsequently releases said at least one buffer of said accumulated transactions.

6. The recording system of Claim 1, wherein said controller, in writing said stored synchronized transactions to said magnetic tape, writes each said stored synchronized transaction to said magnetic tape as a separate transaction.

7. The recording system of Claim 1, wherein said controller, in writing said stored synchronized transactions to said magnetic tape, writes said synchronized transactions in the form of data sets, and for at least one of said synchronized transactions of said detected pattern partially filling a data set, additionally rewrites said accumulated transaction of said data set in another data set, and appends a succeeding said synchronized transaction to said rewritten accumulated transaction.

8. A recording system for a magnetic tape drive, said magnetic tape drive having at least one motor for moving a magnetic tape longitudinally, having at least one read/write head for reading from and for writing to said magnetic tape while said magnetic tape is moved longitudinally by said at least one motor, and having an interface for receiving data to be written to said magnetic tape, said recording system comprising:

at least one buffer coupled to said interface for storing data to be written to said magnetic tape, said data in the form of transactions;

at least one recording channel coupled to said at least one buffer and coupled to said at least one read/write head for operating said at least one read/write head for writing transactions from said at least one buffer to said magnetic tape; and

a controller coupled to and operating said at least one buffer, said at least one motor, and said at least one recording channel, said controller:

detects a synchronizing event for a received transaction stored in said at least one buffer, comprising a synchronized transaction;

writes said detected synchronized transaction from said at least one buffer to said magnetic tape;

writes separator signals to said magnetic tape following said written synchronized transaction, continuing until a subsequently received transaction is written to said magnetic tape following said separator signals; and

repeats said detection of a synchronized received transaction, writing said detected synchronized transaction, and writing said separator signals, for each succeeding said detected synchronized received transaction, while operating said at least one motor to continue to move said tape longitudinally during said repeated writing without stopping.

9. The recording system of Claim **8**, wherein said controller, additionally, for each said detected synchronized transaction, returns a command complete at said interface for said detected synchronized transaction upon completion of said writing said detected synchronized transaction from said at least one buffer to said magnetic tape.

10. A recording system for a magnetic tape drive, said magnetic tape drive having at least one motor for moving a magnetic tape longitudinally, said magnetic tape comprising a plurality of wraps, said magnetic tape drive having at least one read/write head for reading from and for writing to said magnetic tape while said magnetic tape is moved longitudinally by said at least one motor, having a wrap control system for accessing said wraps of said magnetic tape with said at least one read/write head, and

having an interface for receiving data to be written to said magnetic tape, said recording system comprising:

at least one buffer coupled to said interface for storing data to be written to said magnetic tape, said data in the form of transactions;

at least one recording channel coupled to said at least one buffer and coupled to said at least one read/write head for operating said at least one read/write head for writing transactions from said at least one buffer to said magnetic tape; and

a controller coupled to and operating said at least one buffer, said at least one motor, said wrap control system, and said at least one recording channel, said controller:

detects a pattern of synchronizing events for writing said

transactions to said magnetic tape as synchronized transactions, said synchronized transactions stored in said at least one buffer;

operates said wrap control system and said at least one read/write head to access at least one work copy wrap of said magnetic tape and to write each said detected synchronized transaction of said detected pattern from said at least one buffer to said at least one work copy wrap of said magnetic tape;

upon writing each said synchronized transaction from said at least one buffer to said magnetic tape, accumulates said synchronized transaction in said at least one buffer; and

subsequently operates said wrap control system and said at least one read/write head to access at least one normal wrap separate from said at least one work copy wrap, and to recursively write said accumulated transaction from said at least one buffer to said at least one normal wrap of said magnetic tape in a sequence.

11. The recording system of Claim **10**, wherein said controller additionally, upon detecting said pattern of synchronizing events, determines the writable space of said at least one working copy wrap in each longitudinal direction from the longitudinal position of said at least one read/write head, and operates said at least one motor, said wrap

control and said at least one read/write head to begin writing each said detected synchronized transaction in a longitudinal direction of said at least one work copy wrap having the greatest writable space.

12. The recording system of Claim **10**, wherein said controller additionally designates a plurality of said wraps of said magnetic tape as work copy wraps, and, upon detecting said pattern of synchronizing events, determines whether said access to at least one work copy wrap requires a seek of said at least one read/write head, and, if so, selects a work copy wrap having the quickest seek.

13. A magnetic tape drive, comprising:

at least one motor for moving a magnetic tape longitudinally;

at least one read/write head for reading from and for writing to said magnetic tape while said magnetic tape is moved longitudinally by said at least one motor;

an interface for receiving data to be written to said magnetic tape; and

a recording system as claimed in any preceding claim.

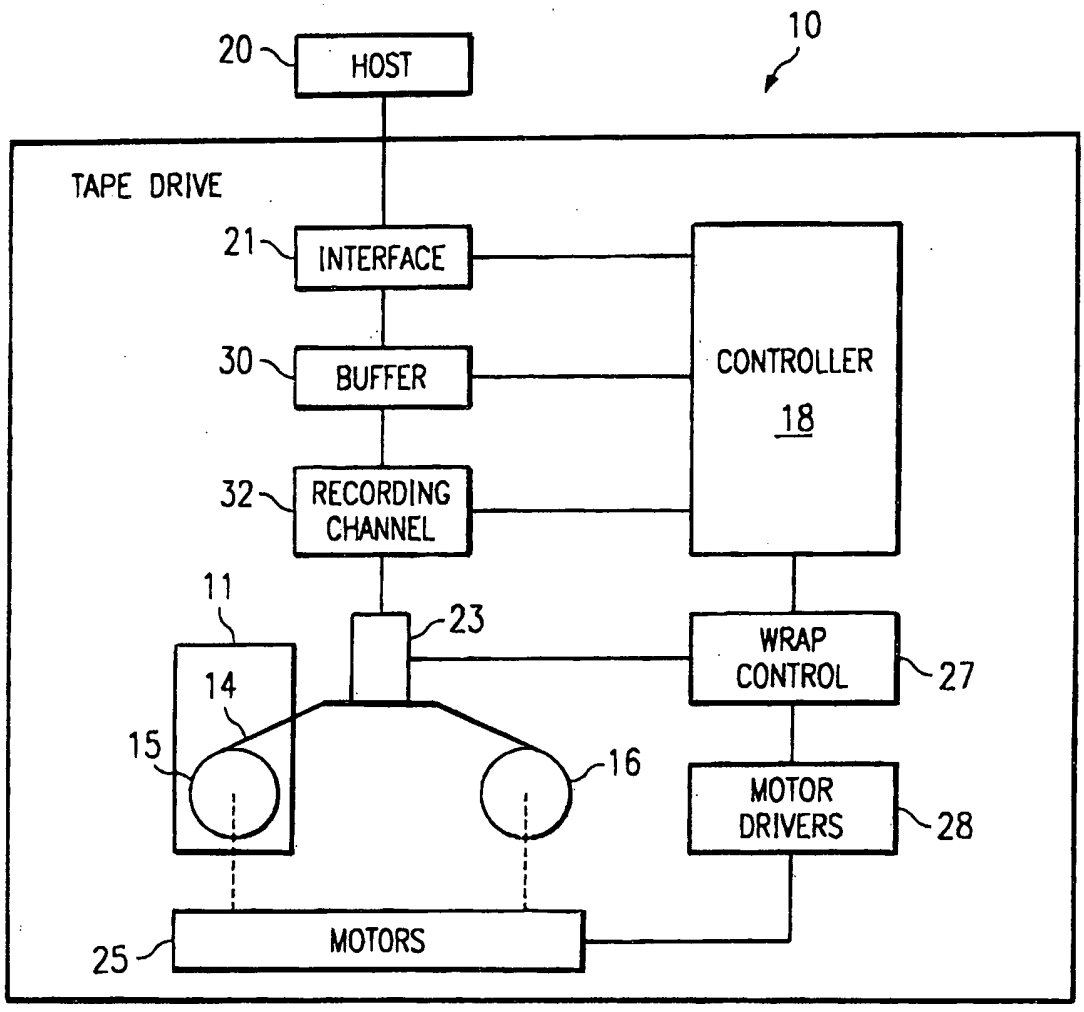

10
20
HOST
TAPE DRIVE
21
INTERFACE
30
BUFFER
32
RECORDING CHANNEL
CONTROLLER
18
11
23
WRAP CONTROL
27
14
15
16
MOTOR DRIVERS
28
25
MOTORS

FIG. 1

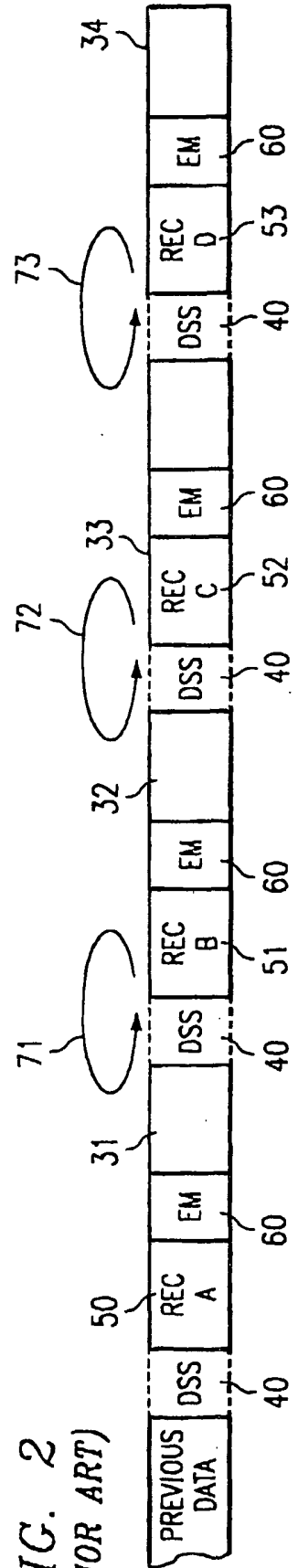


FIG. 2
(PRIOR ART)

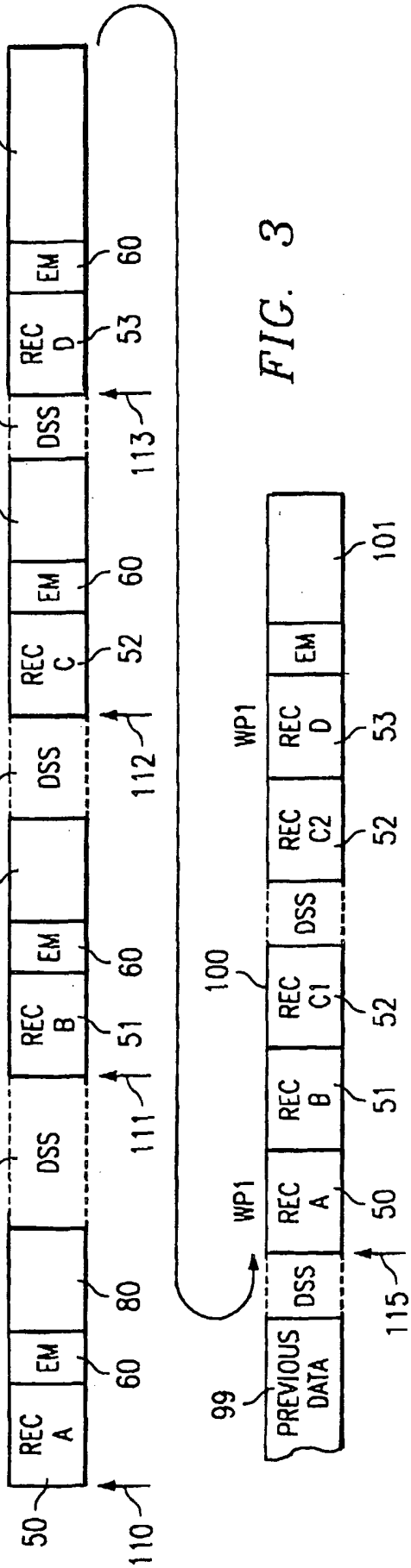


FIG. 3

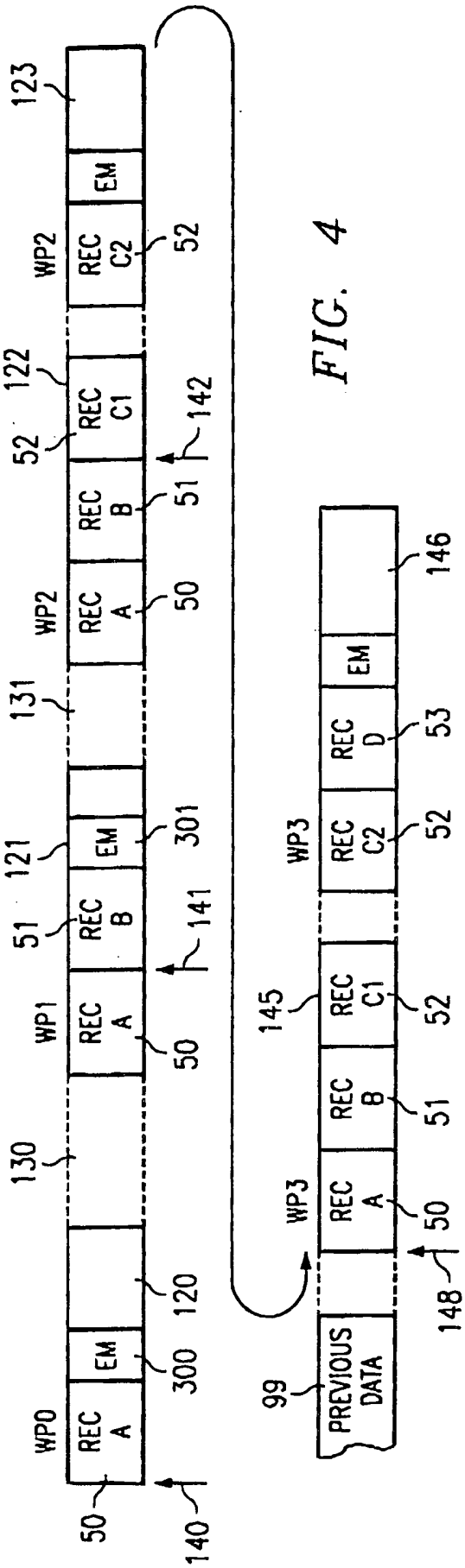

WP0
REC A
EM
50
140
300
120
130
WP1
REC A
REC B
EM
50
51
141
301
121
131
WP2
REC A
REC B
REC C1
50
51
142
52
122
WP2
REC C2
EM
52
123
WP3
REC A
REC B
REC C1
REC C2
REC D
EM
50
51
52
52
53
146
145
148
WP3
99
PREVIOUS DATA

FIG. 4

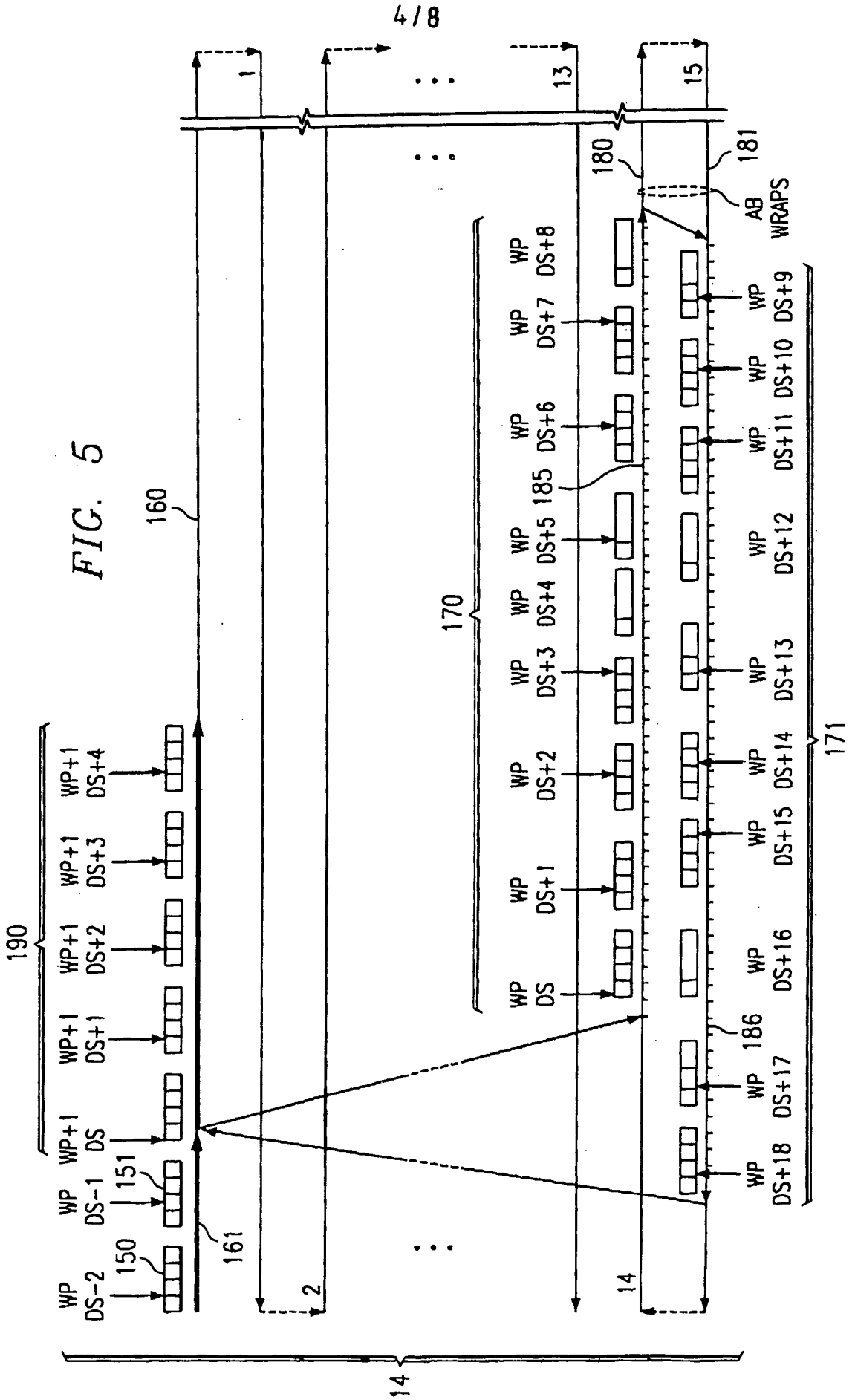

1
2
13
14
15
160
161
170
171
180
181
185
186
190
AB WRAPS
WP DS-2
WP DS-1
WP DS
WP+1 DS+1
WP+1 DS+2
WP+1 DS+3
WP+1 DS+4
WP DS+5
WP DS+6
WP DS+7
WP DS+8
WP DS+9
WP DS+10
WP DS+11
WP DS+12
WP DS+13
WP DS+14
WP DS+15
WP DS+16
WP DS+17
WP DS+18
150
151

FIG. 5

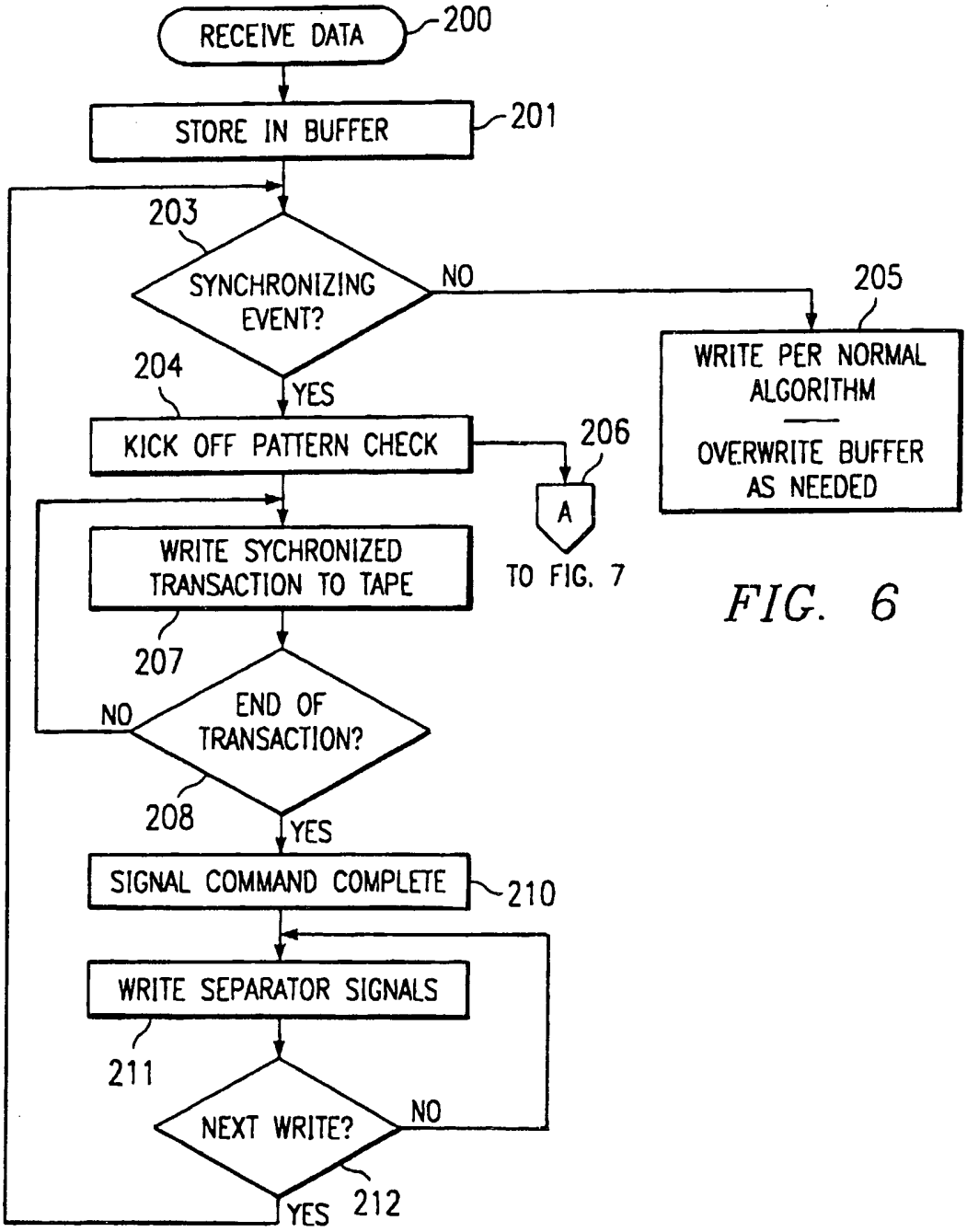

RECEIVE DATA
200
STORE IN BUFFER
201
203
SYNCHRONIZING EVENT?
NO
205
WRITE PER NORMAL ALGORITHM
OVERWRITE BUFFER AS NEEDED
204
YES
KICK OFF PATTERN CHECK
206
A
TO FIG. 7
WRITE SYCHRONIZED TRANSACTION TO TAPE
207
NO
END OF TRANSACTION?
208
YES
SIGNAL COMMAND COMPLETE
210
WRITE SEPARATOR SIGNALS
211
NEXT WRITE?
NO
YES
212

FIG. 6

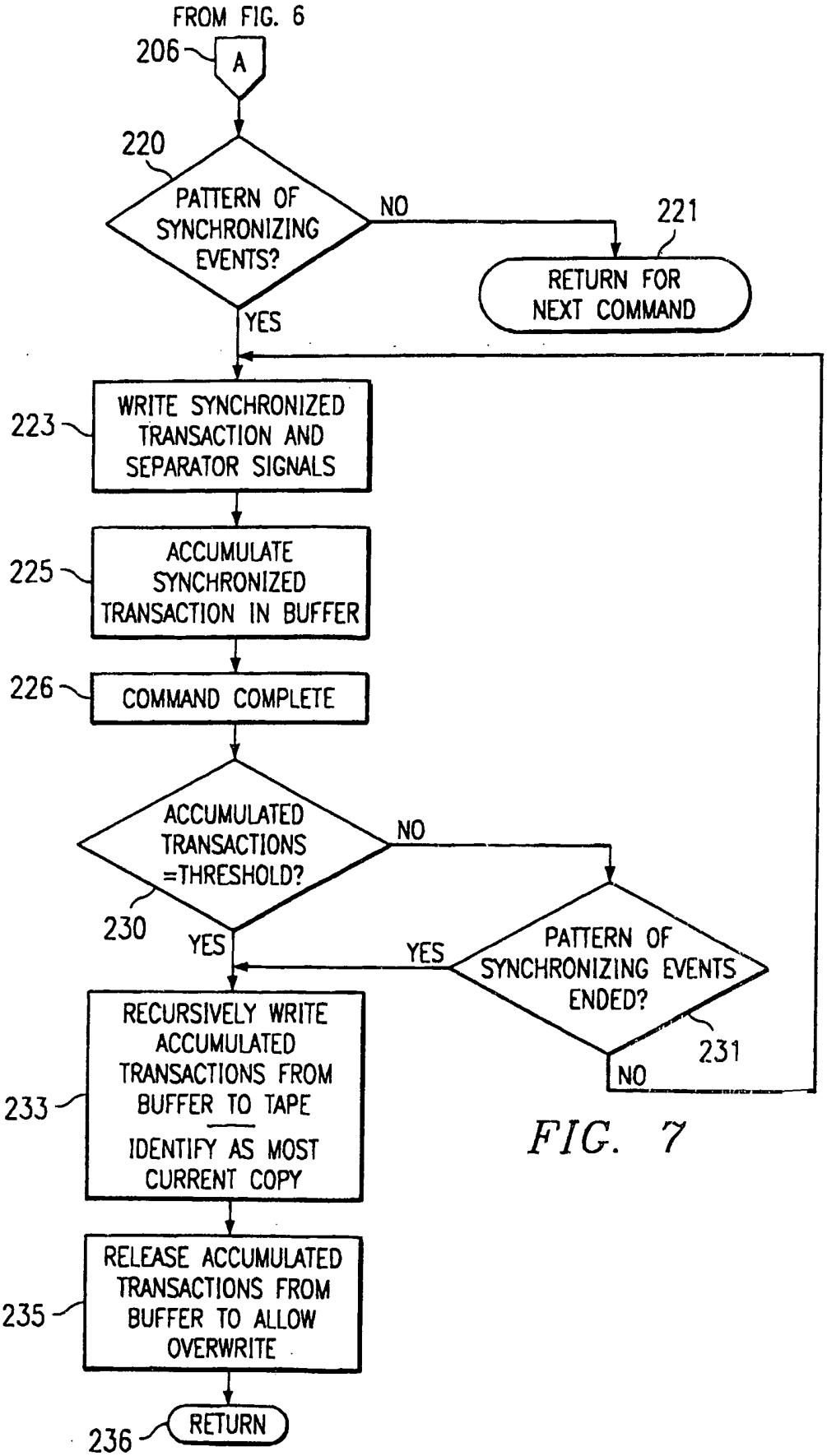

FROM FIG. 6
206
A
220
PATTERN OF SYNCHRONIZING EVENTS?
NO
221
RETURN FOR NEXT COMMAND
YES
223
WRITE SYNCHRONIZED TRANSACTION AND SEPARATOR SIGNALS
225
ACCUMULATE SYNCHRONIZED TRANSACTION IN BUFFER
226
COMMAND COMPLETE
ACCUMULATED TRANSACTIONS =THRESHOLD?
NO
230
YES
YES
PATTERN OF SYNCHRONIZING EVENTS ENDED?
231
NO
233
RECURSIVELY WRITE ACCUMULATED TRANSACTIONS FROM BUFFER TO TAPE
IDENTIFY AS MOST CURRENT COPY
235
RELEASE ACCUMULATED TRANSACTIONS FROM BUFFER TO ALLOW OVERWRITE
236
RETURN

FIG. 7

FIG. 8

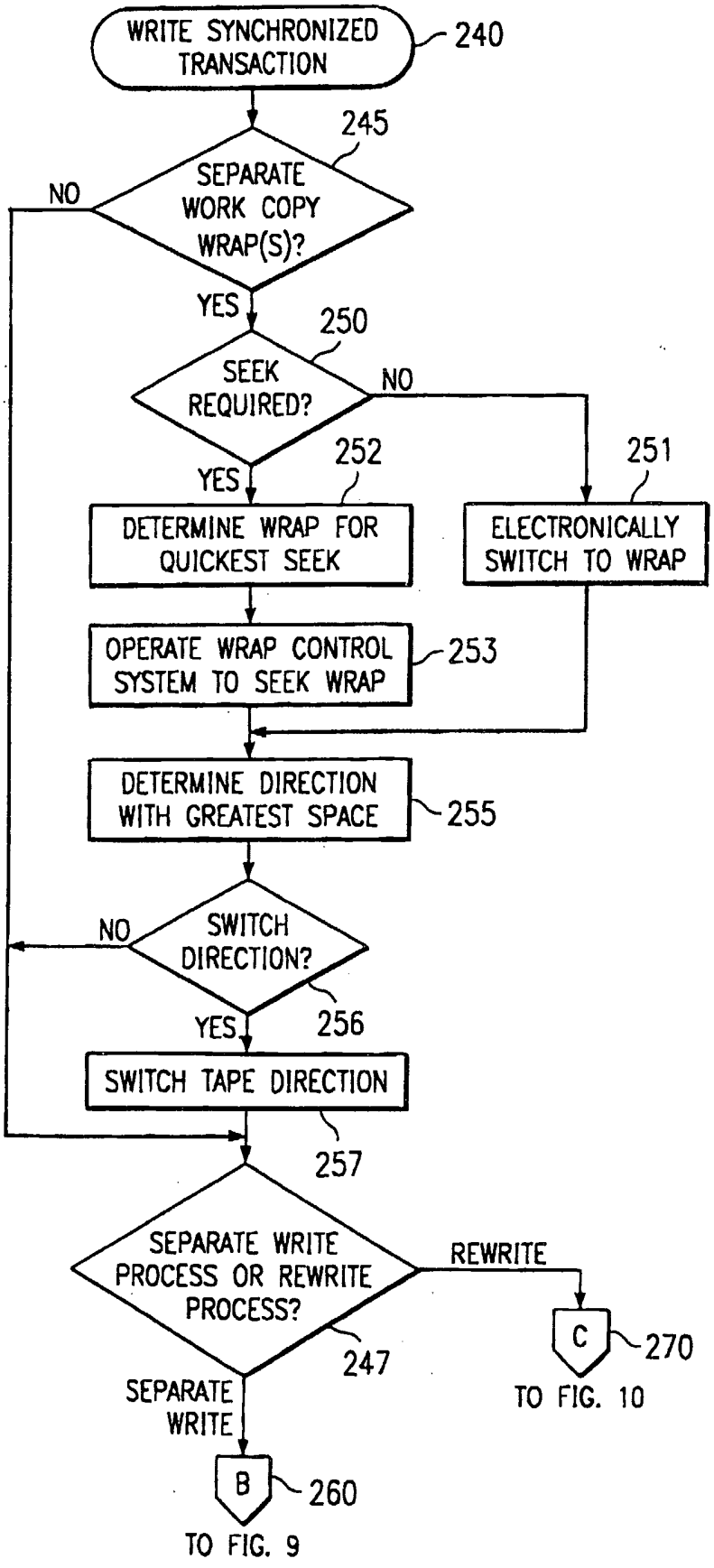

WRITE SYNCHRONIZED TRANSACTION
240
245
SEPARATE WORK COPY WRAP(S)?
NO
YES
250
SEEK REQUIRED?
NO
YES
252
DETERMINE WRAP FOR QUICKEST SEEK
251
ELECTRONICALLY SWITCH TO WRAP
OPERATE WRAP CONTROL SYSTEM TO SEEK WRAP
253
DETERMINE DIRECTION WITH GREATEST SPACE
255
NO
SWITCH DIRECTION?
YES
256
SWITCH TAPE DIRECTION
257
SEPARATE WRITE PROCESS OR REWRITE PROCESS?
REWRITE
247
C
270
TO FIG. 10
SEPARATE WRITE
B
260
TO FIG. 9

FIG. 9

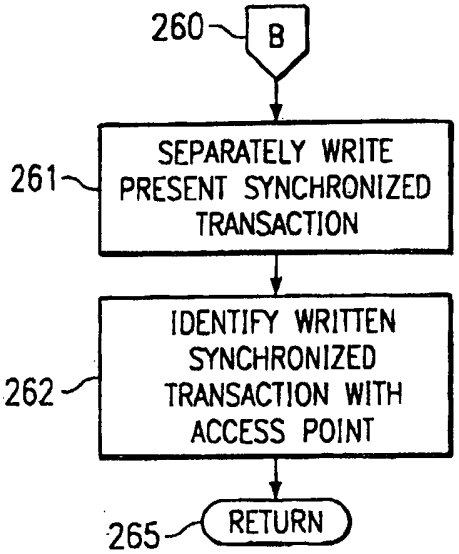


FIG. 11

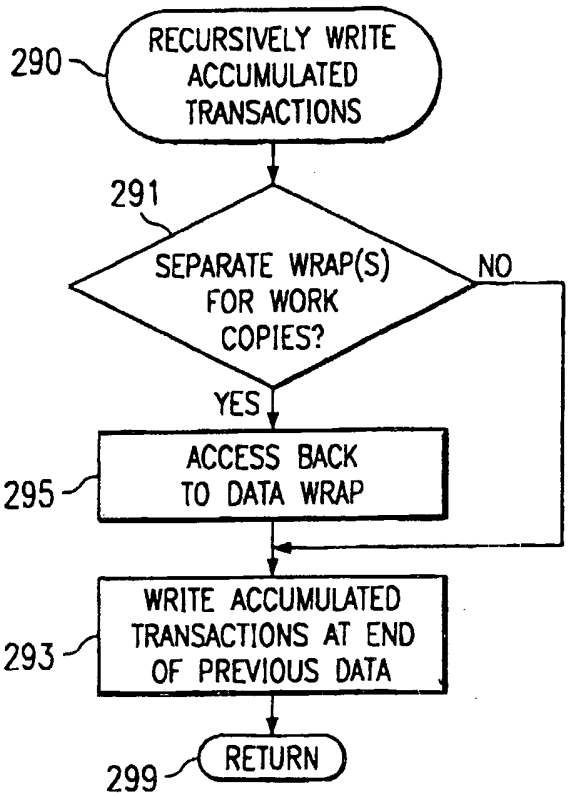
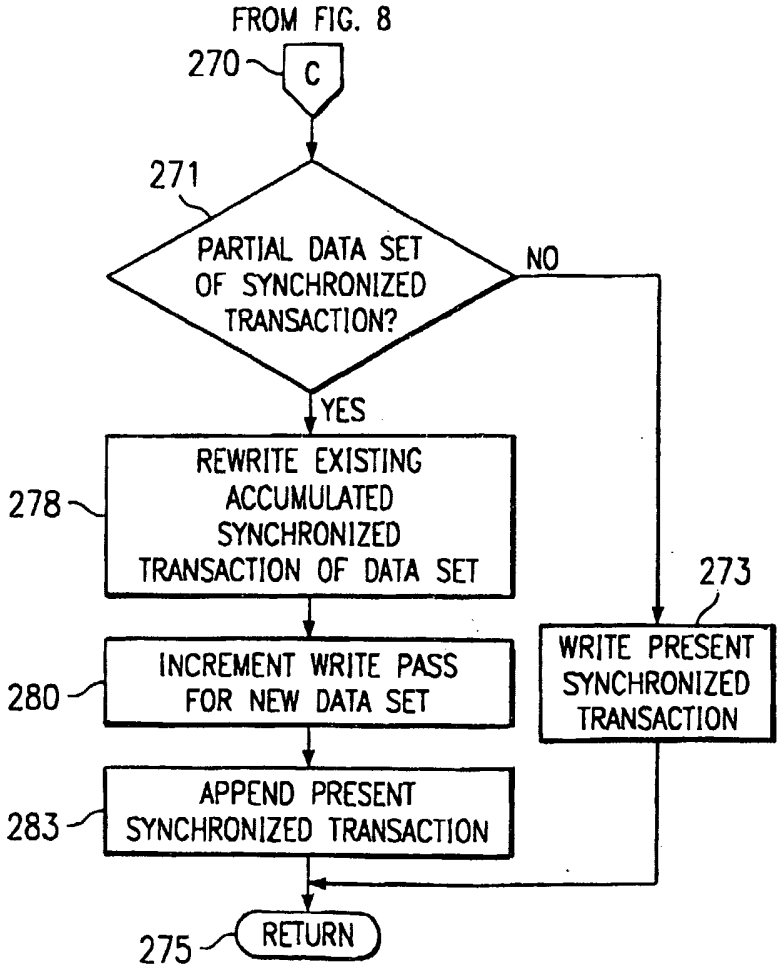


FIG. 10



INTERNATIONAL SEARCH REPORT

Interna application No
PCT/GB 03/00178

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G11B27/36 G11B20/12 G06F3/06

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)
IPC 7 G11B G06F

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, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0 324 542 A (HEWLETT PACKARD CO) 19 July 1989 (1989-07-19) abstract column 1, line 4 -column 4, line 49 column 5, line 30 -column 12, line 27 figure 1 ---	1,8,10
A	PATENT ABSTRACTS OF JAPAN vol. 2000, no. 07, 29 September 2000 (2000-09-29) & JP 2000 123473 A (FUJITSU LTD), 28 April 2000 (2000-04-28) abstract --- -/--	1,8,10

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

[X] Patent family members are listed in annex.

° Special categories of cited documents :

'A' document defining the general state of the art which is not considered to be of particular relevance

'E' earlier document but published on or after the international filing date

'L' document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

'O' document referring to an oral disclosure, use, exhibition or other means

'P' document published prior to the international filing date but later than the priority date claimed

'T' later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

'X' document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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Date of the actual completion of the international search	Date of mailing of the international search report
7 April 2003	14/04/2003

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	Sucher, R

INTERNATIONAL SEARCH REPORT

Interna pplication No
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