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OPTICAL DISK UNDER-RUN PROTECTION

TECHNICAL FIELD

This invention relates to the storage of data in a continuous sequence of sectors, and more particularly to the protection against under-run of the data being organized in a buffer for storage in sectors or blocks of data.

BACKGROUND OF THE INVENTION

Optical disk media typically comprise a continuous spiral groove which extends for the entire data storage capacity of the disk. CD-based (CR-R or DVD-R) optical disk media architecture utilizes the continuous spiral groove with sectors (also called "blocks") of equal length, which are accessed at a constant linear velocity (CLV). Thus, there are a greater number of sectors along the outer tracks of the spiral than at the inner tracks of the spiral.

Herein, the terms "block" and "sector" are used interchangeably.

The CD-R (CD-recordable) optical disk media is CD-based and comprises a continuous spiral CLV media. The coding modulation for CD-R is called "EFM", which means eight-to-fourteen modulation. The encoding turns the input data, along with error correction data, address information, synchronization patterns, and other miscellaneous content, into an encoded binary stream of bits, expanding every eight bits of input data into fourteen, with an additional three bits to separate words, as is well known in the art. In the CD-R format, 24 of the resultant 17 bit symbols are assembled into a frame. 98 frames are grouped together to form a sector. A layered level of error correction is accomplished on a "diamond" or combined lateral and slant pattern across the frames to avoid the total loss of a frame of data, as is known in the art. Thus, each sector comprises a totality of 98 frames of data, together with a sector header, synch information and layered ECC distributed across the frames and sectors. The CD-R media does not provide molded sector or block identification marks to identify data recording positions. The sectors are therefore formatted with headers having a great deal of information to aid in synchronizing the rotation of the disk and obtaining data framing, comprising a great deal of overhead. A limited number of entries may be placed in the table of contents on the disk for locating the beginning of recorded

areas. Therefore, it is very important for CD-R to not interrupt the data writing process because of this overhead penalty.

Current CD-R devices therefore have a buffer to accumulate the input data to organize the data into sectors for writing on the disk in a continuous sequence of sectors.

When the current buffer of a CD-R device fails to receive input data from the host on a timely basis (due to higher priority-tasks or interrupts using host resources), the buffer may under-run and will become empty, causing the writing process to be halted in an orderly fashion, resulting in a data file being partially written. One proposed solution, which is undesirable, is to stop writing sectors upon the occurrence of the under-run. This is because in CD-R devices, it is not possible to restart the writing process without incurring the space and table of contents overhead, and it results in a disk having the appearance of two recorded files. Most often, the user application cannot deal with the complexity or with the two data files where one is expected, so the disk is considered ruined and discarded.

What is needed is a means for protecting the recording of the optical disk against under-run of the input data to the buffer.

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SUMMARY OF THE INVENTION

In an optical data storage device for storing data on a removable optical disk in a continuous sequence of sectors, having a buffer for buffering the input data, which buffer may be subject to under-run, under-run protection is provided by an under-run detector responsive to the buffered data comprising less than a sector of data for indicating an under-run, and a padding provider responsive to the under-run indication for providing padding signals for formatting into sectors. The sectors may be provided with headers indicating the sectors as padding. A reading device for reading the data sectors and providing the data to a host detects padding data and prevents the padding data from being transmitted to the host.

For a fuller understanding of the present invention, reference should be made to the following detailed description taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. 1 and 2 are diagrammatic representations of the format of a sector of frames of optical disk data of the prior art;

FIG. 3 is a block diagram of an optical disk and the read and write electronics for storing data in a continuous sequence

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of sectors of FIGS. 1 and 2, which may be utilized with the present invention;

FIG. 4 is a flow chart depicting the write process of present invention;

FIG. 5 is a flow chart depicting the read process of the present invention;

FIG. 6 is an illustration of a sequence of sectors of an alternative embodiment of the present invention; and

FIG. 7 is an illustration of a command for implementing the present invention in the optical disk of FIG. 3.

DETAILED DESCRIPTION OF THE INVENTION

Referring to FIGS. 1 and 2, the format of a sector of optical disk data is illustrated, as described in the '557 patent. As discussed above, in the CD-R format, 24 of the resultant 17 bit symbols are assembled into a frame, which also includes a synch pattern and error correction data. The sector includes 98 frames grouped together and organized into a sector with a sector header across the frames comprising several channels, including the "Q" channel. A layered level of error correction is accomplished on a "diamond" or slant pattern across the frames to avoid the total loss of a frame of data, as is known in the art. Thus, each sector comprises a totality of 98 frames of data, together with a sector header, synch information

and layered ECC distributed across the frames. The CD-R media does not provide molded sector or block identification marks to identify data recording positions. The sectors are therefore formatted with headers having a great deal of information to aid in synchronizing the rotation of the disk and obtaining data framing, comprising a great deal of overhead. The sector header incorporated in the Q channel of FIG. 1, illustrated in FIG. 2, indicates the sector (block) address and the mode. Identifiers and other information are provided in the other sub-header channels, as is known in the art.

The complexity of the formatting, error correction and encoding, together with the lack of position identification in the media, makes apparent the problem that occurs if an under-run occurs which results in the stoppage of writing. It may be possible to deal with the stoppage with a systems level program which may re-establish the writing process in some way. However, the writing process cannot be restarted at the drive level without incurring the space and table of contents overhead problem, resulting in a disk with the appearance of two recorded files. User applications most often cannot deal with the overhead or the two data files where only one is expected, as discussed above.

FIG. 3 is a block diagram of an optical disk drive 10 and the read and write electronics 11 for storing data in a continuous sequence of sectors of FIGS. 1 and 2. The analog

inputs provided to A/D converter 20 are continuous by definition and not subject to under-run. The inputs from a host that may be subject to under-run are provided on line 25 to digital input 26. An encoder 30, which includes a buffer, and microprocessor 31 generate the formatting, headers and ECC and organize the data into frames and sectors, as is well known in the art. The resultant EFM encoded data stream is supplied on line 35 to the laser recording and reading circuitry 36 for recording on an optical disk 40.

Data encoded on an optical disk 40 is read by the laser recording and reading circuitry 36 and provided to decoder 42 and microprocessor 31 for decoding, error correction and reorganization into output data and supplied by digital output 44 to output line 45 to a host.

FIG. 4 is a flow chart depicting the write process of the present invention for protecting against an under-run condition. In response to a write command 200, writing is initiated and decision block 210 determines whether there is less than a full sector of data in the buffer of encoder 30 of FIG. 3. A full sector of data is 2048 bytes of data. In the CD-R format, the total number of bytes to support 2048 bytes of data is 2352 bytes.

If at least a full sector's worth of data is available, "No" in decision block 210, the next sector is written to the disk in step 212 and the process cycles back to decision block 210. Upon

the occurrence of an under-run, "Yes" in decision block 210, no partial sector will be written to disk unless the end of data has been reached. Thus, decision block 220 looks for an "EOD", or "end of data" character to designate the end of data to be recorded. If the "EOD" character is present, "Yes" in block 220, the data remaining in the buffer of encoder 30 is written to disk 40 in block 222 by microprocessor 31, and the process is exited in block 240.

If decision block 220 is unable to detect an "EOD" character, indicating a true under-run, a padding sector is written to the disk in step 230.

Thus, microprocessor 31 in FIG. 3 determines whether a true under-run condition exists and provides encoder 30 with the commands to write a data sector or a padding sector to the disk.

Referring again to FIG. 4, decision block 231 detects whether the maximum number of pad sectors is written to the disk, as will be explained. If "No", the process cycles back to decision block 210. Once again, if sufficient data has been provided to the buffer to write a sector by the time decision block 210 is reached, step 212 writes the sector to the disk. If, instead, a true under-run remains, step 230 writes another padding sector to the disk.

In the preferred embodiment, the padding sector will be identified by an otherwise unused bit pattern in the subheader field or mode field of the pad sector in the Q channel of FIG. 2.

Any fill character may be used for the padding data field, since the data will be bypassed, as will be explained. A special "MODE SELECT" command may be used to select the fill character.

It is not useful to write a full disk of padding sectors if a communication failure has occurred to the input data channel. Therefore, a number of padding sectors is selected as the maximum to be written. The decision block 231 is provided for this purpose. If the maximum number of sectors has been reached, "Yes", the writing of padding sectors is stopped in step 232 and the process abends. At this point, an unrecoverable "Pad Sector Under-run" error signal is sent to the host. Alternatively, the signal may be called a permanent "Pad Sector Under-run" error.

Thus, the process of the invention is to either write entire sectors of data or entire sectors of padding. The sectors are differentiated from one another by the information in the mode or sub-header field.

FIG. 5 illustrates the read process, entered at step 300, and conducted by the microprocessor 31 and decoder 42 of FIG. 3. The first step is to read the mode or sub-header information for the next sector to be read in step 310. Step 320 checks the mode/sub-header information to see if the present sector is a data or pad sector. If the sector is a data sector, "Yes", the data sector is read in step 321 and transferred to the host. Then, a check is made in step 322 to determine if all the data has been read, per instructions from the host. For example, in

the SCSI environment, the number of sectors to be read is defined in a read command. If there is more to be read, the process loops back to step 310. Otherwise, the read process successfully exits in step 340.

If the sector is identified as a padding sector in decision block 320, the padding sector is read at step 330 at the drive, but the padding data is not transferred to the host in step 331. The padding sector is needed by the drive to maintain the ECC process, but is valueless to the host. Thus, at step 331, microprocessor 31 in FIG. 3 operates decoder 42 to comprise a gate which transmits the data of a data sector at digital output 44 on line 45 to the host, and which blocks the padding data from being transferred to the host.

The process then cycles back to step 310 to check the next sector.

An alternative embodiment to the format of the present invention is illustrated in FIG. 6 which does not use the special MODE character and which enables existing CD-ROM drives to utilize the invention. Specifically, the pad header 400 would use a minimum (00000), maximum (FFFFF), or negative address in the address portion of the header, an address significantly different than the address expected by the drive, such that the drive would bypass the information being read per step 330 of FIG. 3.

The MODE SELECT command may still be used to record the special mode character for new CD-R drives.

An exemplary MODE SELECT command is illustrated in FIG. 7. Bit 1 of byte 0 allows the user to define whether the pad sectors are to be used during under-run conditions. Byte 1 defines the character to be used as pad during the under-run. Allowing the padding sector to be changed allows for future enhancements. Alternatively, a different padding sector could result in using different padding characters for each session or when there is a need to differentiate between the units processed or the drives. Bytes 2 and 3 define the maximum number of pad sectors to be written before terminating the write operation in steps 231 and 232 in FIG. 4. This termination of the write operation should be a low priority event through the use of pad sectors.

Alternatively, a standards group may define the character to be used to identify padding sectors, and, if not a mode character, the MODE SELECT command would not be used.

When an under-run occurs where the limit on pad sectors has not been reached, the device notifies the host with a recovered error code, "Pad Sector Under-run". Alternatively, the signal may be called a temporary "Pad Sector Under-run" error. The host may then interrogate the drive, requesting error statistics such as the number of pad sectors written or the number of tracks padded. This information could also be written on the disk for future reference.

Thus, it has been disclosed that the stoppage of the write process and the possible resultant discard of an optical disk as the result of an under-run condition may be avoided by providing a limited number of padding sectors. The padding sectors may be identified in the control area of the sector (the address, subheader, and/or mode field), so as to be identified in the read process and the sector used for the purpose of ECC by the drive, but blocked from transfer to the host. Also, the existing MODE SELECT command may be utilized to invoke the padding sector function, select the padding character to allow different characters to be used, and define the maximum number of padding sectors to be written before terminating the write operation.

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.

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CLAIMS

1. In a continuous sector writing data storage device responsive to input data for buffering said input data, for formatting said buffered data into sectors, and for writing said sectors, apparatus for continuing said writing upon an under-run of said buffered data, comprising:

an under-run detector responsive to said buffered data comprising less than a sector of data for indicating an under-run of said buffered data; and

a padding provider responsive to said under-run indication for providing padding signals for formatting into said sectors.

2. The apparatus of Claim 1, wherein:

said padding provider provides said padding signals for padding one complete sector at a time.

3. The apparatus of Claim 2, wherein:

said padding provider additionally provides a padding indicator for said formatting to identify said sector as a padded sector.

4. The apparatus of Claim 2, wherein:

any said buffered input data less than a sector remaining at said under-run indication, remains buffered until further input data is buffered which completes a sector.

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5. The apparatus of Claim 4, wherein:

said under-run detector is additionally responsive to said sector completion by said further input data to terminate said under-run indication.

6. The apparatus of Claim 1, wherein:

said input data ends with a special EOD indicator; and

said under-run detector additionally detects the absence of said special EOD indicator for indicating said under-run.

7. The apparatus of Claim 1, wherein:

said formatted sectors comprise a header and data; and

said padding provider provides said padding signals for padding one complete sector at a time, and additionally provides a padding indicator for said formatting to identify said sector as a padded sector in said header.

8. The apparatus of Claim 7, wherein:

any said buffered input data less than a sector remaining at said under-run indication, remains buffered until further input data is buffered which completes a sector.

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9. In a continuous sector data storage device for reading stored data and transferring said stored data to a host, apparatus comprising:

a read padding detector responsive to said stored data for detecting a sector of padding data; and

a data transfer gate responsive to said detection of a sector of padding data for not transferring said sector of padding data to said host.

10. The apparatus of Claim 9, said device having said stored data formatted into sectors having headers, wherein:

said read padding detector is responsive to said sector headers for detecting a sector of padding data.

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11. An optical data storage device responsive to input data for storing said data on a removable optical disk in a continuous sequence of sectors, comprising:

a buffer for buffering said input data;

a formatter for formatting said buffered data into sectors;

an optical data writer for writing said sectors on said removable optical disk;

an under-run detector responsive to said buffered data comprising less than a sector of data for indicating an under-run of said buffered data; and

a padding provider responsive to said under-run indication for providing padding signals for formatting into said sectors.

12. The optical data storage device of Claim 11, wherein:

said padding provider provides said padding signals for padding one complete sector at a time.

13. The optical data storage device of Claim 12, wherein:

said padding provider additionally provides a padding indicator for said formatting to identify said sector as a padded sector.

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14. The optical data storage device of Claim 12, wherein:

any said buffered input data less than a sector remaining at said under-run indication, is held in said buffer until further input data is buffered which completes a sector.

15. The optical data storage device of Claim 14, wherein:

said under-run detector is additionally responsive to said sector completion by said further input data to terminate said under-run indication.

16. The optical data storage device of Claim 11, wherein:

said input data ends with a special EOD indicator; and

said under-run detector additionally detects the absence of said special EOD indicator for indicating said under-run.

17. The optical data storage device of Claim 11, wherein:

said formatter formats said sectors into a header and data; and

said padding provider provides said padding signals for padding one complete sector at a time, and additionally provides a padding indicator for said formatter to identify said sector as a padded sector in said header.

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18. The optical data storage device of Claim 17, wherein:

any said buffered input data less than a sector remaining at said under-run indication, is held in said buffer until further input data is buffered which completes a sector.

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19. An optical data storage device for reading data stored on a removable optical disk, which data is stored in a sequence of sectors, and for transferring said stored data to a host, comprising:

a read padding detector responsive to said stored data for detecting a sector of padding data; and

a data transfer gate responsive to said detection of a sector of padding data for not transferring said sector of padding data to said host.

20. The optical data storage device of Claim 19, said optical disk having said stored data formatted into sectors having headers, wherein:

said read padding detector is responsive to said sector headers for detecting a sector of padding data.

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21. In a continuous sector writing data storage device responsive to input data for buffering said input data, for formatting said buffered data into sectors, and for writing said sectors, the method for continuing said writing upon an under-run of said buffered data, comprising the steps of:

detecting said buffered data comprising less than a sector of data for indicating an under-run of said buffered data; and

providing padding signals for formatting into said sectors in response to said under-run indication.

22. The method of Claim 21, wherein:

said providing step provides said padding signals for padding one complete sector at a time.

23. The method of Claim 22, wherein:

said providing step additionally provides a padding indicator for said formatting to identify said sector as a padded sector.

24. The method of Claim 22, wherein:

said under-run detecting step additionally comprises holding any said buffered input data less than a sector remaining at said under-run indication, buffered until further input data is buffered which completes a sector.

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25. The method of Claim 24, wherein:

said under-run detecting step additionally comprises responding to said sector completion by said further input data to terminate said under-run indication.

26. The method of Claim 21, wherein:

said input data ends with a special EOD indicator; and

said under-run detecting step additionally detects the absence of said special EOD indicator for indicating said under-run.

27. The method of Claim 21, wherein:

said formatted sectors comprise a header and data; and

said providing step provides said padding signals for padding one complete sector at a time, and additionally provides a padding indicator for said formatting to identify said sector as a padded sector in said header.

28. The method of Claim 27, wherein:

said under-run detecting step additionally comprises holding any said buffered input data less than a sector remaining at said under-run indication, buffered until further input data is buffered which completes a sector.

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29. In a data storage device for reading continuous sectors of stored data, the method for reading said continuous sectors of stored data and transferring said stored data to a host, comprising the steps of:

reading said sectors for detecting a sector of stored data and for detecting a sector of padding data; and

in response to said detection of a sector of stored data, transferring said sector of stored data to said host, and in response to said detection of a sector of padding data, not transferring said sector of padding data to said host.

30. The method of Claim 29, having said stored data formatted into sectors having headers, wherein:

said reading said sectors step comprises reading said sector headers for detecting a sector of padding data.

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