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APPARATUS AND METHOD FOR CONTROLLING THE FREQUENCY AT WHICH DATA IS WRITTEN IN A DISK DRIVE SYSTEM

CROSS-REFERENCE TO RELATED APPLICATIONS

DIGITAL DATA PHASE DETECTOR, Serial No. 08/353,553, filed December 9, 1994, assigned to the assignee of the present application which is hereby incorporated by reference.

BACKGROUND OF THE INVENTION

The present invention is generally related to read/write channels in a hard disk drives and disk drive electronic control systems. In particular, the present invention relates to controlling the frequency at which data is written onto a disk in a disk drive system.

Disk drive systems, as shown in Figure 1, includes a microprocessor 9 for controlling the overall operation of the disk drive system, a read channel 10 for recovering data read from the disk, a write channel 12 for writing data onto the disk and a digital phase locked loop 11 for providing a read clock to the read channel 10 and oscillator 13 operating as the write clock for the write channel 12.

During a write operation, the phase locked loop 11, in response to control signals from microprocessor 9 on bus 17, locks up on a frequency determined by the frequency of reference oscillator 13 in preparation for the next read operation. Oscillator 13 provides the write clock on line 19 to write channel 12 which, in response to control signals on bus 19 from microprocessor 9, generates write data on line 23 from the data to be written on line 22.

The disk drive systems spindle motor (not shown) operates at a nominal speed with a speed tolerance of +/-1%. This variation in speed effect both the frequency of the data written onto the disk and the frequency of the data read from the disk. If the speed of the spindle motor increases by +1% then the data

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written on the disk will have a longer wavelength then data that would have had been written with the spindle motor operating at the spindle motors nominal speed. If the same data is read back from the disk with the spindle motor operating at the spindle motors nominal speed, the resulting frequency of the recovered data will be 1% lower than the frequency of the write clock.

Figure 3 shows a format of a data record as recorded on the disk. The data record is comprised of a format area comprising the servo preamble field, the address mark field, the gray code field, the servo data field, the I.D. VFO field, the I.D. sync field and the I.D. field which are written when the disk is originally formatted and a data area comprising the data VFO field, the data sync field, the data field and the error correction code (ECC) field which are written whenever a record is written by write channel 12. The number of bytes of data in each of the above field is shown directly below each field in Figure 3.

Returning to Figure 1, during a read operation the data read from the disk is received by read channel 10 on line 14 and selected portions of the read data is provided on line 19 to digital phase lock loop 11 under control of control signals on bus 16 from microprocessor 9. The phase locked loop 11, in response to control signals on bus 17 from microprocessor 9, locks up on a frequency determined by the frequency of the data received on line 20 from read channel 10 to generate the read clock. Read channel 10, under control of control signals on bus 16 from microprocessor 9, uses the read clock on line 21 to provide detected data on line 15 derived from the read data on line 20.

Returning to Figure 3, during a read operation the read gate is enabled to allow VFO data from the I.D. VFO field and the data VFO field to be provided to the phase locked loop 11 such that phase locked loop 11 will acquire at the frequency of the VFO data in the two VFO fields.

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Since the two VFO fields were written at different times, the frequency of the VFO data recovered from the format VFO field can be different than the frequency of the VFO data recovered from the write VFO field.

The read gate for a write operation is shown to be activated during the I.D. field to allow the read channel 10 to ascertain if the record being sensed is the record being addressed in either a write or read operation. The write gate for a write operation is shown to be enabled during data area of the record which includes a splice field which allows time for the disk drive system to recover from deactivating the read gate and activating the write gate during a write operation.

The number of bytes of data in the I.D. VFO field and the data VFO field is determined by amount of time required for the phase locked loop 11 to acquire synchronization in frequency and phase with the read data in the worst case situation. The worst case situation is where the data in the data area of a record is written and read at the extremes of the speed tolerance of the spindle motor, that is to write data with the spindle motors speed 1% fast and to read that same data with the spindle motors speed 1% slow or vice verse. In the worst case situation the phase lock loop 11 would have to acquire a frequency that is 2% high or lower than the write clock frequency.

SUMMARY OF THE INVENTION

Briefly, the present invention provides an apparatus and method which will cause a write clock to be generated by the phase locked loop which acquires the frequency of the data read from the I.D. VFO field, the I.D. sync field and the I.D. field for the record to be written and then maintains that acquire frequency for the write clock during the writing of the data area (the data VFO field, the data sync field, the data field and the ECC field data) into the record to be written. This results in the data being written into the data area of

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the record to be at the same frequency as the data in the format area of the record being written.

It is an advantage of the present invention is that data written in the data area (the data VFO field, the data sync field, the data field and the ECC field) of a record will be at the same frequency as the data read from the format area (the I.D. VFO field, the I.D. sync field and the I.D. field) of that same record during a write operation.

Another advantage of the invention is that the time required for the phase locked loop to acquire frequency and phase of the data being read during a read operation is reduced.

An advantage of the invention is that the increase in speed for the phase lock loop to acquire frequency and phase lock with the data read from a data record during both a read and write operation.

Another advantage of the invention is that the length of the I.D. VFO field and the data VFO field may be shorter in length.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be described with respect to the particular embodiments thereof and reference will be made to the drawings, in which:

FIGURE 1 is a block diagram of a the prior art disk drive system;

FIGURE 2 is a block diagram of a disk drive system comprising the invention;

FIGURE 3 is a diagram showing the fields of a record as recorded on a disk and the control signal generated by the microprocessor during a read and write operation; and

FIGURE 4 is a logic diagram of the digital phase locked loop comprising the apparatus of the invention.

DETAILED DESCRIPTION OF THE INVENTION

Figure 2 shows a disk drive system that embodies

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the invention which includes a microprocessor 9 for controlling the overall operation of the disk drive system, a read channel 10 for recovering data read from the disk, a write channel 12 for writing data onto the disk and a digital phase locked loop 11 for providing a read clock to the read channel 10 and a write clock to write channel 12, and a reference oscillator 13 connected to the phase locked loop 11 to act as the center frequency of operation of the phase locked loop to which correction will be made.

During a write operation, the phase locked loop 11, in response to control signals from microprocessor 9 on bus 17, locks up on a frequency determined by the ID VFO field of the record that is to be written. The phase locked loop will then be maintained at the acquired frequency during the write operation and the clock output of the phase locked loop is provided as the write clock via line 21 to the write channel 12. The write channel 12 in response to control signals on bus 19 from microprocessor 9 generates write data on line 23 from the data to be written on line 22.

Figure 4 shows the logic for digital phase locked loop 30 which embodies the invention. Phase locked loop 30 receives control signals from microprocessor 9 on bus 18, read data from read channel 10 on line 20, the output signal from reference oscillator 13 on line 19 and provides at different times a read clock on line 21 to read channel 10 and a write clock on line 21 to the write channel 12.

The frequency Fo of the output of reference oscillator 13 is one fourth of the center frequency Fn where center frequency Fn is the data frequency at which data is to be written when the spindle motor operates at the spindle motors nominal speed. A plurality of reference oscillators can be used, where each oscillator defines a center frequency for different bands of tracks on the disk surface. The reference oscillator is selected for the band of tracks which contains the

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address of the data record to be written during a seek operation if the address of the record to be written is not already in the band of tracks presently selected. For ease of understanding, only one reference oscillator is used in the discussion of this invention.

The speed of the spindle motor of the disk drive system is monitored to detect differences between the specified nominal speed for the spindle motor and the actual speed of the spindle motor. Microprocessor 9 generates a speed correction value which is used by a spindle motor controller (not shown) to return the spindle motor back to the spindle motors nominal speed. Micro-processor 9 also generates a digital correction value for use by the phase locked loop 30 that would change the write clock frequency of the phase locked loop 30 so as to compensate for the variation in speed of the spindle motor. For example, if the spindle motors speed was 1% greater than the spindle motors nominal speed than the wavelength of the data written on the disk would be 1% longer and the written data frequency would be 1% lower than the write clock frequency. Microprocessor 9 generates a correction value to increase the clock frequency of the phase locked loop by 1% above the center frequency Fn so as to shorten the wavelength of the data written on the disk by 1%. This has the net effect of having the data written at the same wavelength as data that would have been written with the spindle motor operating at the spindle motors nominal speed. The correction value VEL on line 18-3 is updated periodically and stored in register 39.

Reference oscillator 13 is more stable than the voltage control oscillator 40. Therefore, microprocessor 9 will raise the SEL OSC signal on line 19-4 of bus 19 during idle record time, that is whenever a record is not being read from or written to by the disk drive system such that the voltage controlled oscillator 40 will be maintained at the center frequency

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Fn by oscillator 13. At this same time microprocessor 9 will store a correction value VEL of zero in register 39 such that voltage controlled oscillator 40 will only be controlled by reference oscillator 13 and will acquire the frequency and phase of center frequency Fn.

When SEL OSC signal is raised on line 19, the sine wave output of the reference oscillator 13 is passed through gate 31 to analog to digital convertor (A/D) 33 via line 50. The square wave read or write clock from voltage controlled oscillator 40 is connected to analog to digital convertor 33. Analog to digital convertor 33 samples the sine wave signal on line 19 from oscillator 13 upon detecting each leading edge of the square wave clock on line 21 from voltage controlled oscillator 40. Each sine wave will be sampled four time, two times during the positive excursion of the sine wave generating two positive digital samples and two times during the negative excursion of the sine wave generating two negative digital samples. The digital sample generated by digital to analog convertor 33 are sequentially transferred via bus 54 to VFO digital phase detector 35.

VFO digital phase detector 35 derives from each pair of positive and negative digital samples a digital correction signal for changing the clock frequency of voltage controlled oscillator 40 such that the two digital samples in each positive and negative digital sample pair have the same value. The digital correction signal are transferred to gate 37 via bus 55.

When either SEL OSC signal on line 18-4 is raised or SEL VFO signal is raised on line 18-1, the output of Or 34 on line 57 will be raised so as to condition gate 37. When gate 37 is conditioned, the digital correction signals sequential pass through gate 37 onto bus 58 to an input of adders 43.

Register 41 is an accumulator register which stores an accumulated correction value. When a digital correction signal is received by adder 43, adder 43 adds

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the contents of register 41 appearing on bus 63 with the present digital correction signal appearing on bus 58 to form a accumulated correction signal which is transferred via bus 58 to register 41 for storage and to adder 44. Register 41 contains the algebraic sum of all the preceding digital correction signal appearing on bus 58.

Adder 44 adds the accumulated correction signal on bus 59 to the contents of register 39 appearing on bus 61 to form a total correction signal. The total correction signal is transferred via bus 62 to the digital to analog convertor (D/A) 45. At this time, the contents of register 39 is zero and therefore the total correction signal is equal to the accumulated correction value signal from adder 43. Digital to analog convertor 46 converts the digital total correction signal to an analog correction signal. The analog correction signal is transferred via line 64 to voltage controlled oscillator 40 for controlling the frequency of voltage controlled oscillator 40.

The phase locked loop is complete such that the frequency of the voltage controlled oscillator 40 will be maintained at the desired frequency Fn. When this occurs the sequential error correction signal from VFO digital phase detector 35 will be zero. Register 41 will have the accumulated correction value necessary to maintain the voltage controlled oscillators 40 frequency at frequency Fn and the accumulate correction signal on bus 59 will have a constant value equal to the accumulated correction value stored in register 41.

Microprocessor 9 will lower SEL OSC signal on line 16-4 and transfer the current digital speed correction value VEL via bus 18-3 to register 39. Adder 44 will now generate a total digital correction signal on bus 62 by adding the accumulated correction signal on bus 59 to the speed correction signal appearing on bus 61. The total correction signal on bus 62 contains the correction necessary to have the voltage controlled

oscillator 40 operate at frequency such that the data written on the disk will be the write clock frequency Fn.

However due to the variations in the output frequency of the voltage controlled oscillator 40 and the variation is the speed of the spindle motor during the periodic updates of the speed correction data, the data written during a write operation will vary in frequency from the frequency Fn and the data read during a read or write operation will have a frequency that varies from frequency Fn.

To further reduce the possible difference in frequency between the data in the format area and the data in the data area of a given record, the data read from the format field during a write operation is used to update register 41 during a write operation such that the resulting output frequency of voltage controlled oscillator 40 will cause the data to be written on the disk to have the same wavelength as the data read from the disk for the record being written.

Referring to Figure 3 and 4, microprocessor 9 generates a SEL VFO signal to gate the sequential error correction signal generated by VFO digital phase detector 35 from the VFO data in the I.D. VFO field onto bus 58 for processing by the phase locked loop. Microprocessor 9 generates a SEL DATA signal to gate the sequential error correction signals generated by data digital phase detector 365 from the data in the I.D. sync field, the I.D. field onto bus 58 for processing by the phase locked loop. The data recorded in the VFO field is a sine wave at the frequency of Fn/4 whereas the data in all other format area fields except the servo field are dibits with at frequency of Fn. Where frequency Fn is equal to the center frequency for each band of tracks were more than one oscillator 13 is used.

During a write operation for a record, data is passed through gate 32 to analog to digital convertor 33 and the sequential digital samples are transferred to

the VFO digital phase detector 35 and the data digital phase detector 36. At the proper time, microprocessor 9 raises the SEL VFO signal on line 18-1 such that the sequential error correction signals derived from the sine wave data in the format I.D. VFO field will be passed through gate 37 onto bus 58 to updated the accumulated correction value in register 41 to a value that would cause the data to be written in the data area to have the same wavelength as the VFO data read from the I.D. VFO field.

The SEL VFO signal is then lowered and the SEL DATA signal is raised. This results in the sequential error correction signal generated from the dibit data in the I.D. sync field and the I.D. fields by the data digital phase detector 38 to be passed through gate 38 onto bus 58 for processing by the phase lock loop. At this time the phase locked loop is tracking the frequency of the data in the two I.D. fields. Various data digital phase detectors exist in the art and the data digital phase detector used herein is the heretofore reference data digital phase detector.

Therefore the I.D. VFO field was used to acquire the frequency of the data read from the data record to be written and the I.D. sync field and the I.D. field was then used to track the frequency of the data read for the record to be written. This procedure allow the most up to date value for the accumulated error signal to be stored in register 41 before the writing of the data into the write area of the record to be written by the write channel 12.

The SEL DATA signal in then lowered which will freeze the contents of register 39 after the I.D field has been completely read thereby causing the last value for the accumulated correction signal on bus 59 to be added to the speed correction signal appearing on bus 61. This results in a constant total correction signal to appear on bus 62 during the time that the write gate is raised and the voltage controlled oscillator 40 will

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be maintained at the frequency of the data read from the format area during the entire write operation.

The same procedure is used during a read operation for the format area. When the data area is read, the sine wave data in the data VFO field is used to acquire the frequency of the data in the data area. The frequency of the VFO data should be close to the frequency of the data in the format area and therefore the phase locked loop should acquire both frequency and phase lock quickly. It should be noted that even if the VFO data is at the same frequency as the format data, the phase of the two signal may still differ and therefore phase lock of the data frequency must still be acquired.

After the frequency of the write data has been acquired, the write data frequency is then track by use of data phase detector 36 while the data is being read from the data area.

While this invention has been described using a digital phase locked loop, it is well within the abilities of one skilled in the art to embody this invention in an analog phase locked loop. Further while the invention has been particularly shown and described with reference to the described embodiment therefore, it will be understood by those skilled in the art that changes in form and detail may be made therein without departing from the spirit and scope of the invention. Given the above disclosure of general concepts and specific embodiments, the scope of the protection sought is defined by the following.

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CLAIMS

What is claimed is:

1. An apparatus in a disk drive system where data is stored in the form of a record, said record having a format portion comprised of a plurality of fields including an I.D. VFO field and a data portion, said apparatus including:

a read channel for reading format data from said format portion of a record to be written;

a write channel for writing the data portion of a record to be written:

a phase locked loop for providing a read clock to said read channel and a write clock to the write channel; a microprocessor for generating control signals for controlling the operation of said read channel, said write channel and said phase locked loop;

first means for providing said format data for said record to be written to said phase locked loop whereby said phase locked loop provides said write clock having the frequency and phase as data read from the format portion of said record to be written; and

second means for maintaining constant said frequency and phase of said write clock provided by said phase locked loop during the writing of said data portion of said record to be written wherein said data is written into said data portion at the same frequency and phase as the data in the format portion of said record to be written.

2. The apparatus of Claim 1 wherein said first means comprises;

a gate means connected to said read channel for transmitting the data in said I.D. VFO field of said format portion of each said record read by said read channel to said phase locked loop such that said phase locked loop will acquire the frequency and phase of said data contained in said read I.D. VFO fields.

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3. The apparatus of Claim 1 wherein said second means further comprises;

a hold means for maintaining constant a control voltage applied to a voltage controlled oscillator in said phase locked loop when said phase locked loop acquired said frequency and phase of said data read from said format portion of said record to be written.

4. The apparatus of Claim 3 wherein said phase locked loop is a digital phased locked loop which generates a digital correction value used for controlling the frequency and phase of said voltage controlled oscillator; and

said hold means comprises:

an interrupt means for preventing said digital correction value from being changed during the writing of data into said data portion of said record to be written.

5. A method of writing data into a record in a disk drive system where data is stored in the form of a record, said record having a format portion comprised of a plurality of fields including an I.D. VFO field and a data portion, said disk drive system comprising a read channel, a write channel, a phase locked loop for providing a read clock to said read channel and a write clock to said write channel and a microprocessor for generating control signals for controlling the operation of said disk drive system, said method comprising the steps of:

a) reading format data from said format portion of a record to be written by said read channel;

b) providing said read format data to said phase locked loop;

c) generating a write clock by said phase locked loop having the same frequency and phase as said read format data;

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d) holding constant the frequency and phase of said write clock at said frequency and phase of said data read from said format portion of said data read to be written during the writing of data into said data portion of said record to be written; and

e) writing said data, by said write channel in response to said write clock, into said data portion of said record to be written where said data will be written at the same frequency and phase as said format data in format portion of said record to be written.



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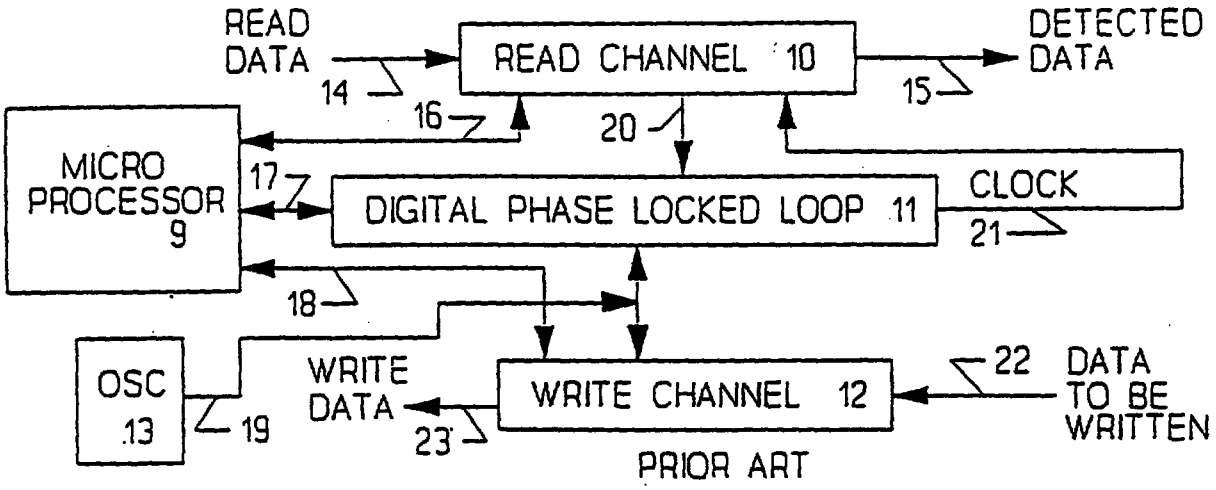

READ DATA
14
READ CHANNEL 10
DETECTED DATA
15
16
20
MICRO PROCESSOR 9
17
DIGITAL PHASE LOCKED LOOP 11
CLOCK
21
18
OSC 13
19
WRITE DATA
23
WRITE CHANNEL 12
22
DATA TO BE WRITTEN
PRIOR ART

FIG. 1

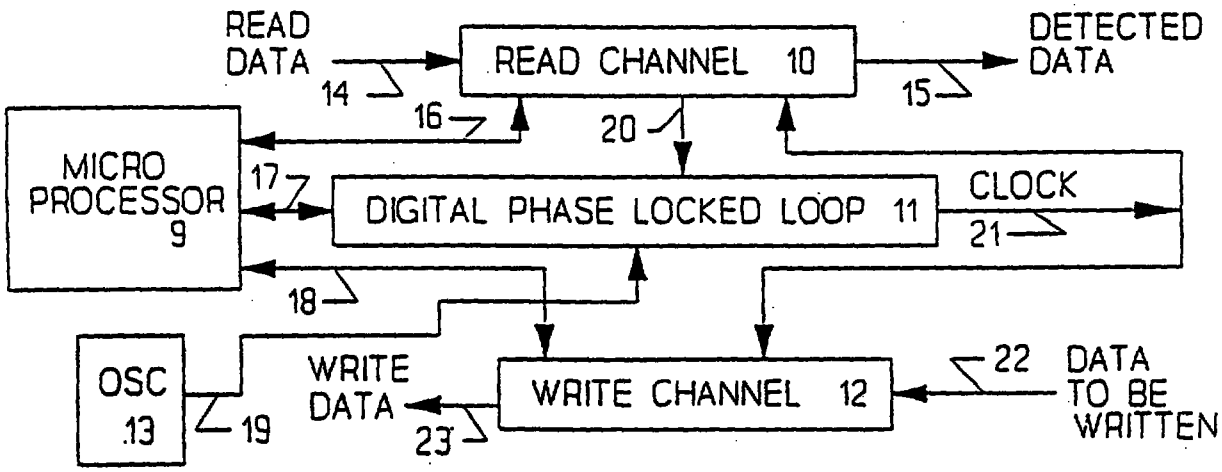

READ DATA
14
READ CHANNEL 10
DETECTED DATA
15
16
20
MICRO PROCESSOR 9
17
DIGITAL PHASE LOCKED LOOP 11
CLOCK
21
18
OSC 13
19
WRITE DATA
23
WRITE CHANNEL 12
22
DATA TO BE WRITTEN

FIG. 2

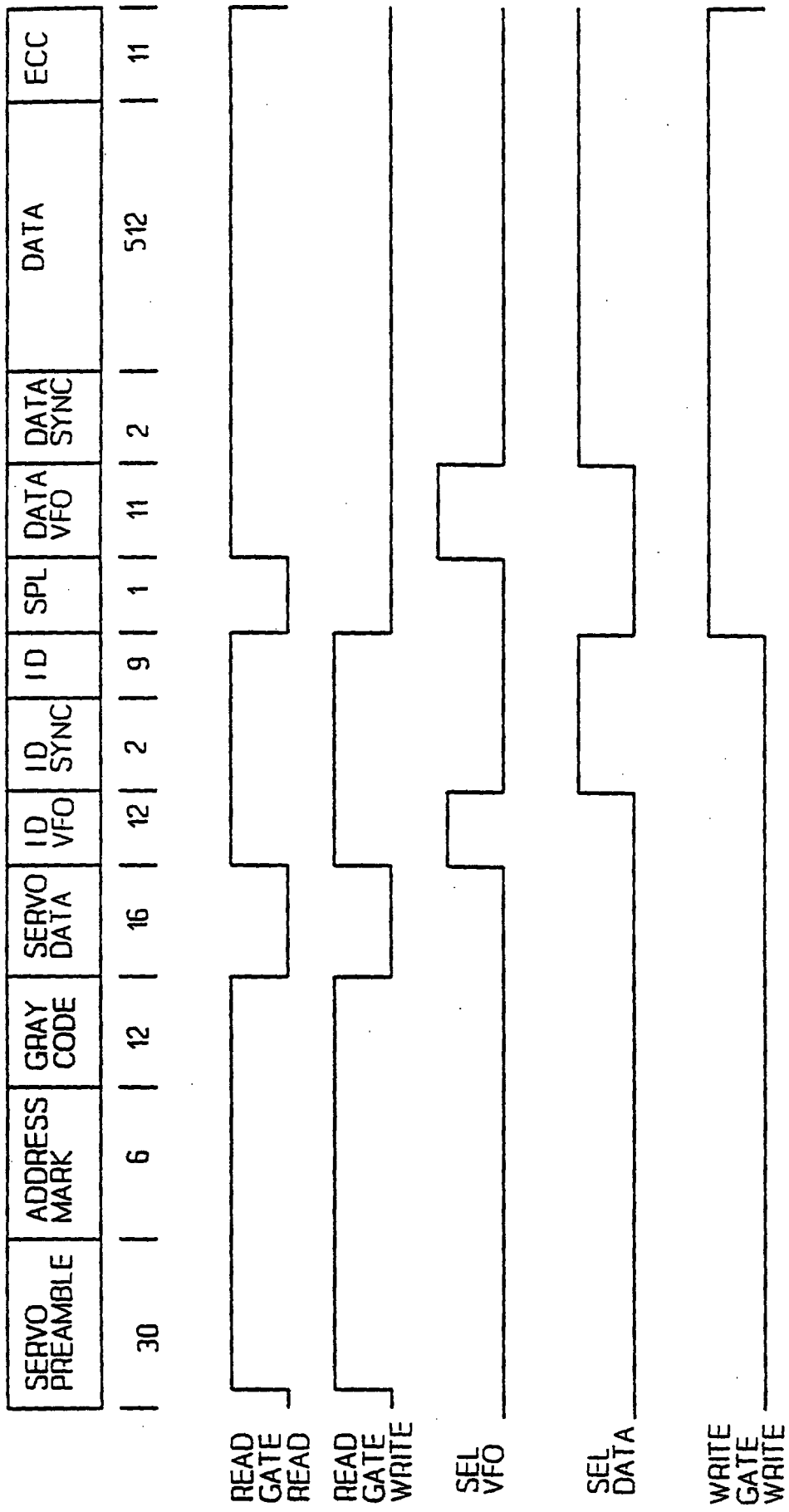

SERVO PREAMBLE
ADDRESS MARK
GRAY CODE
SERVO DATA
ID VFO
ID SYNC
ID
SPL
DATA VFO
DATA SYNC
DATA
ECC
30
6
12
16
12
2
9
1
11
2
512
11
READ GATE READ
READ GATE WRITE
SEL VFO
SEL DATA
WRITE GATE WRITE

FIG. 3

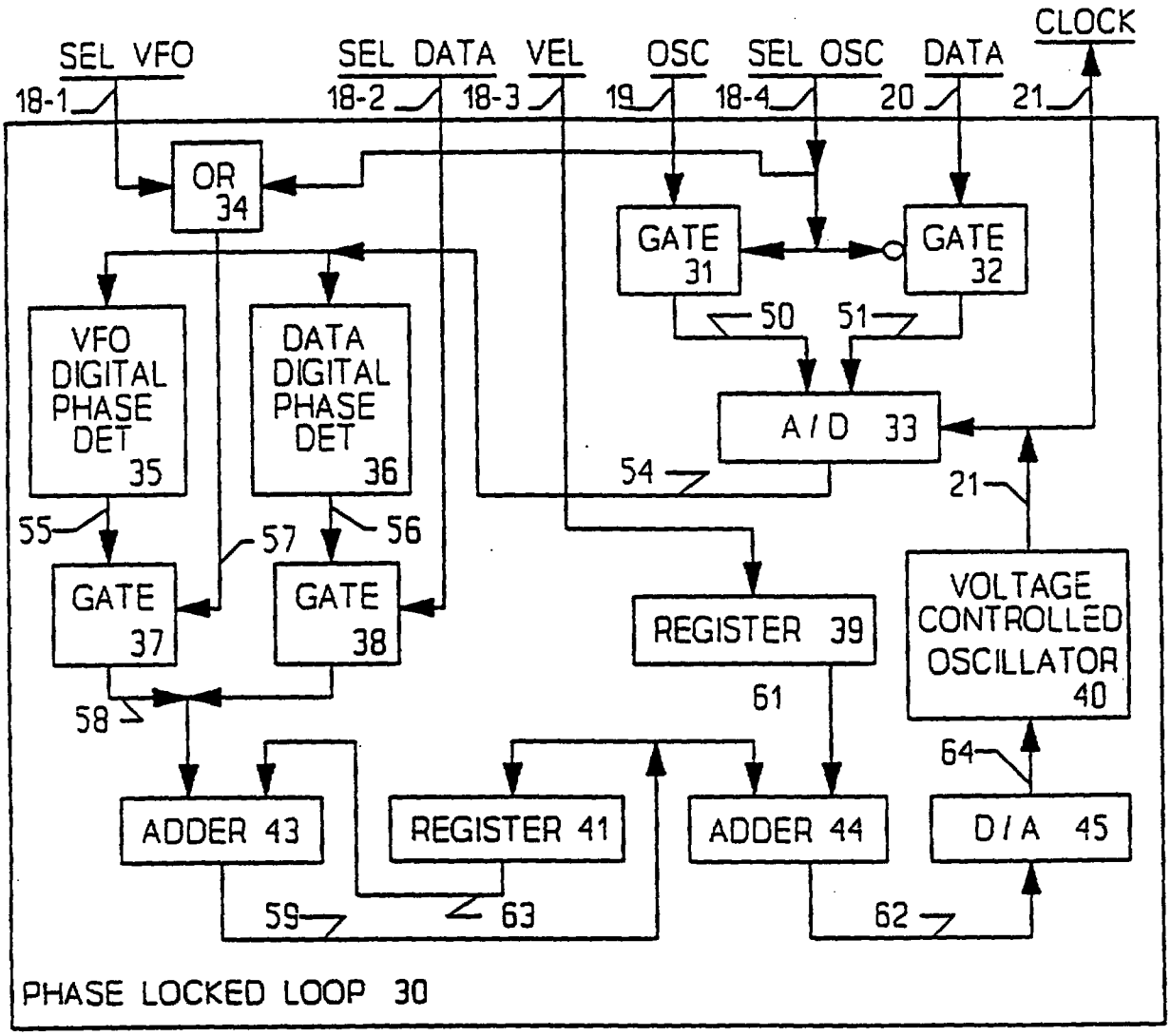

SEL VFO
18-1
SEL DATA
18-2
VEL
18-3
OSC
19
SEL OSC
18-4
DATA
20
CLOCK
21
OR
34
GATE
31
GATE
32
50
51
VFO
DIGITAL
PHASE
DET
35
DATA
DIGITAL
PHASE
DET
36
A/D 33
54
21
55
57
56
GATE
37
GATE
38
REGISTER 39
VOLTAGE
CONTROLLED
OSCILLATOR
40
61
58
64
ADDER 43
REGISTER 41
ADDER 44
D/A 45
59
63
62
PHASE LOCKED LOOP 30

FIG. 4

9702284

PCT WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : G11B 20/10 — A1

(11) International Publication Number: WO 96/18192

(43) International Publication Date: 13 June 1996 (13.06.96)

(21) International Application Number: PCT/US95/16209

(22) International Filing Date: 8 December 1995 (08.12.95)

(30) Priority Data:
08/352,545 9 December 1994 (09.12.94) US

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(81) Designated States: CA, CN, JP, KR, MX, SG, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published

With international search report.

Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

RTMP copy

(54) Title: APPARATUS AND METHOD FOR CONTROLLING THE FREQUENCY AT WHICH DATA IS WRITTEN IN A DISK DRIVE SYSTEM

(57) Abstract

An apparatus and method for use in a disk drive system for providing a write clock having the same frequency and phase of the data included the format portion of the record into which data is to be written. A phase locked loop (11, 30) acquires the frequency and phase from the read format portion of the record and then maintains that frequency and phase as the write clock during the writing of the data portion into the record. The data written into the data portion of the record will have the same frequency and phase as the data in the format portion of that record.

