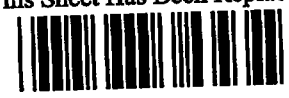
This Sheet Has Been Replaced



PATENT APPLICATION
Express mail number: EF537007955US
Attorney docket no: TIS-27487

FOCUS ERROR GENERATION WITHOUT RADIAL FEEDTHROUGH

BACKGROUND OF THE INVENTION

1. FIELD OF THE INVENTION

This invention relates to improvements in dynamic information storage or retrieval systems and methods, and more particularly to improvements in such systems and methods for the storage or retrieval of arbitrarily variable information which is retained in a storage medium by variation of a optical characteristic thereof by sensing a variation of a physical characteristic of the storage medium by a transducer having relative motion along a continuous path, and still more particularly to improvements in such systems and methods involving optical servo systems for controlling the focus of an optical data sensing transducer and to methods and circuits for focusing the lens of a data sensing transducer, or pickup head, without being perturbed by signal effects experienced by a tracking signal that controls the movement of the pickup head.

2. RELEVANT BACKGROUND

In a typical compact disk (CD) or digital video disk (DVD) system, a data sensing transducer, or head or pickup assembly, is provided to read data patterns, frequently organized in groups, or sectors, that have been previously recorded on a data disk, usually in the forms of lands and grooves along radially arranged concentric tracks in the reflective surface of the disk. The pickup is constructed to contain a focusing lens to focus a laser beam to a spot on the optical disk. The reflected beam is modulated by the

data pattern present on the reflective surface of the disk, and is used for data and positioning detection. After being reflected from the disk, the reflected light reenters the pickup through the lens and is reflected by one or more partially reflective mirrors to impinge on a photodetector array. The photodetector array then converts the received light energies into electric signals.

The focusing lens is typically held in a lens holder attached to the pickup body by a spring mechanism. Wire coils attached to the lens holder carry electric currents that generate magnetic forces that interact with permanent magnets mounted on the pickup body to move the lens holder relative to the pickup body to position the lens. Generally two coils are provided, a focusing coil, to provide the necessary focusing control, and a radial coil, to provide the necessary radial positioning control, respectively.

More particularly, the control of the focusing coil is based on a focus error signal that detects the distance of laser focal point from the highly reflective data layer. The focusing control thus works to minimize the focus error signal magnitude, thereby keeping the laser beam focused on the data layer.

Various focus error generating methods have been proposed. Among the most popular is the astigmatic method, which forms (A+C)- (B+D), where A, B, C, and D are the signals generated by four photodiodes arranged in a square, with A and C on one diagonal and B and D on the other diagonal. The difference signal (A+C)- (B+D) is filtered by a low pass filter to generate the focusing error signal, FE. Shown in Figure 1 is a typical photo-detector circuit in which light reflected from the optical disk is received by the photodiode and is converted to electric current.

This Sheet Has Been Replaced



thus resulting in photodetector output voltage above *Vref*. *Vref* is a fixed voltage, for example 2.5V.

One problem with this conventional method is that, in a "seek" mode, where the beam spot scans across signal tracks on the disk, the FE signal is perturbed as it crosses each track, even though the data layer does not move away from the focal point of the beam. This can be seen in Figure 2 in which the top waveform 3 is the focus error (FE) signal and the bottom waveform 4 is the track error (TE) signal. The track error signal 4 indicates one track crossing per cycle. It can be seen that the focus error signal 3 also, undesirably, has a perturbation once for every track crossed. During access to the target track, when the track crossing speed is lowest, this perturbation frequency lies well within the bandwidth of the focus control feedback loop. Therefore, the focus control might react to this perturbation in such a way as to create an oscillation of the focal point.

This problem can be traced to the fact that the photodetector signal bottom envelope is modulated by track crossings, and since low pass filtering of the signal is equivalent to taking the average of the top envelope and the bottom envelope, each of the signals from the photodetectors A, B, C, and D is modulated during a track crossing. If the photodetectors A, B, C, and D receive equal amounts of light, then the bottom envelope modulation will be identical across all four. Therefore, the signals (A+C) and (B+D) will have equal bottom envelope modulation, and will cancel in the subtraction operation in forming the focus error signal, FE. However, alignment error in manufacturing often leaves the signals A, B, C, and D offset from the optical axis of the pickup. As a result,

This Sheet Has Been Replaced



This Sheet Has Been Replaced



the reflected beam spot may not be centered on the array. This plus other possible manufacturing problems can result in a mismatch of bottom envelope modulation magnitude among the photodetectors. Hence, in such situations, there is not perfect cancellation of radial feed through between (A+C) and (B+D), resulting in nonzero residual radial feed through into the focusing error signal, FE.

More particularly, Figure 3 shows a typical photodetector output signal during track crossing. The RF signal 5 reaches the top envelope 8 whenever the beam spot scans a portion of the disk where there is no pattern, for example where there are pits. Where there are pits or patterns, the RF signal dips to varying depth depending on the length of the pits or patterns but reaches the bottom envelope 9 whenever the beam spot pit or pattern length exceeds the beam spot diameter. When the beam spot is on track, the RF signal swing is maximal, and where it is on mirror (i.e. area between tracks where there is no pattern or pit) the RF signal swing is smallest. It should be noted that the top envelope 8 does not change during track crossing whereas the bottom envelope 9 does so once per track crossing.

What is needed, therefore, is a method and apparatus for producing a focus error signal that is essentially independent of track error perturbations, for example, caused by track crossings, or the like, when alignment errors cause the photodetector signals to be offset from the optical axis of the pickup.

SUMMARY OF THE INVENTION

In light of the above, therefore, it is an object of the invention to provide an improved method of generating a focus error signal that is essentially independent of track

This Sheet Has Been Replaced



error perturbations, for example, caused by track crossings, or the like, when alignment errors cause the photodetector signals to be offset from the optical axis of the pickup.

This and other objects, features, and advantages will become apparent to those skilled in the art from the following detailed description, when read in conjunction with the accompanying drawings and appended claims.

Thus, according to a broad aspect of the invention, a circuit is presented to remove the effects of tracking error perturbations from a focus error signal in an optical disk signal processing path. The circuit includes an array of photodetectors arranged to each receive a portion of a light beam reflected from the optical disk to produce respective photodetector signals. A circuit produces a difference of summed photodetector signals from respective diagonally located ones of the photodetectors and a circuit divides the difference of summed photodetector signals by a sum of all of the photodetector signals. In one embodiment, top envelope detectors detect top envelopes of the photodetector signals prior to the summing. In another embodiment, top envelope detectors detect top envelopes of the photodetector signals after the summing.

According to another broad aspect of the invention, a method is presented for generating a focus error signal of an optical pickup that receives light beam reflections from an optical disk to impinge on a photodiode array. The method includes detecting respective signals produced by photodiodes of the photodiode array arranged in four quadrants with respect to the light beam whose position is to be determined. Voltages are summed from a first diagonal pair of the photodiodes to produce a first signal sum, and

This Sheet Has Been Replaced



from a second diagonal pair of the photodiodes to produce a second signal sum. The second signal sum is subtracted from the first signal sum to produce a subtracted signal sum, and the first and second signal sums are added to produce an added signal sum. The subtracted signal sum is divided by the added signal sum to produce a focus error signal. In a first embodiment, top signal envelopes are detected before summing the voltages from the first and second diagonal pairs of the photodiodes. In a second embodiment, top signal envelopes are detected after summing the voltages from the first and second diagonal pairs of the photodiodes.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention is illustrated in the accompanying drawings, in which:

Figure 1 is an electrical schematic diagram of a typical circuit of the prior art for developing a photodetector output.

Figure 2 is a graph of typical focus error and track error signals, showing the relationship therebetween, according t the prior art.

Figure 3 is a graph showing a typical photodetector output signal during track crossings.

Figure 4 is a block diagram of a pickup head and lens positioning apparatus, and circuit for operating same, with which the focus error signal generator according to the invention can be used.

Figure 5 is a box diagram showing a construction of a circuit for generating a focus error signal, in accordance with a preferred embodiment of the invention.

This Sheet Has Been Replaced



Figure 6 is an electrical schematic diagram of a circuit for top envelope detection that can be used in the circuit of Figures 5 and 7.

Figure 7 is a box diagram showing an alternative construction of a circuit for generating a focus error signal, in accordance with a preferred embodiment of the invention.

In the various figures of the drawing, like reference numerals are used to denote like or similar parts.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

More particularly, with reference now to Figure 4, an optical disk assembly 10 is used in conjunction with an optical disk 11, which is rotated, for example, by a spindle motor 24. An optical head 12 is movably arranged with respect to the optical disk 11, and a head driving motor 26 moves the optical head 12 in a radial direction of the optical disk 11. The optical head 12 emits a light beam 14 that is focused into a spot on the optical disk 11 for reading information from and/or writing information to the optical disk 11.

A semiconductor laser 28 is provided as a light source within the optical head 12. A light beam emitted from the semiconductor laser 28 is directed to an objective lens 36 via a collimator lens 30, a deflection beam splitter 32, and a quarter wave plate 34. The objective lens 36 converges the light beam into a beam spot on the optical disk 11. A reflected beam from the optical disk 11 is reflected in a perpendicular direction by the deflection beam splitter 32 onto a 4-segment photodetector 40 via a condenser lens 38.

A plurality of tracks (not shown) are formed in a radial direction on the optical disk 11. The radial track

This Sheet Has Been Replaced

position, however, may deviate, for instance, by eccentricities of the optical disk 11 or due to positioning errors when the data is written. In addition, the focal position of the beam spot may deviate by undulations of the optical disk 11. Nevertheless, the beam spot, which may have a diameter of 1 μm or less, must follow the track, despite such deviations in the track and the focal positions.

Hence, a focus actuator 42 is provided for adjusting the focal position of the spot by moving the objective lens 36 of the optical head 12 up and down. In addition, a track actuator 44 is provided for controlling the tracking of the beam by moving the objective lens 36 in a direction that is perpendicular to the tracks on the optical disk 11.

The focus actuator 42 is controlled by a focus servo circuit 46, which may be constructed in accordance with a preferred embodiment of the invention, and which drives the focus actuator 42 so that a focus error signal, FE, which is derived from an output light detection signal of the 4-segment photodetector 40, becomes a minimum.

The track actuator 44 is controlled by a tracking servo circuit 48 during a tracking servo operation in which the light beam is controlled to follow the target track. The track actuator 44 is controlled by a velocity control circuit 50 during a track jump operation in which the light beam jumps to an arbitrary track for making a new access.

A circuit 46 for generating a focus error signal, in accordance with a preferred embodiment of the invention, is shown in Figure 5, to which reference is now additionally made. The circuit 46 derives its inputs from the various segments of a photodetector array 40. The photodetector

This Sheet Has Been Replaced

array 40 may be of conventional design, including, for example, four segments A, B, C, and D that are located in the path of the reflected light generated by the optical elements of the pickup head 12. As mentioned, the reflected spot from the optical disk 11 is focused onto the photodetector array 40 to form a light pattern 62 thereon. Ideally the spot or pattern 62 is equally distributed among each of the photodetector segments; however, as mentioned, for many reasons, the pattern may fall disproportionately onto one or more of the photodetectors. When this occurs, a non-zero focus error signal needs to be developed to reposition the lens 36.

Thus, the signals developed by each of the photodetectors of the photodetector array 40 are connected to respective top envelope detectors 64 -- 67. The signals from respective diagonal photodetectors segments A and C, and from respective diagonal photodetectors segments B and D, after top envelope detection, are added by adders 70 and 72. Their difference is then developed by a subtractor 74, the output of which is connected to a variable gain amplifier 76. In addition, the added signals developed at the outputs of adders 70 and 72 are added by adder 73 to control the gain of the variable gain amplifier 76.

The effect of the variation in the gain of the variable gain amplifier 76 is a division of the differences signal produced at the output of the subtractor 74 by the added signal developed by the adder 73. Thus, the output signal FE developed on line 80, which may be used to actuate the driving coil 42 to focus the lens 36, has the formula:

$$FE = \frac{[top(A)+top(C)]-[top(B)+top(D)]}{top(A)+top(B)+top(C)+top(D)}.$$

This Sheet Has Been Replaced



A circuit that can be used to perform the top envelope detection of each of the circuits 64 -- 67 is shown in Figure 6 to which reference is now additionally made. A top envelope detector 82 may receive at its input 84 the output signal from a respective one of the photodetector array segments A, B, C, or D. the signal is rectified by the diode 86 to charge a capacitor 88. A resistor 90 is provided in parallel with the capacitor 88 to filter the signal that is generated on the capacitor 88 to provide a filtered top envelope detected signal on output node 92. A similar circuit can be used for each of the top envelope detectors 64 -- 67.

Another embodiment of the circuit of the invention is shown in Figure 7 to which reference is now additionally made. The circuit 100 shown in Figure 7 provides for top envelope detection after the summation of the signals of the respective diagonal photodetectors of the photodetector array 40, in contrast to the embodiment of Figure 5 in which the top envelope detection preceded the summation of the signals of the diagonal photodetectors. Thus, the signals from the photodetector segments A and C are summed by a summer circuit 102, and the signals from the photodetector segments B and D are summed by the summer circuit 104.

The outputs from the summers 102 and 104 are respectively connected to the inputs of top envelope detectors 106 and 108, respectively. In the construction of the circuit 100, the top envelope detector 82 shown in Figure 6 may be used to provide the top envelope detection function of the top envelope detectors 106 and 108.

The outputs from the top envelope detectors 106 and 108 are subtracted by a subtractor 110, the output of which

is connected to a variable gain amplifier 112. Concurrently, the outputs from the top envelope detectors 106 and 108 are added by an adder 114, the output of which controls the gain of the variable gain amplifier 112. The output signal FE from the variable gain amplifier 112 on line 116 may be used to control the focus coil 42 to focus the lens 36, in a similar fashion to that above described with reference to the circuit 46 of Figure 5, according to the formula:

$$FE = \frac{top(A+C) - top(B+D)}{top(A+C) + top(B+D)}.$$

Although the invention has been described and illustrated with a certain degree of particularity, it is understood that the present disclosure has been made only by way of example, and that numerous changes in the combination and arrangement of parts can be resorted to by those skilled in the art without departing from the spirit and scope of the invention, as hereinafter claimed.

This Sheet Has Been Replaced



CLAIMS:

1. A circuit to remove the effects of tracking error perturbations from a focus error signal in an optical disk signal processing path, comprising:

an array of photodetectors arranged to each receive a portion of a light beam reflected from the optical disk to produce respective photodetector signals,

a circuit for producing a difference of summed photodetector signals from respective diagonally located ones of said photodetectors;

and a circuit for dividing said difference of summed photodetector signals by a sum of all of the photodetector signals.

2. The circuit of claim 1 further comprising top envelope detectors to detect top envelopes of said photodetector signals.

3. The circuit of claim 1 wherein said top envelope detectors detect said top envelopes prior to said summing.

4. The circuit of claim 1 wherein said top envelope detectors detect said top envelopes after said summing.

5. The circuit of claim 1 wherein said circuit for dividing said difference of summed photodetector signals by a sum of all of the photodetector signals is a variable gain amplifier.

6. The circuit of claim 1 wherein said array of photodetectors comprises four photodiodes arranged in a square pattern.

This Sheet Has Been Replaced



* C L M S *

7. A circuit for producing a focus error signal of a pickup for reading information contained on an optical disk, comprising:

an array of photodetectors arranged to each receive a portion of a light beam reflected from the optical disk,

a plurality of top envelope detectors, each associated with a respective at least one photodetector to receive a respective output signal therefrom;

first and second summer circuits each connected to receive a pair of respective outputs from said top envelope detectors that are associated with respective diagonally located ones of said photodetectors to produce first and second summed signals;

a third summer circuit connected to sum said first and second summed signals to produce a third summed signal;

a subtractor circuit connected to subtract said second summed signal from said first summed signal to produce a first subtracted signal;

and a divider circuit connected to divide said subtracted signal by said third summed signal.

8. The circuit of claim 7 wherein said array of photodetectors comprises four photodiodes arranged in a square pattern.

9. The circuit of claim 7 wherein said divider circuit is a variable gain amplifier.

10. A circuit for producing a focus error signal of a pickup for reading information contained on an optical disk, comprising:

This Sheet Has Been Replaced

* C L M S *

an array of photodetectors arranged to each receive a portion of a light beam reflected from the optical disk,

first and second summer circuits, each connected to sum a pair of respective outputs from respective diagonally located photodetectors of said array of photodetectors to produce first and second summed signals;

a plurality of top envelope detectors, each connected to receive a respective one of said first and second summed signals to produce respective first and second top envelope detected summed signals;

a subtractor circuit connected to subtract said second top envelope detected summed signal from said first top envelope detected summed signal to produce a first top envelope detected summed signal;

a third summer circuit connected to sum said first and second top envelope detected summed signals to produce a third top envelope detected summed signal;

and a divider circuit connected to divide said subtracted top envelope detected signal by said third top envelope detected summed signal.

11. The circuit of claim 10 wherein said array of photodetectors comprises four photodiodes arranged in a square pattern.

12. The circuit of claim 10 wherein said divider circuit is a variable gain amplifier.

13. A method for generating a focus error signal of an optical pickup that receives light beam reflections from an optical disk to impinge on a photodiode array, comprising:

This Sheet Has Been Replaced

* C L M S *

detecting respective signals produced by photodiodes of said photodiode array arranged in four quadrants with respect to the light beam whose position is to be determined;

summing voltages from a first diagonal pair of said photodiodes to produce a first signal sum;

summing voltages from a second diagonal pair of said photodiodes to produce a second signal sum;

subtracting said second signal sum from said first signal sum to produce a subtracted signal sum;

adding said first and second signal sums to produce an added signal sum;

and dividing said subtracted signal sum by said added signal sum to produce a focus error signal.

14. The method of claim 13 wherein said detecting respective signals produced by said photodiodes comprises detecting a top signal envelope before summing said voltages from said first and second diagonal pairs of said photodiodes.

15. The method of claim 13 wherein said detecting respective signals produced by said photodiodes comprises detecting a top signal envelope after summing said voltages from said first and second diagonal pairs of said photodiodes and before adding said first and second signal sums.

16. The method of claim 13 wherein said detecting respective signals produced by photodiodes of said photodiode array arranged in four quadrants with respect to

This Sheet Has Been Replaced

the light beam comprises detecting respective signals from four photodiodes arranged in two diagonal sets.

17. A method for generating a focus error signal of an optical pickup that receives light beam reflections from an optical disk to impinge on a photodiode array, comprising:

detecting respective signals produced by photodiodes of said photodiode array arranged in four quadrants with respect to the light beam whose position is to be determined;

summing voltages from a first diagonal pair of said photodiodes to produce a first signal sum;

summing voltages from a second diagonal pair of said photodiodes to produce a second signal sum;

performing top envelope detection on said first and second signal sums to produce first and second top envelope detected signals;

subtracting said second top envelope detected signal from said first top envelope detected signal to produce a subtracted signal;

adding said first and second top envelope detected signals to produce an added signal;

and dividing said subtracted signal by said added signal to produce a focus error signal.

18. The method of claim 17 wherein said detecting respective signals produced by photodiodes of said photodiode array arranged in four quadrants with respect to the light beam comprises detecting respective signals from four photodiodes arranged in two diagonal sets.

This Sheet Has Been Replaced

19. A method for generating a focus error signal of an optical pickup that receives light beam reflections from an optical disk to impinge on a photodiode array, comprising:

performing top envelope detection on respective signals produced by photodiodes of said photodiode array arranged in four quadrants with respect to the light beam whose position is to be determined to produce first, second, third, and fourth top envelope detected signals;

summing first and second top envelope detected signals to produce a first signal sum;

summing third and fourth top envelope detected signals to produce a second signal sum;

subtracting said second signal sum from said first signal sum to produce a subtracted signal sum;

adding said first and second signal sums to produce an added signal sum;

and dividing said subtracted signal sum by said added signal sum to produce a focus error signal.

20. The method of claim 19 wherein said detecting respective signals produced by photodiodes of said photodiode array arranged in four quadrants with respect to the light beam comprises detecting respective signals from four photodiodes arranged in two diagonal sets.

This Sheet Has Been Replaced