A method and apparatus for creating a position error signal (PES) voltage v. track distance curve for the head (20) of a hard disk drive (10). The disk (12) has a dedicated track which contains a plurality of servo bits (34) that allow the head to be centered with the centerline of the track. The dedicated track also has a number of calibration bits (50-60) each embedded at a known location off-set from the track centerline. The PES voltage v. track distance curve is generated by reading each calibration bit and storing the corresponding amplitude of the position error signal in a memory device of the disk drive. Each calibration bit is located from the track centerline a distance that is different from the other calibration bits so that there are provided multiple points on the track curve.
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OFF-TRACK PES CALIBRATION FOR
A MAGNETO-RESISTIVE ELEMENT

BACKGROUND OF THE INVENTION

1. FIELD OF THE INVENTION

The present invention relates to a method for generating a position error signal calibration curve for a read element of a hard disk drive.

2. DESCRIPTION OF RELATED ART

Hard disk drives contain a disk that rotates relative to a head. The head is located at the end of an actuator arm assembly. The actuator assembly includes a voice coil motor which can move the head relative to the surface of the disk. The head contains a transducer which can magnetize and sense the magnetic field of the disk.

Data is stored on the disk within a number of concentric radial tracks. Each track is further divided into a plurality of sectors. To accurately write and read data, it is desirable to maintain the head on the center of the track. To assist in controlling the position of the head, each sector of the disk typically contains a number of servo bits accurately located relative to the centerline of the track. The raw signals produced by the servo bits are typically demodulated into a single position error signal (PES). The electronic circuits of the drive utilize the position error signals to determine the position of the head relative to the track, and to move the actuator arm if the head is not located on the track centerline.

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The servo routine of a hard disk drive typically performed with a position error signal voltage v. track distance curve that is stored within memory of the drive. The voltage v. track distance curve provides a correlation between the amplitude of the position error signal and the distance between the head and the center of the track. For example, a PES signal having an amplitude of approximately 1/2 of the peak amplitude may provide an indication that the head is a 1/4 track width away from the track centerline. In accordance with the track curve, the actuator arm is moved a corresponding distance to center the head. The voltage v. track distance curve is typically based on an ideal curve that is generated from an algorithm stored in the read only memory (ROM) of the drive.

Conventional hard disk drive read/write heads typically have a single transducer that both read and write data onto the disk. Generally speaking, conventional single element heads have reached maximum aerial densities (typically measured in gigabits per square inch). There does exist a dual element head that has been found to provide greater aerial densities than single element transducers. Dual element heads contain a single write element and a separate read element that is constructed from a magneto-resistive material. Such dual element transducers are commonly referred to as magneto-resistive (MR) heads.

Because of manufacturing tolerances, the separate magneto-resistive element may be off-center from the write
element of the head. Therefore, if data is written off the center of the track, to read the data, the servo system must move the head slightly off-center so that the read element is centered with the written data. The routine of moving an MR head during a read operation is commonly referred to as micro-jogging.

The head can be moved in accordance with the voltage v. track distance curve stored in memory. It has been found that the voltage v. track distance curve for a MR head is non-linear in nature and varies greatly between different heads. It would therefore be desirable to provide a method for generating an actual voltage v. track distance for a magneto-resistive head.

SUMMARY OF THE INVENTION

The present invention is a method and apparatus for creating a position error signal (PES) voltage v. track distance curve for the head of a hard disk drive. The disk has a dedicated track which contains a plurality of servo bits that allow the head to be centered with the centerline of the track. The dedicated track also has a number of calibration bits each embedded at a known location off-set from the track centerline. The PES voltage v. track distance curve is generated by reading each calibration bit and storing the corresponding amplitude of the position error signal in a memory device of the disk drive. Each calibration bit is located from the track centerline a distance that is different from the other calibration bits
so that there are provided multiple points on the track curve.

**BRIEF DESCRIPTION OF THE DRAWINGS**

The objects and advantages of the present invention will become more readily apparent to those ordinarily skilled in the art after reviewing the following detailed description and accompanying drawings, wherein:

- Figure 1 is a top view of a hard disk drive;
- Figure 2 is a schematic of a conventional data sector of the disk;
- Figure 3 is a schematic showing a head reading data from a data sector;
- Figure 4 is a graph showing a PES voltage v. track distance curve;
- Figure 5 is a schematic of a dedicated track that contains a number of calibration bits.

**DETAILED DESCRIPTION OF THE INVENTION**

Referring to the drawings more particularly by reference numbers, Figure 1 shows a hard disk drive 10. The disk drive 10 includes a disk 12 that is rotated by a spin motor 14. The spin motor 14 is mounted to a base plate 16. Also mounted to the base plate 16 is an actuator arm assembly 18. The actuator arm assembly 18 includes a number of heads 20 mounted to corresponding flexure arms 22. The flexure arms 22 are attached to an actuator arm 24 that can rotate about a bearing assembly 26. The assembly
18 also contains a voice coil motor 28 which moves the heads 20 relative to the disk 12. There is typically a single head for each disk surface. The spin motor 14, voice coil motor 28 and the heads 20 are coupled to a number of electronic circuits 30 mounted to a printed circuit board 32. The electronic circuits 30 typically include a read channel chip, a microprocessor based controller and random access memory (RAM) device.

As shown in Figure 2, data is typically stored within sectors of radially concentric tracks located across the disk 12. A typical sector will have an automatic gain control (AGC) field 30, a synchronization (sync) pulse 32, a number of servo bits 34, a gray code field 36 that identifies the track, an identification (ID) field 38 that defines the sector, a data field 40 which contains the data and an error correction code field 42. The electronic circuits 30 utilize the servo bits 34 to maintain the heads 20 on the centerline CL of the track. If the heads 20 are off-center the electronic circuits 30 will generate a position error signal (PES) which has a voltage amplitude that varies with the distance that the heads 20 are off-set from the track centerline.

The heads 20 can magnetize and sense the magnetic field of the disk. In the preferred embodiment, each head 20 has a single write element and a separate read element. The read element is preferably constructed from a magneto-resistive material which changes resistance in proportion to the intensity of an external magnetic field.
As shown in Figure 3, the read element 44 is sometimes off-set from the write element 46 because of the tolerances associated with the manufacturing process of the head. Because the write element 46 is off-set from the read element 44, the data is written off-center from the center of the track. To properly read the data, the read element 44 must be moved over to the off-center location of the written data.

The heads 20 are moved in accordance with the position error signal voltage v. track distance curve shown in Figure 4. The off-set distance between the write element 46 and the element 44 for each head is typically calculated when the disk is initially assembled. When both elements are concentric the PES signal should be ideally zero when the read track is centered with the written data. If the read element 44 is off-set from the write element 46 the PES signal is some non-zero value when the read element is centered over the written data. The microprocessor based controller utilizes the curve to determine the position of the heads 20 and the movement required to center the read element 44 with the written data. It has been found that the PES voltage v. track distance curve is typically non-linear for magneto-resistive heads.

Figure 5 shows a plurality of calibration bits 50-60 that are embedded into the disk 12 and used to create the curve depicted in Fig. 4. The calibration bits 50-60 are typically located in a dedicated calibration track of the disk which has no data. The calibration track has an
AGC/ID/SYNC field 64 to provide corresponding functions for the operation of finding, tracking and reading the dedicated track. Although the AGC, ID and SYNC are shown as one field, it is to be understood that these functions can be located within separate fields.

The calibration track also contains a number of servo bits 66 designated A, B, C and D. The boundary formed by the A and B servo bits defines the track CL of the servo calibration track. The boundary formed by the C and D servo bits is offset by a distance corresponding to 1/2 of the track width. The C and D servo bits are not used in the servo signal calibration. The servo bits are detected by the read element 44 of the head and demodulated by the electronics into a single PES signal. The servo bits A and B are used to center the read element 44 with the centerline CL of the dedicated track.

The calibration bits 50-60 each have a centerline located at a predetermined off-set position from the track centerline CL. The calibration bits are typically embedded with the servo bits during the assembly process of the disk drive with instrumentation that accurately controls the location of the bits. The boundary of the first set of calibration bits +50 and -50 defines a centerline that is located at a predetermined distance +d1 from the track centerline CL. The calibrations bit sets +/-52 and +/- 54 define servo bit centerlines that are located distances of +d2 and +d3 from the track centerline, respectively. Likewise the calibration bit sets +/- 56-60 define servo
bit centerlines offset by distances \(-d_4, -d_5, \text{ and } -d_6\) with respect to the track centerline CL, respectively.

When the read element 44 passes over a set of calibration bits, the electronic circuits 30 will generate a demodulated PES signal which has an amplitude that correlates to the location of the pair of calibration bits relative to the centerline of the track. The PES signal will have a larger voltage amplitude for calibration bits that are located farther away from the track centerline.

In operation, the heads are moved to the dedicated calibration track and centered on the track centerline CL using the servo bits A and B. The read element 44 then reads the calibration bits 50-60. Corresponding demodulated PES signals are then generated from the calibration bits and stored in a memory device of the disk drive. The various calibration points are interpolated to create the PES voltage v. track distance curve shown in Fig. 4. Although 6 sets of calibration bits are shown and described, it is to be understood that any number of bits can be used to generate enough data points to create a PES voltage v. track distance curve. The disk drive typically goes through the routine of generating the curve after each "power-on" sequence of the drive. Alternatively, the curve can be generated when the disk drive is initially assembled and then stored in a non-volatile memory medium such as the disk 12.

While certain exemplary embodiments have been described and shown in the accompanying drawings, it is to
be understood that such embodiments are merely illustrative of and not restrictive on the broad invention, and that this invention not be limited to the specific constructions and arrangements shown and described, since various other modifications may occur to those ordinarily skilled in the art.
What is claimed is:

1. A disk for a hard disk drive, comprising:
   a disk that contains a plurality of tracks, each track having a centerline, said tracks including a calibration track that has a first set of calibration bits that each have a bit centerline that is offset from the track centerline an amount that is different than the bit centerlines of the other calibration bits within the first set.

2. The disk as recited in claim 1, wherein said calibration bits are used to generate a plurality of position error signals.

3. The disk as recited in claim 1, wherein said track has a set of servo hits.

4. The disk as recited in claim 3, wherein said set of servo bits includes an A bit and a B bit that have a common boundary located at the track centerline.

5. The disk as recited in claim 1, wherein said first set of calibration bits includes a first calibration bit that has a centerline located approximately a first fraction of a track width from the track centerline, a second calibration bit that has a centerline located approximately a second fraction of a track width from the track centerline, and a third calibration bit that has a
centerline located approximately a third fraction of a track width from the track centerline, wherein the third fraction is larger than the second fraction and the second fraction is larger than the first fraction.

6. A hard disk drive, comprising:
   a housing;
   an actuator arm mounted to said housing;
   a head mounted to said actuator arm;
   a spin motor mounted to said housing; and,
   a disk attached to said spin motor, said disk having a plurality of tracks that each have a centerline, said tracks including a calibration track that has a first set of calibration bits that each have a bit centerline that is offset from the track centerline an amount that is different than the bit centerlines of the other calibration bits within the first set.

7. The disk as recited in claim 1, wherein said calibration bits are used to generate a plurality of position error signals.

8. The hard disk drive as recited in claim 6, wherein said track has a set of servo bits.

9. The hard disk drive as recited in claim 8, wherein said set of servo bits includes an A bit and a B
bit that have a common boundary located at the track centerline.

10. The hard disk drive as recited in claim 6, wherein said first set of calibration bits includes a first calibration bit that has a centerline located approximately a first fraction of a track width from the track centerline, a second calibration bit that has a centerline located approximately a second fraction of a track width from the track centerline, and a third calibration bit that has a centerline located approximately a third fraction of a track width from the track centerline, wherein the third fraction is larger than the second fraction and the second fraction is larger than the first fraction.

11. The hard disk drive as recited in claim 6, wherein said head includes a write element and a separate magneto-resistive read element.

12. A method for obtaining a position error signal calibration curve for a hard disk drive, comprising the steps of:

a) providing a disk that has a plurality of tracks which each have a centerline, said tracks including a calibration track that has a first set of calibration bits that each have a bit centerline that is offset from the track centerline an amount that is different than the bit
centerlines of the other calibration bits within the first set;
   b) aligning a read element over the track centerline;
   c) sensing each calibration bit;
   d) generating a position error signal for each sensed calibration bit, each position error signal having a different amplitude; and,
   e) storing said position error signal amplitudes in a memory device.

13. The method as recited in claim 12, wherein said position error signal amplitudes are stored on said disk.
**INTERNATIONAL SEARCH REPORT**

### A. CLASSIFICATION OF SUBJECT MATTER

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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)

U.S. : 360/131, 135, 77.01-02, 77.04-05, 77.07-08, 77.11, 77.14

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

Electronic database consulted during the international search (name of database and, where practicable, search terms used)

APS (disc or disk drive#, position error#, calibration## track#, bit# centerline#, track centerline#, calibration bit#, offset#)

### C. DOCUMENTS CONSIDERED TO BE RELEVANT

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<td>US, A, 5,400,201 (PEDERSON) 21 March 1995, col. 4, lines 4-57.</td>
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☐ Further documents are listed in the continuation of Box C.  ☐ See patent family annex.

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Date of the actual completion of the international search:

16 JANUARY 1996

Date of mailing of the international search report:

30 JAN 1996

Name and mailing address of the ISA/US Commissioner of Patents and Trademarks

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