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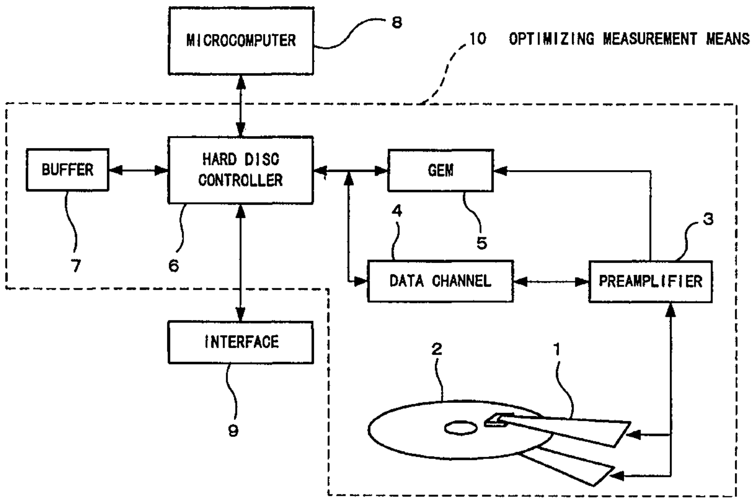

(57) Abstract

It is an object of the present invention to enable a bias current for an MR head to be optimized as appropriate during an operation of a fixed magnetic recording device in order to restrain a possible asymmetrical distortion originating in a saturation in the reproduced signal from the MR head, thereby reducing the error rate during data read-outs. A fixed magnetic recording device acco rding to the present invention comprises optimizing measurement means (10) for conducting measurements for optimizing a bias current value for the MR head in a head structure section (1) each time the MR head accesses a magnetic disc (2), and a microcomputer (8) for controlling optimizing measurement means (10) and outputting an instruction for updating of a bias current value for the MR head to the measured optimum bias current value for storage and an instruction for the supply of the updated and stored optimum bias current to the MR head.

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description

METHOD FOR CONTROLLING BIAS CURRENT FOR MAGNETORESISTIVE HEAD, FIXED MAGNETIC RECORDING DEVICE, AND MAGNETIC DISC THEREFOR

Field of the Invention

The present invention relates to a method for controlling a bias current for a magnetoresistive head by using a magnetoresistive effect, a fixed magnetic recording device and a magnetic disc therefor.

Background of the Invention

Most recent fixed magnetic recording devices (HDDs: Hard Disc Drives) use an MR (MagnetoResistive) head in response to an ever increasing demand for recording density. The MR head is based on a reproduction method using a so-called magnetoresistive effect in which the electric resistance of the MR head is varied by external magnetic fields. Some HDDs use an MR/inductive combined head comprising an MR head and a thin-film head integrally combined together. The MR/inductive combined head writes data by using the thin-film head, while reading out data by using the MR head located adjacent to the thin-film head. Thus, the MR head is characterized, for example, in that it provides a higher reproduction output than the thin-film head despite its exclusive use for read-outs and in that its reproduction output is independent of the peripheral speed of a magnetic disc, so that by setting a read-out track width smaller than a track width for the thin-film head for writes, the effects of adjacent tracks can be minimized during read-outs. Consequently, the MR head is commonly used as a HDD head. Furthermore, GMRs (Giant MagnetoResistive) heads including MR elements with improved sensitivity are being put to practical use.

Disadvantageously, however, the MR head requires bias current due to its operational principle, and the waveform of a signal reproduced by the MR head may be distorted without optimum control of the bias current. This distortion is caused by the offset of a bias point for the bias current, which in turn causes either a positive or negative side of the waveform of the reproduced signal to be saturated. In this case, the positive and negative sides of the reproduced signal waveform are asymmetrical.

Thus, to optimally control the bias current for the MR head, the following three problems must be solved.

A first problem is that the variation of a head resistance value resulting from the dimensional variability of the MR head. The dimensions of the MR head are continuously decreasing, but the tolerances of the dimensional variability are not being improved as fast as the dimensions. In the design of a typical recent device, the tolerances on the MR stripe height represent a ±33% change, or with respect to the ratio of the highest to the lowest, represent a 2:1 ratio. Further, the tolerance of the width of the MR stripe (length in the direction of current flow) is ±20%. The tolerance of the thickness of the MR stripe is ±10%. If these are considered independent variations, the total variation in the resistance of the element is about ±40%, or a high to low ratio of 2.33:1.

Measurements of head resistance values for a plurality of (for example, 80) MR heads showed that the value varied among the MR heads, as shown in FIG. 17. In this figure, the horizontal axis indicates the head resistance value, while the vertical value indicates the number of MR heads. Although the variation distribution of the head resistance value corresponds to a normal distribution around a designed value, the individual MR heads showed different resistance values in their sensor section.

A problem resulting from the large dimensional variability is that a large difference in power dissipation occurs with different heads in a single device.

Further, current density varies significantly as the cross section for the current (MR stripe height by thickness) also varies by a large amount. Product life is inversely related to the cube of the current density. Since the normal biasing method uses a DC current that is fixed for all heads, low stripe heights and thin layer thicknesses result in higher resistance and higher current density. The resulting power dissipation causes significantly more temperature rise, that is, a higher heat, than associated with a high and thick stripe. Thus, temperature and current density compound and cause a much shorter life expectancy for low-stripe-height and thin MR elements, compared to higher and thicker elements.

Another consideration is that all the factors that make the resistance higher also make the signal level higher. Thus, the best signal to noise ratio occurs with the highest-resistance heads. Thus, low stripe heights, thin layers, and wider stripes cause good signal to noise ratios, while high, thick, and narrow stripes produce poorer signal to noise ratios. A fixed bias current must then be a compromise between good signal and short life.

When the bias current values for a plurality of (for example, four) MR heads were varied, the variation of outputs showed a waveform such as one shown in FIG. 18. Sine the bias current yielding the largest output value is optimum for reads, this figure indicates that the optimum read bias current characteristic varied with the individual heads.

A second problem is that a good electronic signal to noise ratio depends on preamplifier design. Preamplifier design has significant limits due to the reduction of voltage available to the preamplifier circuit and reduced power dissipation goals. Present designs typically have a single +5 volt supply (±5%). The variation in the resistance of the head also provides limits on the amount of bias current that can be used for operation due to the voltage drop across the head and leads. If too much current is run through a head of high resistance, the preamplifier stage will saturate and distort the signal, causing a degradation in performance.

A third problem is the gradual resistance increase phenomenon (GRIP) which is related to the leads within the MR head. The effect of this phenomenon on performance becomes greater than expected in the case where there is an addition of several ohms to the resistance of the MR head over the life of the fixed magnetic recording device. Thus, excessively small design margins provided during manufacture may induce a saturation in the amplifier as the resistance increases late in product life, causing significant performance loss.

As a solution for the above three problems, a well-known conventional HDD is described in JPA7-201005.

This HDD is comprised of a plurality of (for example, four) MR heads 31a to 31d, a preamplifier 32, a GEM (Generalized Error Measurement) 33, a head/disc assembly controller 34, and a microprocessor 35, as shown in FIG. 19. An optimum current value for each head is stored on a disc surface of the HDD during manufacture. When the HDD is powered on, these values are transferred to a random access memory. Upon execution of each head switching command, the random access memory is used to apply a corresponding bias current to a corresponding active MR head, which is then subjected to measurements. Then, the GEM 33 reoptimizes and updates the bias current, whereby the updated bias current is applied to the MR head.

Measurements of the MR head are implemented by the circuit shown in FIG. 20. To measure, for example, the MR head 31a, only switches 36a, 37a are conductively connected to this MR head so that a feedback control circuit 40 can supply bias current thereto. Then, a measured value Vcap is obtained by measuring the voltage of a capacitor 39 and this value Vcap and a known bias current value Ib are used to calculate a head resistance value Rmr of the MR head. The MR head resistance value Rmr is calculated based on Equation 1, which is shown below.

$$Rmr = (Vcap - Vbe)/Ib \quad \text{... (Equation 1)}$$

An optimum current is determined based on the calculated head resistance value Rmr of the MR head. In this manner, for the conventional HDD, the bias current value is optimized on each power-on based on the head resistance values for the MR heads recorded on the disc surface before delivery from the factory = f.

Since, however, the bias current value is optimized on each power-on based on the head resistance values for the MR heads recorded on the disc surface before delivery f, the conventional fixed magnetic recording device cannot deal with temporal changes in MR head characteristics. Accordingly, if the MR head resistance value changes, a bias current value determined to be optimum before delivery f may be used over a product life or a bias current value determined to be optimum during the preceding measurements may be used until the following periodical reoptimization for updating. This bias current value is not always optimum for the current heads, whereby the head output characteristics may be degraded to increase the error rate. Since the life expectancy of heads is inversely related to the cube of the current density, the flow of an unnecessarily high bias current may reduce the average life expectancy.

In addition, determination of the effect of changes in resistance on the life expectancy is based only on comparison with the guaranteed number of invocations. As a result, an actual change in resistance cannot be detected, thereby preventing the life expectancy from being determined accurately.

On the other hand, fixed magnetic recording discs are becoming popular which use an amplitude-detecting reproduction method such as a partial response which processes a signal read out from a magnetic disc, directly using the amplitude value for the read-out signal. If such a fixed magnetic recording device includes an MR head, and if a signal reproduced by the MR head is distorted to have a waveform with different absolute values on its positive and negative sides relative to a baseline, which values must be inherently the same, then the amplitude of a detected reproduced signal may be significantly asymmetrical. Disadvantageously, this error in amplitude may increase the error rate of the signal reproduced by the MR head to degrade the reliability of the entire system. In addition, if the above described MR head is used in a fixed magnetic recording device using a conventional peak-detecting reproduction method and a similar distortion occurs, then the differential value at a peak of the waveform of a reproduced signal is smaller on a saturated side of the waveform. As a result, the device is substantially affected by noise, thereby similarly increasing the error rate of the reproduced signal.

As described above, a disadvantage of the fixed magnetic recording device using the MR head for data read-outs and using the amplitude-detecting reproduction method such as a partial response is that no method has been established for optimally regulating the bias current for the MR head though the error rate of the reproduced signal may be degraded without optimization of the bias current for the MR head. The fixed magnetic recording device using the MR head and peak-detecting reproduction method is similarly disadvantageous in that without optimizing the bias current for the MR head, the device is substantially affected by noise to increase the error rate.

It is an object of the present invention to provide a method for controlling a bias current for a magnetoresistive head as well as a fixed magnetic recording device and a magnetic disc therefor which enable a bias current for an MR head to be optimized as appropriate during an operation of a fixed magnetic recording device in order to restrain a possible asymmetrical distortion originating in a saturation in the reproduced signal from the MR head, thereby reducing the error rate during data read-outs.

Disclosure of the Invention

1. A method for controlling a bias current for a magnetoresistive head according to the present invention is operative in controlling a bias current supplied to a magnetoresistive head for reading out data recorded on a magnetic disc, and comprises the steps of: conducting measurements for optimizing a bias current value for the above described magnetoresistive head each time the above described magnetoresistive head accesses the magnetic disc; updating the bias current value for the above described magnetoresistive head to the above described measured optimum bias current value for storage; and supplying the above described stored optimum bias current to the above described magnetoresistive head to read out the above described data.

According to this aspect of the present invention, the bias current for the magnetoresistive head can be optimized as appropriate depending on an operation of the magnetoresistive head during an operation of a fixed magnetic recording device to maintain an optimum bias current despite temporal changes in characteristics of the magnetoresistive head in operation. In addition, a possible asymmetrical distortion induced by a saturation in the waveform of a reproduced signal from the magnetoresistive head can be restrained to reduce the error rate during data read-outs. In addition, the supply of the optimum bias current to the magnetoresistive head can prevent the flow of an unnecessarily high bias current and also prevent the average life expectancy of the magnetoresistive head from being reduced by an excess current.

Specifically, the bias current for the magnetoresistive head can be optimized as appropriate depending on an operation of the magnetoresistive head during an operation of a fixed magnetic recording device, thereby preventing the variability of the components of the magnetoresistive head, the variability of a preamplifier circuit, and a degradation in performance arising from the gradual resistance increase phenomenon. In practical use, the optimum value of the bias current can be updated each time the environment varies, thereby preventing the characteristics of the present device from being degraded over time. In addition, a design with reduced margins at normal temperature can be provided to improve the yield of products.

2. A method for controlling a bias current for a magnetoresistive head according to the present invention is operative in controlling a bias current supplied to a magnetoresistive head for reading out data recorded on a magnetic disc, and comprises the steps of: conducting measurements for optimizing a bias current value for the above described magnetoresistive head when the above described magnetoresistive head enters a standby state; updating the above described bias current value for the above described magnetoresistive head to the above described measured optimum bias current value for storage; and supplying the stored optimum bias current to the above described magnetoresistive head to read out the above described data.

This aspect of the present invention has effects similar to those of the method for controlling a bias current for a magnetoresistive head which is set forth in above described Claim 1.

3. The present invention provides a fixed magnetic recording device for recording data on a magnetic disc and

reading the data using a magnetoresistive head, comprising optimizing measurement means for conducting measurements for optimizing a bias current value for the above described magnetoresistive head each time it accesses the magnetic disc, and processing means for controlling the optimizing measurement means and outputting an instruction for updating of the bias current value for the above described magnetoresistive head to above described the measured optimum bias current value for storage and an instruction for the supply of the above described updated and stored optimum bias current to the above described magnetoresistive head.

This aspect of the present invention can implement the method for controlling a bias current for a magnetoresistive head which is set forth in above described Claim 1.

4. The present invention provides a fixed magnetic recording device for recording data on a magnetic disc and reading the data using a magnetoresistive head, comprising optimizing measurement means for conducting measurements for optimizing a bias current value for the above described magnetoresistive head when it enters a standby state, and processing means for controlling the optimizing measurement means and outputting an instruction for updating of the bias current value for the above described magnetoresistive head to the above described measured optimum bias current value for storage and an instruction for the supply of the above described updated and stored optimum bias current to the above described magnetoresistive head.

This aspect of the present invention can implement the method for controlling a bias current for a magnetoresistive head which is set forth in above described Claim 2.

5. The present invention provides a magnetic disc having a control routine recorded thereon for operating a central processing section for controlling a fixed magnetic recording device, the above described control routine comprising a

first step of optimizing a bias current value for the magnetoresistive head each time it accesses the magnetic disc, a second step of updating the bias current value for the above described magnetoresistive head to the above described measured optimum bias current value for storage, and a third step of supplying the above described updated and stored optimum bias current to the above described magnetoresistive head.

According to this aspect of the present invention, the bias current value for the magnetoresistive head can be optimized by executing the control routine recorded on the magnetic disc.

6. According to the magnetic disc according to the present invention, the first step comprises optimizing a bias current value for the magnetoresistive head when it enters a standby state.

This aspect of the present invention has effects similar to those of the magnetic disc set forth in above described Claim 5.

7. The present invention provides a fixed magnetic recording device for recording data on a magnetic disc and reading the data using a magnetoresistive head, comprising storage means storing a temperature characteristic of a head resistance value for the above described magnetoresistive head, measurement means for measuring the head resistance value for the magnetoresistive head when it enters a standby state, and arithmetic means for calculating the temperature based on the above described measured head resistance value.

According to this aspect of the present invention, the magnetoresistive head can be used as a temperature sensor to monitor the temperature without providing a separate temperature sensor.

8. The present invention provides a magnetic disc having a control routine recorded thereon for operating a central

processing section for controlling a fixed magnetic recording device, the control routine comprising a first step of storing a temperature characteristic of a head resistance value for the magnetoresistive head, a second step of measuring the head resistance value for the magnetoresistive head when it enters a standby state, and a third step of calculating the temperature based on the measured head resistance value.

According to this aspect of the present invention, the magnetoresistive head can be used as a temperature sensor by executing the control routine recorded on the magnetic disc.

9. The present invention provides a fixed magnetic recording device having a plurality of magnetoresistive heads for reading data recorded on a magnetic disc, comprising storage means storing temperature characteristics of head resistance values for the above described plurality of magnetoresistive heads, measurement means for measuring the head resistance value for each of the above described magnetoresistive heads when it enters a standby state, and prediction means for calculating the temperatures of the plurality of magnetoresistive heads based on the above described measured head resistance values and temperature characteristics and predicting the degradation level of the characteristics of each magnetoresistive head based on the above described calculated temperature.

According to this aspect of the present invention, temporal changes in magnetoresistive heads can be monitored to predict the life expectancy of the present fixed magnetic recording device.

10. According to the fixed magnetic recording device of the present invention, the fixed magnetic recording device in 9 further comprises alarm means for alarming a user for the degradation level of the characteristics of each magnetoresistive head predicted by the prediction means, thereby enabling the user to be alarmed.

11. The present invention provides a fixed magnetic recording device for recording data on a magnetic disc and reading the data using a magnetoresistive head, comprising a projection provided on the magnetic disc at a particular position thereof and monitor means for monitoring the above described magnetoresistive head for a variation in floatation based on a variation in output from the above described magnetoresistive head observed when it passes over the above described projection.

According to this aspect of the present invention, the magnetoresistive head can be monitored for a variation in floatation to prevent a possible crash.

12. According to the fixed magnetic recording device of the present invention, the fixed magnetic recording device in 11 further comprises alarm means for alarming a user when the output variation exceeds a threshold.

This aspect of the present invention can alarm the user for a possible crash.

13. The present invention provides a magnetic disc having a control routine recorded thereon for operating a central processing section for controlling a fixed magnetic recording device, the control routine comprising a first step of measuring and storing a variation in output from the above described magnetoresistive head observed when it passes over the projection, a second step of determining whether the above described stored output variation exceeds a threshold, and a third step of alarming a user if the above described threshold is exceeded.

According to the present invention, the magnetoresistive head can be monitored for a variation in floatation by executing the control routine recorded on the magnetic disc.

14. According to the present invention, the first step in the magnetic disc set forth in 13 comprises measuring and storing a possible variation in output from the

magnetoresistive head observed when the control routine passes over the projection, after the magnetoresistive head enters a standby state.

The present invention has effects similar to those of the magnetic disc set forth in 13.

Brief Description of the Drawings

FIG. 1 is a block diagram showing a configuration of a fixed magnetic recording device according to First embodiment of the present invention;

FIG. 2 is an explanatory drawing showing a format of a recording surface of a magnetic disc according to First embodiment;

FIG. 3 is an explanatory drawing showing measurement pattern areas of the magnetic disc according to First embodiment;

FIG. 4 is an explanatory drawing showing a measurement pattern of the measurement pattern areas according to First embodiment;

FIG. 5 is a waveform diagram showing a reproduced waveform obtained when the measurement pattern areas according to First embodiment are reproduced;

FIG. 6 is an explanatory drawing showing changes in signal to noise ratio vs. changes in bias current according to First embodiment;

FIG. 7 is a block diagram showing a configuration of a fixed magnetic recording device according to Second embodiment of the present invention;

FIG. 8 is a table showing correspondence between head resistance values and optimum bias current values according to Second embodiment;

FIG. 9 is a block diagram showing a configuration of a fixed magnetic recording device according to Third embodiment of the present invention;

FIG. 10 is a characteristic diagram showing the dependence of the head resistance value on temperature according to Third embodiment;

FIG. 11 is a table showing correspondence between the head resistance value and temperature;

FIG. 12 is a block diagram showing a configuration of a fixed magnetic recording device according to Fourth embodiment of the present invention;

FIG. 13 is a block diagram showing a configuration of a fixed magnetic recording device according to Fifth embodiment of the present invention;

FIG. 14 is a sketch drawing showing a shape of a bump according to Fifth embodiment;

FIG. 15 is a waveform diagram showing variations in output caused by the TA phenomenon in a normal case according to Fifth embodiment;

FIG. 16 is a waveform diagram showing variations in output caused by the TA phenomenon in an abnormal case according to Fifth embodiment;

FIG. 17 is a distribution graph showing variations in head resistance value for a conventional MR head;

FIG. 18 is a waveform diagram showing the dependence of a conventional head on bias current;

FIG. 19 is a block diagram showing a configuration of a conventional fixed magnetic recording device; and

FIG. 20 is a block diagram showing a configuration of an essential part for measuring a head resistance value for a conventional MR head.

Best Mode for Carrying Out the Invention

A method for controlling a bias current for a magnetoresistive head as well as a fixed magnetic recording device and a magnetic disc therefor will be described based on specific embodiments.

(First Embodiment)

As shown in FIG. 1, a fixed magnetic recording device according to a first embodiment of the present invention has optimizing measurement means 10 for conducting measurements for optimizing a bias current value for an MR (MagnetoResistive) head in a head structure section 1 each time the MR head accesses a magnetic disc 2, and a microcomputer 8 operating as processing means for controlling the optimizing measurement means 10 and outputting an instruction for updating of the bias current value for the MR head to the above described measured optimum bias current value for storage and an instruction for the supply of the above described updated and stored optimum bias current to the MR head.

The optimizing measurement means 10 is comprised of a magnetic disc 2, a preamplifier 3, a data channel 4, a hard disc controller 6, and a buffer 7.

The magnetic disc 2 typically has a plurality of circumferential tracks extending from inner circumference to outer circumference, as shown in FIG. 2. Each track has a plurality of servo areas A and data areas B, and if the MR head accesses one of the data areas B to read or write data from or to the magnetic disc, it always reads out positional information written to the servo area A, before accessing a desired place. Thus, the magnetic disc 2 of First embodiment has a measurement pattern area C (the area between the servo area A and first data of the data area B) provided immediately after each of the servo areas A, and the measurement pattern area C has a measurement pattern formed therein for measuring the signal to noise ratio in order to optimize the bias current value. Whichever data area B is accessed, the MR head accesses the measurement pattern C to pass through the measurement pattern before a read-out or write of data from or to the data area B. As shown in FIG. 3, each track has a plurality of identical measurement patterns. The measurement pattern area C has a signal with a fixed periodicity which was written thereto before delivery from the factory. This signal with a fixed periodicity indicates data precoded in a pattern that uses 1 to 12 Ts (T is an amount of time determined by the performance of the MR head, for example, 5 ns) as one period.

The head structure section 1 has an MR head and is connected to a wire leading to the preamplifier 3. An output from the preamplifier 3 is supplied to the data channel 4. Once accessed, the MR head is connected to a bias current source (not shown) when the corresponding switches shown in FIG. 20 are set.

The GEM 5 has a general-purpose error measurement function to measure the signal to noise ratio, and is designed to allow the fixed magnetic recording device to implement a test system onboard which is conventionally realized by connecting the device with a measurement test system data storage device and recovery system such as a conventional digital oscilloscope and logical analyzer.

The buffer 7 stores therein an optimum bias current value for the MR head and an ideal signal waveform standardized by sampling the data shown in FIG. 4 and precoded using 1 to 127 Ts as one period, wherein the optimum bias current value and the ideal signal waveform were first stored before delivery from the factory.

Then, an operation of the fixed magnetic recording device will be described which updates the bias current value for the MR head to an optimum one.

On receiving an instruction for an access to the magnetic disc 2 from the micro computer 8, a hard disc controller 6 controls the head structure section 1 with the MR head so as to access a desired position of the magnetic disc 2, which is rotating at a high speed.

When the MR head accesses a desired servo area A of the magnetic disc 2 and then the measurement pattern C, a current source (not shown) for supplying a bias current to the MR head is set, for example, at 7 mA, and this current is supplied to the MR head. The GEM 5 carries out analysis by comparing an actual reproduced waveform such as one shown in FIG. 5 which is obtained by reading out the measurement pattern, with the corresponding ideal standardized waveform stored in the buffer 7, for one period (1 to 127 Ts) in terms of level difference. Next, the current source is set at 8 mA to calculate the signal to noise ratio as described above. In this manner, the signal to noise ratio is continuously calculated until the current source reaches 11 mA. Changes in signal to noise ratio relative to changes in bias current represent peaked waveforms as shown in FIG. 6.

Specifically, if the actually measured signal to noise ratio relative to the bias current value is 25, 26, 26.8, 27, and 26.9 dB when the current source is set for 7, 8, 9, 10, and 11 mA, respectively, and its waveform is shown at a, the microcomputer 8 determines the optimum bias current value to be 10 mA because the optimum bias current value is obtained when the signal to noise ratio has the largest value.

This MR head has been measured with a bias current between 7 and 11 mA; the buffer 7 stores therein an optimum bias current for this MR head which was obtained before delivery from the factory or during the last measurement at least if measurements have previously been conducted, and in this case, stores therein an optimum bias current value of 9 mA, so that the actual reproduced waveform has been obtained with a bias current within a range, in this case, of ±2 mA of this optimum bias current value.

The microcomputer 8 instructs the optimum bias current value (9 mA) stored in the buffer 7 to be updated to a new one (10 mA) for storage.

The microcomputer 8 then instructs the updated and stored new optimum bias current value (10 mA) to be supplied to the MR head.

With this configuration, the bias current for the MR head can be optimized as appropriate depending on an operation of the MR head during an operation of the fixed magnetic recording device. In addition, despite changes in characteristics of the operating MR head, the optimum bias current can be maintained. In addition, a possible asymmetrical distortion induced by a saturation in the waveform of a reproduced signal from the MR head can be restrained to reduce the error rate during data read-outs. In addition, the supply of the optimum bias current to the MR head can prevent the flow of an unnecessarily high bias current and also prevent the average life expectancy of the MR head from being reduced by an excess current.

Although, in the first embodiment, the microcomputer 8 has a control routine provided therein for controllably operating the fixed magnetic recording device, similar effects can be obtained by recording, in a DISCKWARE for storing a program for the magnetic disc 2 or in the buffer 7, a control routine comprised of the first step of optimizing the bias current value for the MR head each time it accesses the magnetic disc 2, the second step of updating the bias current value for the above described MR head to the above described measured optimum bias current value for storage, and the third step of supplying the above described updated and stored optimum bias current to the above described MR head.

(Second embodiment)

As shown in FIG. 7, a fixed magnetic recording device according to a second embodiment of the present invention has, instead of the optimizing measurement means 10 in the above described first embodiment, an optimizing measurement means 11 for conducting measurements for optimizing a bias current value for an MR (MagnetoResistive) head when it enters a standby state. A magnetic disc 12 is free from the measurement pattern area C in the above described first embodiment and from the measurement pattern.

The optimizing measurement means 11 is comprised of a plurality of (for example, two) preamplifiers 3a, 3b, a data channel 4, a GEM 13, a hard disc controller 14, and a buffer 15.

Head structure sections 1a, 1b with corresponding MR heads are configured for connection to either preamplifier 3a or 3b. An output from the preamplifier 3a, 3b is supplied to the data channel 4. One of the MR heads which has been accessed is connected to a current source (not shown) for supplying bias current when the corresponding switches shown in FIG. 20 are set.

The GEM 13 has a general-purpose error measurement function to measure an MR head resistance value Rmr, and is designed to allow this fixed magnetic recording device to implement a test system onboard which is conventionally realized by connecting the device with a measurement test system data storage device and recovery system such as a conventional digital oscilloscope and logical analyzer.

The buffer 15 has beforehand therein optimum bias current values for the MR heads stored therein before delivery from the factory. The optimum bias current for each MR head is set, for example, as a function of the resistance of the MR head.

Then, an operation of the fixed magnetic recording device will be described which updates the bias current value for each MR head to an optimum one.

When data from the head structure section 1a is transferred through the preamplifier 3a and when the head structure section 1a enters a standby state, the hard disc controller 14 receives an instruction from the microcomputer

8 to control the preamplifier 3b so as to connect to the head structure section 1b.

To measure the corresponding MR head, an interhead voltage value Vmr is detected using BHV (Buffered head Voltage Monitor) terminals of the preamplifiers 3a, 3b arranged near the head structure sections 1a, 1b, respectively.

The hard disc controller 14 calculates the MR head resistance value Rmr based on Equation 2, which is shown below. However, a value Ib of a current supplied by the current source to the MR head is fixed and known.

Rmr = Vmr/Ib ... (Equation 2)

The hard disc controller 14 determines an optimum bias current value Ib in accordance with the correspondence characteristic shown in FIG. 8 and indicating the optimum bias current value Ib determined statistically depending on the head resistance value Rmr of the MR head. Signals from the BHV terminals are analog outputs, and the hard disc controllers 14 converts analog signals into digital ones.

Specifically, if the value I of a current from the current source is set at 9 mA and a voltage value Vmr detected at the BHV terminals is 0.3 V, then the hard disc controller calculates the head resistance value Rmr of the MR head at about 33.3Ω based on the above Equation 2, and determines the optimum bias current value Ib to be 9.5 mA in accordance with the correspondence characteristic shown in FIG. 8 because the head resistance value Rmr of the MR head (about 33.3Ω) is between 30 and 35Ω. This optimum bias current value (9.5 mA) is stored in the buffer 15, for example, as a 4-bit serial data (0010).

The 4-bit serial data is transmitted to the head structure section 1b to set it so that the optimum bias current value (9.5 mA) can be supplied to the MR head during a normal operational state.

When the head structure section 1b enters the normal operational state, while the head structure section 1a enters a standby state, the hard disc controller 14 receives an instruction from the microcomputer 8 to control the preamplifier 3b so as to connect to the head structure section 1a, thereby optimizing the bias current for the MR head of the head structure section 1a as described above.

In the current fixed magnetic recording device, the system side theoretically controls sectors to carry out reads and writes for each section. Since, however, which sector is to be accessed by a particular MR head depends on settings on the drive side, users do not have to pay special attention to this point. Currently, many fixed magnetic recording devices require a shorter time for head switching than for track seeking, so that head switching is often given top priority if the MR head writes data to one section and then shifts to another. That is, the MR head is frequently switched.

With this configuration, the bias current for each MR head can be optimized while the MR head is in the standby state, thereby enabling the optimum bias current to be maintained despite temporal changes in characteristics of the operating MR head. In addition, a possible asymmetrical distortion induced by a saturation in the waveform of a reproduced signal from the MR head can be restrained to reduce the error rate during data read-outs. In addition, the supply of the optimum bias current to the MR head can prevent the flow of an unnecessarily high bias current and also prevent the average life expectancy of the MR head from being reduced by an excess current.

In addition, the magnetic disc 12 does not require the measurement pattern area C for forming the measurement pattern as in First embodiment.

Although, in the second embodiment, the microcomputer 8 has a control routine provided therein for controllably operating the fixed magnetic recording device, similar effects can be obtained by recording, in a DISCKWARE for storing a program for the magnetic disc 12 or in the buffer 15, a control routine comprised of the first step of optimizing the bias current value for the above described MR head when it enters the standby state, the second step of updating the bias current value for the above described MR head to the above described measured optimum bias current value for storage, and the third step of supplying the updated and stored optimum bias current to the MR head.

In this second embodiment, a plurality of preamplifiers are provided, however, even though a single preamplifier is provided, while all of the MR heads are in the standby state where they do not access the magnetic disk 12, the head resistance values of the MR heads can be measured to set the optimum bias current value.

(Third Embodiment)

As shown in FIG. 9, a fixed magnetic recording device according to a third embodiment of the present invention has a buffer 16 additionally storing a temperature characteristic of a head resistance value for an MR head, instead of the buffer 15 in the above described second embodiment, and also has a microcomputer 17 having an additional arithmetic function for calculating the temperature based on a measured head resistance value, instead of the microcomputer 8 in the second embodiment.

The buffer 16 has the temperature characteristic of the head resistance value for each MR head stored therein.

The head resistance value for the MR head depends on the design of a corresponding MR element. The dependence of the head resistance value on temperature, however, is predictable because it varies almost linearly relative to temperature as seen in changes in head resistance values for a plurality of (for example, six) MR heads associated with changes in their temperatures and as shown in FIG. 10. A temperature gradient of the head resistance value is known before design.

For example, a certain MR head is assumed to have a temperature gradient of 0.15Ω/°C. The head resistance value is assumed to be determined at 25Ω during a delivery inspection process carried out at a constant temperature of 20°C. This head resistance value at the known temperature before delivery is stored in the buffer 16. A relationship between the head resistance value and temperature is shown in FIG. 11.

Then, an operation of the fixed magnetic recording device will be described which measures the head resistance value for the MR head to control temperature.

Similarly to the above described second embodiment, when the MR head of the head structure section 1b enters the standby state, the hard disc controller 14 receives an instruction from the microcomputer 17 to control the preamplifier 3b so as to connect to the head structure section 1b. The interhead voltage value Vmr is measured using the BHV terminal of the preamplifier 3b. The hard disc controller 14 calculates the MR head resistance value Rmr based on the above Equation 2 because the value Ib of a current supplied by the current source (not shown) to the MR head is fixed and known.

The microcomputer 17 calculates the temperature based on the measured head resistance value.

If the measured head resistance value is, for example, 26.5Ω, the microcomputer 17 calculates the temperature at 30°C based on the dependence of the head resistance value on temperature shown in FIG. 11.

In addition, when the head structure section 1a, instead of the head structure section 1b, enters the standby state, the hard disc controller 14 controls the preamplifier 3a so as to connect to the head structure section 1a and measures the head resistance value to calculate the temperature as described above. Due to the frequent switching of the MR head, the head resistance value for the MR head is frequently measured to calculate the temperature.

With this configuration, the temperature can be controlled by monitoring the head resistance value. Although the guaranteed operation temperature of a hard disc depends on its design, if it is between 0 and 50°C, then the guaranteed range is assumed to correspond to a range of the head resistance value between 22 and 29.5Ω based on the dependence of the head resistance value on temperature shown in FIG. 11. If the head resistance value is outside the range between 22 and 29.5Ω, then the peripheral temperature is assumed to be outside the guaranteed range. In addition, if the present device is continuously operated at this environmental temperature that is outside the guaranteed range, the present device or data may be destroyed in the worst case. Thus, alarm means can be connected to the interface 8 for alarming the user so that an alarm signal can be issued to the alarm means through the interface 8 to alarm the user if the measured head resistance value is outside the range between 22 and 29.5Ω.

Although, in the third embodiment, the microcomputer 17 has a control routine provided therein for controllably operating the fixed magnetic recording device, similar effects can be obtained by recording, in a DISCKWARE or the like for storing a program for the magnetic disc 12, a control routine comprised of the first step of storing the temperature characteristic of the head resistance value for each MR head, the second step of measuring the head resistance value for the above described MR head when it enters the standby state, and the third step of calculating the temperature based on the above described measured head resistance value.

(Fourth Embodiment)

As shown in FIG. 12, a fixed magnetic recording device according to a fourth embodiment of the present invention includes, instead of the microcomputer 17 in the above described third embodiment, a microcomputer 18 having an additional function for calculating the temperatures of a plurality of MR heads based on their measured head resistance values and temperature characteristics and predicting the degradation level of each of the MR heads based on the calculated temperature.

Similarly to the above described third embodiment, when one of the MR heads enters the standby state, the head resistance value for this MR head is calculated and stored in the buffer 16, and the measured head resistance values for all the MR heads are also stored therein. Alternatively, the measured head resistance values for a plurality of MR heads to be measured may be stored therein. In general, these plurality of MR heads are constantly alternately operating or standing by.

The microcomputer 18 calculates the temperatures of the plurality of MR heads based on their measured head resistance values stored in the buffer 16. If any of the MR heads indicates an extremely higher temperature than the others, this MR head is predicted to be subjected to a temporal change.

With this configuration, a possible temporal change can be predicted by storing head resistance values or their changes in the buffer 16 and constantly monitoring the latest values for variations relative to the stored values. In general, if the head resistance value varies significantly despite a constant peripheral temperature, the corresponding MR element is assumed to be subjected to a temporal change. It is difficult, however, to determine whether a change in resistance is caused by the peripheral temperature or a temporal change, by monitoring only a single head, except for an instantaneous increase in resistance value caused by the thermal asperity (TA) phenomenon. Accordingly, the plurality of MR heads can be used to assume whether a change in head resistance value is induced by the peripheral temperature or is permanent. If, for example, in a fixed magnetic recording device with four MR heads, all the four MR heads have their head resistance value changed, this is assumed to due to a change in temperature. In addition, if only one of the MR heads has its head resistance value changed, its characteristics are assumed to have changed compared its characteristics before delivery from the factory. During designing, statistical data must be obtained indicating a level of a change in head resistance value at which the performance may significantly affected.

If, for example, the head resistance value has varied by 10% or more for any reason other than the temperature factor, the corresponding MR element is assumed be subjected to certain damage. For a disc device the life of which is expected to be nearly at end, the device is constantly monitored for temporal changes in resistance value to check whether the value has varied by 10% or more compared to the one before delivery from the factory. If so, the user's data recorded on the media may be lost or the device may be destroyed.

Thus, alarm means 19 is connected to the interface 8 for alarming the user for the degradation level of the characteristics so that an alarm signal can be issued to the alarm means 19 through the interface 8 if a change occurs corresponding to 10% or more. By issuing an alarm to the user, the user can be alarmed for the degradation level of the characteristics to prevent the present device or data from being destroyed.

(Fifth Embodiment)

As shown in FIG. 14, a fixed magnetic recording device according to a fifth embodiment of the present invention has a bump 23 provided at a particular position of a magnetic disc 20 as a projection, and a monitor means 21 (see FIG. 13) for monitoring each MR (MagnetoResistive) head for a variation in floatation based on a variation in output from the MR head observed when it passes over the bump 23.

On a surface of the magnetic disc 20, the bump 23 is formed of the same material as the magnetic disc 20, as shown in FIG. 14. The bump 23 has a diameter, for example, between 2.0 and 3.0 μm and a height, for example, between 0.1 and 0.15 μm. A plurality of bumps 23 may be formed on the magnetic disc 20. The laser zone texture technique is used to form a desired bump 23 on the surface of the magnetic disc 20. The MR head essentially detects and outputs changes in resistance value and depends heavily on the thermal stability of its sensor section. During a normal operation, if the MR head section comes in contact with an abnormal projection on the surface of the magnetic disc 20, the head resistance value instantaneously increases to vary the output. This phenomenon is generally called "Thermal Asperity (TA)," and magnetic disc designs have coped with this phenomenon by preventing it using an improved circuit or improving the smoothness of the magnetic disc.

With respect to the thermal asperity phenomenon, with the same bump, the level of the output variation increases with decreasing floatation due to intensified collisions.

Then, an operation of the fixed magnetic recording device will be described which prevents a possible crash by measuring an output value for each MR head.

On receiving an instruction from the microcomputer 22, the preamplifier 3 monitors each MR head in the head structure sections 1 for an increase in its head resistance value, which leads to an increase in its output value, each time the MR head passes over the bump 23 formed on the disc 20 at the predetermined position.

The monitor means 21 stores therein a possible variation in output from the MR head observed when it passes over the bump 23, wherein the variation was first stored during manufacture as an initial value. In response to an instruction from the microcomputer 22, the monitor means 21 periodically measures the output variation to compare the measured value with the initial value in order to estimate a change in floatation, thereby monitoring the MR head a possible crash.

Specifically, if the floatation is appropriate, the output variation observed when the MR head passes over the bump 23 is, for example, about 100 mV as shown in FIG. 15. Accordingly, the monitor means 21 has an output variation of 100 mV stored therein during manufacture as an initial value. The monitor means 21 has a threshold for a possible crash set at 120 mV assuming that a crash may occur when the variation increases by 20% or more. If the periodic measurement of the output variation indicates a decrease in floatation, the output variation observed when the MR head passes over the bump 23 increases up to about 170 mV as shown in FIG. 16. Since this is larger than the threshold of 120 mV, the alarm signal is output to the alarm means through the interface 8 to inform the user of a possible crash.

With this configuration, a possible change in floatation of the MR head can be estimated by monitoring the MR head for a output variation so that the user can be informed of a possible crash if the variation reaches the predetermined value or above, thereby preventing the present device or data from being destroyed.

Although, in the fifth embodiment, the microcomputer 22 has a control routine provided therein for controllably operating the fixed magnetic recording device, similar effects can be obtained by recording, in a DISCKWARE or the like for storing a program for the magnetic disc 20, a control routine comprised of the first step of measuring and storing a variation in output from the MR head when it passes over the bump 23, the second step of determining whether the above described stored output variation exceeds the threshold, and the third step of alarming the user if the above described threshold is exceeded.

Although the fifth embodiment measures and stores the output variation of the MR head during a normal operation, similar effects can be obtained if the output variation of the MR head during the standby state is measured and stored.

In addition, although the above embodiments each use the MR (MagnetoResistive) head as a reproduction-exclusive head, similar effects can be obtained with a GMR (Giant Magnetoresistive) head.

CLAIMS

1. A method for controlling a bias current for a magnetoresistive head, the method being operative in controlling a bias current supplied to a magnetoresistive head for reading out data recorded on a magnetic disc, characterized by comprising the steps of:

conducting measurements for optimizing a bias current value for said magnetoresistive head each time said magnetroresistive head accesses the magnetic disc;

updating the bias current value for said magnetoresistive head to said measured optimum bias current value for storage; and

supplying said stored optimum bias current to said magnetoresistive head to read out said data.

2. A method for controlling a bias current for a magnetoresistive head, the method being operative in controlling a bias current supplied to a magnetoresistive head for reading out data recorded on a magnetic disc, characterized by comprising the steps of:

conducting measurements for optimizing a bias current value for said magnetoresistive head when said magnetoresistive head enters a standby state;

updating the bias current value for said magnetoresistive head to said measured optimum bias current value for storage; and

supplying said stored optimum bias current to said magnetoresistive head to read out said data.

3. A fixed magnetic recording device for recording data on a magnetic disc and reading the data using a magnetoresistive head, characterized by comprising:

optimizing measurement means for conducting measurements for optimizing a bias current value for said magnetoresistive head each time it accesses the magnetic disc; and

processing means for controlling said optimizing measurement means and outputting an instruction for updating of the bias current value for said magnetoresistive head to said measured optimum bias current value for storage and an instruction for the supply of said updated and stored optimum bias current to said magnetoresistive head.

4. A fixed magnetic recording device for recording data on a magnetic disc and reading the data using a magnetoresistive head, characterized by comprising:

optimizing measurement means for conducting measurements for optimizing a bias current value for said magnetoresistive head when it enters a standby state; and

processing means for controlling said optimizing measurement means and outputting an instruction for updating of the bias current value for said magnetoresistive head to said measured optimum bias current value for storage and an instruction for the supply of said updated and stored optimum bias current to said magnetoresistive head.

5. A magnetic disc having a control routine recorded thereon for operating a central processing section for controlling a fixed magnetic recording device,

said control routine characterized by comprising:

a first step of optimizing a bias current value for the magnetoresistive head each time it accesses the magnetic disc;

a second step of updating the bias current value for said magnetoresistive head to said measured optimum bias current value for storage; and a third step of supplying said updated and stored optimum bias current to said magnetoresistive head.

6. The magnetic disc according to Claim 5, characterized in that the first step comprises optimizing a bias current value for the magnetoresistive head when it enters a standby state.

7. A fixed magnetic recording device for recording data on a magnetic disc and reading the data using a magnetoresistive head, characterized by comprising:

storage means storing a temperature characteristic of a head resistance value for said magnetoresistive head;

measurement means for measuring the head resistance value for said magnetoresistive head when it enters a standby state; and

arithmetic means for calculating the temperature based on said measured head resistance value.

8. A magnetic disc having a control routine recorded thereon for operating a central processing section for controlling a fixed magnetic recording device,

said control routine characterized by comprising:

a first step of storing a temperature characteristic of a head resistance value for the magnetoresistive head;

a second step of measuring the head resistance value for said magnetoresistive head when it enters a standby state; and

a third step of calculating the temperature based on said measured head resistance value.

9. A fixed magnetic recording device having a plurality of magnetoresistive heads for reading data recorded on a magnetic disc, characterized by comprising:

storage means storing temperature characteristics of head resistance values for said plurality of magnetoresistive heads;

measurement means for measuring the head resistance value for each of said magnetoresistive heads when it enters a standby state; and

prediction means for calculating the temperatures of the plurality of magnetoresistive heads based on said measured head resistance values and said temperature characteristics and predicting the degradation level of the characteristics of each magnetoresistive head based on said calculated temperature.

10. The fixed magnetic recording device according to Claim 9, characterized by further comprising alarm means for alarming a user for the degradation level of the characteristics of each magnetoresistive head predicted by the prediction means.

11. A fixed magnetic recording device for recording data on a magnetic disc and reading the data using a magnetoresistive head, characterized by comprising:

a projection provided on said magnetic disc at a particular position thereof; and

monitor means for monitoring said magnetoresistive head for a variation in floatation based on a variation in output from said magnetoresistive head observed when it passes over said projection.

12. The fixed magnetic recording device according to Claim 11, characterized by further comprising alarm means for alarming a user when the output variation exceeds a threshold.

13. A magnetic disc having a control routine recorded thereon for operating a central processing section for controlling a fixed magnetic recording device,

said control routine characterized by comprising:

a first step of measuring and storing a variation in output from said magnetoresistive head observed when said control routine passes over the projection;

a second step of determining whether said stored output variation exceeds a threshold; and

a third step of alarming a user if said threshold is exceeded.

14. The magnetic disc according to Claim 13, characterized in that the first step comprises measuring and storing a possible variation in output from the magnetoresistive head observed when said control routine passes over the projection, after the mangnetoresistive head enters a standby state.

FIG. 1

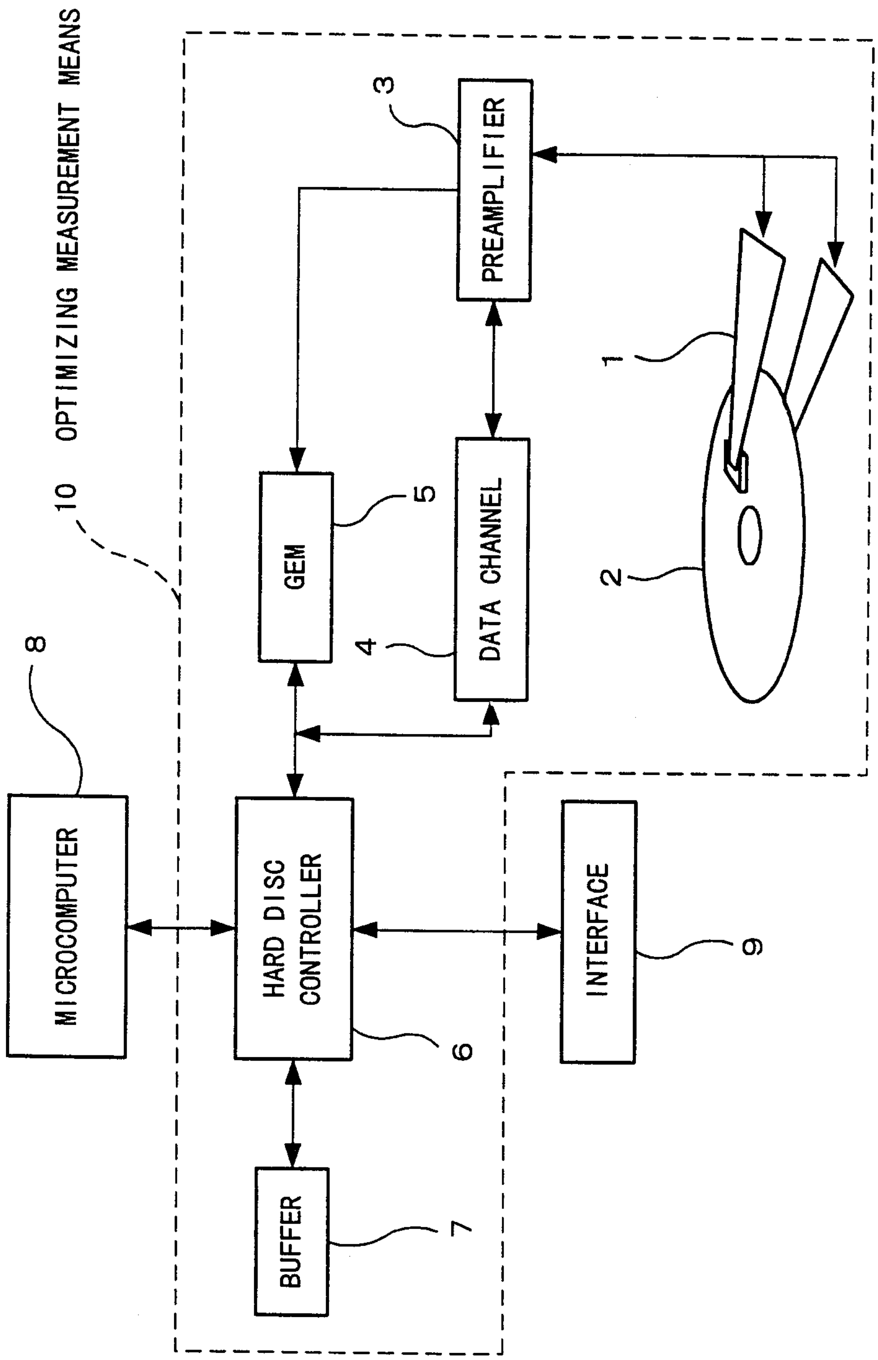

10 OPTIMIZING MEASUREMENT MEANS
PREAMPLIFIER
3
GEM
5
DATA CHANNEL
4
1
2
MICROCOMPUTER
8
HARD DISC CONTROLLER
6
INTERFACE
9
BUFFER
7

FIG. 2

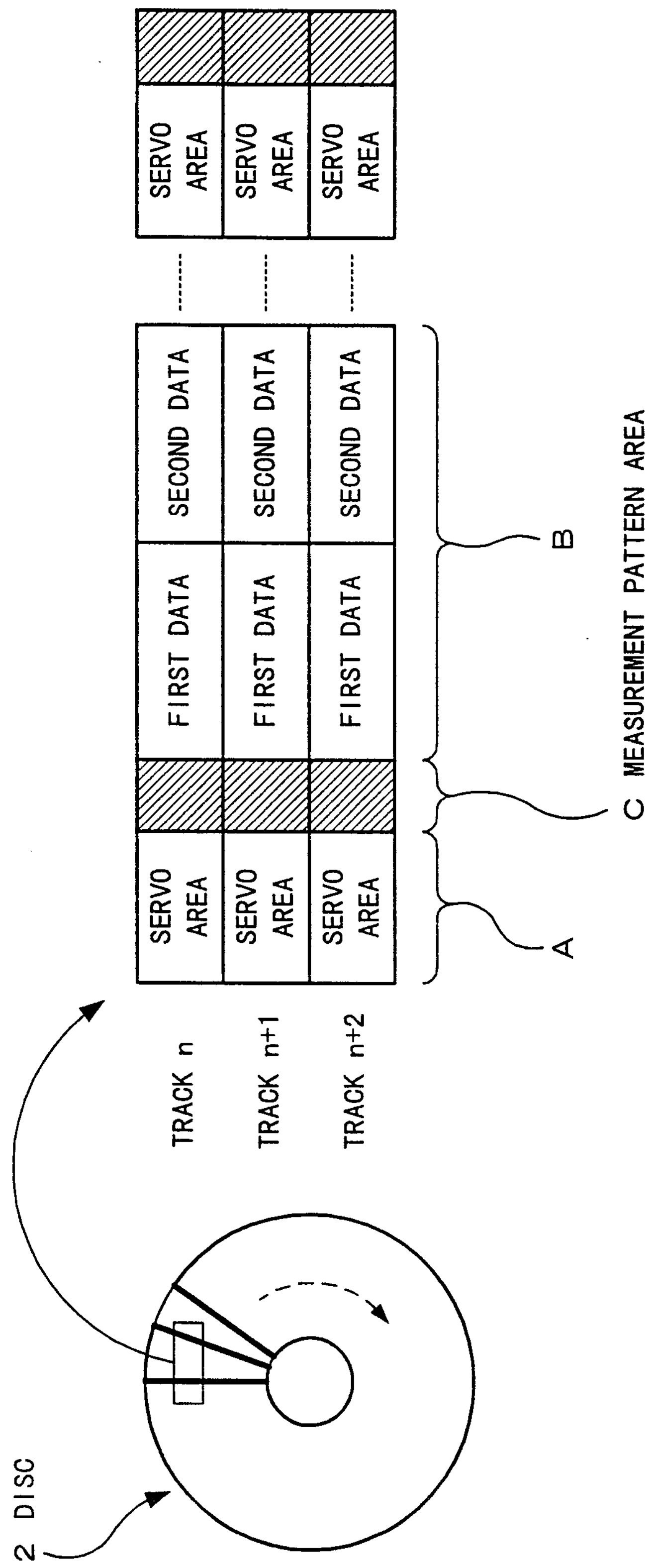
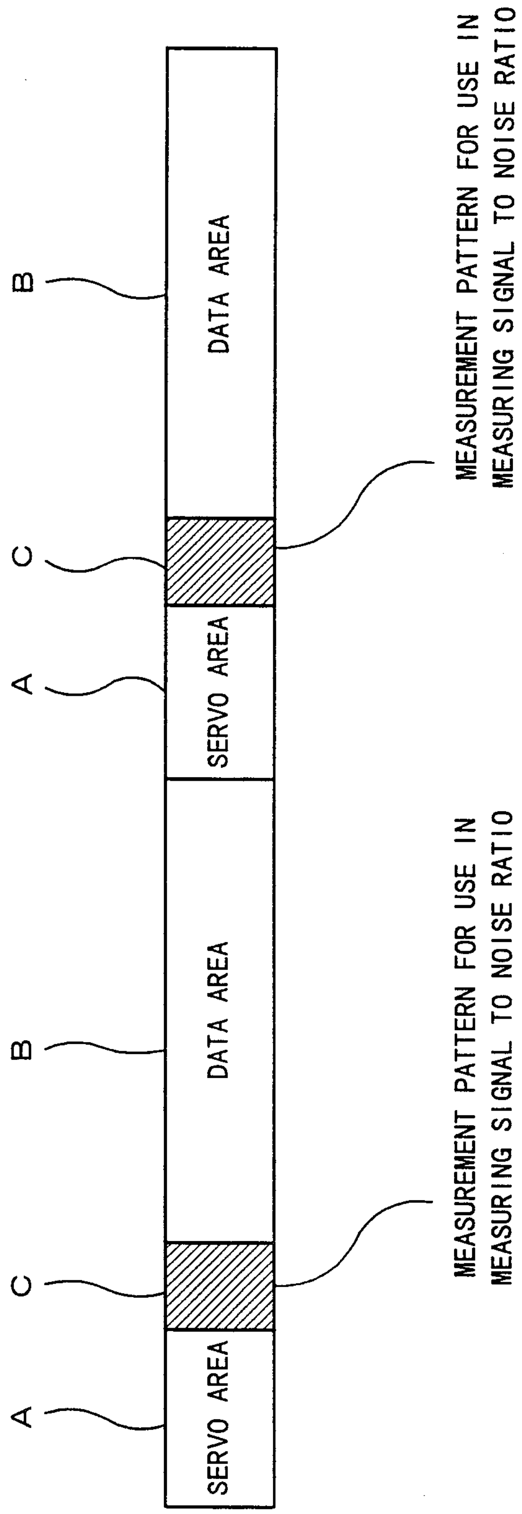

TRACK n
TRACK n+1
TRACK n+2
SERVO AREA
FIRST DATA
SECOND DATA
A
B
C MEASUREMENT PATTERN AREA
2 DISC

FIG. 3


SERVO AREA
DATA AREA
SERVO AREA
DATA AREA
A
C
B
A
C
B
MEASUREMENT PATTERN FOR USE IN MEASURING SIGNAL TO NOISE RATIO
MEASUREMENT PATTERN FOR USE IN MEASURING SIGNAL TO NOISE RATIO

F I G. 4

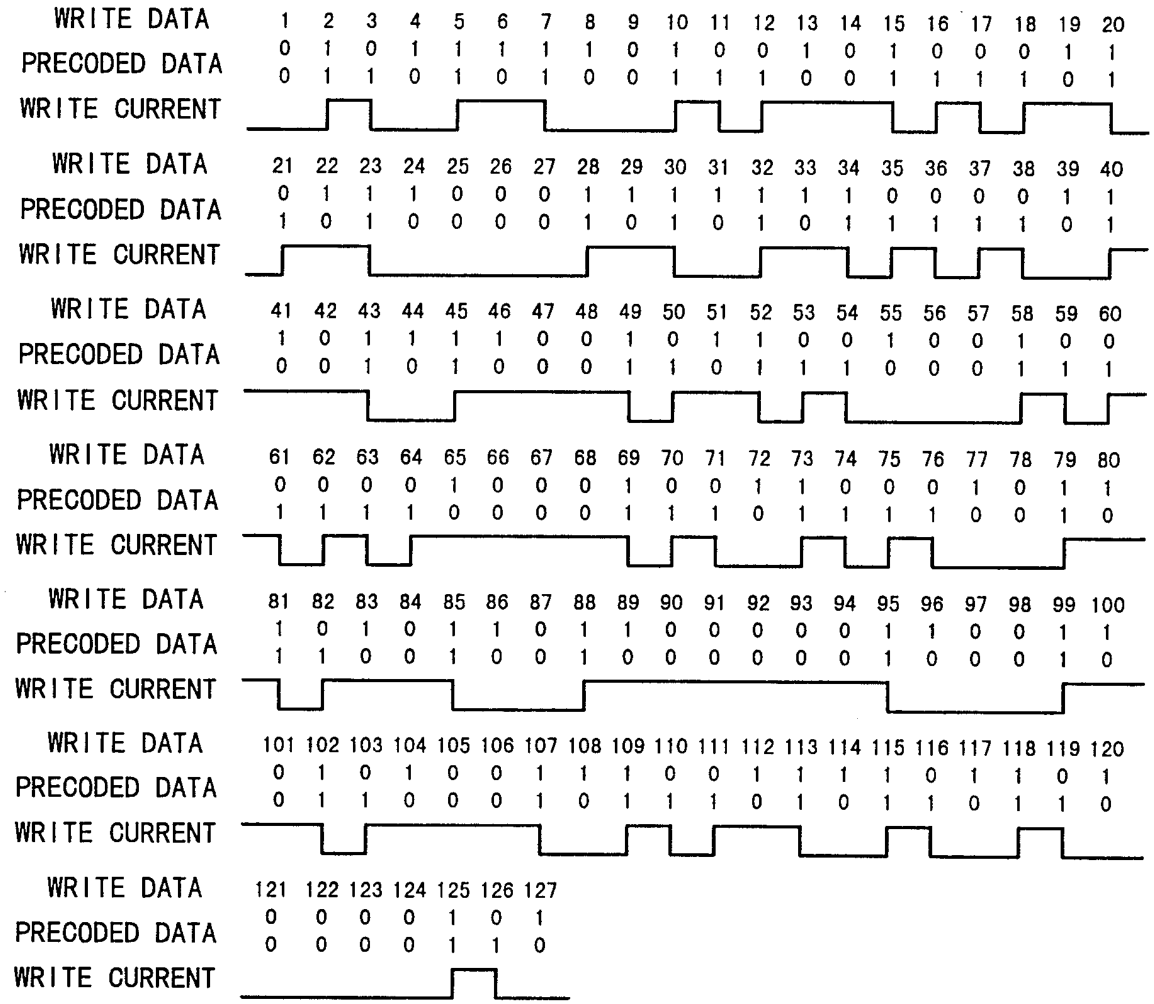
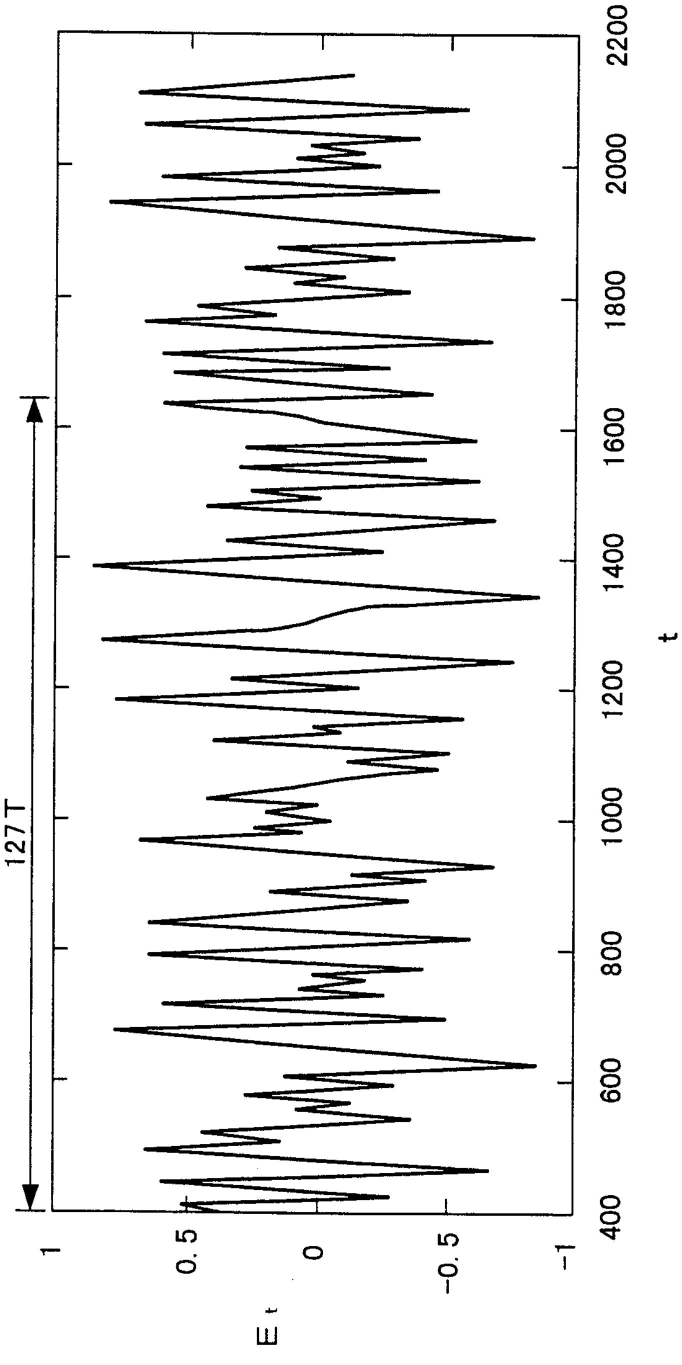

WRITE DATA
PRECODED DATA
WRITE CURRENT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
0 1 0 1 1 1 1 1 0 1 0 0 1 0 1 0 0 0 1 1
0 1 1 0 1 0 1 0 0 1 1 1 0 0 1 1 1 1 0 1
21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40
0 1 1 1 0 0 0 1 1 1 1 1 1 1 0 0 0 0 1 1
1 0 1 0 0 0 0 1 0 1 0 1 0 1 1 1 1 1 0 1
41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60
1 0 1 1 1 1 0 0 1 0 1 1 0 0 1 0 0 1 0 0
0 0 1 0 1 0 0 0 1 1 0 1 1 1 0 0 0 1 1 1
61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80
0 0 0 0 1 0 0 0 1 0 0 1 1 0 0 0 1 0 1 1
1 1 1 1 0 0 0 0 1 1 1 0 1 1 1 1 0 0 1 0
81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100
1 0 1 0 1 1 0 1 1 0 0 0 0 0 1 1 0 0 1 1
1 1 0 0 1 0 0 1 0 0 0 0 0 0 1 0 0 0 1 0
101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120
0 1 0 1 0 0 1 1 1 0 0 1 1 1 1 0 1 1 0 1
0 1 1 0 0 0 1 0 1 1 1 0 1 0 1 1 0 1 1 0
121 122 123 124 125 126 127
0 0 0 0 1 0 1
0 0 0 0 1 1 0

FIG. 5


127T
E t
1
0.5
0
-0.5
-1
400
600
800
1000
1200
1400
1600
1800
2000
2200
t

F I G. 6

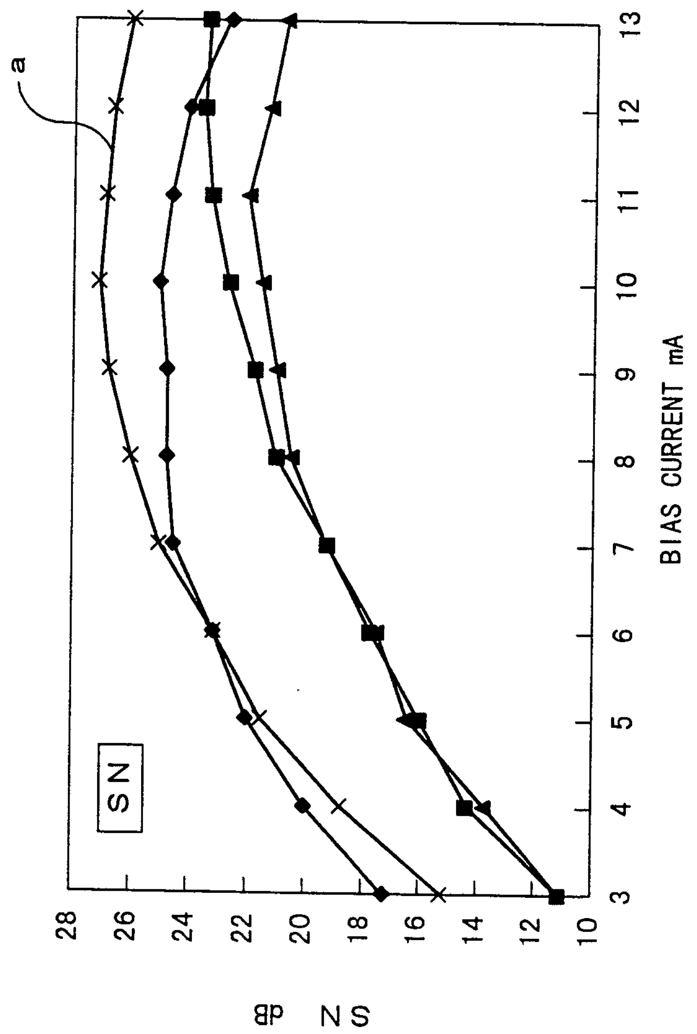
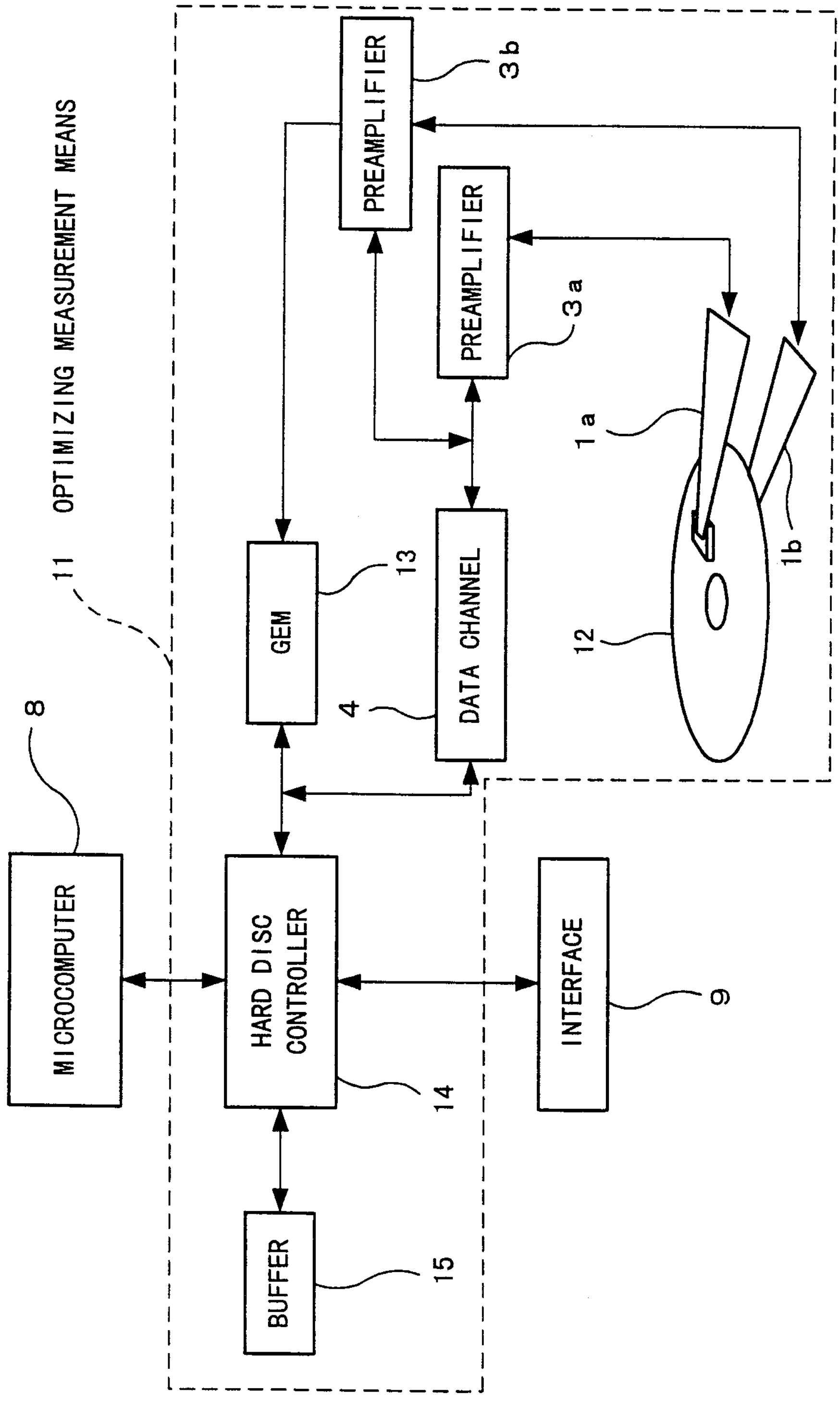

a
SN
SN dB
28
26
24
22
20
18
16
14
12
10
3
4
5
6
7
8
9
10
11
12
13
BIAS CURRENT mA

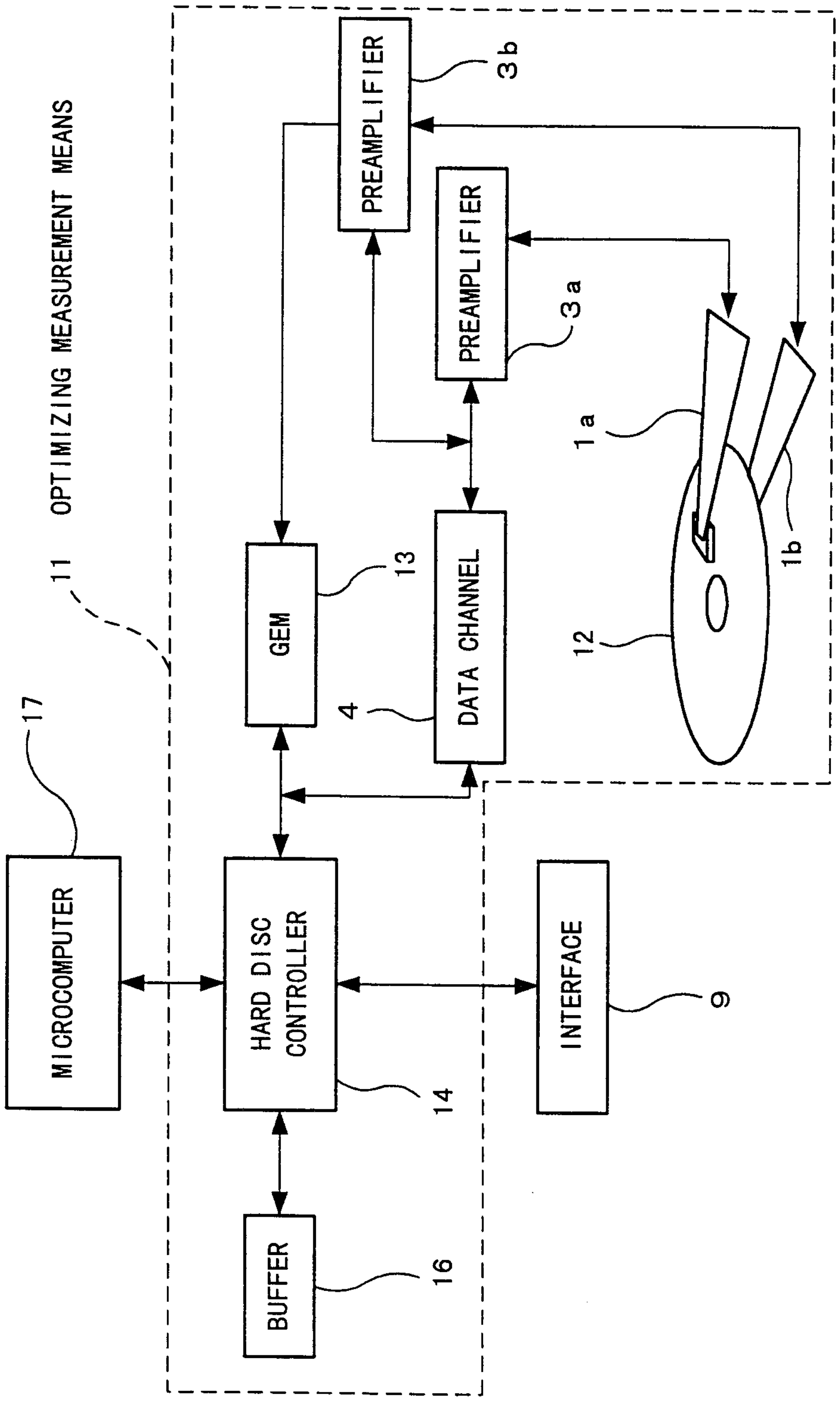
FIG. 7


OPTIMIZING MEASUREMENT MEANS
11
8
MICROCOMPUTER
HARD DISC CONTROLLER
14
BUFFER
15
GEM
13
DATA CHANNEL
4
PREAMPLIFIER
3b
PREAMPLIFIER
3a
1a
1b
12
INTERFACE
9

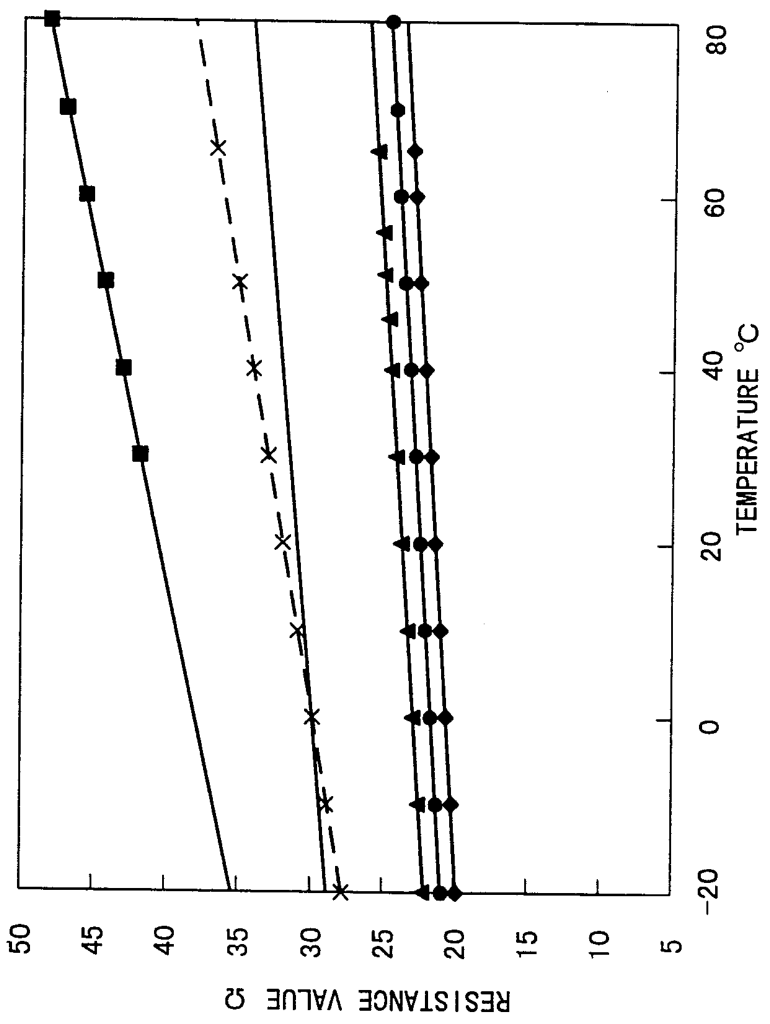
F I G. 8

Rmr (Ω)	I b (mA)	SERIAL DATA FOR DETERMINING BIAS
>40	6. 5	0000
35～40	8. 0	0001
30～35	9. 5	0010
25～30	11. 0	0011
20～25	12. 5	0100
15～20	14. 0	0101

FIG. 9


OPTIMIZING MEASUREMENT MEANS
11
17
MICROCOMPUTER
HARD DISC CONTROLLER
14
BUFFER
16
GEM
13
DATA CHANNEL
4
INTERFACE
9
PREAMPLIFIER
3b
PREAMPLIFIER
3a
1a
1b
12

F I G. 10


RESISTANCE VALUE Ω
50
45
40
35
30
25
20
15
10
5
TEMPERATURE °C
−20
0
20
40
60
80

F I G. 11

TEMPERATURE (℃)	HEAD RESISTANCE VALUE (Ω)
0	22
10	23. 5
20	25
30	26. 5
40	28
50	29. 5
60	31
70	32. 5
80	34

FIG. 12

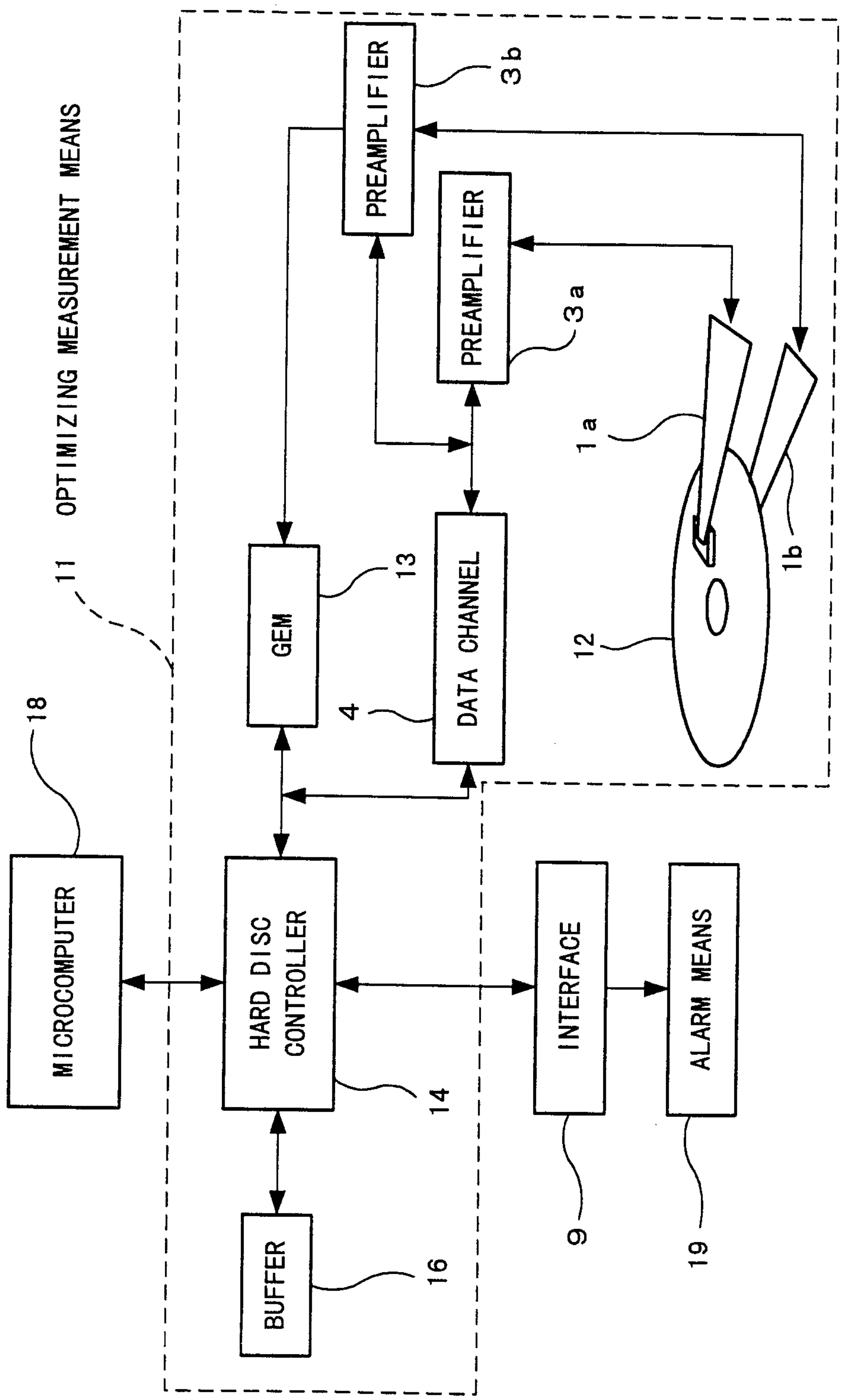

11
OPTIMIZING MEASUREMENT MEANS
PREAMPLIFIER
3b
PREAMPLIFIER
3a
1a
1b
GEM
13
DATA CHANNEL
4
12
MICROCOMPUTER
18
HARD DISC CONTROLLER
14
INTERFACE
9
ALARM MEANS
19
BUFFER
16

FIG. 13

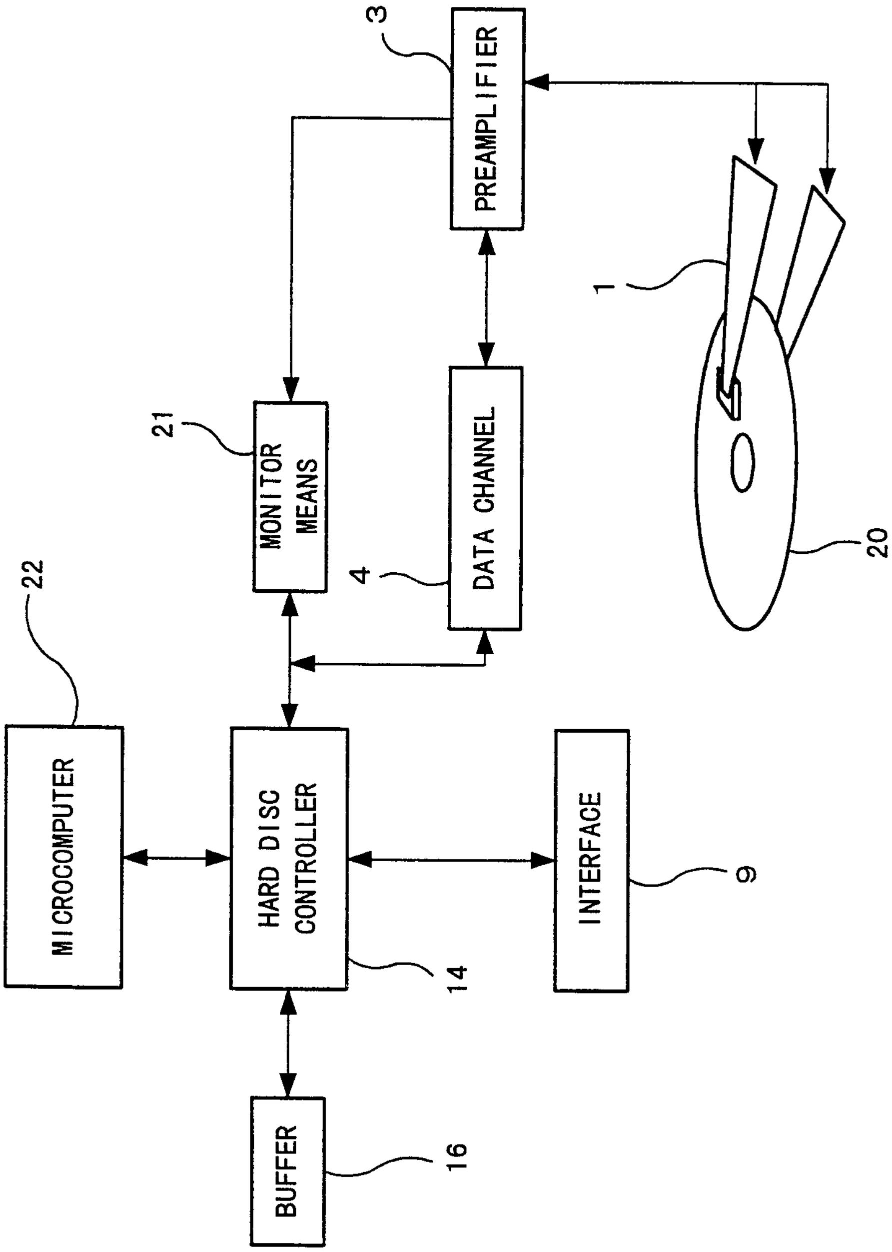

3
PREAMPLIFIER
21
MONITOR MEANS
4
DATA CHANNEL
1
20
22
MICROCOMPUTER
HARD DISC CONTROLLER
14
INTERFACE
9
BUFFER
16

FIG. 14

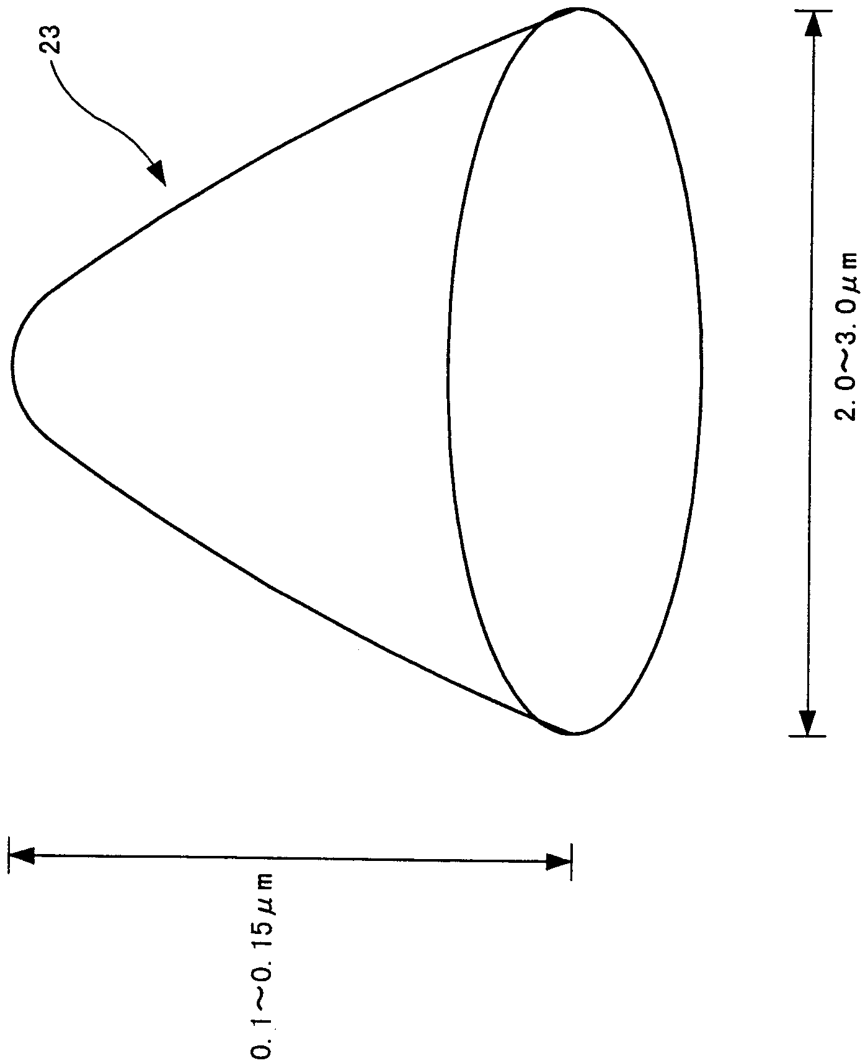
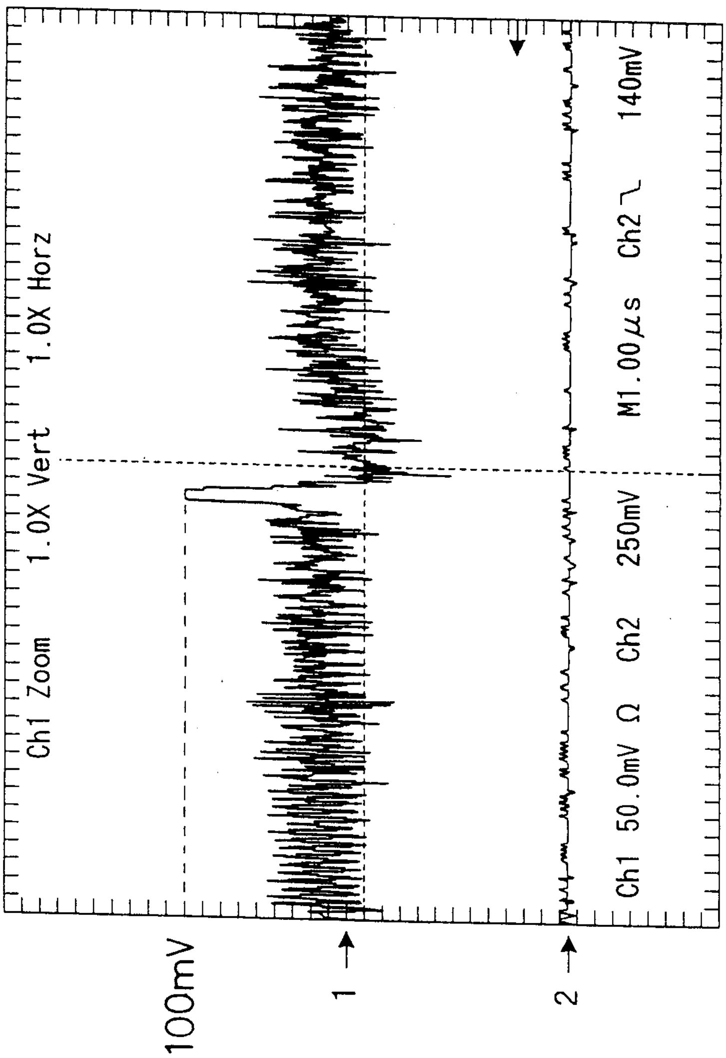
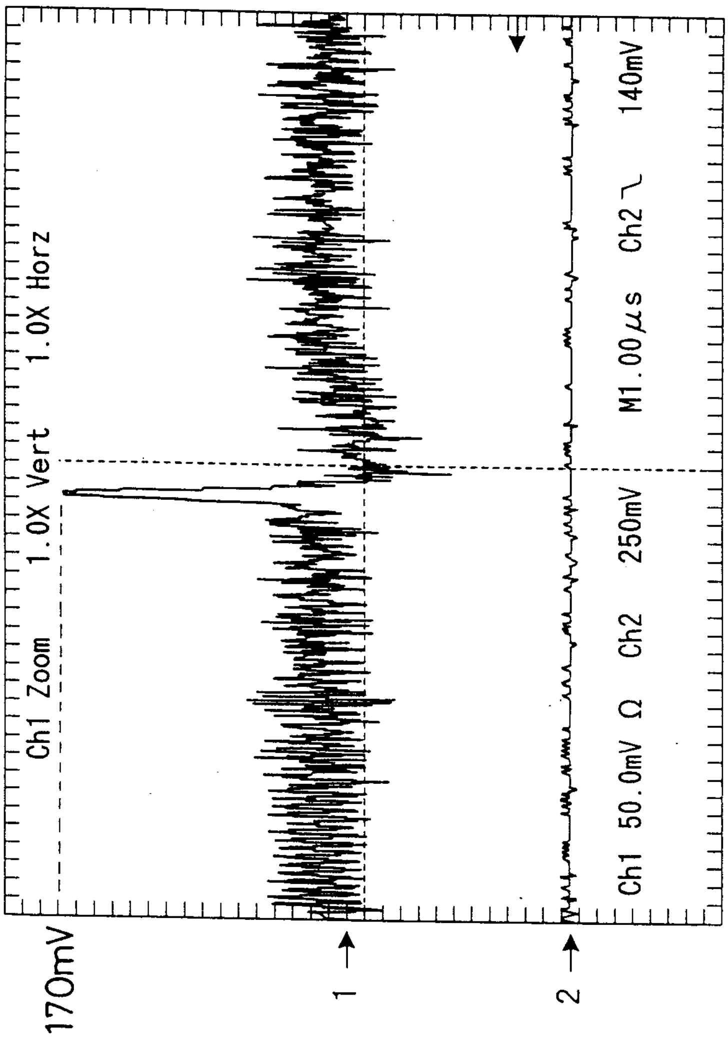


FIG. 15


Ch1 Zoom 1.0X Vert 1.0X Horz
Ch1 50.0mV Ω Ch2 250mV M1.00μs Ch2 ╲ 140mV
100mV
1
2

F I G . 16


Ch1 Zoom 1.0X Vert 1.0X Horz
170mV
1
2
Ch1 50.0mV Ω Ch2 250mV M1.00μs Ch2 140mV

F I G. 17

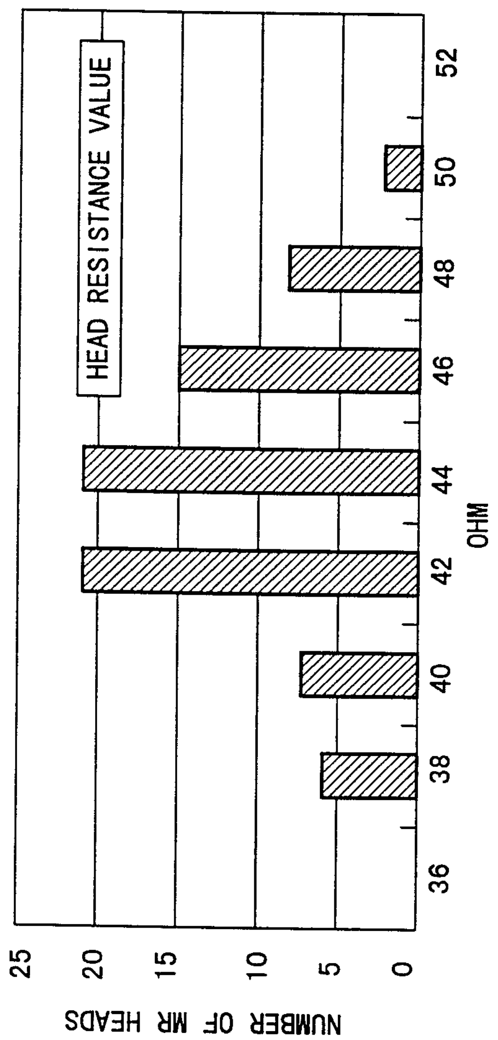
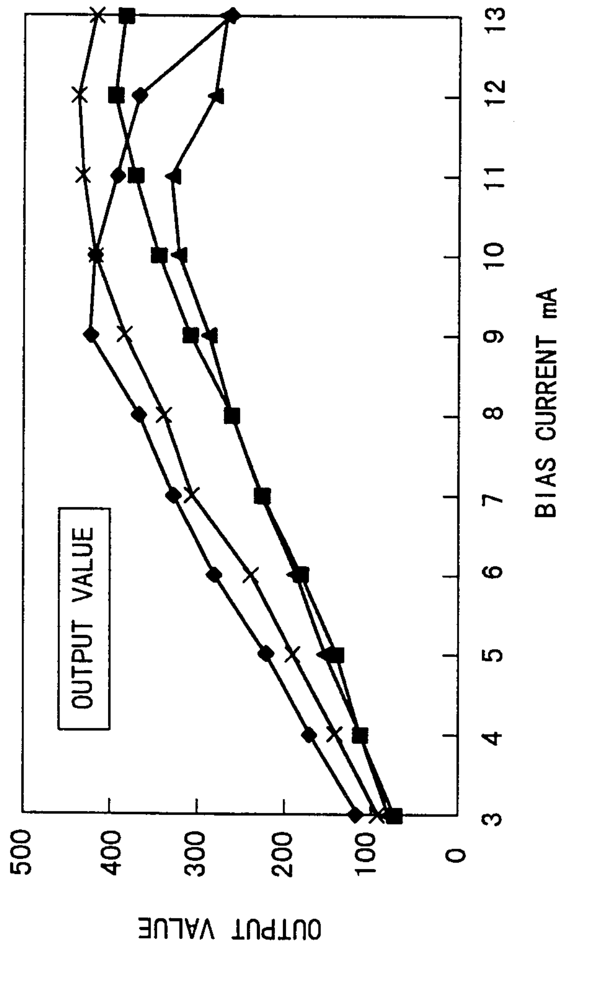
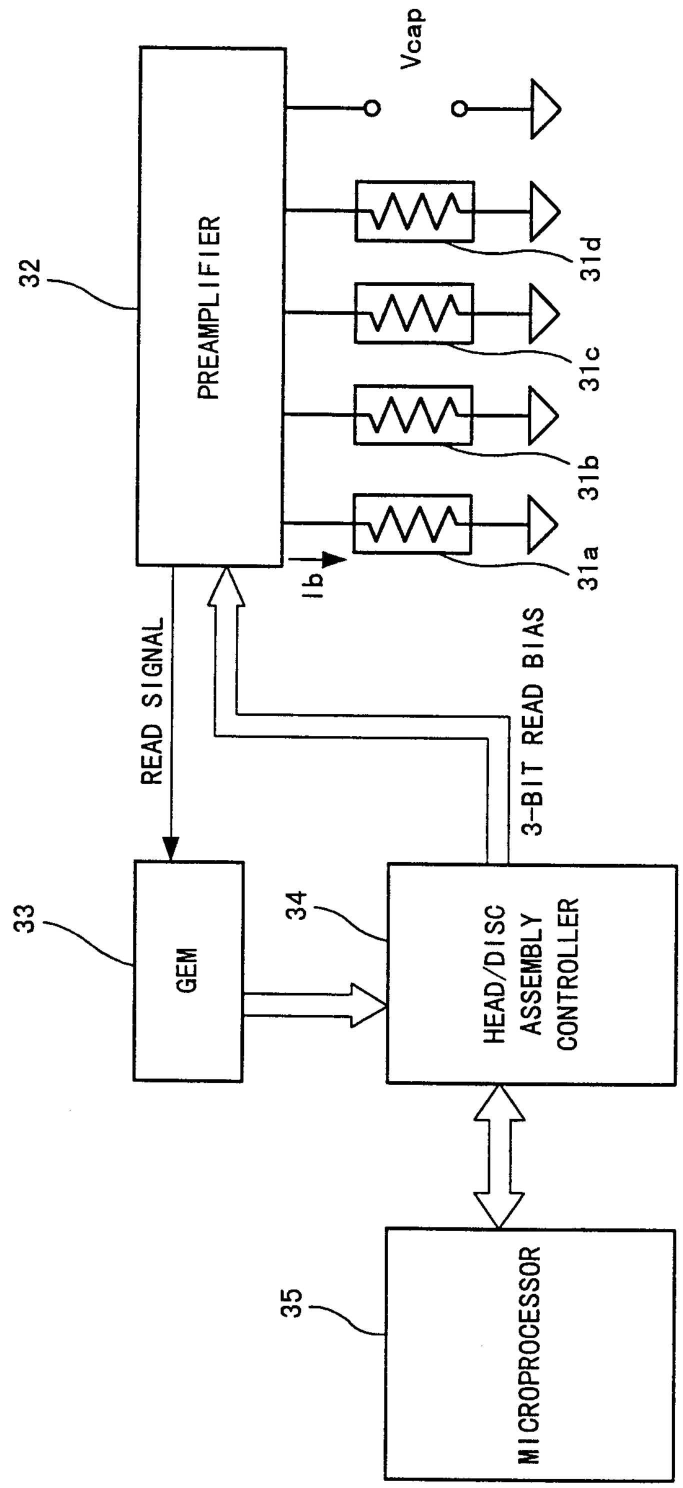

HEAD RESISTANCE VALUE
NUMBER OF MR HEADS
25
20
15
10
5
0
36
38
40
42
44
46
48
50
52
OHM

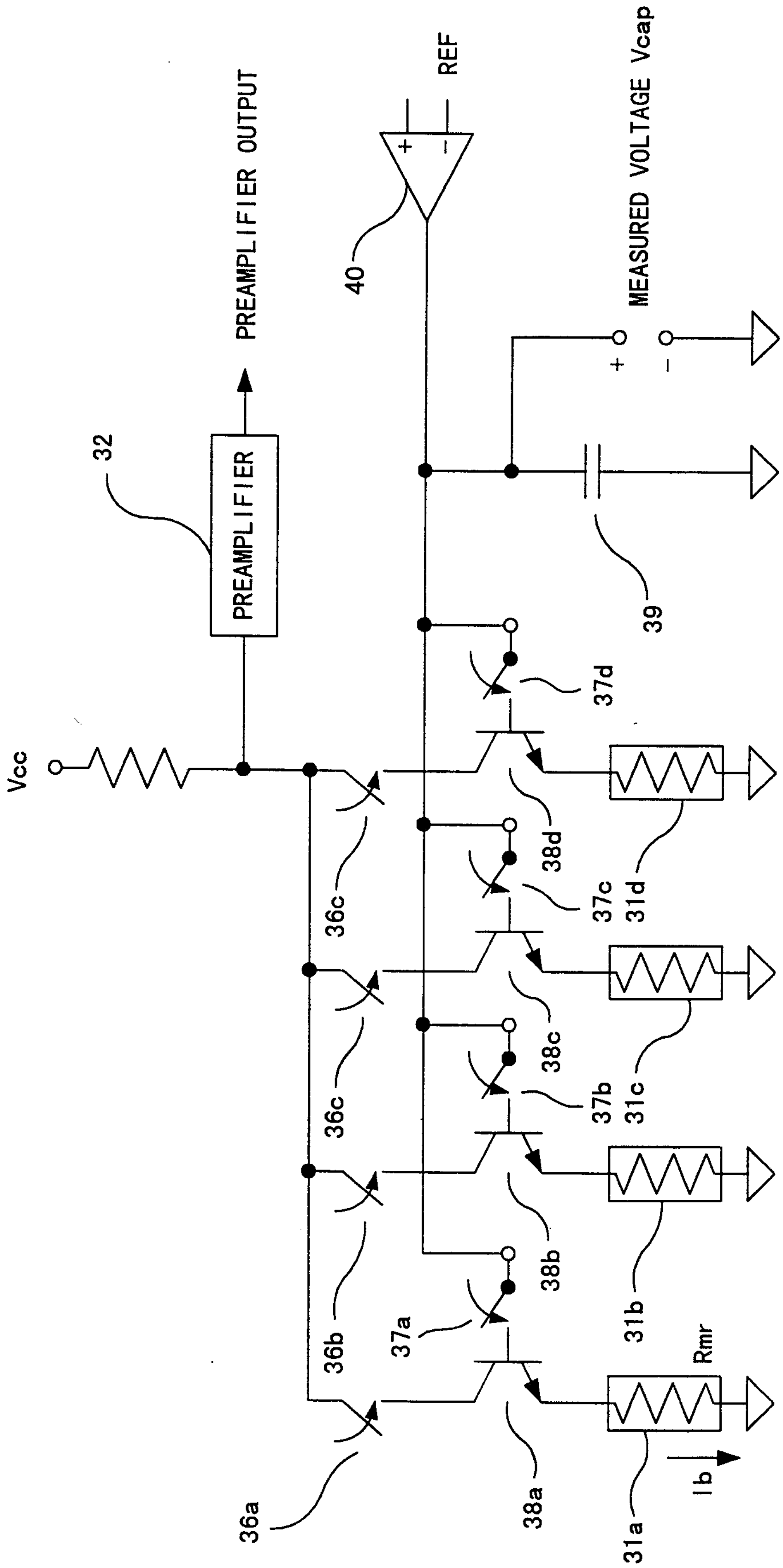
FIG. 18


OUTPUT VALUE
0
100
200
300
400
500
3
4
5
6
7
8
9
10
11
12
13
BIAS CURRENT mA
OUTPUT VALUE

F I G. 19


32
PREAMPLIFIER
Vcap
31d
31c
31b
31a
Ib
READ SIGNAL
3-BIT READ BIAS
33
GEM
34
HEAD/DISC
ASSEMBLY
CONTROLLER
35
MICROPROCESSOR

F I G. 20


PREAMPLIFIER OUTPUT
REF
MEASURED VOLTAGE Vcap
40
+
-
32
PREAMPLIFIER
39
Vcc
37d
38d
31d
36c
37c
31c
38c
36c
37b
38b
31b
36b
37a
Rmr
36a
38a
31a
Ib

INTERNATIONAL SEARCH REPORT

International Application No
PCT/JP 00/00770

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G11B5/02 G11B5/012 G11B19/02 G11B19/04

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G11B

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

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, PAJ, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 98 16918 A (QUANTUM CORP) 23 April 1998 (1998-04-23) the whole document ---	1-6,13, 14
X	EP 0 853 310 A (HITACHI LTD) 15 July 1998 (1998-07-15) page 7, line 27 - line 31; figure 10 ---	1
X	US 5 537 034 A (LEWIS WILLIAM D) 16 July 1996 (1996-07-16) column 4, line 27 - line 31 column 6, line 22 - line 56 column 7, line 39 - line 55; claim 3 ---	11
A	US 5 412 518 A (CHRISTNER JODIE A ET AL) 2 May 1995 (1995-05-02) cited in the application the whole document ---	1

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

[X] Patent family members are listed in annex.

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

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
9 June 2000	21/06/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Fux, J

1

International Application No
PCT/JP 00/00770

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	US 5 790 334 A (CUNNINGHAM EARL ALBERT) 4 August 1998 (1998-08-04) column 6, line 55 -column 12, line 67 column 13, line 65 -column 14, line 62	7-9
A	PATENT ABSTRACTS OF JAPAN vol. 1999, no. 05, 31 May 1999 (1999-05-31) -& JP 11 039839 A (HITACHI LTD), 12 February 1999 (1999-02-12) abstract the whole document	7-9
A	WO 96 39697 A (MAXTOR CORP) 12 December 1996 (1996-12-12) page 7, line 23 -page 8, line 5 page 15, line 4 - line 15	9
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INTERNATIONAL SEARCH REPORT

Information on patent family members

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