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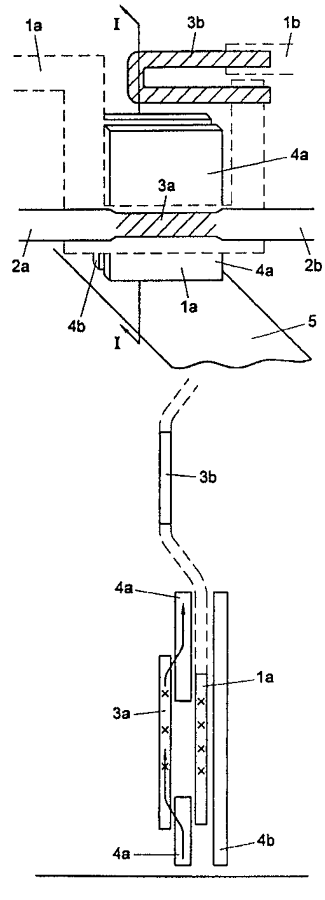
(54) Title: MAGNETIC FLUX SENSOR

(57) Abstract

A magnetic flux sensor built up from a layer structure, said sensor comprising a magnetoresistive sensor element forming part of a layer in the layer structure and incorporated into a measuring current circuit, and said sensor further comprising a bias current circuit for generating a bias field in the sensor element, characterized in that in the bias current circuit, a reference resistor is incorporated which is structured correspondingly and located in the same layer as the sensor element. The advantage of this invention is that in the same process step of applying the magnetoresistive layer for the magnetic flux sensor, a portion of this layer can be reserved for incorporation into the bias current circuit, so that in one process step, a magnetoresistive layer with an associated setting of a bias resistor can be realized. Thus, the magnetic flux sensor according to the invention realizes a simpler setting of the working point of the bias field.



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Title: Magnetic flux sensor

The invention relates to a magnetic flux sensor built up from a layer structure, which sensor comprises a magnetoresistive sensor element forming part of a layer in the layer structure and incorporated into a measuring current circuit, and a bias current circuit for generating a bias field in the sensor element.

Such sensor is known from EP 0 725 388. In such sensor, a measuring current is passed through a magnetoresistive layer, while the resistance of this layer changes at a changing external magnetic field. The magnetoresistive layer has the shape of a strip and is also referred to as "MR strip". Essential to the optimal functioning of a magnetic flux sensor is the setting of the proper angle between the direction of the measuring current and the magnetization in the MR strip of the sensor element. Various methods are known for this, such as the setting of a bias field by means of a separate, electrically separated bias winding layer, by means of barberpole biasing, wherein so-called short-circuit strips are provided at a specific angle transverse to the magnetoresistive layer, so that the current through the magnetoresistive layer is forced at an angle relative to the MR strip direction, or by means of shunt biasing, wherein the current is divided over the magnetoresistive layer and a nonmagnetic, electrically conductive shunt layer provided thereon, or by setting a bias field via an adjacent magnetic layer (SAL: soft adjacent layer) or by setting a bias field via a magnetic preferred direction shifted relative to the MR strip direction. When these methods are used, one should always take into account the so-called "self-biasing effect" caused by the field generated by the measuring current in the sensor in interaction with adjacent magnetic material. Depending on the direction of the measuring current and the location of the magnetic material, this self-bias field is either against the bias field or along with this field. Variations in the self-bias field influence the setting of the working point by means of a bias field. An important parameter which defines the magnitude of the self-bias effect is the thickness of the magnetoresistive layer in the sensor. Hence, control of this thickness is of great importance in order to effect a reproducible working point for the sensor. Because an exactly reproducible thickness of the magnetoresistive layer cannot be realized, due to limitations in the manufacturing process, there is the need to compensate the bias field for a changing thickness of the magnetoresistive layer. A known solution, such as for instance described in the above-mentioned EP 0 735 388, consists of a first conductor connected in series with the sensor element, which conductor generates a bias field, and a second conductor connected in parallel with this conductor. Thus, a setting is realized that can compensate for the varying thickness of the magnetoresistive layer, because the second conductor can be given a resistance setting an optimum working point.

A drawback of the known magnetic flux sensor, however, is that the magnitude of the setting resistance to be applied should be determined by experiment. This setting can be realized in various manners: by a control chip, by manual setting of the bias field per head in each system, by a setting circuit for the bias on a printed circuit board or by a fixed setting with no correcting for varying layer thickness. All methods have as a drawback that there is no direct feedback to the thickness of the sensor element.

The object of the invention is to overcome or reduce this drawback by simplifying the setting of the working point of a magnetic flux sensor. Also, an improved operation of the sensor is aimed at. This object is realized in that a reference resistor is incorporated into the bias current circuit, which resistor is structured in accordance with and is located in the same layer as the sensor element. As a result, a simpler setting of the working point of the magnetic flux sensor is possible, the number of process steps of the manufacture of the magnetic head with the associated control electronics can be reduced and that the number of necessary parts of the magnetic head can be reduced.

In particular, during the application of the magnetoresistive layer for the magnetic flux sensor, a portion of this layer can be reserved for incorporating a thus correspondingly structured resistance into the bias current circuit.

This reference resistance is realized in the same process step as the step for applying a magnetoresistive layer, so that it has the same thickness and composition as the sensor element. Thus, the bias resistance is formed together with the corresponding sensor element, without requiring manufacturing and setting a separate bias resistance.

Preferably, the circuit of the bias current is separate from that of the measuring current, so that the bias current circuit can be arranged entirely for generating an optimal bias field.

In particular, the effect of feedback of the layer thickness is optimal in the case where a fixed voltage is applied over the bias current circuit, because according as the magnetoresistive layer is thinner, the reference resistor will have a higher resistance. At a fixed voltage, the corresponding bias current will have a proportionally lower value, so that a smaller bias field is generated, which at the smaller layer thickness of the sensor element is required for a correspondingly lower working point setting.

The invention can in particular be used for magnetic flux sensors of the AMR (anisotropic magnetoresistive) or the GMR (giant magnetoresistive) type, because for these types, the above-mentioned coupling effect of layer thickness and bias field applies.

A suitable use of a magnetic flux sensor according to the invention is to integrate this into a magnetic head for scanning a magnetic surface by also incorporating flux conductors into the layer structure. The bias current in a bias current conductor, generating the bias field in the sensor element, is directed parallel to the measuring current.

A suitable location for this current conductor is the place between the flux conductor and the sensor element, or on the side of the sensor element facing away from the flux conductor.

The invention is also suitable for use in a so-called multichannel head, i.e. a magnetic head suitable for reading out several parallel channels. In this case, the advantageous effect achieved is that only one bias current circuit is needed for generating a bias field in the respective sensors, the feedback being realized by means of one reference resistance according to the invention.

The invention further relates to a recorder for reading out data stored on a magnetic surface, such as disc drives or tape recorders, wherein such magnetic head is provided.

The above objects and advantages of the invention can be better understood when considering the following, more detailed description of a preferred embodiment, with reference to the accompanying drawing. In this drawing:

Fig. 1 shows a preferred embodiment of the magnetic flux sensor according to the invention, used in a magnetic head of the yoke type;

Fig. 2 shows a section taken on the line I-I in Fig. 1;

Fig. 3 is a characteristic of the voltage over the sensor element in relation to the magnetic flux through the sensor element for separate thicknesses of the sensor element;

Fig. 4 shows the flow diagram of the magnetic flux sensor according to the invention;

Fig. 5 shows another preferred embodiment of the magnetic flux sensor according to the invention, used in a multichannel head of the yoke type.

In the magnetic head of Fig. 1, there is shown a sensor element 3a as part of the measuring current circuit with connecting strips 2a and 2b. The bias current circuit for this sensor element is formed by the connecting strips 1a, 1b and the corresponding reference resistor 3b, having the same thickness and formed from the same layer as the sensor element. The sensor element is in magnetic connection with a flux conductor 4a. A corresponding flux conductor located at the rear of the magnetic flux sensor is designated by reference numeral 4b. The assembly 4a and 4b forms a so-called yoke. Reference numeral 5 designates the magnetic tape with, stored therein, the data read out by the magnetic flux sensor. The currents of the bias current circuit and the measuring current circuit are parallel, and perpendicular to the flux passing through the flux conductor and coming from the magnetic tape 5. The bias field that is generated is predominantly parallel to the direction of the flux. In the sensor element, a preferred direction (so-called easy axis) of the magnetoresistive layer is parallel to the direction of the measuring current I_{sense}. Through the provision of the bias field, the internal field of the magnetic layer is turned, to cause a change of resistance, and a corresponding change of voltage over the element. Through the provision of the proper bias voltage V_{bias}, the working point of the magnetic flux sensor is set.

Fig. 2 shows the buildup of the layer structure of the magnetic head of Fig. 1, along the line I-I. The Figure demonstrates that the layer from which the reference resistor 3b is formed, forms part of the same layer from which the sensor element 3a is built up. Also, the arrows through the sensor element 3a represent the flux current coming from the magnetic tape 5, via the flux conductor 4a, into the sensor element. The bias field in the sensor element is generated in the current conductor 1, located between the flux conductor 4a and the sensor element 3a.

As shown in Fig. 3, a shift in the optimal working point can be observed, due to a variation in the thickness of the layer of the sensor element. A greater sensitivity to flux changes is realized at thinner magnetoresistive layers. The working point is proportionally much lower. In the Figure, reference numeral 7 designates a very thin layer, reference numeral 8 designates a layer of average thickness and reference numeral 9 designates a thicker layer. As can be seen, the respective associated working points 7a, 8a and 9a shift. A characteristic according to line 7 has a working point that is very difficult to set, and a characteristic according to line 9 responds relatively little to small flux changes. An optimal characteristic is a characteristic according to line 8. This characteristic involves a specific thickness of the magnetoresistive layer. The deviations in this thickness, caused by variations within the tolerance of the production process, can be corrected with a reference resistor according to the invention.

Fig. 4 is a simplified representation of the flow diagram, wherein identical parts have the same reference numerals as in Fig. 1. In this Figure, the bias current circuit and the measuring current circuit are shown separately, with the bias current circuit formed by a fixed voltage V_{bias}, connecting strips 1a and 1b and a reference resistor 3b, which has a higher resistance according as the magnetoresistive layer is thinner. The corresponding bias current will be proportionally lower, so that a lower bias field is generated, required for a lower working point setting. The measuring current circuit is formed by connecting strips 2a and 2b for the measuring current I_{sense}, and the sensor element 3a, corresponding with the reference resistor 3b.

Finally, Fig. 5 shows another preferred embodiment, used in a multichannel head for reading out data from several parallel channels. In the Figure, the magnetic head contains four sensor elements, and as many connecting strips 2a, 2a', 2a'' and 2a''', and 2b, 2b', 2b'', 2b''' for the measuring currents I_s, I_s', I_s'', I_s'''. In a usual multichannel head, the number of sensor elements may be a few tens. The sensor elements 3a, 3a', 3a'', 3a''' are formed from the same magnetoresistive layer, and can hence be set with the same bias current at their working point, which bias current flows through connecting strips 1a, 1b and the single corresponding reference resistor 3b. The flux conductors of the respective sensor elements are designated by reference numerals 4a, 4a', 4a'', 4a''', while the rear side of the flux conductor is not shown. The magnetic tape is designated by reference numeral 5.

The invention is not limited to the exemplary embodiments described with reference to the drawing, but comprises all types of variations hereof, of course in so far as they fall within the protective scope of the following claims. It is explicitly pointed out that although the exemplary embodiments of this patent application relate to magnetic heads of the yoke type, the invention also relates to magnetic heads of the shielded type, such as is, for instance, described in EP 0 725 388, and that the invention further relates to tape recorders, hard disks, etc. in which magnetic heads according to the invention are used.

Claims

1. A magnetic flux sensor built up from a layer structure, said sensor comprising a magnetoresistive sensor element forming part of a layer in the layer structure and incorporated into a measuring current circuit, and a bias current circuit for generating a bias field in the sensor element, characterized in that in the bias current circuit, a reference resistor is incorporated which is structured correspondingly and located in the same layer as the sensor element.

2. A magnetic flux sensor according to claim 1, characterized in that the reference resistor has the same composition and thickness as the sensor element, and is manufactured simultaneously therewith.

3. A magnetic flux sensor according to claim 1 or 2, characterized in that the measuring current circuit and the bias current circuit are electrically separated.

4. A magnetic flux sensor according to claim 3, characterized in that a fixed voltage is applied over the bias current circuit.

5. A magnetic flux sensor according to claim 1 or 2, characterized in that the sensor element can consist of an AMR or GMR element.

6. A magnetic head comprising flux conductors and a magnetic flux sensor according to any one of the preceding claims, integrated into the layer structure.

7. A magnetic head according to claim 6, characterized in that the current through the bias current circuit is directed parallel to the current through the measuring current circuit.

8. A magnetic head according to claim 6 or 7, characterized in that a flux conductor is located between the sensor element and a conductor layer forming part of the bias current circuit.

9. A magnetic head according to claim 6 or 7, characterized in that the sensor element is located between a conductor layer forming part of the bias current circuit and a flux conductor.

10. A magnetic head according to claim 5-8, for reading out in parallel data in several channels by means of as many sensor elements as channels, said sensor elements being integrated into one layer of a layer structure, characterized in that one bias current circuit generates a bias field in the sensor elements.

11. A recorder with a magnetic head according to any one of claims 6-10.

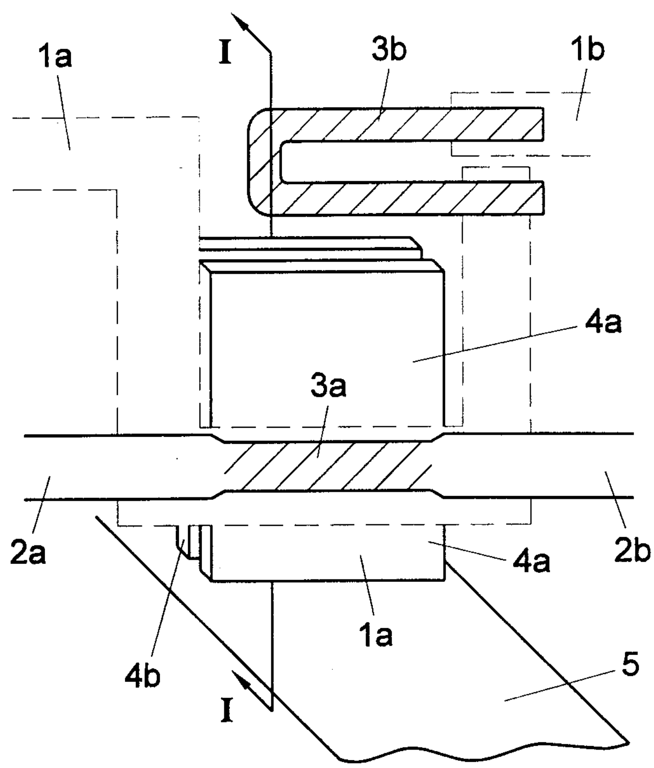

Fig. 1

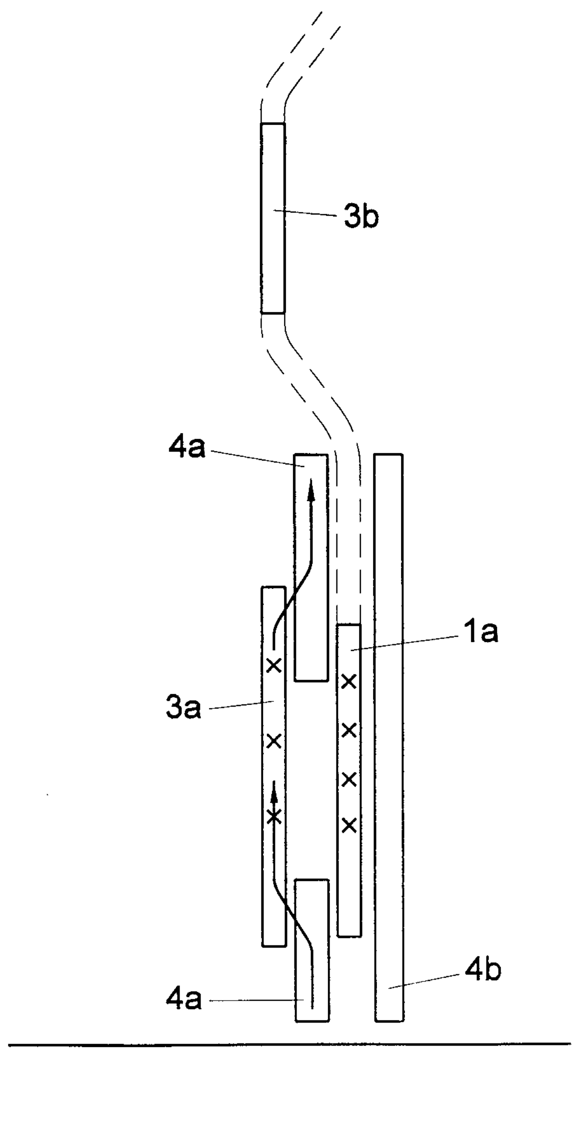

Fig. 2

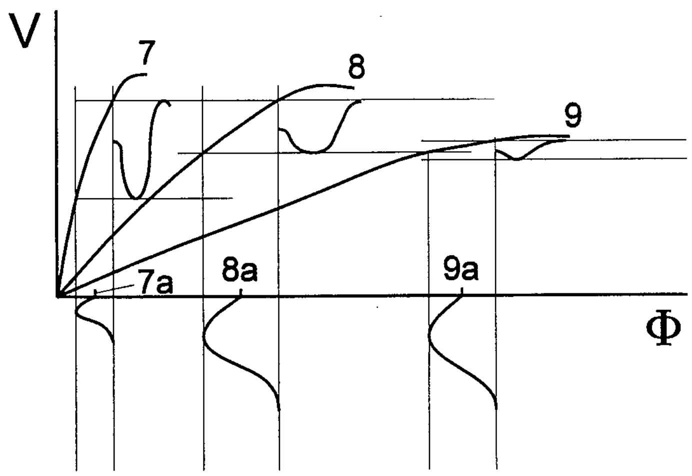

Fig. 3

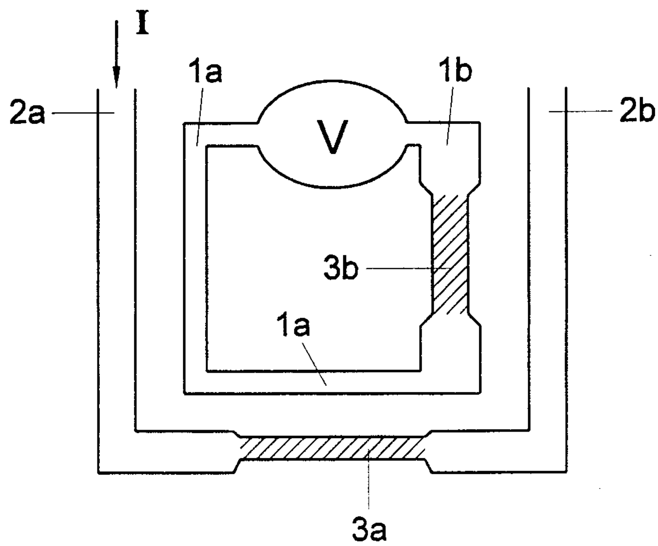

Fig. 4

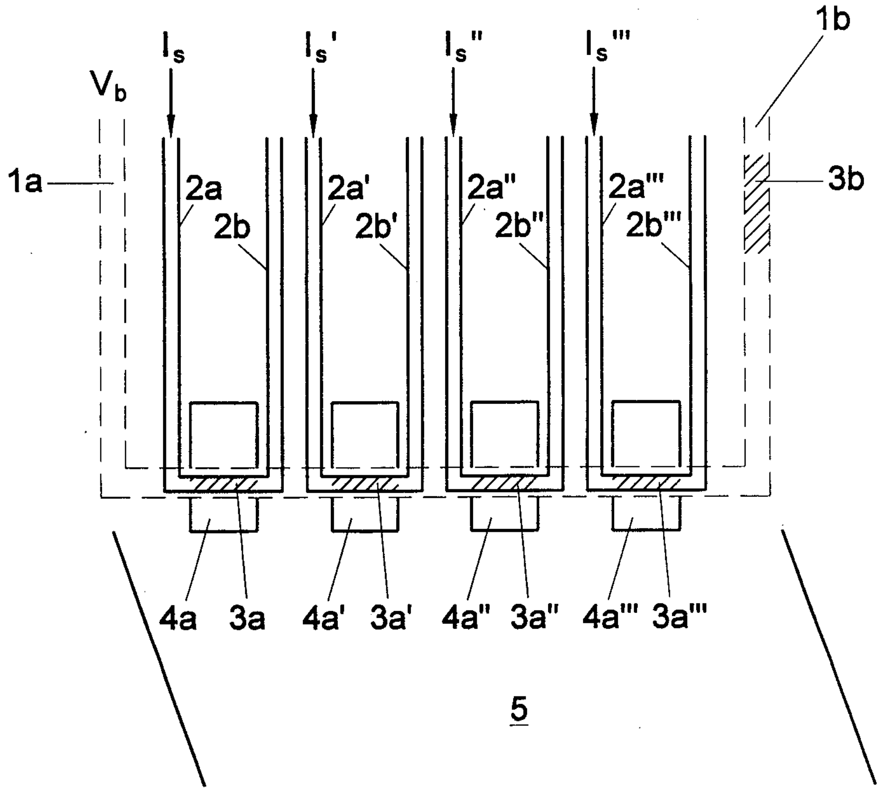

Fig. 5

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A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G01R33/09 G11B5/39

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

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Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G01R G11B

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C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	column 9, line 46 -column 12, line 6; figures 9-14	2-7,9,10
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A	PATENT ABSTRACTS OF JAPAN vol. 009, no. 097 (P-352), 26 April 1985 (1985-04-26) -& JP 59 221823 A (SONY KK), 13 December 1984 (1984-12-13) abstract	1
A	figures 2-4	6,10

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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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