US Patent & Trademark Office
Patent Public Search | Text View

United States Patent Application Publication	20250264552
Kind Code	A1
Publication Date	August 21, 2025
Inventor(s)	HARATANI; Susumu et al.

MAGNETIC SENSOR

Abstract

Disclosed herein is a magnetic sensor that includes a sensor chip having a magnetosensitive element, a magnetic field collecting body for collecting a magnetic field to the magnetosensitive element, an excitation coil wound around the magnetic field collecting body, and a modulation circuit that supplies an excitation current having a predetermined frequency to the excitation coil so as to periodically magnetically saturate the magnetosensitive element without magnetically saturating the magnetic field collecting body.

Inventors: **HARATANI; Susumu (Tokyo, JP), ONODERA; Ikuhito (Tokyo, JP)**

Applicant: **TDK Corporation** (Tokyo, JP)

Family ID: **1000008460756**

Appl. No.: **19/057109**

Filed: **February 19, 2025**

Foreign Application Priority Data

JP	2024-024349	Feb. 21, 2024

Publication Classification

Int. Cl.: **G01R33/00** (20060101); **G01R33/09** (20060101)

U.S. Cl.:

CPC **G01R33/0017** (20130101); **G01R33/09** (20130101);

Background/Summary

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of Japanese Patent Application No. 2024-024349, filed on Feb. 21, 2024, the entire disclosure of which is incorporated by reference herein.

BACKGROUND OF THE ART

Field of the Art

[0002] The present disclosure relates to a magnetic sensor and, more particularly, to a magnetic sensor capable of detecting a magnetic field in a low frequency region with high sensitivity.

Description of Related Art

[0003] Magnetic sensors using a magnetosensitive element are now in use in various fields. In order for magnetic sensors to detect an extremely weak magnetic field, they need to have a high S/N ratio. As a factor that reduces the S/N ratio of a magnetic sensor, 1/f noise can be cited. The 1/f noise becomes more conspicuous as the frequency component of a magnetic field to be measured becomes lower, so that it is important to reduce the 1/f noise for high-sensitivity detection of a magnetic field in a low frequency region of 1 kHz or less, for example.

[0004] JP-T-2020-522696 discloses a magnetic sensor having reduced 1/f noise. This magnetic sensor periodically saturates a magnetosensitive element using a modulator to reduce the 1/f noise.

[0005] However, the magnetic sensor described in JP-T-2020-522696 has a simple configuration in which a current line for saturating the magnetosensitive element is disposed near the magnetic sensor, posing a problem that it requires a large current to saturate a magnetosensitive element.

SUMMARY

[0006] The present disclosure describes a technology for reducing, in a magnetic sensor capable of detecting a magnetic field in a low frequency region with high sensitivity, the amount of current required for modulation.

[0007] A magnetic sensor according to an aspect of the present disclosure includes: a sensor chip having a magnetosensitive element; a magnetic field collecting body for collecting a magnetic field to the magnetosensitive element; an excitation coil wound around the magnetic field collecting body; and a modulation circuit that supplies an excitation current having a predetermined frequency to the excitation coil so as to periodically magnetically saturate the magnetosensitive element without magnetically saturating the magnetic field collecting body.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] The above features and advantages of the present disclosure will be more apparent from the following description of some embodiments taken in conjunction with the accompanying drawings, in which:

[0009] FIG. **1** is a schematic perspective view illustrating the outer appearance of a magnetic sensor **1** according to a first embodiment of the present disclosure;

[0010] FIG. **2** is a schematic perspective view of the sensor chip **100**;

[0011] FIG. **3** is a schematic perspective view of the magnetic field collecting body **120**;

[0012] FIG. **4** is a schematic plan view of the sensor chip **100**;

[0013] FIG. **5** is a schematic cross-sectional view taken along the line A-A in FIG. **4**;

[0014] FIG. **6** is a circuit diagram for explaining the connection relationship between the magnetosensitive elements R**1** to R**4**;

[0015] FIG. **7** is a circuit diagram of a closed loop circuit including the magnetosensitive elements R**1** to R**4**;

[0016] FIG. **8** is a schematic perspective view illustrating the outer appearance of a magnetic sensor **2** according to a second embodiment of the present disclosure; and

[0017] FIG. **9** is a schematic plan view illustrating the configuration of the main part of a magnetic sensor **3** according to a third embodiment of the present disclosure.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0018] Some embodiments of the present disclosure will be explained below in detail with reference to the accompanying drawings.

[0019] FIG. **1** is a schematic perspective view illustrating the outer appearance of a magnetic sensor **1** according to a first embodiment of the present disclosure.

[0020] As illustrated in FIG. **1**, the magnetic sensor **1** according to the first embodiment includes a sensor chip **100** having a magnetosensitive element, magnetic field collecting bodies **110** and **120** for collecting a magnetic field to the magnetosensitive element provided in the sensor chip **100**, and an excitation coil C**1** wound around the magnetic field collecting body **110**. The magnetic field collecting bodies **110** and **120** are each a block made of a high permeability material such as ferrite. The magnetic field collecting body **110** has a bar-like shape elongated in the Z-direction, and the end portion thereof in the positive Z-direction faces the sensor chip **100**. The magnetic field collecting body **110** is wound with the excitation coil C**1** having its axis extending in the Z-direction.

[0021] FIG. **2** is a schematic perspective view of the sensor chip **100**.

[0022] As illustrated in FIG. **2**, the sensor chip **100** has an element formation surface **101**, a back surface **102**, and side surfaces **103**, **104**, **105**, and **106**. The element formation surface **101** and back surface **102** constitute the XY surface and are positioned on the mutually opposite sides. The side surfaces **103** and **104** constitute the YZ surface and positioned on the mutually opposite sides. The side surfaces **105** and **106** constitute the XZ surface and are positioned on the mutually opposite sides. There are formed, on the element formation surface **101** of the sensor chip **100**, magnetosensitive elements (to be described later) and magnetic layers M**1** to M**3** (to be described later).

[0023] FIG. **3** is a schematic perspective view of the magnetic field collecting body **120**.

[0024] As illustrated in FIG. **3**, the magnetic field collecting body **120** has a main body part **121** elongated in the Z-direction, a pair of protruding parts **122** and **123** protruding, in the negative Z-direction, from the negative Z-direction end portion of the main body part **121** and having a thickness in the X-direction smaller than that of the main body part **121**, an overhung part **124** protruding, in the negative X-direction, from the negative Z-direction end portion of the protruding part **122**, and an overhung part **125** protruding, in the positive X-direction, from the negative Z-direction end portion of the protruding part **123**. The sensor chip **100** is disposed in a space surrounded by the main body part **121**, protruding parts **122** and **123**, and overhung parts **124** and **125**.

[0025] FIG. **4** is a schematic plan view of the sensor chip **100**, and FIG. **5** is a schematic cross-sectional view taken along the line A-A in FIG. **4**.

[0026] As illustrated in FIGS. **4** and **5**, four magnetosensitive elements R**1** to R**4** are formed on the element formation surface **101** of the sensor chip **100**. The magnetosensitive elements R**1** to R**4** are not particularly limited in type as long as they are elements whose electric resistance varies depending on the direction of magnetic flux and may be, for example, an MR element. The fixed magnetization directions of the magnetosensitive elements R**1** to R**4** are the same direction (for example, positive side in the X-direction). The magnetosensitive elements R**1** to R**4** are covered with an insulating layer **107**, on the surface of which magnetic layers M**1** to M**3** made of permalloy or the like are formed. The magnetic layers M**1** to M**3** are covered with an insulating layer **108**. The magnetic layer M**1** is disposed at substantially the center of the element formation surface **101** in the X-direction. The magnetic layers M**2** and M**3** are disposed at both sides of the element formation surface **101** in the X-direction so as to sandwich the magnetic layer M**1** in the X-direction.

[0027] The magnetic layers M**1** and M**2** form two gaps G**1** and G**3** each having a width in the X-direction and extending in the Y-direction. The gaps G**1** and G**3** are at the same X-direction position and arranged in the Y-direction. The magnetic layers M**1** and M**3** form two gaps G**2** and G**4** having a width in the X-direction and extending in the Y-direction. The gaps G**2** and G**4** are at the same X-direction position and arranged in the Y-direction. The gaps G**1** and G**4** are arranged in the X-direction, and the gaps G**2** and G**3** are arranged in the X-direction. The magnetosensitive elements R**1** to R**4** are disposed at positions overlapping the gaps G**1** to G**4**, respectively, in a plan view (as viewed in the Z-direction). With this configuration, magnetic fields in the X-direction passing through respective magnetic gaps G**1** to G**4** are applied respectively to the magnetosensitive elements R**1** to R**4**.

[0028] In FIGS. **4** and **5**, reference numeral **110***a* denotes an area covered in the Z-direction with the XY surface of the magnetic field collecting body **110** positioned at one end in the Z-direction, and reference numerals **124***a* and **125***a* respectively denote areas covered in the Z-direction with the overhung parts **124** and **125** of the magnetic field collecting body **120**. The side surface **103** of the sensor chip **100** is covered with the protruding part **122** of the magnetic field collecting body **120** in the X-direction, and the side surface **104** of the sensor chip **100** is covered with the protruding part **123** of the magnetic field collecting body **120** in the X-direction. The back surface **102** of the sensor chip **100** is covered with the main body part **121** of the magnetic field collecting body **120**.

[0029] The areas **110***a*, **124***a*, and **125***a* respectively overlap the magnetic layers M**1** to M**3**. Thus, the magnetic layer M**1** is covered with the magnetic field collecting body **110** in the Z-direction, the magnetic layer M**2** is covered with the overhung part **124** of the magnetic field collecting body **120** in the Z-direction, and the magnetic layer M**3** is covered with the overhung part **125** of the magnetic field collecting body **120** in the Z-direction. Then, a magnetic field in the Z-direction (magnetic field to be detected) is collected by the magnetic field collecting body **110** and applied to the magnetic layer M**1** through the magnetic field collecting body **110**. The magnetic field thus applied to the magnetic layer M**1** is curved in the positive and negative X-directions in the magnetic layer M**1**. Magnetic flux components curved in the positive X-direction in the magnetic layer M**1** are supplied to the magnetic layer M**2** through the gaps G**1** and G**3** and then flow to the overhung part **124**, protruding part **122**, and main body part **121** of the magnetic field collecting body **120**. At this time, a part of the magnetic flux that passes through the gaps G**1** and G**3** in the positive X-direction is applied to the magnetosensitive elements R**1** and R**3**. On the other hand, magnetic flux components curved in the negative X-direction in the magnetic layer M**1** are supplied to the magnetic layer M**3** through the gaps G**2** and G**4** and then flow to the overhung part **125**, protruding part **123**, and main body part **121** of the magnetic field collecting body **120**. At this time, a part of the magnetic flux that passes through the gaps G**2** and G**4** in the negative X-direction is applied to the magnetosensitive elements R**2** and R**4**.

[0030] The magnetic field collecting body **120** need not necessarily have the overhung parts **124** and **125**; however, covering the magnetic layers M**2** and M**3** respectively with the overhung parts **124** and **125** makes it possible to significantly reduce a magnetic resistance between the magnetic field collecting bodies **110** and **120**. Further, even when the overhung parts **124** and **125** are absent, it is possible to reduce the magnetic resistance between the magnetic field collecting bodies **110** and **120** by covering the side surfaces **103** and **104** of the sensor chip **100** respectively with the protruding parts **122** and **123**. Furthermore, it is possible to efficiently apply a magnetic field in the Z-direction (magnetic field to be detected) to the magnetosensitive elements R**1** to R**4** by covering the back surface **102** of the sensor chip **100** with the main body part **121** of the magnetic field collecting body **120**.

[0031] FIG. **6** is a circuit diagram for explaining the connection relationship between the magnetosensitive elements R**1** to R**4**.

[0032] As illustrated in FIG. **6**, the magnetosensitive elements R**1** to R**4** are bridge-connected between a power supply Vcc and a ground GND. That is, the magnetosensitive elements R**1** and R**2** are connected in series between the power supply Vcc and the ground GND, and the magnetosensitive elements R**4** and R**3** are connected in series between the power supply Vcc and the ground GND. A potential difference between a potential Va appearing at a node between the magnetosensitive elements R**1** and R**2** and a potential Vb appearing at a node between the magnetosensitive elements R**4** and R**3** is used as an output signal ΔV (=Va−Vb). As described above, the magnetosensitive elements R**1** to R**4** constitute a differential bridge circuit, and a change in the electrical resistance of the magnetosensitive elements R**1** to R**4** according to a magnetic flux density appears as the level of the output signal ΔV.

[0033] As illustrated in FIG. **1**, a modulation circuit **130** is connected to the excitation coil C**1** wound around the magnetic field collecting body **110**. The modulation circuit **130** supplies an excitation current i**1** having a predetermined frequency to the excitation coil C**1** to thereby apply an excitation magnetic field to the magnetosensitive elements R**1** to R**4** through the magnetic field collecting body **110**. When the excitation current i**1** is made to flow through the excitation coil C**1**, the magnetosensitive elements R**1** to R**4** are saturated at least at a timing when the excitation current i**1** becomes maximum. The excitation current i**1** has a predetermined frequency, and thus the magnetosensitive elements R**1** to R**4** are periodically saturated.

[0034] That is, in a period during which the excitation coil C**1** is not excited, the magnetosensitive elements R**1** to R**4** can detect a magnetic field to be detected, and the output signal ΔV according to the strength of the magnetic field to be detected appears. On the other hand, in a period during which the excitation coil C**1** is excited, the magnetosensitive elements R**1** to R**4** are magnetically saturated and thus cannot detect the magnetic field to be detected, with the result that the output signal ΔV becomes zero. The output signal ΔV output from the sensor chip **100** is modulated by the frequency of the excitation current i**1** supplied from the modulation circuit **130** to the excitation coil C**1**, so that 1/f noise is significantly reduced.

[0035] The maximum value of the excitation current i**1** supplied from the modulation circuit **130** to the excitation coil C**1** is less than the amount of current that magnetically saturates the magnetic field collecting body **110**. Therefore, even when the excitation current i**1** having a predetermined frequency is supplied from the modulation circuit **130** to the excitation coil C**1**, the magnetic field collecting body **110** is not magnetically saturated. This reduces the amount of excitation current i**1** to be supplied from the modulation circuit **130**, whereby it is possible not only to reduce current consumption but also to suppress heat generation by the excitation current. Thus, the magnetic field collecting body **110** is not magnetically saturated even when the excitation current i**1** is supplied to the excitation coil C**1**, so that the magnetic field to be detected is collected by the magnetic field collecting body **110** even at a timing when the excitation current i**1** becomes maximum and applied to the magnetosensitive elements R**1** to R**4**. However, since the magnetosensitive elements R**1** to R**4** are magnetically saturated at this timing, the sensitivities of the magnetosensitive elements R**1** to R**4** are zero.

[0036] In order to periodically saturate the magnetosensitive elements R**1** to R**4** without magnetically saturating the magnetic field collecting body **110**, magnetic field collection efficiency is designed such that the magnetic flux density of a magnetic field flowing through the magnetic field collecting body **110** is higher than the magnetic flux density of magnetic fields flowing through the magnetosensitive elements R**1** to R**4**. That is, a magnetic field collection efficiency G defined by B/A (B=magnetic flux density of magnetic fields flowing through the magnetosensitive elements R**1** to R**4**, and A=magnetic flux density of a magnetic field flowing through the magnetic collecting body **110**) is designed to exceed 1, and the amount of the excitation current i**1** supplied from the modulation circuit **130** to the excitation coil C**1** is adjusted so as to make the magnetic flux density A equal to or lower than the saturation magnetic field of the magnetic field collecting body **110** and to make the magnetic flux density B exceed the saturation magnetic field of the magnetosensitive elements R**1** to R**4**. The saturation magnetic field refers to a magnetic field where magnetization of a ferromagnetic body is saturated.

[0037] When the magnetic field collection efficiency G exceeds 1, the saturation magnetic field of

the magnetic field collecting body **110** may be lower than the saturation magnetic field of the magnetosensitive elements R**1** to R**4**. For example, assuming that the saturation magnetic field of the magnetic field collecting body **110** is a and that the saturation magnetic field of the magnetosensitive elements R**1** to R**4** is b, it is possible to periodically magnetically saturate the magnetosensitive elements R**1** to R**4** without magnetically saturating the magnetic field collecting body **110** when $b/a<G$ is satisfied even though a is lower than b. For example, when the saturation magnetic field a of the magnetic field collecting body **110** is about 1.5 Oe, and the saturation magnetic field b of the magnetosensitive elements R**1** to R**4** is about 1000 Oe, the magnetic field collection efficiency G may be designed to be about 67 or more. Actually, when a ferrite block is used as the material of the magnetic field collecting bodies **110** and **120**, and a permalloy thin film is used as the material of the magnetic layers M**1** to M**3**, the magnetic field collection efficiency G can be designed to be 1200 to 2000. Thus, even when the saturation magnetic fields of the magnetic field collecting body **110** and magnetosensitive elements R**1** to R**4** are above values, it is possible to periodically magnetically saturate the magnetosensitive elements R**1** to R**4** without magnetically saturating the magnetic field collecting body **110**.
[0038] FIG. **7** is a circuit diagram of a closed loop circuit including the magnetosensitive elements R**1** to R**4**.
[0039] The closed loop circuit illustrated in FIG. **7** includes an operation amplifier **141** receiving the output signal ΔV, a compensation coil C**2** connected between the output node of the operation amplifier **141** and an output terminal **140**, and a resistor **142** connected between the output terminal **140** and a ground GND. The compensation coil C**2** is integrated in the sensor chip **100** as illustrated in FIG. **2**. When a compensation current i**2** output from the operation amplifier **141** flows through the compensation coil C**2**, a canceling magnetic field is generated. Thus, when the output signal ΔV according to the magnetic flux density of the magnetic field to be detected is generated, corresponding compensation current i**2** flows through the compensation coil C**2** to generate a canceling magnetic field in an opposite direction, whereby the magnetic field to be detected is cancelled. Then, the compensation current i**2** is subjected to current-voltage conversion using the resistor **142** to generate an output signal Vout, whereby the strength of the magnetic field to be detected can be detected. Using the thus configured closed loop circuit enables highly accurate detection of magnetic fields collected through the magnetic field collecting bodies **110** and **120**.
[0040] When such a closed loop circuit is used, the maximum value of the excitation magnetic field that the excitation coil C**1** applies to the magnetosensitive elements R**1** to R**4** is designed to be larger than the maximum value of the canceling magnetic field that the compensation coil C**2** applies to the magnetosensitive elements R**1** to R**4**, whereby it is possible to periodically magnetically saturate the magnetosensitive elements R**1** to R**4** while preventing the excitation magnetic field from being completely cancelled by the canceling magnetic field.
[0041] The excitation current i**1** generated by the modulation circuit **130** may be an alternating current having a sine waveform or a pulse-like direct current having a predetermined frequency. When a pulse-like direct current having a predetermined frequency is used as the excitation current i**1**, a state where the current value becomes zero continues for a certain period of time in one cycle of the excitation current i**1**, allowing a sufficient period of time during which the output signal Vout can be observed to be ensured. In this case, by designing such that a time period during which the current value becomes zero (duty ratio) exists 25% or more of one period of the excitation current i**1**, it is possible to provide a more sufficient time period during which the output signal Vout can be observed.
[0042] As described above, the magnetic sensor **1** according to the present embodiment has the magnetic field collecting bodies **110** and **120** for collecting a weak magnetic field to be detected in the sensor chip **100** and the excitation coil C**1** wound around the magnetic field collecting body **110**.
[0043] Thus, by making the excitation current i**1** having a predetermined frequency flow through

the excitation coil C**1** using the modulation circuit **130**, the detection signal (ΔV or Vout) obtained from the magnetosensitive elements R**1** to R**4** can be modulated. As a result, even when the frequency of a weak magnetic field to be detected is low, 1/f noise can be reduced significantly. In addition, the excitation magnetic field generated by the excitation coil C**1** is of a level that periodically magnetically saturates the magnetosensitive elements R**1** to R**4** without magnetically saturating the magnetic field collecting body **110**, which reduces current consumption. When a common magnetic material is used, the saturation magnetic field of the magnetic field collecting body **110** is lower than the saturation magnetic field of the magnetosensitive elements R**1** to R**4**; however, by designing such that the magnetic field collection efficiency G becomes large, it is possible to periodically magnetically saturate the magnetosensitive elements R**1** to R**4** without magnetically saturating the magnetic field collecting body **110**.

[0044] FIG. **8** is a schematic perspective view illustrating the outer appearance of a magnetic sensor **2** according to a second embodiment of the present disclosure.

[0045] As illustrated in FIG. **8**, the magnetic sensor **2** according to the second embodiment differs from the magnetic sensor **1** according to the first embodiment in that the excitation coil C**1** is wound around the magnetic field collecting body **120**. Other basic configurations are the same as those of the magnetic sensor **1** according to the first embodiment, so the same reference numerals are given to the same elements, and overlapping description will be omitted. As exemplified by the magnetic sensor **2** according to the second embodiment, the excitation coil C**1** may be wound around the magnetic field collecting body **120** instead of being wound around the collecting body **110**.

[0046] FIG. **9** is a schematic plan view illustrating the configuration of the main part of a magnetic sensor **3** according to a third embodiment of the present disclosure, where the collecting bodies **110** and **120** are omitted.

[0047] As illustrated in FIG. **9**, the magnetic sensor **3** according to the third embodiment differs from the magnetic sensor **1** according to the first embodiment in that the excitation coil C**1** is integrated in the sensor chip **100** and wound around the magnetic layers M**2** and M**3**. Other basic configurations are the same as those of the magnetic sensor **1** according to the first embodiment, so the same reference numerals are given to the same elements, and overlapping description will be omitted. As exemplified by the magnetic sensor **3** according to the third embodiment, the excitation coil C**1** may be wound around the magnetic layers M**2** and M**3** on the sensor chip **100** instead of being wound around the collecting body **110**.

[0048] While some embodiments of the technology according to the present disclosure have been described, the technology according to the present disclosure is not limited to the above embodiments, and various modifications may be made within the scope of the present disclosure, and all such modifications are included in the technology according to the present disclosure.

[0049] The technology according to the present disclosure includes the following configuration examples, but not limited thereto.

[0050] A magnetic sensor according to an aspect of the present disclosure includes: a sensor chip having a magnetosensitive element; a magnetic field collecting body for collecting a magnetic field to the magnetosensitive element; an excitation coil wound around the magnetic field collecting body; and a modulation circuit that supplies an excitation current having a predetermined frequency to the excitation coil so as to periodically magnetically saturate the magnetosensitive element without magnetically saturating the magnetic field collecting body. With this configuration, it is possible to periodically magnetically saturate the magnetosensitive element with less amount of current.

[0051] In the above magnetic sensor, the magnetic field collecting body may be lower than the magnetosensitive element in terms of saturation magnetic field. This allows a common magnetic material such as ferrite to be used as the material of the magnetic field collecting body.

[0052] The above magnetic sensor may further include a compensation coil integrated in the sensor

chip and acting to cancel a magnetic field to be applied to the magnetosensitive element. This allows closed loop control to be performed. In this case, the maximum value of an excitation magnetic field that the excitation coil applies to the magnetosensitive element may be larger than the maximum value of a canceling magnetic field that the compensation coil applies to the magnetosensitive element. This prevents the excitation magnetic field to be applied to the magnetosensitive element from being cancelled by the compensation coil.
[0053] In the above magnetic sensor, a state where a current value of the excitation current becomes zero may continue for a certain period of time in one cycle of the excitation current. This allows a sufficient period of time during which an output signal can be observed to be ensured. In this case, a time period during which the current value becomes zero exists 25% or more of one cycle of the excitation current. This can provide a more sufficient time period during which the output signal can be observed.

Claims

1. A magnetic sensor comprising: a sensor chip having a magnetosensitive element; a magnetic field collecting body for collecting a magnetic field to the magnetosensitive element; an excitation coil wound around the magnetic field collecting body; and a modulation circuit that supplies an excitation current having a predetermined frequency to the excitation coil so as to periodically magnetically saturate the magnetosensitive element without magnetically saturating the magnetic field collecting body.
2. The magnetic sensor as claimed in claim 1, wherein the magnetic field collecting body is lower than the magnetosensitive element in terms of saturation magnetic field.
3. The magnetic sensor as claimed in claim 1, further comprising a compensation coil integrated in the sensor chip and acting to cancel a magnetic field to be applied to the magnetosensitive element.
4. The magnetic sensor as claimed in claim 3, wherein a maximum value of an excitation magnetic field that the excitation coil applies to the magnetosensitive element is larger than a maximum value of a canceling magnetic field that the compensation coil applies to the magnetosensitive element.
5. The magnetic sensor as claimed in claim 1, wherein a state where a current value of the excitation current becomes zero continues for a certain period of time in one cycle of the excitation current.
6. The magnetic sensor as claimed in claim 5, wherein a time period during which the current value becomes zero exists 25% or more of one cycle of the excitation current.