origin, and the X1 element 12 and the X2 element 13 are point-symmetrically positioned with respect to the origin as the center of symmetry, while the Y element 14 is by itself point-symmetrically positioned with respect to the origin as the center of symmetry.

The single soft magnetic body 21 is formed in the shape of a button above the origin (that is to say, above the Y element 14), and the two soft magnetic bodies 22 are formed in the shape of a button in a substrate 11 and positioned at the ends of the X1 and X2 elements, which ends constitute two outer edges of the substrate 11 in the longitudinal direction, respectively.

[0028]

The structure of the GSR elements 3 (hereafter referred to as "element structure") is described in reference to FIG. 3.

In the structure of the three elements 3, an amorphous wire (hereafter referred to as "wire") with a diameter of 10 μm is used at a length of 120 μm for the elements 12 and 13 for the x-axis, and at a length of 200 μm for the element 14 for the y-axis. A wire 31 is positioned in a central portion and surrounded by a detecting coil (hereafter referred to as "coil") 32 with an inner diameter of 20 μm and a coil pitch of 3 μm, containing 30 turns. To both ends of the wire 31 and the detecting coil 32, wire terminals 33 and coil terminals 35 are attached, respectively. Wire electrode pads 34 from the wire terminals 33 and coil electrode pads 36 from the detecting coil terminals 35 are used to correspond to integrated circuit terminals (not shown), respectively. The above respective terminals of each element 3 are electrically bonded to the respective terminals of the integrated circuit through the electrode pads.

[0029]

Initially, the basic operation of an electronic circuit 5A of a GSR sensor is illustrated referring to FIG. 5.

The electronic circuit 5A includes a pulse generating circuit (pulse generator) 51 and a signal processing circuit 52. The signal processing circuit 52 is composed of a buffer circuit 53, a detection timing adjusting circuit 54, an electronic switch 55, a sample hold circuit 56, and an amplifier 57. A pulsed current of a high frequency corresponding to 2 GHz that is generated by the pulse generating circuit 51 is fed to the wire 31 of a GSR element 3. Then, a magnetic field generated on the surface of the wire 31 by the pulsed current and an external magnetic field act on each other to generate a voltage corresponding to the external magnetic field on the coil 32. For convenience' sake, the pulse frequency as referred to herein is defined to be the reciprocal of the cycle of the pulsed current, with the cycle being assumed to last for a time four times as long as the "fall" time Δt of the pulsed current.

[0036]

The output voltage from the coil 32 is input to the buffer circuit 53. The output voltage from the buffer circuit 53 is held as a capacitor voltage of the sample hold circuit 56 by a brief switching (on-off switching) of the electronic switch 55 by the detection timing adjusting circuit 54 at a specified timing after the fall of the pulsed current. The sampled voltage is amplified by the amplifier 57 and output.

[0037]

Next, the function of an electronic circuit 5B of the present example that includes three GSR elements 3 is illustrated referring to FIG. 6.

The electronic circuit 5B includes a pulse generating circuit (pulse

generator) 51, signal processing circuits 52, and a digital circuit 58. The pulse generating circuit (pulse generator) 51 is a single circuit, while the signal processing circuits 52 are three in number in order to measure the outputs of the respective elements at a time. The outputs from the three GSR elements (X1, X2 and Y1) are input to the digital circuit 58, sequentially converted into digital data by an A-D converter 582 using a selector switch 581, then transferred to an arithmetic circuit 583 to subject them to an appropriate arithmetic processing. Thus, the outputs are each converted into the strength of a three-dimensional vector. Subsequently, the strength values are transferred to a central processing unit controlling such a system as a smartphone through a data communications circuit 584.

[0038]

The three-dimensional magnetic field detection device according to the present example is rectangular in shape, and has a length of 540 μm, a width of 250 μm, and a thickness of 120 μm including the thickness of the soft magnetic body above the origin. The three-dimensional magnetic field detection device as such is reduced in size to, for instance, one fourth of a three-dimensional magnetic field detection device in a square shape that is composed of four magnetic field detecting elements and three soft magnetic bodies.

[0039]

Example 2

FIG. 7 is a cross-sectional view of a three-dimensional magnetic field detection device according to Example 2.

The three-dimensional magnetic field detection device of the present example is produced by cutting both end portions of the three-dimensional

magnetic field detection device 1 of Example 1 (FIG. 1) along lines B-B'. The state of cut surfaces is shown in the cross-sectional view as taken along line A-A' in FIG.1. The soft magnetic bodies in the end portions are each originally in the shape of an inverted cone, and have been subjected to cutting.

As a result of machining along line B-B' in the middle of the soft magnetic body 22 at an end of the X1 element 12 and along line B-B' in the middle of the soft magnetic body 22 at an end of the X2 element 13, the end faces of the soft magnetic bodies 22 appear on the left and right sides of the three-dimensional magnetic field detection device, respectively.

The machining as above makes it possible to reduce the length of the three-dimensional magnetic field detection device. In the present example, the soft magnetic bodies 22 are partially removed by cutting along with the substrate 11, while the remaining parts thereof are adequate to maintain the magnetic circuits in crank form and, accordingly, the magnetic field detecting capability is in no way affected.

[0040]

The three-dimensional magnetic field detection device according to the present example is reduced in size in the longitudinal direction by 50 μm at each end as compared with the device of Example 1, that is to say, has a length of 440 μm. The width of 250 μm and the thickness of 120 μm are kept unchanged. Therefore, a further reduction in size by about 20% is achieved.

INDUSTRIAL APPLICABILITY

[0041]

The three-dimensional magnetic field detection device of the present invention is necessary for a three-dimensional azimuth meter requiring