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Time-coded GMI Magnetic Field Sensor

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A time-coded GMI magnetic field sensor has been investigated and designed. The laboratory model has been successfully constructed and tested, demonstrating the sensitivity of 5 μs/μT in the field range of ± 200 μT. Sensing element is in the form of amorphous thin wire, 100 μm in diameter × 50 mm in length, which was fit into a small field modulation coil of 60 mm long. The sensor is working based on a really simple principle that, with the magnetic field modulation was chosen in range of hundreds of Hz, the change in time interval of two adjacent GMI peaks relating to external DC magnetic field is proportional to the intensity of the external field along the sensing element. This mechanism has made improvement to linearity and resolution of the sensor.

Keywords: magnetic field sensor, GMI, amorphous wire

Since Panina and Mohri reported the Giant magneto-impedance (GMI) phenomenon in soft magnetic amorphous wires (as being called a-wire) [1] in 1994, GMI effect has provided a novel method for detecting the low magnetic field at a very high sensitivity. Recent studies on the GMI effects have exhibited the possibility of fabricating magnetic sensors with high performance [2-4]. Due to their high sensitivity, fast response, good stability, low power consumption and easy miniaturization, GMI sensors show great potential as the next generation of magnetic sensors for low magnetic field detection [5-6].

In general, GMI effect of a-wire, however, reveals an even function in AC modulation field which leads to problem of compensation. In order to obtain high linearity, some previous works presented a method of using bias field and feed back coil for chosen working point [2,5]. The others conducted compensating item by utilizing another identical sensing element (pair of GMI element) for getting differentiation of symmetric configuration [7]. In the most cases, those conventional methods were unable to neglect the GMI effect drawbacks of non-linearity of operating points, so need compensation treatment. To overcome such the problems, the present work focuses on proposing another idea, which rose from suggestion in [8] combined with great feature of GMI effect of sensing element, and then constructing a laboratory model of such a proposed sensor to show a proof of the

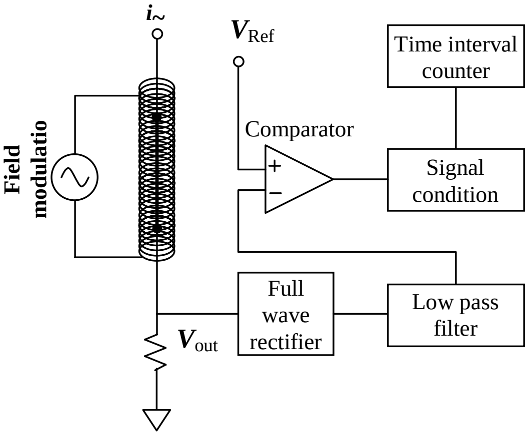

Fig. 1. Block diagram of designed sensor.

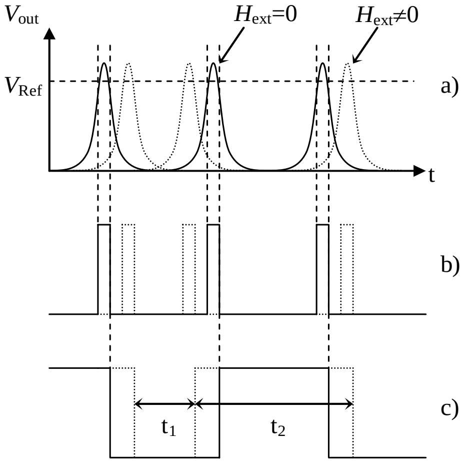

Fig. 2. Operational principle of sensor. a) drop voltage output. b) comparator output, and c) final output for time counting

correctness of the proposed idea.

Amorphous micro-wire with diameter of 100 µm and length of 50 mm was employed as active magnetic element due to the circumferential magnetic anisotropy which leads to extremely high GMI ratio [1]. A-wire was fitted into a modulation coil which is long enough to cover the whole its length while it was subjected to AC current at frequency of few hundreds of kHz. Basically, the working principle of sensor was shown in Fig. 1. The mode of operation of measurement procedure was pointed out in Fig. 2. From the time based progress of drop voltage resulted from GMI effect as shown in Fig. 2a), we could realize that the output signal was changeable with external DC field. When H_{ext} = 0, V_{out} signal stands in the time symmetry position (solid line curve). Once $H_{ext} \neq 0$ is acting along a-wire axis, it causes a shift of peaks correspondent with the change of external field (dot line curve). Like as fluxgate principle, if the modulation field is enough to get saturation of GMI curve, the shifts of separated peaks due to the change in external field express the change in time interval, Δ*t* (= t_2 - t_1), which is defined as proportional to the external field. To measure Δt, the rectangular voltage signal was created in output through the signal condition by means of flip-flop counting from previous pulse stage output of comparator and then transfer to final stage of time encoding for counting (Fig. 2b-c). Therefore, if this time-based progress is chosen as a means of measuring the external magnetic field, the problem of non-linearity will be neglected. This method along with the GMI effect advantages has made improvement to important application terms of the sensor such as linearity, no hysteresis loop, and no memory effect. Besides, without related electronics and compensation items, the present sensor can be advanced to more compactable form for the later manufactured stage.

In actual experiment, excitation AC current feeding to a-wire was set at frequency of 300 kHz. Sinusoidal field modulation frequency was set at 100 Hz which was enough to be imposed on the external magnetic field, producing correspondent sinusoidal variation of the output. Time intervals were measured by Universal Counter HP 53131A which ensures the resolution of 0.5 ns.

Fig. 3 presents the characteristic of sensor operated in range of ± 500 µT and of ± 200 µT. The resolution of this laboratory model sensor has been estimated about 1×10^{-8} T. The sensitivity of magnetic field measurement of the sensor is in order of 5 µs/µT, which is strongly dependent on interval between two GMI-resulted voltage peaks of a-wire, and hence the properties of chosen a-wire. The linearity of measurement characteristic calculated by means of standard derivation method shows the value of 0.3% for ± 200 µT range, indicating a very good acceptance in such a wide range measurement.

In conclusion, a new proposed magnetic field GMI-sensor has been designed, constructed and tested successfully. The functional principle of operation of this sensor is based on the time-coded measurement of

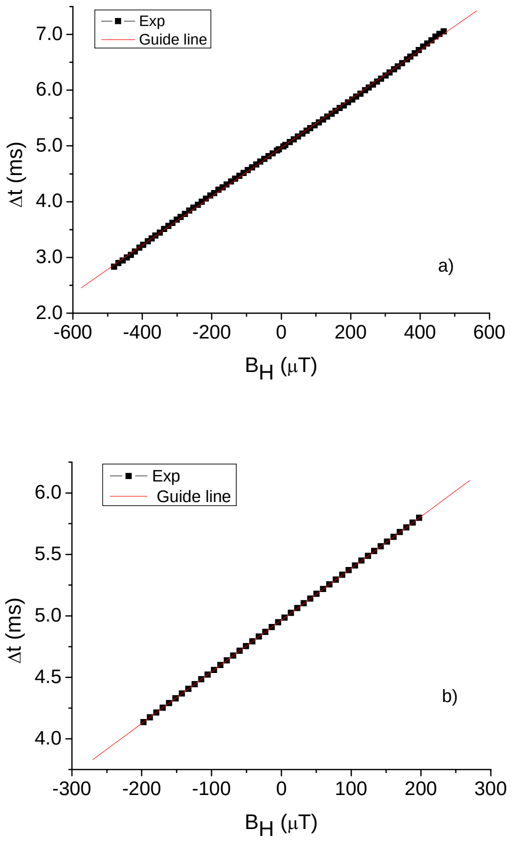

Fig. 3. Characteristic of designed sensor in ranges of ± 500 µT (a), and of ± 200 µT (b).

the changes in time interval of drop voltage peaks when there is presence of external DC magnetic field. The main purpose of the work was to show a proof of the correctness of the proposed idea for the operation principle of the present sensor rather than a complete design of such a device. Results obtained here are preliminary results which are well accepted for the next advanced stage where the more microminiaturized and optimized size will be developed. The sensitivity and resolution of the model may be significantly increased by careful choice of the sensing element and working conditions along with the optimized electronics.

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