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GMI Magnetic Field Sensor based on Time-coded Principle

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A GMI magnetic field sensor working based on time-coded principle has been investigated and designed. The laboratory model has been constructed and tested carefully, demonstrating the sensitivity of 3 μs/μT in the field range of ± 100 μT. An amorphous thin wire, 100 μm in diameter × 50 mm in length, was chosen to be sensing element which was fit into a small field modulation coil of 60 mm in length. The sensor is working based on a time-coded 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 to be measured. This mechanism has made a great improvement to the linearity of the sensor.

Keywords: time-coded, magnetic field sensor, GMI, amorphous wire

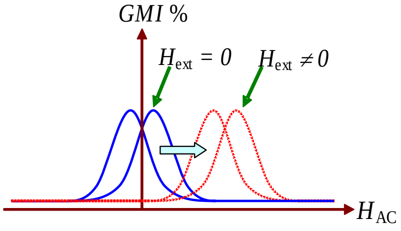

Fig. 1. GMI curve shifts corresponding in the presence of an external DC magnetic field.

Giant magneto-impedance (GMI) effect has provided a novel method for detecting the low magnetic field at a very high sensitivity [1-2]. Recent developments of GMI sensors have exhibited the possibility of fabricating magnetic sensors with high performance [3-6] such as high sensitivity, fast response, good stability, low power consumption and easy miniaturization. As the result, GMI sensors show great potential as the next generation of magnetic sensors for low magnetic field detection [7-9]. Although there is an existence of small hysteresis [10], some previous studies [4,7,11,12] presented the methods for obtaining high linearity. In most cases, these conventional methods were unable to overcome the GMI-effect drawbacks of hysteresis and the non-linearity of the operating points.

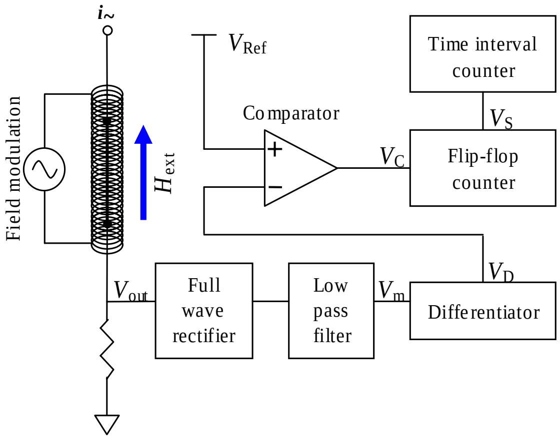

Fig. 2. Block diagram of designed sensor.

On the basis of the finding in which the GMI profile shifts with respect to the presence of external magnetic field to be measured (as shown in Fig 1), we constructed successfully a first laboratory model of the newly proposed sensor [14] to realize the idea.

At the first study stage [14], the laboratory model sensor was studied with the GMI signal inputting to the comparator was directly obtained from output of the low pass filter. In this work, we proceeded an advanced way for improving the signal linearity and stability by using a stage of differentiator right after the low pass filter, as shown in Fig. 2.

Basically, the mode of the operation principle of the sensor is shown in Fig. 3, where the time-based progresses of V_m, V_D, V_C, and V_S are presented with respect to those in Fig. 2. When $H_{ext} = 0$, the V_m signal occurs in the time symmetry position (solid line curve). Once $H_{ext} \neq 0$, it shifts the peaks corresponding to the change of the external field (dotted line curve). As the result, the crossing points of differentiated signal to zero line behave the same shifts. Consequently, these shifts due to the change in the external magnetic field express the change in the time interval, Δt (= t_2 - t_1), which is proportional to the external field, as shown in Figs. 3-c) and 3-d). Therefore, if this time-based progress would be used to measure the external magnetic field the problem of non-linearity is eliminated.

In actual experiment, excitation AC current feeding to a-wire was set at frequency of 300 kHz. Triangular field modulation frequency was set at 100 Hz. Time intervals (Δt) were measured by Universal Counter HP 53131A which has the resolution of 0.5 ns.

Fig. 4 presents the characteristic of sensor operated in range of ± 250 μT and of ± 100 μT. The sensitivity of magnetic field measurement of the sensor is in order of 3 μs/μT, which is strongly dependent on the properties of chosen amorphous wire. The linearity of measurement characteristic calculated by means of standard deviation method shows the value of 0.3% for ± 100 μT range, indicating a very good acceptance in such a wide range measurement.

In conclusion, a time-coded magnetic field GMI-sensor has been designed, constructed and tested based on the proposed idea [14]. This time-coded method, in combination with the advantages of the GMI effect, facilitated the following improvements to important application in terms of the sensor: high linearity, no hysteresis, and no memory effect.

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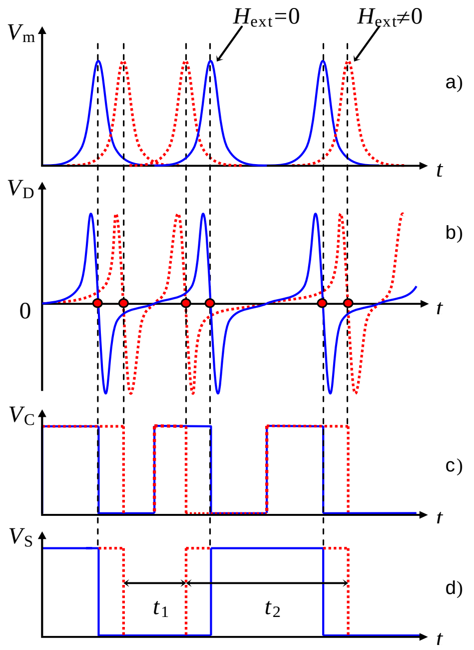

Fig. 3. Operational principle of the sensor: a) GMI voltage signal under modulation field, b) GMI voltage signals after differentiation stage, c) comparator output of VD and 0 V reference, and d) final output for time interval counting.

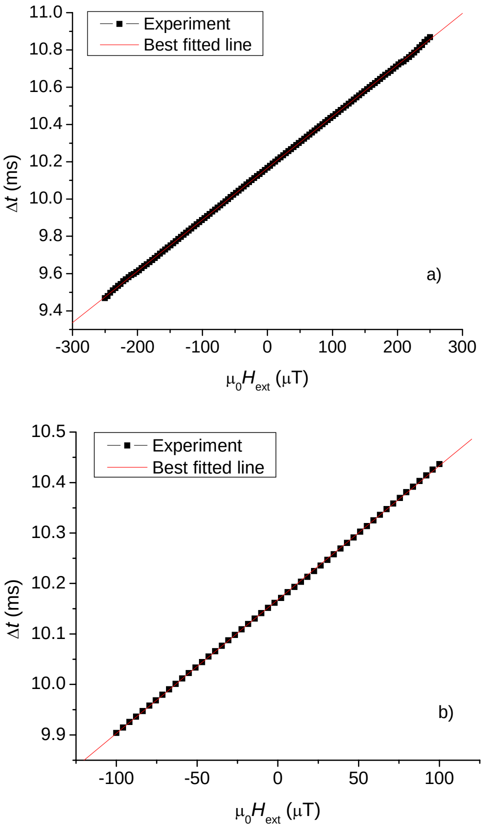

Fig. 4. Characteristic of designed sensor in ranges of ± 250 μT (a), and of ± 100 μT (b).

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