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Advanced AMR sensor using spread spectrum technology

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Abstract: This paper describes invention of magnetometer with protection against detection by electronic countermeasure (ECM) registered by Czech patent office as patent no. 305322 (Vala (2015)). Magnetic sensors are often used as part of dual use or security instruments and equipment. For this purpose is very interesting to build sensor with is hidden against electronic countermeasure. In this case is very important behavior and level of electromagnetic radiation produced by sensor. And also electromagnetic compatibility of electronic devices is the area which significant grows nowadays too. As the consequence of this growth there is a continuous process of making more strict standards focused on reducing of electromagnetic radiation generated by electronic devices. Sensors technology begins to be a part of these issues due sensors bandwidth increasing and approaching to frequency of radio communication band. Nowadays high speed digital circuits are integrated into sensors devices and it brings new sources of electromagnetic radiation in modern smart sensors.

Keywords: Anisotropic magnetoresistors, AMR, magnetic sensor, spread spectrum, electronic countermeasure, ECM

1. INTRODUCTION

Although the magnetoresistive effect is known for a long time, its mass use as a magnetoresistor is a matter of more recent times. Magnetoresistive effect was discovered in 1857 by W. Thomson, but only the last three or four decades of intense research and development allow deployment of sensors of this type in current industrial practice and is used for read heads in magnetic recording devices. Current developments in the field of modern microelectronic technology has enabled the miniaturization of sensors into today's form.

Magnetoresistive sensors are suitable for measuring weak and moderately strong magnetic fields to navigate in Earth's magnetic field and position measurement, translation or rotation etc. They can also be the sensors including compensatory and drive circuitry located on a single chip, thanks to the use of technology manufacture and packaging of integrated circuits. This not only reduces their temperature dependence, but also reduces the constructional dimensions of the entire system and in particular the final price, which contributes to their mass distribution. Conversely, manufacturing (technological) intensity, however difficult the further development of sensors and restricts him so at a few places in the world where it is currently concentrated. Description of AMR technology may be found in several books like Magnetic sensors and magnetometers (Ripka (c2001)) or patents like US4847584A (Pant (1989)), US5247278 (Pant et al. (1993)), US5521501 (Dettmann and Loreit (1996)) or US5952825 (Wan (1999)) and in this contribution will be described only important part form invention point of view.

By using materials making magnetoresistive sensor layer is not more physical reasons dispense with repeated magnetization sensor, especially when measuring weak magnetic fields, or in the case of large dynamic range of the sensor (He and Shiwa (2011)).

AMR sensor magnetization and its management is designed primarily with respect to the function of the sensor element of the sensor, not with regard to its possible negative impacts on electromagnetic radiation sensor. As the constantly increasing operating frequency of the sensor, there is a significant shift frequency of magnetization (orientation) pulses, thereby shortening their duration. This leads to a higher intensity current in the demagnetizing coils of the sensor, which are repeated at a higher frequency and consequently the higher the radiation sensor, particularly at higher frequencies.

In some applications, it may be a magnetizing impulse or a source thereof, a source of undesirable interference, for example, from the perspective of self interference "passive" sensor. The actual sensor is due to the method of measuring the intensity of the magnetic field in its own phase measurements completely "passive", ie. DC power supply and does not emit any electromagnetic alternating fields. Unlike the sensor type "Fluxgate" where there are periodic magnetization of the core sensor, which is based on the principle function of this type of sensor. When using the feedback measurement of the magnetic field is generated while the sensor magnetic field, but it also does not change if it is the steady state an external magnetic field. In this case too the coil generating the compensation field, supplied "DC" current. However, if it is necessary to perform periodic magnetization magnetoresistor, and then, due to its physical properties can not be avoided,

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it is to bring the positive and negative pulses to the magnetization (”flip”), coils, and thereby violation of the ”passivity” sensor. This may adversely affect, or prevent the use of these sensors in some applications where it is necessary to reduce their emission to a minimum.

The usual effective method in sensor technology, the electromagnetic shielding of the sensor, which in addition to reducing the level of electromagnetic radiation from the sensor itself has a positive influence on the shielding of the sensor compared to the external undesired electromagnetic fields. This method, however, can not be used with magnetic field sensors, because their electromagnetic shielding (and due to shielding or alteration of the measured magnetic field) is in direct contradiction with the principles and requirements for the sensor.

2. ANISOTROPIC MAGNETO-RESISTIVE SENSOR

Anisotropic Magneto-Resistive (AMR) sensors are fabricated with permalloy (NiFe) thin films that create changes in resistivity with respect to external magnetic fields, see Ripka (c2001). These film materials are similar to magnetic recording tapes in that strong magnetic fields can disrupt the magnetic domains of the film particles from a smooth factory orientation to arbitrary directions. Accuracy and resolution of these sensors will suffer until the film magnetic domains are reset to recreate a uniform direction. In application notes AN213 (AN2 (2002)) is detailed description of the set and reset functions for AMR sensors including the reasons to perform this function, characteristics of set/reset components, and example circuits showing the present state of the art in set/reset pulse generation.

AMR sensors are designed in Wheatstone bridge configurations, with four magnetoresistive elements that remain identical electrically when no external magnetic fields are applied. With linear-mode AMR sensors, the externally applied magnetic fields are to be limited in strength so as to not disrupt the factory set magnetic domains of the permalloy thin-film elements. Figure 1 shows three examples of magnetic orientation of the film domain structure.

3. MAGNETIZATION OF AMR SENSOR CORE

The reasons to perform a set or reset on an AMR sensor are:

(1) to recover from a strong external magnetic field that likely has re-magnetized the sensor,

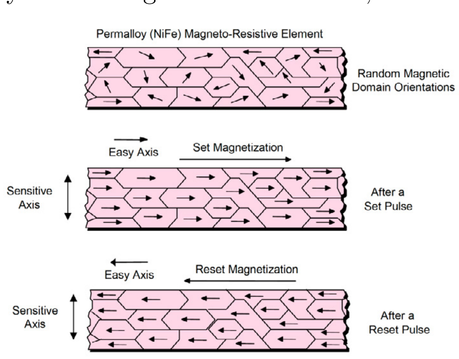

Fig. 1. Domain orientation in permalloy magneto-resistive element

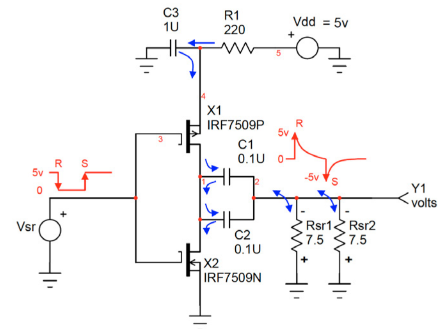

Fig. 2. Simplified schematic of set/reset pulse

(2) to optimize the magnetic domains for most sensitive performance, and
(3) to flip the domains for extraction of bridge offset under changing temperature conditions.

Strong external magnetic fields that exceed a 1 to 2 mT ”disturbing field” limit, can come from a variety of sources. The most common types of strong field sources come from permanent magnets such as speaker magnets, nearby high-current conductors such as welding cables and power feeder cables, and by magnetic coils in electronic equipment such as CRT monitors and power transformers. Magnets exhibit pole face strengths up to unit of Tesla. These high intensity magnetic field sources do not permanently damage the sensor elements, but the magnetic domains will be realigned to the exposed fields rather than the required easy axis directions. AMR sensors are also ferromagnetic devices with a crystalline structure. This same thin film structure that makes the sensor sensitive to external magnetic fields also has the downside that changing magnetic field directions and thermal energy over time will increase the self-noise of the sensor elements. This noise, while very small, does impair the accurate measurement of sub-micro Tesla field strengths or changes in field strength in nano Tesla increments. By employing frequent set and reset fields on the sensor, the alignment of the magnetic domains in each permalloy element drops the self-noise to its lowest possible level. More information you can find in AN2 (2002) .

The above description explained that providing pulses of electrical current creates the needed magnetic fields to realign the magnetic domains of the sensor resistive elements. Also the rationale for performing these set and reset pulses has been justified. The following paragraphs shall show when and how to apply these pulsed currents, and circuits to implement them. The tempco math shows the importance of choosing appropriate strap voltages to create the correct strap currents and that both resistanc-es and currents are variables to be dealt with. The direction of the strap currents also determines what is considered a set or a reset pulse. Set pulses are defined as pulsed currents that enter the positive pin of the set/reset strap. Like-wise negative pulsed currents are considered reset pulses. Figure 2 shows a simplistic schematic of a set/reset circuit.

These set and reset pulses are shown on figure 3 as dampened exponential pulse waveforms because the most popular method of generating these relatively high current,