Construction of an AMR magnetometer for car detection experiments

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Abstract. A new construction of magnetometer with commercially available AMR (anisotropic magnetoresistive) sensors intended for vehicle detection experiments is presented. Initial experiments with simple AMR gradiometer indicated viability of the approach in a real-world setup. For further experiments and acquisition of representative data, a new design of precise multi-channel magnetometer was developed. The design supports two models of commercial AMR sensors: the proven and reliable, but obsolete Honeywell HMC1021-series sensors and newly available Sensitec AFF755B sensors. In the comparison the two types are similar in most achieved parameters, except offset stability in flipped operation regime. Unfortunately, the new AFF755B sensors seem to have perhaps inferior coupling of the flipping (set/reset) coil to the ferromagnetic core that causes insufficient saturation of the AMR material. The issue is being solved by Sensitec, current deliverables of the AFF755B have “product sample” status (September 2015).

1. Introduction

In the framework of an industrial cooperation project, we develop car detection system with AMR sensors as the preferred solution. Initial experiments with simple AMR gradiometer made of pair of Phillips KMZ51 (with fluxgate magnetometer Billingsley TFM100G2 as a reference) indicate viability of the scheme in accordance with literature [1, 2, 3]. The typical car signature is well in excess of 1 µT deviation from background in 4 m distance. In order to conduct further experiments and accumulate larger amount of representative real-world data in the field of car detection, a new construction of an AMR magnetometer is developed, offering flexible operating parameters (sample rate, flipping, feedback compensation).

Well established and proven AMR sensors (Honeywell HMC1001, HMC1021 and Phillips KMZ51) have unfortunately recently became obsolete and stock shortages are imminent. For modern constructions, new types of sensors with (at least nominally) comparable parameters are available, namely AFF755B from Sensitec. In order to compare the new sensors with their obsolete counterparts, we decided to make overall testing of their parameters when used in new AMR magnetometer. The design supports two possible types of 3-axis sensor probe construction, with slightly different magnetic field feedback compensation coils. Internal (on chip) compensation/test coils are not used.

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due to poor coil constant and thus high current needed. The flipping is frequently used in AMR sensors to periodically re-magnetize the ferromagnetic sensor core using another built-in (on chip) coil and short intense unipolar current pulses. It is also possible to alternate the core magnetization between two polarities (N-S or S-N) using positive and negative current pulses, effectively alternating the sensor response polarity which may help in suppressing offsets and/or hysteresis [4, 5, 6]. The flip current RMS value (i.e. thermal effects) must be carefully considered, which dictates short maximum pulse duration.

2. Experiment

The analog output signals from sensors are processed and sampled by a quad (or octal), max. 144 kSa/s, simultaneous sampling 24-bit delta sigma ADC (ADS1278 by Texas Instruments). In the basic configuration, three magnetic channels (x, y, z) and temperature is measured at 10.3 kSa/s rate. Lower than maximum sample rate is used in order to save power. Optionally, another 3-axis probe can be added, thus forming gradiometric configuration. Full scale range of the instrument is ±350 µT. The device is controlled by a 32-bit microcontroller Microchip PIC32MX795F512L (an FPGA is considered as an alternative solution), permitting change of many parameters on the fly.

In the current test implementation the feedback compensation of measured field is permanently active. The flipping pulses (set/reset in Honeywell parlance) can be optionally activated at 10 kHz (at the expense of theoretically limited signal bandwidth), deactivated, or single-fired at request. With flipping active, the signal is preprocessed with switching synchronous detector. The digital output rate can be configured in wide range (1 to 10 300 Sa/s) in order to suit target application. The output data are averages of raw inputs sampled at 10.3 kSa/s. Sleep mode with ADC and flipping deactivation is available. The block diagram of one channel is shown in figure 1. The data are transmitted via USB or RS232 interface to the host computer, processed and graphically displayed in custom application written in National Instruments LabView.

![Figure 1. Block diagram of the magnetometer (one channel of analog signal is shown).](image)

The magnetic calibration (determining offsets, scale factors and angular deviations from x-y-z orthogonality) was performed by scalar calibration method in homogenous field using nonmagnetic positioning device [7]. The noise data were acquired with sensors in a 6-layer permalloy tubular shield in lab environment. In all cases, the noise spectra are calculated from output digital data incoming at 206 Sa/s rate (each output value is an average of 50 raw ADC readings sampled at 10.3 kSa/s).

3. Results and discussion

The main focus of the current development was comparison of classical but obsolete sensors of Honeywell HMC1021-series with newly available Sensitec AFF755B-series. In most aspects, these
two models of sensors are quite comparable, e.g. open loop sensitivity is about 1 mV/V / 100μT in both models. However, we have observed strong differences in offset stability and noise behavior of these two sensors in flipped and non-flipped mode.

Firstly, the noise of electronics measured without the sensors connected was only some 46 pT/sqrtHz@1Hz, so it is safely below either sensor noise level. The output noise PSD (power spectral density) with HMC1021 sensors in operating mode with flipping (current pulse 454 mA pk) is about 240 pT/sqrtHz@1Hz as shown in figure 2 (the best case was about 120 pT/sqrtHz@1Hz). Interestingly, without flipping the noise was somewhat worse, typically 800 pT/sqrtHz@1Hz.

For the AFF755B sensors without flipping the PSD was similar (300 pT/sqrtHz@1Hz) to that of HMC1021 with flipping. However, with flipping, the AFF755B noise did not improve as expected, but was much worse: in the order of 10 nT/sqrtHz@1Hz - see figure 3.

Increasing the flipping current amplitude did not improve the noise either. The figure 4 (left) provides comparison of PSD measured values for various flipping currents. It was also observable that output offset in AFF755B is quite unstable with flipping - see figure 4 right.

4. Conclusions

We have constructed multiple-axis AMR magnetometer with feedback compensation and compared two types of commercially available AMR sensors. The only significant difference observed between the two models of AMR sensors was in flipped mode. The flipping (set/reset) in classical Honeywell HMC1021 works very well, suppressing offsets without compromising the noise quality. Also the current peaks needed for effective flipping is reasonably small: 450 mA pk. In contrast, in Sensitec AFF755B sensors (sample deliverables), similar or even higher level of flipping current peaks perhaps
does not guarantee good saturation of the core and results in unacceptable offset instability after each flip pulse (the noise PSD is in the order of 10 nT/sqrtHz@1Hz, i.e. 50x worse than HMC1021).

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