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Choice of Topic: The Research Question
MULTIWIRE CORE FLUXGATE

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Abstract: Fluxgate sensors with core made of multiple microwires are analyzed. We show that any study on sensors based on microwires should begin with detailed characterization of the magnetic properties of the wire, as they are dramatically changing within centimeters. Increasing the number of wires increases the sensitivity and lowers the sensor noise; by proper grouping into serioparallel configuration the current and power consumption can be optimized. The achieved sensitivity of 30 mV/µT and noise level is 0.34 nT/√Hz@1Hz for double-wire core with dipolar interaction.

Keywords: orthogonal fluxgate, multiwires, magnetic wires

INTRODUCTION

Miniature precise low-power magnetic sensors are required for many applications including security, position sensing and compass [1]. High linearity, high temperature stability, low noise and low perming are needed. Although significant effort was invested into the development of new magnetic sensors, the only candidates for the precise applications are AMR sensors and fluxgates. Although some authors report magnetoresistors with 10 pT noise, however this is white noise measured at frequencies higher than of 100 Hz. The best noise values for magnetoresistors measured at 1 Hz are 200 pT/√Hz [2,3]. AMR sensors have other precision limits [4] and often cannot meet mentioned requirements, research effort is therefore invested into the miniaturization of fluxgate sensors. Thin low-cost PCB fluxgate sensor can reach temperature offset stability of 0.2 nT/K [5]. The sensor size can be further reduced by using microtechnology [6]. Serious problem is to find proper material for the core of miniature fluxgates. Sputtered and electrodeposit sputtered permalloy do not possess required parameters. Microfluxgate sensor with amorphous sputtered Co85Nb12Zr3 shows promising properties: coercivity of 0.03 Oe, and the permeability of 10 000 was reported in [7]. Orthogonal fluxgates represent another approach to the miniaturization of fluxgate sensors. These almost forgotten sensors [8] reappeared recently; with wire core they have several advantages:
- low demagnetization factor which results in low crossfield error
- low power consumption
- no excitation coil is necessary since the excitation current flows directly through the wire
Sasada introduced fundamental mode of transverse fluxgate [9,10]. Some sensors have lower noise in this mode (which was not the case for our sensors), but in its simple mode fundamental-mode fluxgated exhibit high offset, which is changing with temperature [11]. Sasada offered in [11] an improved mode by periodical changing of the polarity of the excitation bias. This technique requires more complicated circuitry and it is in fact equivalent to fluxgate symmetrically excited by current waveform of complex shape. We may conclude that [11] confirmed that only deep saturation into both polarities guarantee operation with long-term offset stability. However in this study we consider only second-harmonic excitation, which for our sensors gave both higher sensitivity and lower perming compared to fundamental mode.

Single-wire transverse fluxgate sensors of 2nd harmonic type with amorphous cores were studied in [12]. Later it was shown that if the permeability tensor has non-zero off-diagonal component, sensor output can be detected from the voltage induced between the wire terminals, i.e. the fluxgate sensor has no coil at all [13].
Transverse fluxgate sensor can also be manufactured by planar technology [14].

One of the disadvantages of orthogonal fluxgate sensors with wire cores is relatively low sensitivity caused by low cross-sectional area [15]. Multiwire cores can solve this problem. In the first multiwire fluxgate sensor all wires were connected in parallel [16]. The authors of [16] observed non-linear increase of the sensitivity with increasing number of wires for very closely packed wire cores. They...
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