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# 磁通门传感器接口 ASIC 设计

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**摘要:**基于磁通门传感器的二次谐波选择法原理,采用 $0.6\ \mu\text{m}$ ,N-well 标准模拟 CMOS 工艺,设计并实现了磁通门传感器专用集成电路接口(ASIC)。这种集成磁通门接口电路能够减小传统分立元件接口电路的体积,降低系统能耗,满足航天、军事等领域的微型化、低功耗需求。在分析磁通门传感器结构和特点的基础上,完成了激励电路及检测电路的设计,芯片面积为 $2.0\ \text{mm}\times 2.0\ \text{mm}$ ,并采用 HSPICE 对电路各部分功能及其指标进行验证。对与微型磁通门探头集成的电路系统进行了测试,结果表明,当测量范围为 $\pm 90\ \mu\text{T}$ 时,灵敏度可达 $16.5\ \text{mV}/\mu\text{T}$ ;在 $5\ \text{V}$ 电源电压下,其功耗为 $35\ \text{mW}$ 。

**关键词:**磁通门传感器;专用接口电路;CMOS

**中图分类号:**TP212.13 **文献标识码:**A

## Design of fluxgate sensor interface ASIC

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**Abstract:** A fluxgate sensor interface, Application Specific Intergrate Circuits(ASIC) based on the Complementary Metal Oxide Semiconductor(CMOS), is designed and manufactured by a  $0.6\ \mu\text{m}$  DP-DM P-sub brief process and the second-harmonic detection of output voltage. This kind of integrated interface circuit of the fluxgate can decrease the dimension of traditional discrete components, and can reduce the power consumption to meet the requirements for miniaturization and low-power consumption in aviation and military domains. In consideration of the structure and specification of the fluxgate sensor, the excitation and pick-up circuits with the size of  $2\ \text{mm}\times 2\ \text{mm}$  for the sensor are proposed, and the functions and parameters of all parts of the circuits are verified by a HSPICE. The experiment results of the circuit system with the fluxgate sensor show that the circuit can offer a sensitivity of  $16.5\ \mu\text{V}/\text{nT}$  and the linear ranges of  $\pm 90\ \mu\text{T}$ . With a voltage supply of  $5\ \text{V}$ , the total power consumption of the circuit is as low as  $35\ \text{mW}$ .

**Key words:** fluxgate sensor; ASIC; Complementary Metal Oxide Semiconductor(CMOS)

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## 1 Introduction

Fluxgate sensors are vector magnetic field sensors used widely in measuring weak magnetic fields<sup>[1]</sup>. They are characterized by high resolutions and wide measurement ranges, and are suitable for high-speed systems for reliable, inexpensive and durable properties. Since the first fluxgate sensor appeared in the early 1930s, they have been still used in many aspects of science study, such as the research of geomagnetism, exploration, military fields, and measurements of magnetic space. In recent years, with the development and popularization of semiconductor technology, especially MEMS technology, the design principle of many sensors has been transformed from conventional fabrication processes to the processes based on semiconductor technology, which benefits from advantages such as miniaturization, systematization, integration and reliability<sup>[2-4]</sup>.

The design of the fluxgate interface ASIC is introduced in this paper, and the simulative and experimental results of the circuit are given in the end.

## 2 Structure of fluxgate sensors

The fluxgate sensor is based on the non-linear  $B-H$  curve of ferromagnetic materials. Excitation coils drive the core periodically into saturation. Pick-up coils located on the same core measure changes of the magnetic flux inside the core via the induced voltage. This sensor exhibits the higher harmonics of the excitation frequency due to the non-linear  $B-H$  behavior. The even harmonics ( $2f, 4f, \dots$ ) in particular depend on the external magnetic field, which is applied parallelly to the axis of the core. Soft magnetic materials like nickel-iron alloy, with a

small hysteresis, low values of saturation magnetization and high values of relative permeability, are commonly used for the core.

The fluxgate sensor shown in Fig. 1 consists of two parallel core supports. The sensor is used in classical voltage output. Ferromagnetic core is placed in the slot of each core support that also serves as a bobbin for the excitation coil. The pick-up coil is located in the outside of the excitation coil. For the symmetry is of great importance, the excitation coil is wound on a toroid winding-machine. The excitation coil is used to excite the magnetic core and thereby to change the magnetic susceptibility of the core. A pick-up coil is made to compass the excitation coil and to pick up leakage flux from the core. Ideally, this flux is only produced when the core is exposed to an external field<sup>[5]</sup>. When the excitation coil is driven by a sine voltage, the out signal from the pick-up coil can detect which ingredient of the second-harmonic is directly proportional to the external magnetic field.

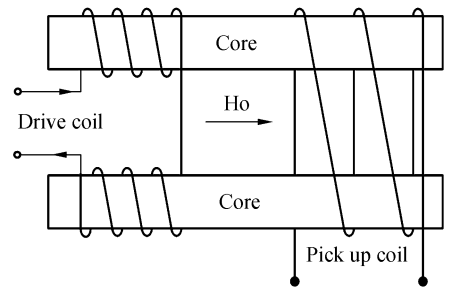


Fig. 1 Structure scheme of fluxgate sensor

## 3 Interface circuit design of fluxgate sensors

The interface circuits generate the excitation voltage, detect the even harmonics of output voltage of the fluxgate sensor and operate the sensor in open-loop. So the include driving and pick-up circuits. The block diagram of the fluxgate interface circuit is shown in Fig. 2.

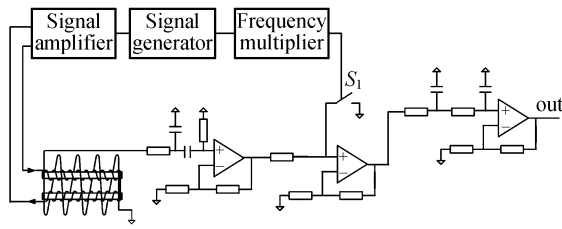


Fig. 2 Block diagram of fluxgate interface circuit

There are several typical excitation methods. Because sine waveform has a steady signal amplitude and it can avoid the distribution of other harmonics (here we select it as driving waveform). The driving circuit can generate a sine voltage with a frequency of 1.165 kHz. The pick-up circuit has the functions of excluding noise signals and extracting the second harmonic. All harmonic of fluxgate has the feature of phase sensitivity<sup>[6]</sup>. Therefore, filtration and phase-sensitive demodulation are the main functions of pick-up circuits. In these circuits, the band filter is adopted for filtrating. At first, the signal is transmitted to the switch-mode phase-sensitive demodulation. Then it passes the low-pass filter; finally output signal is obtained. As a result, the output signal is directly proportional to the external magnetic field<sup>[7]</sup>.

The whole circuit has been simulated, based on the model of 0.6  $\mu\text{m}$  DPDM P-sub Brief Process. The voltage supply was 5 V. Fig. 3 shows the results of simulation.

The signal of Sin out is the excitation wave from the excitation circuit. The signal of Sensors out is the simulated wave of the model of the sensor probe. The Multiplier out is the output signal of the multiplier. The PSD out is the output signal from the phase-sensitive demodulation. The U out is the final signal. From Fig. 3 we can see that the system tends to balance in 0.014 s.

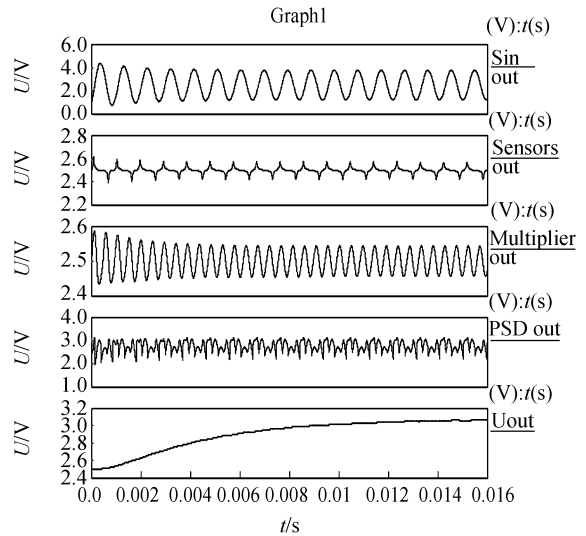


Fig. 3 Simulative results of full system

This interface circuit includes 396 MOS transistors, 13 operation amplifiers, 1 boosting reference current resource, 1 comparator and 1 multiplier. It has a sine wave generator, a phase shifter, a frequency multiplier, a band filter, a low-pass filter and phase-sensitive demodulation device. Fig. 4 is the practical picture of the fluxgate interface circuit.

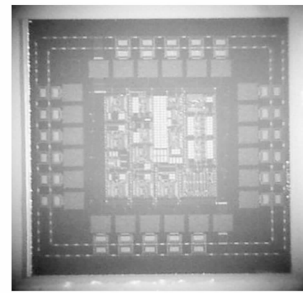


Fig. 4 Practical picture of fluxgate interface circuit

The system is built on a printed circuit board. External devices like resistors and capacitors are used for adjusting some bias levels. The sensor and the ASIC are connected with shielded cables of non magnetic material. The experimental set-up consists of a solenoid, a current source and a digital voltmeter. Fig. 5 shows the output signal of the system for magnetic fields between  $-90 \mu\text{T}$  and  $+90 \mu\text{T}$ .

The data of the system is summarized in Tab. 1.

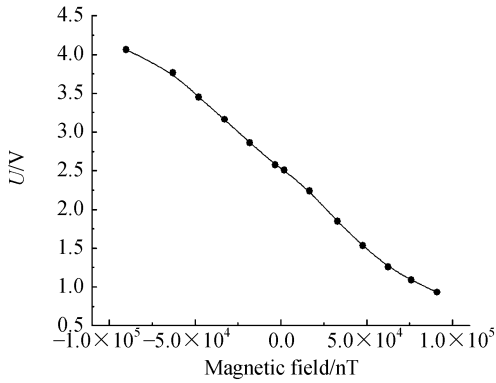


Fig. 5 Output signals of system vs magnetic fields

Tab. 1 Data of fluxgate interface ASIC

Voltage supply	5 V
Excitation frequency	1.165 kHz
Measurement range	$\pm 90 \mu\text{T}$
System sensitivity	16.5 mV/ $\mu\text{T}$
Power consumption	35 mW
Area	2 mm $\times$ 2 mm

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## 4 Conclusions

In this paper, a fluxgate sensor interface ASIC is designed based on the principle of second-harmonic detection of the output voltage, and the simulation and the layout of the whole circuit are completed. The experiment results of system with the fluxgate sensor show that the circuit offers a sensitivity of 16.5  $\mu\text{V}/\text{nT}$  and the linear ranges of  $\pm 90 \mu\text{T}$ , which indicates that the interface ASIC is suitable for measuring magnetic fields with the probe of the fluxgate sensor.

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● 下期预告

## 掩模偏转方向对硅尖形状的影响

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为制备高纵横比的纳米硅尖,研究了掩模的偏转方向对硅尖形状的影响。设计了硅尖制备的工艺流程,采用 KOH 溶液湿法各向异性腐蚀(100)单晶硅的方法制备硅尖,根据实验结果和{411}晶面模型,分析了硅尖侧壁的组成晶面,讨论了掩模偏转方向对硅尖形状的影响,得到了制备高纵横比纳米硅尖的工艺参数。实验结果表明:当腐蚀溶液浓度和温度一定时,正方形掩模的方向并不影响快腐蚀晶面的类型,利用正方形掩模的偏转,可以制备出八面体和四面体的硅尖。当正方形掩模边缘沿 $\langle 110 \rangle$ 晶向时,在 78 °C、浓度 40% 的 KOH 溶液中腐蚀硅尖,经 980 °C 干氧氧化 3 小时进行削尖,可制备出纵横比 $>2$ 的八面体纳米硅尖阵列,硅尖侧壁是由与(100)面夹角为 76.37°的{411}晶面组成。