Integrated Magnetic Fluxgate Sensor using Costas Loop based Detection Circuitry

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I. Project Objective

The main objective of this project is to analyze a new output signal processing technique for the fluxgate sensors, which are used for magnetic field measurements. In the next stage of the project we would like to post-fabricate the sensors over the sensing chip.

There has been a large demand for the integrated fluxgate sensors[1] for the bio-medical applications (like EKG and ECG), defense applications (submarine detections), navigational application etc. Integrated sensors offer better sensor sensitivity and low power consumption, a very crucial factor for the navigational and defense applications, where these sensors are extensively used.

To fabricate these sensors on a planar substrate, quasi three dimensional micro-machining techniques, which are compatible to CMOS process are required. At UC we have developed UV-LIGA based CMOS compatible fabrication techniques and had demonstrated integrated fluxgate sensors over the silicon substrate [2], [3].

II. Background and Significance

In the conventional fluxgate sensors, discrete components are used for the sensor realization [4], which increases the sensor dimensions and the excitation current requirements in the Ampere (~1.5 A) range. Because of the current limitation of the CMOS circuit, it is impossible to fabricate CMOS based integrated excitation and sensing circuit for these sensors . By using integrated sensor approach and modified core geometry, this current requirement can be reduced to mA range and hence CMOS based excitation and read-out circuitry can be realized.

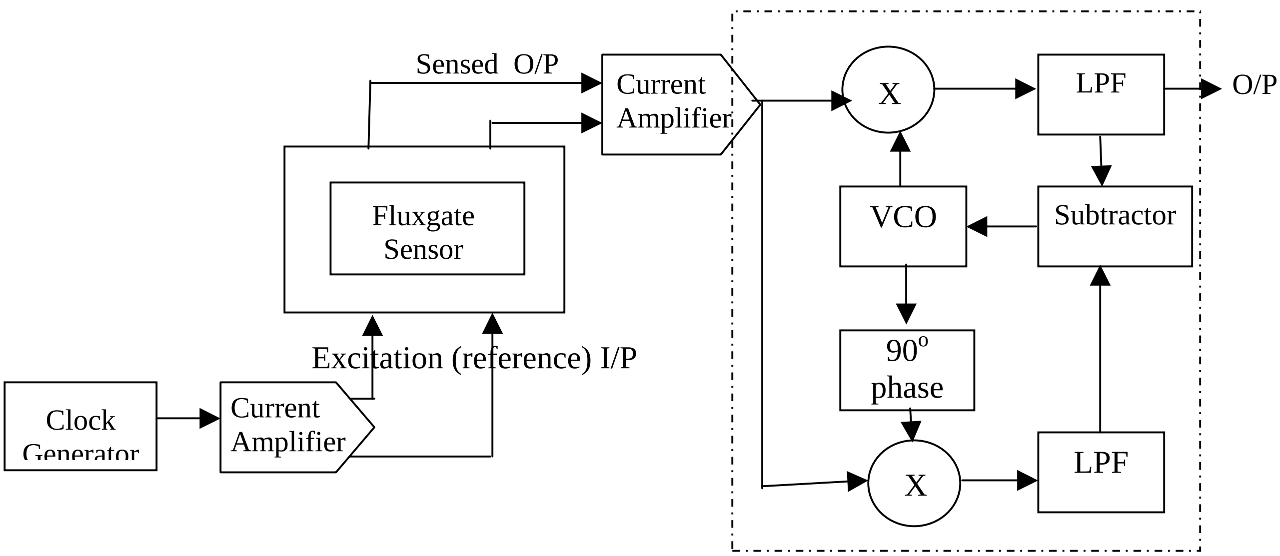
III. Theory of Operation

In the fluxgate sensor, for external magnetic field measurement, it is compared with an excitation field which is used as a reference. If the excitation field has a frequency ***fo***, and the sensor is exposed to the external magnetic field, sensor output is a DSB (double sideband modulated) modulated signal and the second harmonic of the sensor output (***2fo***) is proportional to the external magnetic field.

In the conventional sensing circuit, this second harmonic is extracted by multiplying the sensor output with twice of the reference excitation signal and passing the output through a low pass filter. The basic assumption involved in this demodulation technique is that, that there is a constant phase difference between the sensor output and the reference excitation signal. This assumption is not very true for fluxgate sensors as in this case sensor output is generated by a variable inductor (whose inductance is changed by the excitation signal) and hence the phase difference between the reference signal and the sensed output is not fixed.

So in the proposed circuit, for the first time we are using costas loop based receiver, which automatically takes care of this variable phase difference by extracting the control signal of the voltage controlled oscillator (VCO) from the difference of in-phase and quardature-phase components. This VCO output is used as a reference signal for the extraction of the second harmonic of the sensor output.

Block Diagram



Costas Loop

IV. Schedule

Task	Duration	Completion date
circuit design and schematic entry	10 days	08/15/01
initial simulation using schematics	5 days	08/20/01
cell layout (overlap with simulation)	11 days	08/31/01
block layout	3 days	09/03/01
block simulation with layout capacitance	3 days	09/06/01
top-level layout	3 days	09/091
final simulation	3 days	09/12/01
Submission to MOSIS		09/20/01

V. Simulation Software and the Initial Results

Tanner tools have been used in this project for simulation and layout (S-Edit and T-Spice for simulation and L-Edit for the layout). We have already simulated the excitation and sensing circuit and now we are working on the simulation of the whole sensor (magnetic sensor and the sensing circuit) in spice by using the non-linear core models provided by the Intusoft and the final layout.

VI. Sensor Testing & Characterization

In the first phase of the project, excitation and sensing circuitry will be tested by the help of external sensor module (excitation and the sensing ends will be connected to external bonding pad for this purpose) and in the second phase post fabrication will be done on the unpacked modules.

VII. Estimated project size

AMI 1.5 micron ABN process will be used in this process. Since we are also planning to post fabricate the sensor over the chip (1.5 mm X 1.5 mm), desired chip size is 2.2 mm X 2.2 mm. Rest of the area will be used for the sensing and excitation circuitry. Main primary cells involved in this project are as follows:

- Schmitt trigger based astable multi-vibrator for clock.
- Current Amplifier
- Phase sensitive Detector
- Integrator or low pass filter
- Voltage controlled Oscillator

VIII. References

[1]. Ripka, P., Review of fluxgate sensors, *Sensors and Actuators A*, Vol. 33, 1992, pp. 129-141.

[2]. Liakopoulos, Trifon M.; Ahn, Chong H., A micro-fluxgate magnetic sensor using micromachined planar solenoid coils, *Sensors and Actuators A: Physica,l* Volume: 77, Issue: 1, September 28, 1999, pp. 66-72

[3]. Rub, Rahman A., Gupta Sukirti, Chong Ahn H., High Directional Senstivity of micromachined magnetic fluxgate sensors, *Transducers' 01 Eurosensors XV*, June 10-14th, 2001 Munich, Germany, pp. 148-151.

[4]. Kejík, Pavel; Chiesi, Laurent; Janossy, Balazs; Popovic, Rade S., A new compact 2D planar fluxgate sensor with amorphous metal core, *Sensors and Actuators A: Physical*, Volume: 81, Issue: 1-3, April 1, 2000, pp. 180-183.