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Fully Integrated Sensor Interface Circuits

A Thesis

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STATEMENT

This dissertation is submitted to Ain Shams University for the degree of Master of Science in Electrical Engineering (Electronics and Communications Engineering).

The work included in this thesis was carried out by the author at the Electronics and Communications Engineering Department, Faculty of Engineering, Ain Shams University, Cairo, Egypt.

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Abstract

MEMS inertial sensors are considered one of the most appealing types of sensors that have been adopted recently in many applications. Extensive research efforts have been invested either to enhance the specifications of the MEMS device or the interface circuitry to allow the competency of these sensors to wide applications requirements. These applications vary from high-end applications requiring very aggressive noise specification with relaxed power and area specifications to consumer applications where power and area specifications are highly appreciated

This thesis aims to introduce the usage of continuous-time sigma delta modulators in MEMS force feedback sensing through a design procedure based totally on continuous-time domain analysis.

It starts with introduction about MEMS inertial sensors and the motivation to use these types of sensors. Next, it presents an overview on MEMS inertial sensor concepts, structures and types. Also an introduction about the basics of sensor interface systems is demonstrated with focusing on the differences between open loop and closed loop systems.

Afterwards, a more elaborate view is highlighted on the sensor interface systems based on closed loop (Force feed-back) identifying system main blocks. Also an overview on sigma delta modulator concepts, types and their employment in force feedback sensing systems is presented. A design procedure is proposed to design electro-mechanical continuous-time sigma delta modulators.

Different implementation topologies for continuous-time sigma delta were shown. The proposed design was implemented using 0.18µm HVCMOS technology.

Keywords: MEMS sensors, MEMS, Inertial Sensor, Accelerometer, Gyroscope, Electro-mechanical modulator, Continuous-time Sigma Delta modulator, Force-Feedback

Summary

MEMS inertial sensors are considered one of the most appealing types of sensors that have been adopted recently in many different applications: consumer, industrial and military. With its wide field of applications, the interface circuitry for these sensors became more challenging to design to achieve the required specifications.

This thesis aims to introduce the usage of continuous-time sigma delta modulators in MEMS force feedback sensing. A work flow for continuous-time electro-mechanical sigma delta design that is based totally on continuous-time domain analysis is introduced. Finally, an ASIC implementation based on 0.18µm HVCMOS technology is implemented to verify the proposed architecture.

The thesis is divided into five chapters including lists of contents, tables and figures as well as list of references.

Chapter 1
It includes thesis introduction and motivation for MEMS inertial sensors and their interface circuitry. This chapter ends with the thesis outline.

Chapter 2
This chapter presents an introduction about MEMS inertial sensors and their interface circuits. First, we will give a quick overview on MEMS technology. Then we will follow it by introducing the concepts of inertial sensors operation, their types and their different applications. Finally, the sensor interface system is presented while highlighting the differences between open loop and closed loop sensing.

Chapter 3
In this chapter, a more elaborate view will be introduced on the force feedback sensing system with insight for its main building blocks. Then, an introduction will be presented for sigma delta modulators explaining its concepts, architectures, types and their employment in force feedback inertial sensor sensing forming what is known as the electro-mechanical sigma delta modulators. Finally, we will present a summary for existing research and industrial sensors.

Chapter 4
In the start of this chapter, we will present the linear model of the electro-mechanical sigma delta modulator. Following that, we will introduce the proposed work flow used to design the continuous-time electro-mechanical modulator comparing it with previously used flows. Then we will apply the proposed flow in designing an electro-mechanical sigma delta modulator for gyroscope interface.

Chapter 5
This chapter starts by a survey on the different implementation techniques for continuous-time sigma delta modulators. Then, it presents the implementation of the proposed architecture based on 0.18µm HVCMOS technology accompanied with achieved results.

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