Design of Low-Cost Smart Accelerometers

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1. Introduction

The goal of this Project is to design a low-cost smart accelerometer, making use of a piezoelectric element as basic sensing material, and adding a mixed-mode conditioning circuit. This synthetic goal, consist of a number of combined objectives, which must be achieved:

1. Development of calibration, compensation and frequency range extension techniques of basic sensing elements made typically of piezoelectric ceramics.
2. Development and implementation of novel signal processing techniques as they apply to the above mentioned sensors for the estimation (parametric, non-parametric, blind,..) of mechanical systems, and excitation signals (impact). Both multiple and single sensor applications will be considered.
3. Adaptation or development of new calibration techniques, to make the above mentioned methods possible
4. Implementation of the preceding techniques on a physical device consisting of a basic sensing element (piezoelectric) and a mixed mode conditioning circuit
5. Validation of the so designed sensors in a significant and varied number of applications.

The project has been active for two years now, and is carried out by three different research teams from the Public University of Navarre, and the Polytechnic University of Catalonia. The results shown in the next section correspond mainly to the accomplishments of the UPNa teams

2. Results and Discussion

Figure 1 shows a general block diagram of the different systems and task that need to be designed within the Project framework

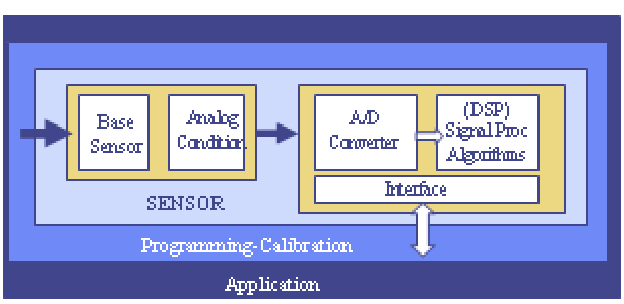

Figure1. Smart Sensor Block Diagram

The base sensor selected, based on a previous experience of the team, corresponds to a low cost piezoelectric device Murata PKGS, with low sensitivity and high bandwidth [1]. To cut it short, the hardware-software that will process the signal coming from the sensor, should be capable not only to correct and compensate the sensor drifts, but also to counteract the high frequency peaking resonance, extending the useful bandwidth of the device beyond it. Figure 2 shows an example of the raw signal given by the sensor+conditioner, under an impact, and the compensated signal after a deconvolution algorithm.

In addition, and depending on the application, the sensor should be able to provide processed measurement parameters. To achieve this goal, a combination of hardware techniques and signal processing algorithms have to be used. The complete systems will be integrated on a chip (ASIC), and on commercial DSPs, depending on the target application.

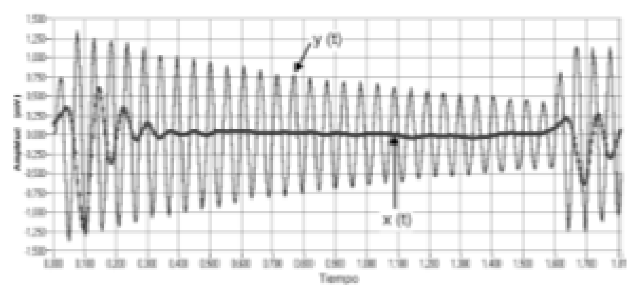

Figure 2. Typical Sensor Signal, before and after deconvolution

The accomplishment of the project, as of to date, can be summarized as follows:

Sensor Characterization:
A procedure has been developed, and is currently being improved, to characterize sensor sensitivity in a wide frequency range. A combination of impulsive and vibration techniques is used. The method will be used during the calibration process.

Analog Conditioning
A charge amplifier has been designed to cope with a specific limitation of the application: the need to provide current common mode rejection,

maximizing signal to noise ratio. This is required for applications where the sensor needs to be placed on metallic surfaces, with potential capacitive coupling for electro-static discharges. Some innovative designs have been proposed [2-4]. Both discrete and fully integrated versions for the charge amplifier have been implemented and tested.

Analog to Digital Converter.
An incremental architecture has been implemented on silicon, and is currently being tested. It has been specifically designed for sensor application such as that described in this paper. The design specifications are 12 bits with a sampling frequency of about 100kHz [5]. A new version is under development to achieve 14 bits of resolution and a sampling frequency of more than 200 kS/sec., which are more convenient for the sensor at hand.
The basic building blocks are implemented with a novel design that leads to operation with very-low supply voltage and at the same time efficient power consumption. These cells are called Super Class-AB [6]. Moreover several strategies at algorithm level on the incremental converter have been incorporated in order to fully exploiting the performance of such cells and minimizing second order effects. The converter can operate with a supply voltage of ±1.35V and a static power consumption of 3.5mW.

Signal Processing-Blind Deconvolution
There are two basic approaches to process the digitized signal coming from the sensor. The first one assumes no prior knowledge of the “system response”, which accounts for sensor response plus effects due to impedances, both mechanical and electrical. Then, blind techniques are mandatory. First, regularization steps are applied to compensate for singularities such as those due to noise or resonance peaking (i.e. poles). Then, redundant information must be used to deconvolve the incoming signal which represents the acceleration. In our case, we are mostly interested in impacting (non-repetitive) signals and thus, such redundant information can only be obtained through multichannel acquisition. Details of one the methods developed can be found in [7]

The second approach makes use of system information obtained through the sensor calibration process. Due to the requirements of wide bandwidth a specific calibration combining impact and vibration measurements needs to be designed. .From those measurements, and resorting on only regularization methods, impacting signals can be measured.

Sensor Packaging
A sensor casing is being designed to host the sensor and ASIC, so that the sensor can be electrically isolated and protected, without the introduction of interfering vibration modes.

3. Conclusion

We have described in this paper the main objectives accomplished in a Project whose aim is to design a low-cost, wide-band accelerometer for impact applications

4. References

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