Development of a Digital Lock-In Amplifier to Measure Photoconductivity in Photorrefractive Materials

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Abstract
A digital Lock-in Amplifier is the object of this Research Project, to be used as the main element in a larger project aiming the development of a dedicated Photoconductimeter for the research on Photoconductive materials and particularly for the characterization of Photorefractive Crystals. The presently proposed frequency tuned synchronous Lock-in Amplifier using FPGA is expected to allow reliably extracting the useful signals out from the noisy environment, even using weak light sources, to be further processed for materials characterization in the intended Photoconductimeter.

Key words:
Photosensitive Materials, Synchronous Detection, Embedded Systems.

Introduction

Photorefractive crystals are electro-optic and photoconductive materials that are particularly useful for 3D optical memories, holographic recording and many application concerning the recording of a spatially modulated pattern of light. Their photoconductivity is an essential characteristic of these materials and arises from the presence of photoactive centers in the forbidden Band Gap (BG) where electrons (and/or holes) may be excited from into the Extended States (Conduction Band for electrons and Valence band for holes). The knowledge of the position and density of these photoactive centers in the BG is of the highest relevance for adequately handling of these crystals and photoconductivity in the transverse (photocurrent measurement and illumination beam directions being perpendicular to each other) configuration has been shown to be an excellent tool for such an objective, provided experimental data to be adequately processed.

The main difficulty here is the low photocurrent (in the picoamperes range) produced by even moderately large (in the mW/cm² range) illumination. A preliminary setup based on almost monochromatic LEDs with different wavelengths ranging from the near IR to near UV was already developed and successfully used for photorefractive characterization.

Accordingly, we are now developing a digital Lock-in Amplifier as a first step towards a much better performing electronics to improve photoconductivity measurement in photorefractive materials.

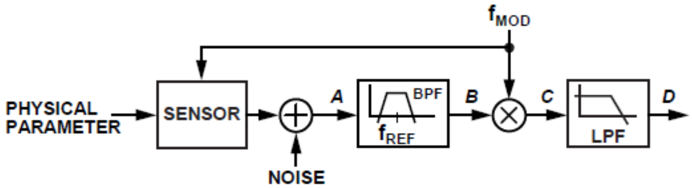

Figure 1. Synchronous demodulator used to measure a physical parameter, [1].

Lock-in amplifiers are synchronous demodulators (Fig.1) that enable the accurate measurement with small AC signals in the presence of noise interference in much larger orders of magnitude than the signal amplitude. Synchronous demodulators use of the phase sensitive detection (PSD) to improve signal extraction from noise with different phases from the one of the reference signal.

Results and Discussion

For such a purpose was used an Altera FPGA MAX 10 device, the project flow is described by Simulink System modelling and simulation, design the soft-core NIOS II hardware including RAM memory, Digital to Analog Converter (DAC) and external high resolution Analog to Digital Converter (ADC) peripherals, NIOS II software as embedded operational system, firmware in Verilog HDL and Altera DSP Builder system modeling for digital filters implementation.

The main results include simulation of proposed device under different noise parameters, specification of filter order and bandwidth, and signal recovery analysis. These simulation results are important for the design specification. In addition, the soft-core Nios II design was completed for all hardware peripherals.

Conclusions

The presently projected amplifier is the main element to be incorporated to a much more performing instrument for photorefractives characterization. Such an improved instrument will be carried out as the author's undergraduate Final Project.

Acknowledgement

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[1] Analog Devices. “Synchronous Demodulator and Configurable Analog Filter: ADA2200”. Rev. 0, **2014**.