Ph.D. in Information Technology: Thesis Defenses

March 22nd, 2019

Room Beta – 9.30 am

Alessandro COMINELLI - XXXI Cycle

"High-Speed, Low-Distortion Solutions for Time-Correlated Single Photon Counting Measurements"

Advisor: Prof. **Ivan Rech**

Abstract:

The goal of this work is to explore novel solutions to speedup Time-Correlated Single Photon Counting experiments, avoiding at the same time the trade-offs that affects multichannel systems proposed so far.

First of all, this thesis work proposes a novel solution to keep distortion around zero, paving the way to a significant speedup of TCSPC experiments, up to almost an order of magnitude using a single measurement channel.

A novel router-based readout architecture is also presented to maximize in all respects the performance of large multichannel systems: a detector array is shared with a limited set of high-performance time-measurement circuits, while a smart routing logic dynamically connects the two parts. The proposed architecture permits at the same time to maximize speed and to choose the best-suited technology for the design of different parts of the system.

Cristiano Rocco MARRA – XXXI Cycle

"Time-Switched Frequency-Modulation for Low-Offset-Drift, Wide Range, Fully Integrated 3-axis MEMS Accelerometers"

Advisor: Prof. **Giacomo Langfelder**

Abstract:

In state-of-the-art MEMS accelerometers, a marked trade-off between maximum full-scale-range and offset stability arises. This issue is limiting their adoption in next generation high-stability applications, as mixed reality and inertial navigation.

This thesis describes the working principle, the design, and the characterization of a three-axis frequency modulated MEMS accelerometer, in which the differential frequency readout is performed through a novel time-switched approach. The proposed methodology is based on a double sampling of the oscillation frequency of a single resonator, consecutively biased in two different configurations in time. This technique enables to avoid offset thermal drift contributions typical of differential resonant accelerometers based on two distinct resonators with unavoidable mismatch in the temperature coefficient of frequency. The MEMS system is designed from the sensor to the digital output demonstrating the feasibility, with the proposed approach, of a low-power, low-noise, consumer-grade system-in-package capable to overcome the aforementioned trade-off.

Davide PORTALUPPI – XXXI Cycle

“Microelectronics and Instrumentation for Single-Photon Imaging”

Advisor: Prof. **Franco Zappa**

Abstract:

In recent years, an increasing number of applications have emerged which can significantly benefit from the ability of detecting fast and faint light signals, requiring sensitivity down to the single-photon level and sub-nanosecond resolution in determining the arrival time of each photon; these requirements are usually paired with the necessity of acquiring high frame rate, two- and three-dimensional movies of the scene under analysis. These applications range from industrial and automotive uses, such as object or obstacle recognition, road safety, distance-resolved ambient surveillance, to biomedical applications like fluorescence lifetime microscopy or time-resolved spectroscopy, study of physics of materials, and even to consumer applications such as gaming and gesture recognition.

This Ph.D. research aimed at developing an image sensor and camera system capable of acquiring such videos, employing the Time-of-Flight (TOF) technique to obtain per-pixel distance information. The developed camera is based on SPAD (Single-Photon Avalanche Diode) detectors, which offer very high sensitivity, ruggedness, room-temperature operation, and can be fabricated within standard CMOS processes, allowing their monolithic integration with front-end and processing electronics. This work started from the design of a "smart pixel" composed of multiple detectors and shared electronics, capable of time-resolved detection and counting of incoming photons, with the ability to reject optical signals outside of temporal regions of interest and flexible data readout options to allow the user to maximize data throughput depending on the specific application. The developed pixel structure was then built into a full image sensor, which was fabricated in a 0.18 Âµm BCD (Bipolar-CMOS-DMOS) technology, and then integrated into a compact camera system, using an FPGA to interface the custom sensor to a PC and pre-process the raw sensor data. System characterization shows remarkable noise performance, close to state of the art for SPAD detectors, and state of art Photon Detection Efficiency (PDE) for “thin” SPAD devices, exceeding 60% PDE at 500 nm wavelength. The image sensor shows a single-shot timing accuracy of 60 ps rms (equivalent to about 9 mm depth accuracy), which can be increased by performing repeated distance measurements.

PhD Committee:
Prof. **Federica Alberta Villa**, DEIB
Prof. **Daniele Faccio**, University of Glasgow
Prof. **Lucio Pancheri**, Universita' di Trento