Ph.D. in Information Technology
Thesis Defenses

September 5th, 2023
at 09:30
Room ”Alpha” and online by Teams

Andrea Giudici– XXXV Cycle
High-speed, high-fidelity solutions for single photon counting and timing applications
Supervisor: Prof. **Ivan Rech**

Abstract:

The growing need for larger transduction forces to be applied by piezoelectric actuators in MEMS devices leads to the increase of their footprint, capacitance and voltage level. This is in trade-off with low power dissipation needs, and thus new driving circuits shall be conceived. In this thesis, a two-output, single-inductor, H-bridge based driver is presented, with charge-recovery technique. The linear time-invariant (LTI) model is obtained using state-space averaging technique and linearization. A state-space based control for an energy-recovery switching-driver is presented, considering its multivariable, non-linear and discontinuous nature. To track a large-dynamic reference (50-100 V, 100-200 Hz waveform), four driver working-modes and therefore plants are needed. For each, a triplet of LQR controllers is designed, linked through linear gain scheduling. A Discontinuity Handler is included to determine the correct instant of phase-change. The closed-loop system is implemented and tested through realistic behavioural models, tracking the sawtooth signal with 2.9mV RMS error for the 10%-90% of the full-scale. Finally, the driver core is implemented at transistor level. Dedicated level-shifter and gate-driving circuits are designed. Open-loop tests are carried out at different actuators voltage levels to determine the driver power consumption. Overall, to drive two 50 nF piezoelectric actuators with a 40 V peak, 120Hz sawtooth, typically used in MEMS micromirrors, the energy dissipated is equal to 120μJ, which is 50% less than state of the art implementations, with a reduced number of external passive components.

Matteo Gianollo- XXXV Cycle
Low power driver for PZT MEMS actuators
Supervisor: Prof. **Giacomo Langfelder**

Abstract:

Single Photon Avalanche Diodes (SPADs) find diverse applications spanning remote sensing, biological studies, quantum key distribution, and non-invasive medical imaging. For example, in satellite Light Detection and Ranging (LiDAR) applications, they enable the extraction of crucial atmospheric parameters through the analysis of backscattered photon counts. In addition it has been demonstrated that it is possible to perform oceanic sub-surface analysis where almost half of the world oxygen-carbon exchange processes occur. However, in order to carry out these

measurements, an electronic acquisition system that is able to operate in multiple real scenarios is required: this condition translates into having a system characterized by a high dynamic range. To obtain a high dynamic range it is possible to use simultaneously multiple highly optimized SPADs in a matrix structure. Managing a large array of photodetectors involves a considerable miniaturization effort and reduction of the power dissipated by the front-end and data extraction electronics.

Within the biological field, SPADs' exceptional temporal response proves invaluable for imaging systems focused on protein-protein interaction investigation, notably through techniques like time-correlated single photon counting (TCSPC). Unfortunately, TCSPC's repetitive process hampers its speed, despite efforts to accelerate it through multi-channel integrated designs in the past decade. However, existing solutions haven't yielded proportional speed gains with increasing channel count, limiting the advantages of the multi-channel approach.

The thesis work aims to develop two architectures for the two applications mentioned above: a first integrated architecture capable of obtaining a high dynamic range while a second integrated architecture capable of overcoming the speed and data management limits of current implementations to reduce the acquisition time of the TCSPC technique.

PhD Committee

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