

A MULTI-CHANNEL MCP-PMT BASED READOUT INTEGRATED CIRCUIT FOR LIDAR
APPLICATIONS

By

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ABSTRACT

Photon counting techniques are becoming more critical in fields such as LiDAR, high energy physics (HEP), and positron emission tomography (PET). For space-based aerosol-cloud-ocean (ACO) LiDAR, the total aggregate photon flux signal has a very high dynamic range, from a single-photon up to giga-photons per second for a single channel. This dissertation focuses on the design of a multichannel, photon counting readout circuit that can interface with MCP-PMTs for high dynamic range, space-based LiDAR applications.

Chapter 2 presents the conventional current mode approach that has been employed to realize a photon counting circuit. A transimpedance amplifier, a 6-bit delay line based time to digital converter (TDC), and an 8-bit ring oscillator based time to digital converter were designed and implemented in AMS' 350nm SiGe BiCMOS process. Measurement results showed that the transimpedance amplifier has a gain of 14 K Ω and a bandwidth of 96 MHz. Similarly, the delay line based TDC and ring oscillator based TDC have a timing resolution of 530 ps and 534 ps respectively. The resolution of the ring oscillator based TDC can be tuned between 534 ps to 691 ps, thus making it useful for various applications. The performance of the photon counting circuits were improved using the proposed circuits that are presented in Chapter 3. A multi-channel current mode photon counting circuit and a high speed current mode summing circuit were designed, simulated, and fabricated in a TowerJazz's 180 nm SiGe BiCMOS process. The measurement results convey that the proposed photon counting circuit can detect current pulses of 5ns FWHM pulse width at amplitudes of 24 μ A to 1.3 mA. The photon counting circuit was also tested for high speed and was able to detect signals with a 2 ns pulse width. A high speed current mode summing circuit also detects the pulse width of 5 ns, but with a lower input current range

of 100uA. The proposed photon counting circuit can be used as the front end readout for long range LiDAR applications.

The key contributions in this dissertation includes: 1) Design of a wide input range, high speed, current mode readout circuit; 2) Design of a high speed current mode summing circuit; 3) Development of radiation hard circuits and layouts; 4) Investigation and improvement of existing TDC architectures with variable timing resolution; 5) Implementation of extensive testing techniques to validate the results.

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To my parents and my sister

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EDUCATION

- Ph.D. in Electrical Engineering, University of Nevada, Las Vegas, USA December 2020
- M.S. in Computer Engineering, Villanova University, USA December 2015
- B.Tech. in Electronics & Communication Engg, Amrita Vishwa Vidyapeetham, India May 2012

TECHNICAL SKILLS

EDA tools: Cadence Virtuoso, ModelSIM, Xilinx ISE, Altera

HDLs: Verilog, VHDL

Packages/Simulation Tools: MATLAB, Spectre, NI Multisim, LTspice, Labview, and HFSS

Programming Languages: C/C++

Printed Circuit Board design and Layout tool: Eagle

Assembly level programming language: PIC, 8085, 8086

EXPERIENCE

- Research assistant, University of Nevada, Las Vegas, USA August 2016-December 2020
- Research Assistant, Villanova University, USA August 2013 – December 2015
- Electrical Engineering Intern, Florida Research Instruments, FL May 2014 - August 2014
- Research Associate, Amrita University, India August 2012 - July 2013

PUBLICATIONS

- **Namboodiri, S. P.**, Arteaga, G., Skelly, J., Mata-carlos, F., Roy, A., and Baker, R. J., "A Current-Mode Photon Counting Circuit for Long-Range LiDAR Applications," in the proceedings of IEEE 63rd International Midwest Symposium on Circuits and Systems, August 9-12, 2020.
- Vinayaka, V., **Namboodiri, S. P.**, Roy, A., and Baker, R. J., "Segmented Digital SiPM," in the proceedings IEEE 62nd International Midwest Symposium on Circuits and Systems, August 4-7, 2019
- Mellott, J. K., Monahan, E., Vinayaka, V., **Namboodiri, S. P.**, Roy, A., and Baker, R. J., "Variable Fast Transient Digitizer," in the proceedings of IEEE 62nd International Midwest Symposium on Circuits and Systems, August 4-7, 2019
- V. Vinayaka, **S. P. Namboodiri**, S. Abdalla, B. Kerstetter, F. Mata-carlos, D. Senda, J. Skelly, A. Roy, and R. J. Baker, "Monolithic 8x8 SiPM with 4-bit Current-Mode Flash ADC with Tunable Dynamic Range," in the Proceedings of GLSVLSI '19: 2019 Great Lakes Symposium on VLSI, May 9-11, 2019, Tysons Corner, VA, USA. ACM, New York, NY, USA
- **S. P. Namboodiri**, H. Zhu, L. Khuon, J. Van der Spiegel and R. Caverly, " Low Cutoff Frequency Integrated Neural Amplifiers Using Symmetrical Pseudo Resistors ", in the Proceedings of 42nd Annual Northeast Bioengineering Conference, Binghamton, NY, April 5-7, 2016.

PROFESSIONAL MEMBERSHIP

- IEEE- Student member
- Tau Beta Pi- The Engineering Honor Society