Basics of Hardware for Medical Applications: Time-Domain Diffuse Optics (TD-DO).

1.Introduction

Time-domain diffuse optics (TD-DO) is a technique within functional near-infrared spectroscopy that investigates how light propagates through highly scattering media. In the red to near-infrared wavelength range, biological tissues are relatively transparent to light, which enables the examination of deeper tissue layers and supports a broad spectrum of in vivo applications and clinical research.

In this method, a short light pulse (typically less than 100 picoseconds) is introduced into the medium. The injected photons undergo multiple scattering and absorption events, and the scattered photons are detected at a certain distance from the light source. The arrival times of these photons are recorded and used to construct a histogram that represents the distribution of photon time-of-flight (DTOF), also known as the temporal point spread function. Compared to the original pulse, the DTOF is delayed, attenuated, and broadened due to interactions within the medium.

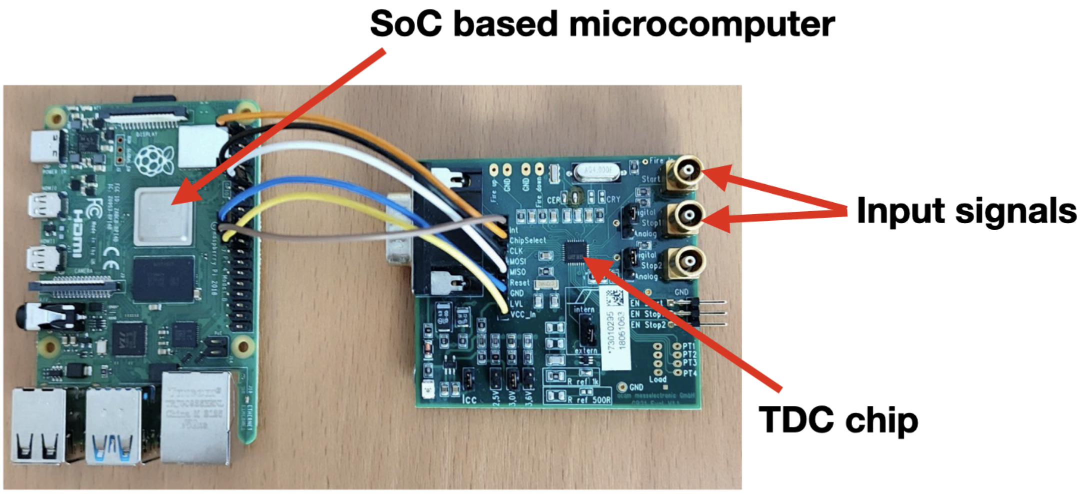
2. Main Part

The instrumentation used in time-domain diffuse optics (TD-DO) consists of three key components: a pulsed laser source, a single-photon detector, and timing electronics. In this training, you will get a basic understanding of the TD-DO method, applied statistics, and the Time-to-Digital Converter (TDC), which measures the time delay between the laser pulse and the detection of a photon.

You will also learn how to program a TDC chip using a SoC-based microcomputer (such as a Raspberry Pi, Orange Pi, or similar device).

As a final outcome, you will obtain a photon time-of-flight (DTOF) distribution measured from a phantom that simulates real biological tissue.

3. Project work description



The main setup will consist of a TDC chip and an SoC-based microcomputer with an SPI interface. The first part of the training involves writing code in Python or C++ to implement the logic for configuring the TDC chip, reading data from it, and saving the results to a file. Once everything is working, you will connect the device to a test stand, which includes a phantom for measurements, a pulsed laser source, and a single-photon detector. You will then collect real data and plot a histogram representing the distribution of photon time-of-flight (DTOF).

4. Requirements

Basic knowledge of Python and/or C++, electronics, Linux and SPI interface. Experience with an oscilloscope and logic analyzer is preferred.

5. Recommended reading

1. https://www.sciosense.com/wp-content/uploads/2023/12/TDC-GP22-Datasheet.pdf
2. https://www.raspberrypi.com/documentation/computers/getting-started.html

6. Number of project participants

One student from South Africa

7. Supervisor

Sokolov Sergei Anatolievich
Senior engineer, Dzhelepov Laboratory of Nuclear Problems, Experimental Department of Particle Physics.

My scientific and engineering work focuses on methodological studies and R&D of photodetectors, as well as their application in high-energy physics experiments. I have been involved in several large-scale projects related to photodetectors for high-energy physics.
My experience includes:

- Mass testing of large-area photomultiplier tubes (PMTs) using a scanning station for the JUNO experiment (China);
- Development and testing of the light readout system for the liquid argon TPC of the DUNE Near Detector (United States), including the preparation of technical design documentation;
- Design and implementation of the power supply system for the TAO/JUNO detector, along with the development of a test stand for mass testing of SiPMs;
- Final testing of large-area PMTs prior to their installation in the JUNO detector.