Development of a TDC-based Laser Scanner

Graduate

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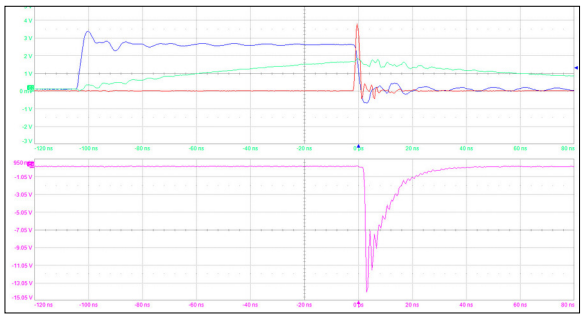
Introduction: Time-to-Digital Converters (TDCs) are capable of measuring extremely short time intervals in the picosecond range, making them a promising technology for high-precision distance measurements in 3D laser scanners. Especially for reflected high-energy laser pulses, where an ADC may saturate, a TDC can provide a precision advantage.This bachelor's thesis investigates the integration of an Agilex 5 field-programmable gate array (FPGA)-based TDC measurement system into a 3D laser scanner from Hexagon.

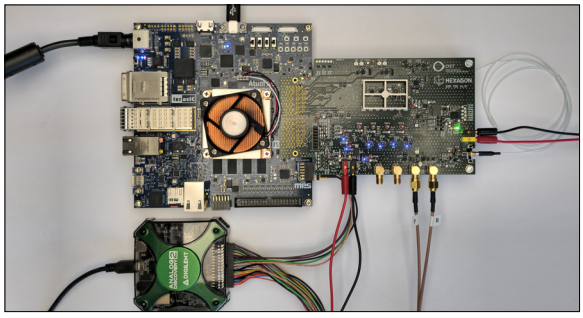
Approach: The project consisted of three main tasks: hardware development, FPGA implementation, and Python-based software development. For the TDC receiver path, a signal-conditioning concept was developed to convert the analog photodetector output into suitable digital timing signals for the TDC. Simulations were carried out to verify the feasibility of the concept before it was implemented on a custom printed circuit board (PCB) for electronic distance measurement (EDM). On the FPGA side, the required digital logic was implemented and tested in VHDL, including modules for laser pulse generation, SPI-based communication with the hardware components, control via an AXI4-Lite bus, and temporary data storage. Python scripts were developed to control the different subsystems and were later combined into a GUI for convenient operation.

Result: The EDM board and FPGA evaluation board were successfully tested and commissioned. During operation, system parameters can be adjusted and measurements can be performed via a Python-based graphical user interface (GUI). Both measurement paths, including the comparator-based signal digitization for the TDC, operated as intended. Using the ADC, very small pulses can be captured for further timestamp extraction. The TDC outputs the rising and falling timestamps of each pulse, enabling pulse-width calculations and error correction. The newly developed hardware enables the further development of combined ADC- and TDC-based distance measurements, increasing the overall precision over a wider dynamic range of reflected pulse amplitudes in real-world scanning applications.

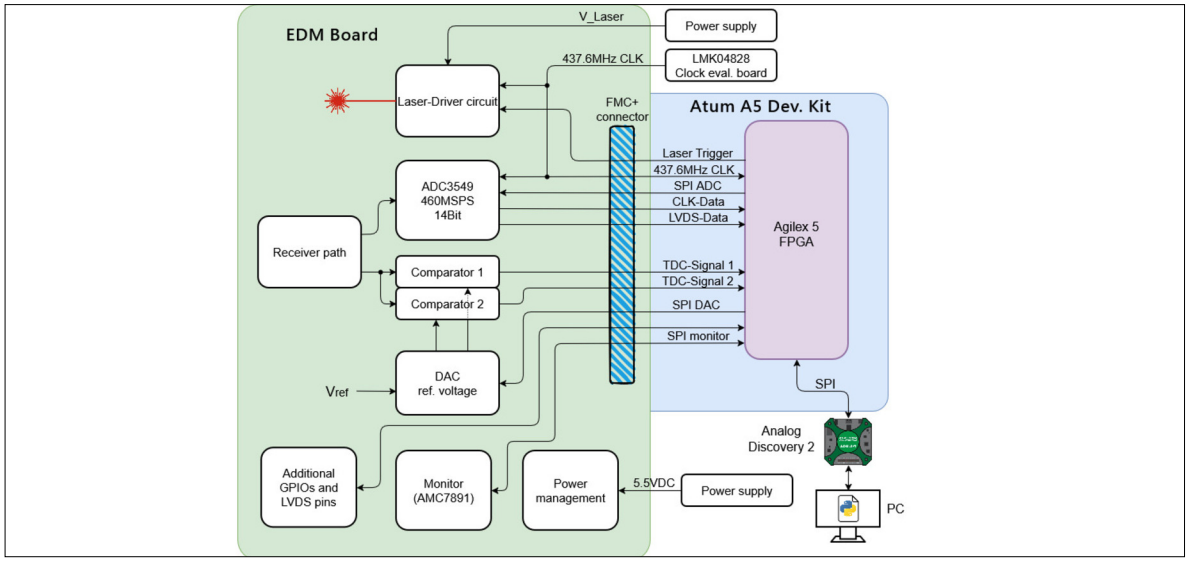
Input and output signals of the pulse-shortener circuit and resulting nanosecond pulse capable of driving laser diodes.
Own presentment



Final hardware assembled and ready for testing.
Own presentment



Block diagram of the EDM board system design and its connections to the Agilex 5 FPGA on the Atum A5 development kit.
Own presentment



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