Notes on article – English lesson

Electronic Module of Laser Altimeter – 5 normostran

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Abstract

This paper deals with the electronics of a laser altimeter implemented in a Complex Programmable Logic Device, a Time-to-Digital Converter and a PIC microcontroller. The introduction describes the principles of function of a single photon laser altimeter. It contains the description of types of programmable logic devices and a description of the CPLD Lattice ispLSI0132E. A short description of the 8-bit microcontroller PIC18F4620, Time-to-Digital Converters in general and the ACAM TDC GP1 is given. The paper describes the module CTU ET, which serves as the hardware for this laser altimeter. The practical part contains a program for the implementation of a range gate of a laser altimeter in a Complex Programmable Logic Device and a program for the PIC microcontroller, which serves for data acquisition and communication with the TDC. This paper helps to understand the issue of designing digital logic circuits and gives an idea what it takes to use the selected hardware components.

*Keywords:* laser altimeter, HDL, CPLD, microcontroller, TDC

Introduction

The goal of this paper is to describe the function of a program for the module CTU ET which will work as a single photon laser altimeter. The design has to fulfil a requirement of broad applications and is mainly considered to be a single photon lidar demonstrator in space applications. The desired functions are: generation of a gate signal to control a photon counting detector, generation of a start signal for the laser, recording of the laser pulse epoch, time interval measurement between sent and received optical pulse and data collecting. The result of the measurement is a histogram of pulse detections. Two main approaches are used in echo signal detection and processing: multiphoton detection and photon counting approach. The multiphoton approach principle is as follows: The optical signal is received by a photodetector and this optical signal with a certain amplitude temporal profile is transferred to an electrical signal with a corresponding temporal profile. It is possible to gather a complete temporal profile of the echo from each measurement. This approach calls for high power lasers and large optical telescopes. The photon counting approach solves this problem by utilizing a different point of view. Trying to analyse echo LIDAR signals from distant targets, the echo signal splits to the contributions of individual photons. Repetitive measurements and statistical treatment of the data set must be applied.

Materials and methods

1. Design of the laser altimeter
2. Photon counting data processing objectives
3. Design of the module CTU ET
4. Software development
5. Verification experiment
6. Testing with pulse generator
7. Testing with real laser and detector

Results

Discussion

Conclusion

II. Design

1. Photon counting data processing objectives

B. Design of the module CTU ET

The module CTU ET on which the demonstrator of the laser altimeter is programmed, was designed and constructed by Jan Kodet in 2008 and is described in his thesis: *Time measurement control box with 100 ps resolution*. Most elements of the board are SMD. The small and compact SMD components reduce parasitic capacitances and thus enable faster signal transmission and reduce power consumption. The serial and parallel interface and the programmers are accessible via a pin field. Our version of the module has a 10 MHz internal clock oscillator IQXO - 350. It is however possible to connect an external clock through a SMA connector. The board has signal LEDs, providing information whether the power is on or the measurements of various states. The main parts of the board include:

Microcontroller Microchip PIC18F4620

Complex Programmable Logic Device Lattice ispLSI 1032E

Time-to-digital converter Acam TDC-GP1

Internal oscillator IQXO - 350 with a 10 MHz frequency

Software development (krátký úvodní odstavec)

The PLD Lattice ispLSI 1032E is programmed using the Hardware Description Language ABEL HDL.

1. Communication between the components of the laser altimeter demonstrator

We can see the basic idea of data flow between the module CTU ET, detector and laser on one side and the user on the other in **Figure 23**. The user enters commands and data (value of preset time interval, number of measurements) through a suitable terminal program (e.g. REALTerm) to the PIC microcontroller. The PIC microcontroller processes these data and sends them to the CPLD Lattice and initiates the TDC. The Lattice was intended to serve as a coarse counter with 100 ns resolution. The Lattice measures the number of clock cycles based on the data from the PIC microcontroller and the signals from laser (emitted photon) and detector (recorded photon) and these data are sent to the PIC. The LASER signal indicates the moment when the laser fires. Counting of the preset time interval starts based on this signal. After counting down the preset time interval, the detector gate is opened. The detector is waiting for the first returned photon and the detector gate is closed after receiving it. It then sends the DETECTOR signal to the CPLD. The TDC was intended to be used as a fine counter with a 125 ps resolution. It would measure the time intervals between LASER signal and first rising edge of the clock signal and the time interval between DETECTOR signal and first rising edge of the clock and send them back to the PIC.

The complete time interval using the TDC and CPLD together would then be computed as:

This computation is illustrated in **Figure 24**. However, for testing in a laboratory, this approach cannot be realized and is only theoretical. Measurements of time intervals were performed separately with the CPLD and TDC, but not together. For more information, see Paragraph 5.2.2. It is very important to manage switching of the input multiplexers. The data from the CPLD and TDC are collected by the PIC after each measurement and processed. The result of each measurement batch is then sent to the user.

1. Principle of function of the time gate realized in the CPLD Lattice

The principle of function of the time gate realized in CPLD Lattice is shown in **Figure 25**. Whenever the laser emits a photon, it will send the information about this event to the PLD. The time of arrival of the echoed photon is expected approximately in the time interval given by the preset time interval. The preset time interval counts down and when it reaches zero, the detector opens. The detector remains open until the first echoed photon arrives. It is possible to eliminate most of the background noise by setting the appropriate value of the preset time interval. The width of the time window is typically a few μs*.*

1. PIC microcontroller programming

RESULTS

Testing

The photon counting detector of the PDM series by MPD (Micro Photon Devices) was used. The PDM is a solid state instrument equipped with a SPAD (Single Photon Avalanche Diodes). The peak photon detection efficiency is 49 % at 550 nm. The detector generates a TTL level output pulse per detected photon. The SPAD is cooled by a Peltier module. The detector offers a fast gating option which is triggered by an external TTL signal. The gating function is used for viewing a signal that occurs in a small time window and therefore enabling to detect weak signals with high background noise.

The laser used is from JDS Uniphase, model NG-10120-110. It is a pulsed diode pumped, passively Q-switched microchip laser. The primarily wavelength is 532 nm. It has a minimum power performance of 15 mW. The power output per pulse is 1 μJ and the typical pulse width is 0.6 ns.

Experimental setup

The experimental setup is shown in **Figure 40** and **Figure 41**. The experimental setup is quite easy. The laser fires into a group of four filters with a transmission coefficient of , so the laser pulse is attenuated by an factor of:

The laser beam then reflects from a mirror and hits a beam blocker. The beam is scattered and the reflected photons are detected by the SPAD. The Result of an experimental measurement showing peak of backscattered signal. The width of one channel is 250 ps. This data set can be further fitted with a Poisson distribution using a data processing program.

The next experiment that was carried out had a similar setup as the previous one, but instead of one beam blocker, two were used. The diagram of the experiment is in **Figure 44.** The beam hits and is scattered from both beam blockers and therefore two peaks are visible in the histogram. The distances between the two beam blockers is then computed according to formula:

where:

- distance between beam blockers

c - speed of light

- channel number of peak No.2 maximum value

- channel number of peak No.1 maximum value

- width of channel

DISCUSSION – to jsem v prdeli

CONCLUSION AND FUTURE - OSEKAT

The issue of this Master‟s Thesis consists of implementing a single photon-counting laser altimeter technology demonstrator in an electronic circuit consisting of a microcontroller, a complex programmable logic device and a time-to-digital converter.

The first two chapters contain a theoretical introduction to the problem. The first chapter introduces the reader to the history of laser altimeters used in the history of space exploration, describes the main parts of a laser altimeter and lists the main differences between the single and multiphoton data processing approaches. Basic information about the hardware - the PIC microcontroller, Acam TDC GP1, the complex programmable logic device Lattice and the module CTU ET - are given in the second chapter. The problems solved in the next parts of the Master‟s Thesis are based on these parts. Because of this it is an important part of this Master‟s Thesis.

The third chapter deals with the development of the software for the complex programmable logic device Lattice and the PIC microcontroller. The principle of function of a time gate realized in CPLD Lattice is given. The program for the PIC microcontroller, which serves for data acquisition and communication with the user is described. An operator‟s manual for the PIC microcontroller program is included.

The fourth chapter examines the measurement limits and the parameters of the device. This part is important, because it gives an idea what the theoretical limits of the device are. The fifth chapter focuses on the experiments. Basic distance measurements and noise measurements were carried out in laboratory environment. These experiments proved, that the module CTU ET is capable of working as a single photon laser altimeter. All the project goals were met successfully:

In the future, the photon-counting laser altimeter technology demonstrator could be tested in more situations than presented in Paragraph 5.2.2. Better results could be obtained by using better circuit technology (shorter data delay, faster CPLD). A better user interface could be developed instead of the simple interface described in Paragraph 3.5.2.

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NOMENCLATURES AND APPENDICES

REFERENCES