Time-of-Flight Rangefinder

ECE 445
Project Proposal
Team 28
Spring 2012
TA – Mustafa Mir

Chee Loh, Ping-Wen Wang, Xingliang Wu

Introduction

Title: 1D LiDAR Time-of-Flight Rangefinder

We have chosen to pursue this project because our group has a strong interest in optical applications. We are excited to work on this project because we believe our system can easily be extended to many different types of applications such as object detection on cars when reversing, speed detection on cars, or even large terrain mapping. Consequently, not only is the project quite versatile with respect to its practical applications, but it also incorporates topics that we are passionate about.

Objectives:

Two of the main goals of our project are to not only be able to accurately measure the distance to an object, but also be capable of determining if an object is moving and at what speed. Our goal is to design a system that can produce a measurement that is accurate to within 10 cm when limited to objects that are a maximum of 20 m away. After the system is powered on and initialized, the user will be able to choose what type of measurement they would like to take.

Benefits:

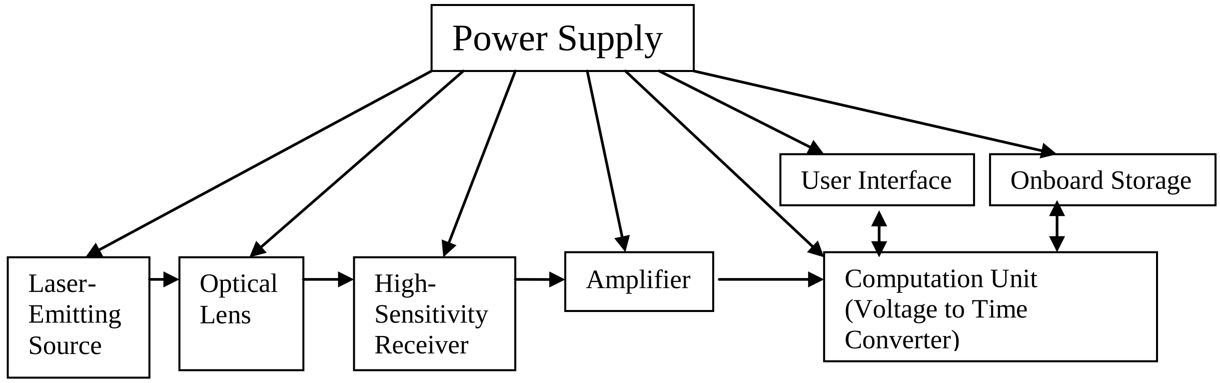
- Relatively compact design that can be easily transported(roughly 1.5x1.5x1.5 ft box)
- Can be used in a variety of applications
- Maintains accuracy for objects within the stated range
- Fast results that can be identified in seconds
- Affordable cost for the average consumer
- Minimal environmental impact

Features:

- Can be extended upon to complete the full design of a LiDAR system through modular design
- Clear display of results on LCD screen in real-time
- Tripod attachment for easy stabilization
- Light filtering to account for environmental ambient light
- Onboard storage in order to make speed estimates

Design

Block Diagram:



Block Descriptions:

Laser-Emitting Source:
This component of the system consists of a pulsed semiconductor laser diode which will mark the start and stop time for each trip the laser takes to the desired object.

Optical Lens:
We will position an optical lens in front of the avalanche photodiode receiver in order to amplify the intensity of light for better reception as well as filter out frequencies of light that are not desired

High-Sensitivity Receiver:
This component consists of an avalanche photodiode. We chose to use an avalanche photodiode because it has much greater responsiveness for low intensity light when compared to an ordinary photodiode.

Amplifier:
This stage consists of a simple voltage amplifier in order to increase the voltage input to the microcontroller. We will design this amplifier on a bread board using an operational amplifier and the appropriate value resistors in order to amplify the voltage by the desired amount.

Computation Unit (Voltage to Time Converter):
This component will consist of a capacitor circuit as well as the appropriate logic in order to convert the voltage we measure across the capacitor to a measure of time. This time value represents the total time of flight of the laser beginning from

Onboard Storage:
Onboard storage will also be implemented in our system in order to use multiple distance measurements to generate a speed calculation. The storage that will be used will be on the microcontroller itself in order to minimize acquisition time and maximize output generation.

User Interface:
We will design a simple user interface in order to display the final result to the user. The final result will either be a distance measurement or a speed measurement.

Performance Requirements:

Maximum Measurement Error: $\leq$10 cm
Maximum Measurement Distance: $\leq$20 m
Result Display Delay: $\leq$5 sec

Verification

Testing Procedures:

We will test each of the components in our system in a methodical manner. First, we will start by testing the response of the photodiode. We will shine the laser on various reflective objects at various distances. We will connect the laser supply voltage to one input on an oscilloscope to mark when the laser is turned on. We will connect the other input signal of the oscilloscope to the output voltage generated by the photodiode when it receives the reflected laser pulse. From these two signals we will be able to measure exactly how fast the photodiode can respond to a laser pulse.

Our next testing procedure consists of testing the calculations performed on the microcontroller. We will input a voltage value measured across the capacitor into the microcontroller. This voltage will then be used to search a look-up table based on the charging characteristics of a capacitor in order to find out how long it took the capacitor to charge up to the given voltage level. This time period will then be used to calculate how far the object is based on the speed of light. We will input a variety of voltage values and make sure the calculations performed on the microcontroller produce the expected output.

We must also test the amplifier circuit that we design. We will conduct some simulations using PSPICE in order to calculate what resistor values we need to produce a high enough voltage gain. After acquiring the desired amplifier circuit through simulation, we will move our design to bench testing. We will build our amplifier circuit on a breadboard and make sure the voltage output of the photodiode is amplified to the desired voltage.

After these three components are tested and verified, we will combine them to make sure the entire system is functional. We will test the entire system in its entirety to make sure all the components can work in conjunction with each other. Similar to the testing of the receiver circuit, we will set up a series of tests using many different reflective objects at varying distances in order to test the accuracy of our entire system. We must also make sure our system can measure the speed of objects as well. This requirement will be tested using simple scenarios such as rolling a ball, riding a bike, and possibly driving a car.

Tolerance Analysis:

The one engineering component in our system that most affects the performance of our project is the accuracy of the measurement that our microcontroller can perform. Our microcontroller must be able to measure the voltage across the capacitor with very high accuracy in order to retrieve a very accurate time measurement from the look up table. This high-accuracy time measurement is needed in order to maintain small error in the distance measurements. Our system is expected to be accurate within 10 cm for objects at a maximum distance 10 m – 20 m. This requires our time of flight measurement to be correct within 1 nanosecond of the actual time of flight.

An equally critical component that will affect the accuracy of our system will come from the sensitivity of our photodiode receiver. We chose to make use of an avalanche photodiode due to its much greater ability to detect small intensity light when compared to ordinary photodiodes. However, we believe it will prove to be difficult to maintain a high level of accuracy when measuring objects at far distance(>20-30m). Through the use of an avalanche photodiode we attempt to maximize the distances that we can measure.

Cost and Schedule

Cost Analysis:

LABOR	
Employee	Cost
Chee Loh	$40/hour * 2.5 * 12 hours/week * 12 weeks = $14,400
Xingliang Wu	$40/hour * 2.5 * 12 hours/week * 12 weeks = $14,400
Ping-Wen Wang	$40/hour * 2.5 * 12 hours/week * 12 weeks = $14,400
Total	$43,200

PARTS			
Part	Quantity	Location	Cost
Laser Photodiode	1 * $100	Online Order	$100
Avalanche Photodiode	1 * $200	Online Order	$200
Optical Lens	3 * $20	Online Order	$60
Microcontroller	1 * $10	Texas Instruments	$10
Housing Box to Contain Design	1 * $100	Machine Shop	$100
Misc. Circuit Parts(Capacitors, Resistors, etc.)	Many	ECE Part Shop	$50
Total	$520		

Grand Total = $43,720

Schedule:

Week	Tasks	Members
Week 1(1/29 – 2/4)	-Research use of capacitance to convert to voltage to time measure	Wu
	-Research photodiode receiver and amplifier circuitry	Wang
	-Research photodiode receiver and amplifier circuitry	Loh
Week 2(2/5 – 2/11)	-Research and order parts	Wang
	-Design the receiver circuitry	Wu
	- Complete project proposal	Loh
Week 3(2/12 – 2/18)	-Sign up for design reviews -Build and test the receiver and laser	Wang
	-Build and test the receiver and laser	Loh
	-Program the microchip	Wu
Week 4(2/19 – 2/25)	-Assemble the parts	Loh

	-Test and simulate the receiver and transmitter	Wang
	-Program the user interface	Wu
Week 5(2/26 – 3/3)	-Optimize respond time of detector -Debugging	Wang
	-Optimize the calculation speed and find correction factor from device -Debugging	Wu
	-Optimize the amplifier and noise filtering -Debugging	Loh
Week 6(3/4 – 3/10)	-Test and debugging	Wu
	-Test and debugging	Wang
	-Test and debugging	Loh
Week 7(3/11 – 3/17)	-Complete individual report -Combine microchip and user interface	Wu
	-Complete individual report -Interface receiver and amplifier to microchip	Wang
	-Complete individual report -Interface receiver and amplifier to microchip	Loh
Week 8(3/18 – 3/24)	-Testing and verification	Wu
	-Testing and verification -Sign up the mock-up Demo	Wang
	-Testing and verification	Loh
Week 9(3/25 – 3/31)	Mock-up Demo	All
Week 10, 11(4/1 – 4/14)	-Work on final design optimization and debugging	All
Week 12, 13(4/15 – 4/28)	-Prepare demo -Prepare presentation and start final paper	Wu
	- Prepare demo -Prepare presentation and start final paper	Wang
	- Prepare demo -Prepare presentation and start final paper	Loh
Week 14(4/29 – 5/5)	Demo and complete the final paper	All