University of Colorado - Boulder

ASEN 5067: Microavionics for Aerospace

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Final Project Proposal

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I. Project Overview

A. Project Description

One of the senior projects this semester is concerned with developing an autonomous aerial vehicle that uses onboard sensors to detect and localize robotic ground vehicles. To accomplish this, there will be an onboard RGB camera and a secondary sensor to supplement the primary to get a more accurate estimation of the inertial position of the robotic ground vehicles. One of the options my team explored for the secondary sensor was LiDAR (Light Detection and Ranging). LiDAR sensors work by measuring the Time of Flight of a pulsed light beam to estimate the range of the object it is pointed at. By measuring the time between the emitted pulse and the received measurement, the distance can be estimated. The following figure showcases the principle utilized by the sensor.

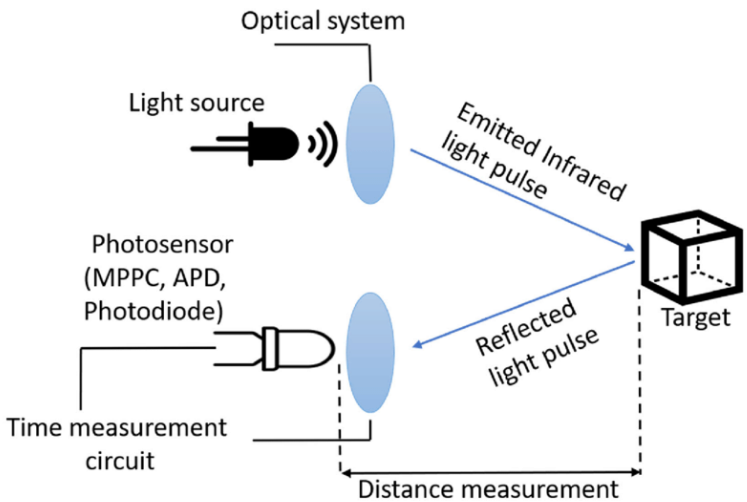

Fig. 1 LiDAR Time of Flight Principle.

In the context of my team's objective, the LiDAR sensor would be used for an accurate measurement of the altitude of the aerial vehicle. LiDAR sensors used in this context are commonly called laser altimeters and are mounted on the bottom of the drone and point directly down at the ground. With this setup, the emitted pulse will reflect off the ground and the sensor will measure the time it takes from emission to reception of the beam to get an accurate altitude measurement. This altitude measurement is an integral component of the localization algorithm and thus an accurate reading is important to reduce the overall uncertainty of the inertial estimate. As such, this project seeks to prototype and test a LiDAR sensor with the PIC microcontroller to ensure we can get accurate readings of distance measurements. To this end, the LiDAR sensor will need to communicate with the PIC microcontroller and the PIC will need to communicate to a ground station to have a live feed of the distance measurement of the sensor. This project seeks to prototype this subsystem with the PIC to ensure the feasibility of placing such a system onboard the aerial vehicle.

B. Functionality

The overall goal of the project is to use a LiDAR sensor to get an accurate distance measurement between the sensor and an object. To accomplish this, the PIC microcontroller will interface with the LiDAR sensor to acquire the sensor data and will then send this data to a ground station (in this case just a PC via serial communication). The sensor will need a steady mount to maintain an accurate base position for a consistent relative distance measurement. There will also need to be a test object for the sensor to detect such as simple as a piece of paper or cardboard. In addition to the sensor and mount, there will need to be a ground station; in this case this will be simulated by the connection to a PC. Between all of these components, there will need to be communication interfaces. The PIC will interface with the LiDAR sensor and also the PC though serial communication modules. The collected data from the sensor will be sent to the PC for processing, and the PC can send commands back to the PIC. The important elements of the project are summarized in the following list:

- LiDAR Module (TF-Luna LiDAR Module)

- Sensor Power/Battery
- Tripod Mount
- PIC and LiDAR interface (USART)
- PIC and PC interface (USART)

C. Levels of Success

The base level of success for this project is to successfully interface with the LiDAR module using the PIC and send this data over to a PC to get an accurate measurement of the distance between the sensor and the object it is pointed at. To achieve this, the PIC must use USART with the sensor and the PC to send the data. The PC must have a program to receive the transmitted data and display the results. For the base level of success, this will be done with Tera-Term or PuTTY. The connection between the LiDAR sensor and the PIC is integral in completing this project and will be prioritized before the connection from the PIC to the PC. If this base level of success is achieved, then the interface between the PC and PIC can be improved with the ability to send certain commands to the PIC to adjust the data collected by the sensor. These commands can vary but can be used to set the mode of the sensor to on/off detection or adjust the sampling frequency. Beyond this, the sensor could be attached to a servo which could be controlled to point the sensor in a certain direction. This would be the highest level of success but will only be pursued if the base level is achieved and time permits.

D. Off Ramps

The main component of the project is interfacing with the sensor to get an accurate distance measurement. If this proves to be too difficult with USART, then I will transition into either using I2C which is also available on the sensor I have acquired, or I will try a different TOF sensor. In my bill of materials, I have two different TOF sensors that can be used and if the first one doesn't work or if I have issues with it I can shift to the second sensor. The second sensor uses I2C which could be the backup serial communication protocol if UART doesn't work as expected. For the serial connection to the PC, if using UART to get the data displayed on the PC is too difficult, I can display the output on the LCD of the PIC board rather than using another USART module to send/receive data. To simplify the LiDAR sensor's functionality even further, the sensor has an on/off mode which simply outputs whether or not it detects an object. This could be used if getting accurate distance data proves too difficult.

II. Graphics

A. Software Flowchart

The following figures detail the software logic that will be applied to this project. The main loop with call the Check_Command subroutine which checks if there is a command to be sent to the sensor. This is continually checked in the main loop and there will be interrupts that will go to the other subroutines. Namely, there will be an interrupt for when data is received from the sensor. This will reroute to the Read_Data subroutine which will get the received data from the receiver register and call Send_Data which will send the received data over UART to the PC. The other interrupt occurs when a command from the PC is received. This will reroute to the Read_Command subroutine which will parse the command and send the corresponding command to the sensor with Send_Command. The main loop will continuously run and the interrupts will occur when there is data or commands to send. See Figures 2-5 for the detailed graphics.

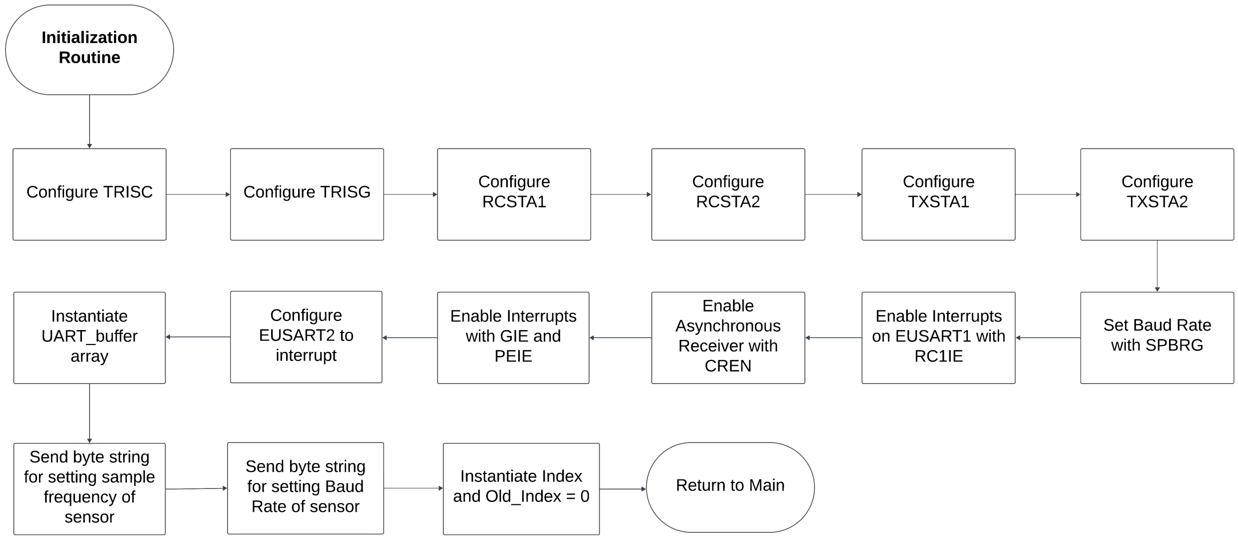

Fig. 2 Initialization routine.

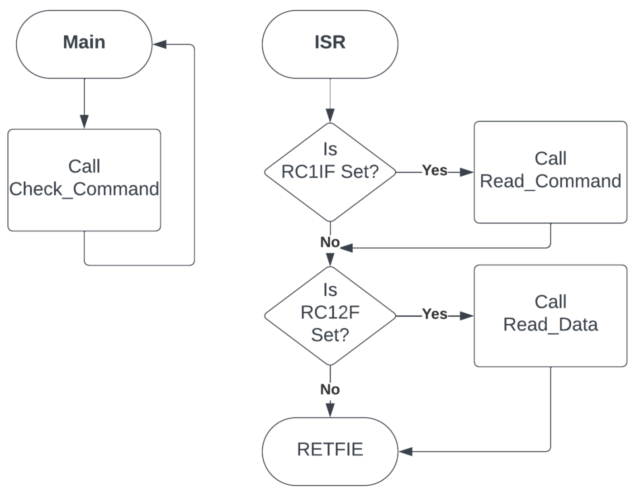

Fig. 3 Main and Interrupt Service Routine flowchart.

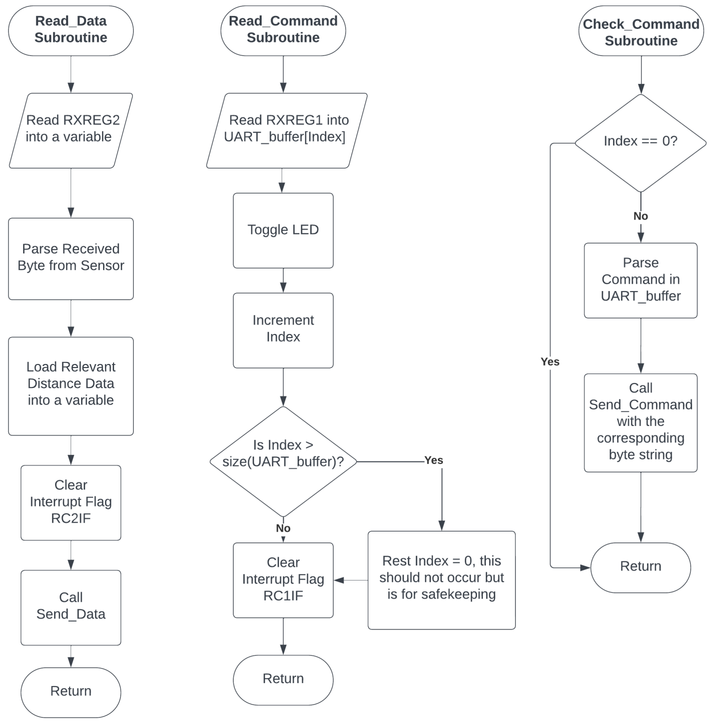

Fig. 4 Read subroutines flowchart.

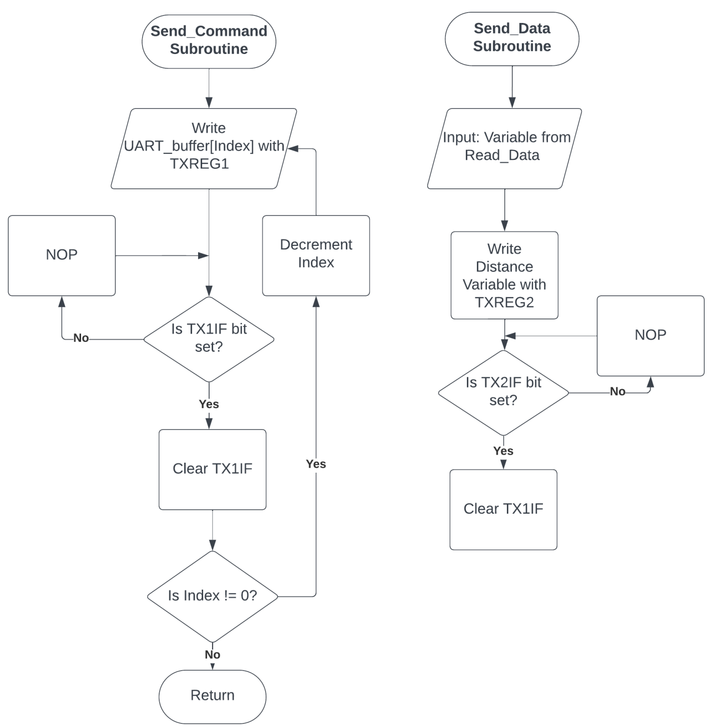

Fig. 5 Send subroutines flowchart.

B. Functional Block Diagram

The following graphic shows the functional block diagram for this system. The main components are the electrical hardware including the LiDAR sensor, power supply, PIC, and PC. The PC and LiDAR sensor will interface with the PIC using USART serial protocols. This will allow for the data to be transmitted and processed before the distance measurement is outputted on the PC. There is also a tripod that will be used for mounting the LiDAR sensor. The sensor requires between 3.7 and 5 V for the power supply so a 3.7 V battery will be used to provide power. Lastly, there is a Real World Object which will be simulated by a piece of paper placed between 20cm and 8m away from the sensor. The USART communication will occur on PORTC and PORTG using the EUSART1 and EUSART2 modules.

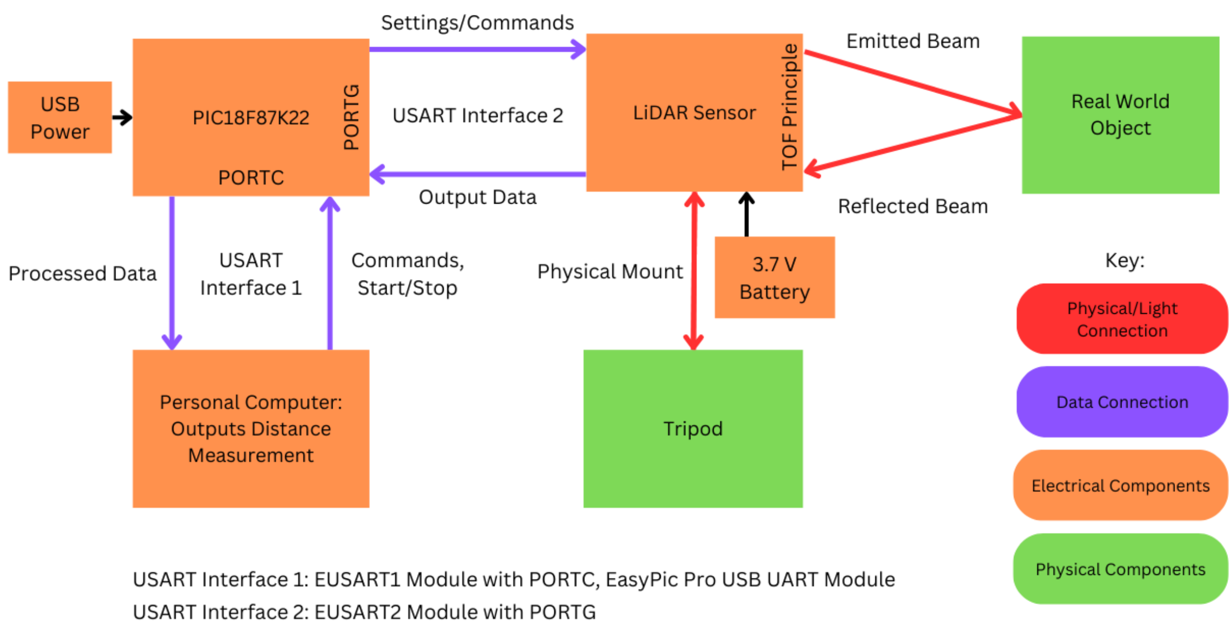

Fig. 6 System Functional Block Diagram.

C. Electrical Wiring Diagram

The following figure shows the pin configuration for the TF-Luna sensor. Pin 5 will be connected to 3.3 V to set the sensor in its UART communications protocol. Pin 1 will need to be connected to a 3.7-5 V power supply and Pin 4 to ground. Pins 2 and 3 are the relevant pins for UART communication and will be connected to the PIC board using the EUSART2 module. Pin 6 will not be used as the default mode will be implemented for data collection. Using these pins with EUSART2 will result in the following pin configuration showcased in Figure 4.

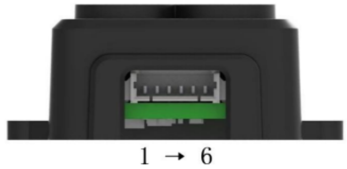

Figure 4 TF-Luna's pin numbers

Table 6: The Function and Connection Description of each pin

No.	Function	Description
1	+5V	Power supply
2	RXD/SDA	Receiving/Data
3	TXD/SCL	Transmitting/Clock
4	GND	Ground
5	Configuration Input	Ground: I2C mode /3.3V: Serial port Communications mode
6	Multiplexing output	Default: on/off mode output I2C mode: Data availability signal on but not switching value mode

Fig. 7 LiDAR Sensor Pin Configuration.

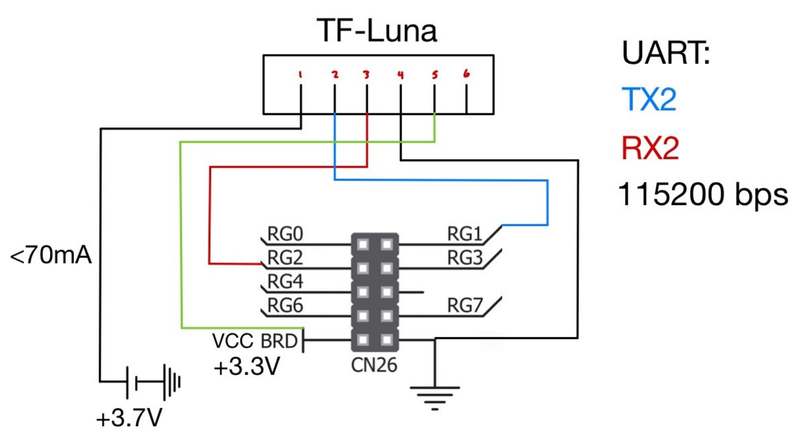

Fig. 8 PIC and LiDAR UART connection wiring diagram.

For the serial connection to the PC, as shown in Figure 2, the EUSART1 module will be utilized. The EasyPic Pro board has a USB UART module which uses an FT232RL controller to convert the UART signals to the appropriate USB standard. With this module, the PC can be connected to the board with a USB connection which will allow for UART communication between the PC and the PIC. The following figure shows the wiring diagram for the USB connection and the PIC. The USB port will then be connected to the computer using a simple USB A to USB B cable.

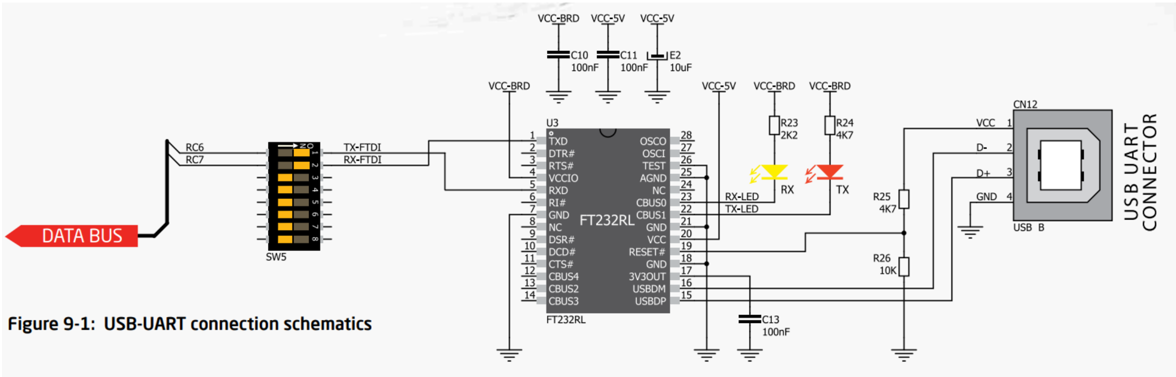

Fig. 9 PC and PIC UART connection wiring diagram.

III. Resources

A. Bill of Materials

The parts purchased for this final project include two time-of-flight sensors and a mini tripod for mounting. There is also a 3.7 V battery which will be used to power the sensor. The second time of flight sensor was included as an off-ramp in case there were issues with the first sensor. Links to the part are embedded in the table below.

Part	Price	Order Status	Manufacturer	Link
LiDAR Luna	$23.99	Received	Benewake	benewake.com
Mini Tripod	$8.99	Received	Tigayan	amazon.com
VL53L1CXV0FY/1	$7.99	Received	STMicroelectronics	digikey.com
3.7 V Battery	$11.99	Ordered	EEMB	amazon.com

IV. Status

A. Current Progress

I have obtained my sensor and the tripod for the sensor. Those are the main components of the project and the success relies heavily on being able to interface with the sensor and get accurate data from the sensor output. I have been looking into how I am going to implement the UART communication but I have not finalized anything yet at this point. The next steps would be to finalize how I am going to implement UART communication in code and test the result with the sensor connected to the controller. The first step is two test if I can get data from the sensor and if the data makes sense. After completing this step I will move onto the next part which is the UART communication with the PC.

B. Risk Mitigation

I am most concerned with having my serial communication set up properly to get the data from the sensor accurately. I am also concerned about implementing the PC as a receiver and transmitter to get data and send commands. I have off-ramps for this but I want to get the full system working and will need to allocate more time to ensure both serial interfaces work as expected. The biggest risk to the success of this project is the LiDAR sensor itself. If it malfunctions or does not act as expected I will not be able to complete the project. To mitigate the consequences of this risk I have another TOF sensor and can look into acquiring other TOF sensors if necessary. If the issue is with the UART communication I can transition to the I2C interface with the same sensor. If I cannot achieve a successful connection with the LiDAR sensor and get accurate data on the PIC by fall break I will transition into using the other TOF sensor. The other main risk is with the communication with the PC. If there are significant issues with getting data to output to the PC and for commands to be sent to the PIC then I will transition to using the LCD as an output of the measured distance rather than the PC. My deadline for this is before December; this provides enough time to implement the LCD.