COMPENG 2DX3
Project Report
L08

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As a future member of the engineering profession, the student is responsible for performing the required work in an honest manner, without plagiarism and cheating. Submitting this work with my name and student number is a statement and understanding that this work is our own and adheres to the Academic Integrity Policy of McMaster University and the Code of Conduct of the Professional Engineers of Ontario. (Abrar Tamjid)

1.0 Device overview

The two hardware devices used for this project included the Texas Instruments MSP432E401Y microcontroller and the VL53L1X ToF sensor.

1.1 Features

Texas Instruments MSP432E401Y:

- Processor: Cortex-M4F Processor - Harvard Architecture
- Bus Speed: 120 MHz
- Two SAR based 12 bit ADC modules
- Memory: 1024 kB flash memory
- Compatible with C or Assembly language
- Communication Protocols: Serial communication (I2C and UART)
- Baud Rate: 115200 bps

VL53L1X ToF sensor:

- Maximum Range is 4 metres
- 27-degree field of view
- 2.6 to 3.5 voltage range
- Provides distance measurements in mm
- Utilises I2C communication protocol to communicate with Microcontroller
- Upto 50 Hz of ranging frequency

1.2 General Description

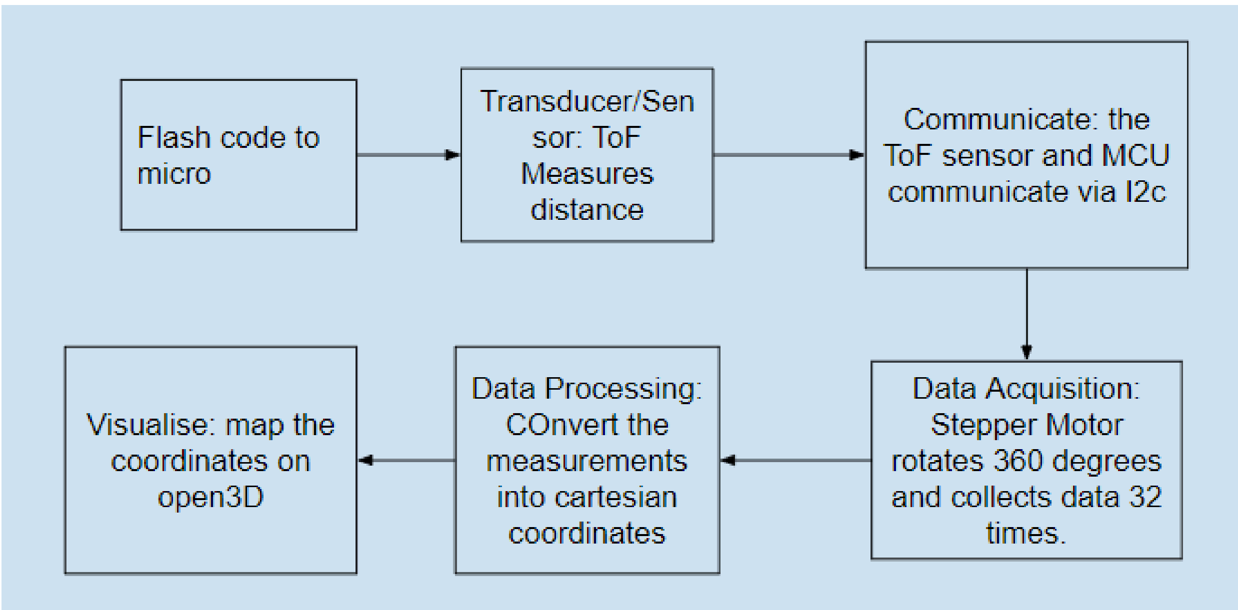
The goal of this project is to generate a 3D model of various spaces, such as hallways and small rooms, by mapping them out. To accomplish this, the MSP432E401Y microcontroller and the VL53L1X Time-of-Flight (ToF) sensor were used. The sensor uses LIDAR technology, its emitter projects an infrared light beam that reflects off objects and then the time it takes for the data to reach the receiver is divided by 2 and multiplied by the speed of light. The VL53L1X sensor is mounted to a stepper motor using super glue, which enables it to rotate and stop every 11.25 degrees to gather data, completing 32 measurements per rotation.

These measurements are analog at first and then converted to digital by the ToF sensor, it is then sent to the microcontroller via the I2C communication protocol. The data is then transmitted to a PC through UART (Com 7) at a baud rate of 115200 bps and saved in an Excel file using Python 3.8. This file records the z and y coordinates, which are calculated with manual increments of 20 cm along the x-axis to simulate movement along the corridor.

$$\textit{Max Quantization Error} = \textit{Max Distance} / 2^{\#\text{ ADC bits}} = 4000 / 2^{16} = 0.06104$$

The Open3D software is used to visualize this data, it plots each point in 3-D space. The points are with lines in the 3D model, creating an accurate representation of the space. This entire process occurs in order after each 11.25-degree interval, the data is written to the file only after a complete rotation. In summary, this approach combines hardware and software to model and represent indoor spaces in 3D.

1.3 Block Diagram



2.0 Device Characteristics Table

Feature	Unit	Value
Bus Speed	MHz	80
Status LEDs	N/A	Measurement: PN0 additional: PN1
Pins Used	N/A	PB2, PB3, PH0-PH3, Vcc, GND
Baud Rate	bps	115200
Languages	N/A	Python and C
Microcontroller		

Model	N/A	Texas Instruments MSP432E401Y
Memory	kB	1024 Flash
ToF Sensor		
Model	N/A	VL53L1X
Pins Used	N/A	Vin, GND, SDA, SCL
Maximum Range	m	4
Voltage Range	V	2.6-3.5
Field of View	◦	27

3.0 Detailed Description

3.1 Distance measurement

The VL53L1X ToF sensor measures distance by emitting infrared laser pulses and timing how long it takes for the pulse to come back to the receiver. Then the distance is calculated by multiplying the time by the speed of light and 0.5. The sensor is capable of sensing distances up to 4 metres at a maximum rate of 50 Hz. For the project, the microcontroller and Sensor communicate via I2C protocol. These sensors have many applications in the real world, for example, Lidar and Robotics.

Using the I2C protocol Microcontroller (MCU) and ToF sensor exchange data. This is done by resetting the MCU and activating the Python script at the same time. Then the stepper motor starts rotating. When the motor rotates 11.25 degrees, the motor stops and lets the ToF sensor collect data. Once the data is collected it is sent to the MCU using I2C. Then it is sent to the PC using UART, at a rate of 115200 bps. Then the data is converted to cartesian coordinates using the following formulae. Which was then plotted and the data points were connected to create a 3-D model

$$\text{Y-coordinate (y)} : y = r \cdot \sin(\theta)$$
$$\text{Z-coordinate (z)} : z = r \cdot \cos(\theta)$$

3.2 Visualization

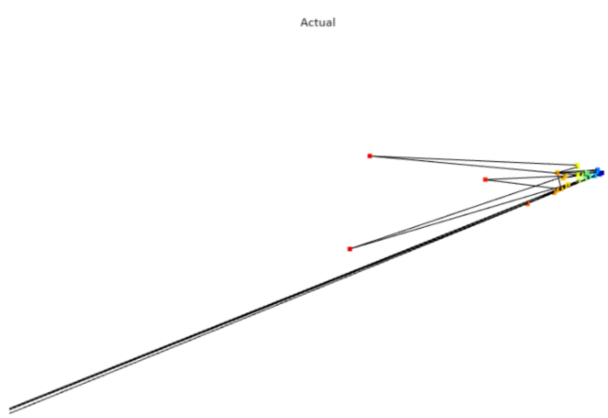
Visualization is done using the Open3D library. After converting the received points to Cartesian coordinates, the program creates a point cloud object using Open3D. This is achieved by creating a PointCloud object and assigning the converted points to it.

Once the point cloud object is created, the program uses Open3D's visualization module to render it. The draw_geometries function is then used to display the point cloud in a 3D viewer window. This allows for an interactive mapping of the space.

4.0 Application Note

Instructions:

1. Build the circuit using the schematic (section 6)
2. Run the Python script and press enter when prompted
3. Flash the program onto the microcontroller and reset the microcontroller
4. The time of flight sensor will start reading and the script will convert the polar coordinates into cartesian coordinates.
5. The cartesian coordinates will be printed in the terminal, be sure to keep an eye on them to ensure there are no abnormalities.
6. The 3D map will be produced after all scans are complete
7. To repeat the process more than 3 times, modify the loops to accommodate the requirements.



The image on the left is the 3D model after the data is collected and the left is the halfway that was supposed to be scanned. The data is not accurate as the ToF sensor was damaged.

5.0 limitations

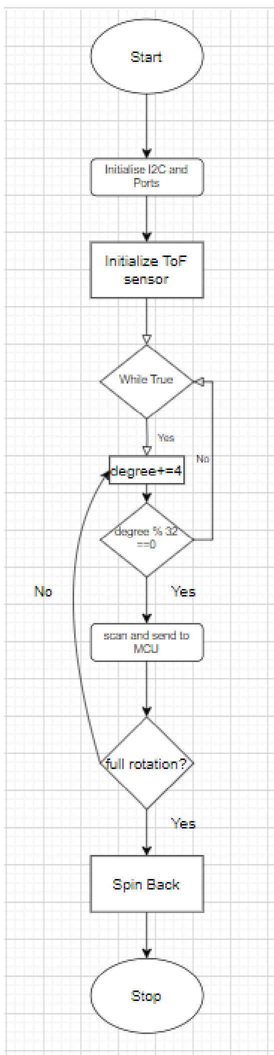
Trigonometric functions are required to visualize the data, but they produce long decimals that are handled by the microcontroller Floating-point unit (FPU) in the arithmetic logic unit.

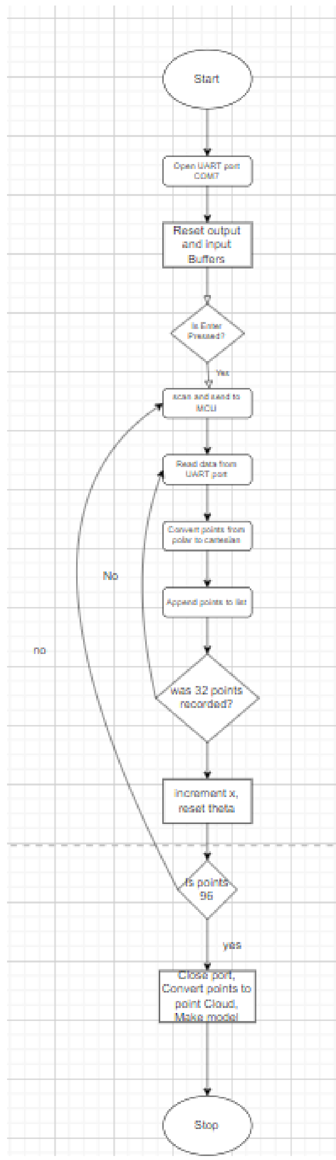
The maximum is calculated below:

$$Max\ Quantization\ Error = Max\ Distance\ /\ 2^{\#\ \mathrm{ADC\ bits}} = 4000\ /\ 2^{16} = 0.06104$$

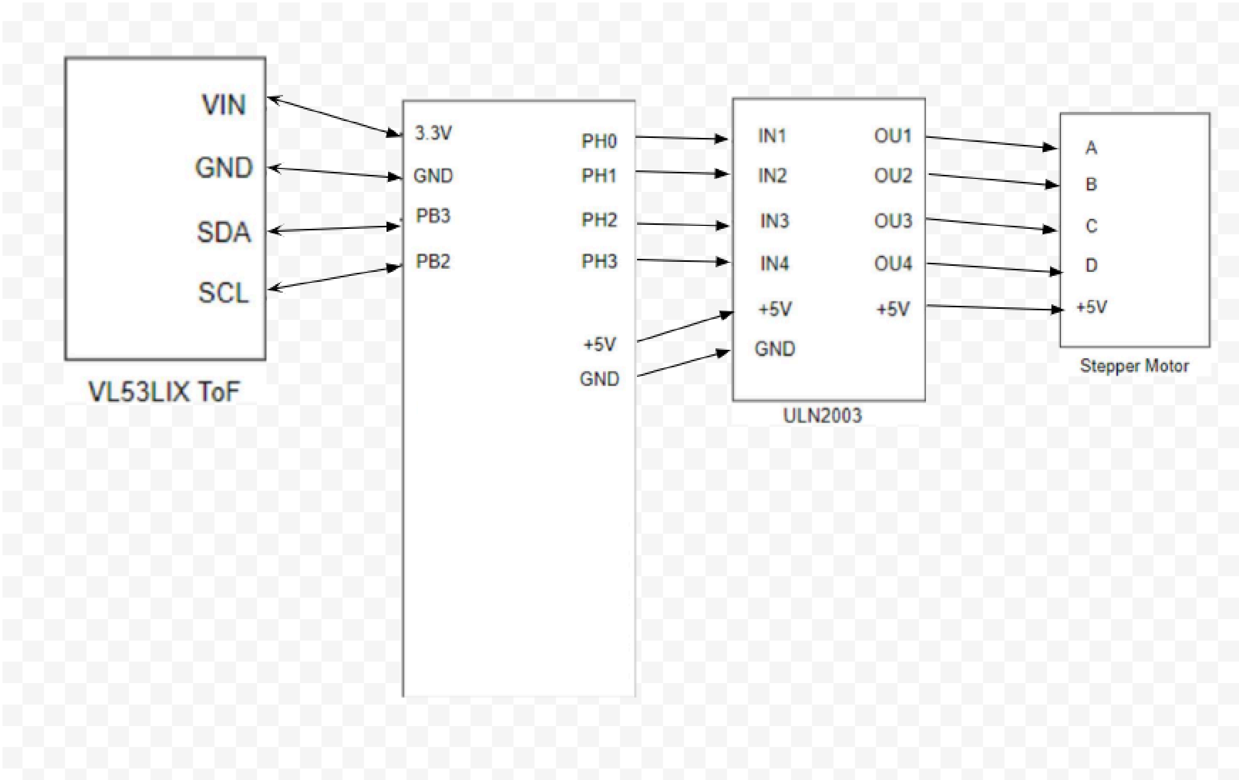
The serial communication rate is 115200 bps, the PCs Port 7 has a communication rate of 9600 bps. This could lead to issues such as data corruption, Noise, and other errors.

6.0 Schematic and Flowcharts

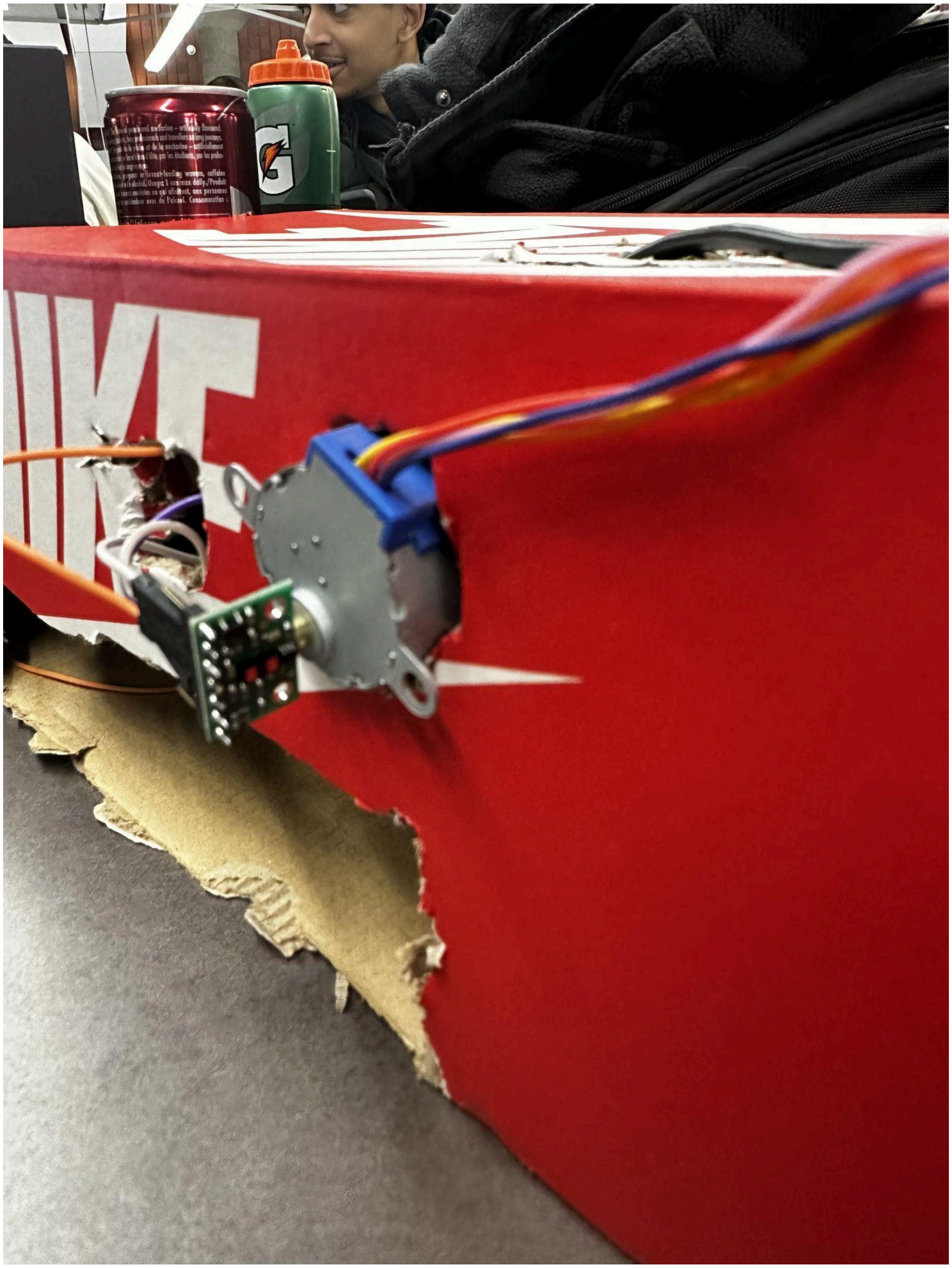




The Flowchart on the left is the MCU Program and the flowchart on the right is for visualization.



This is the Schematic of the physical circuit



This is the setup that was used.

Bibliography

[1] “MSP-EXP432E401Y Development kit | TI.com.”
https://www.ti.com/tool/MSP-EXP432E401Y (accessed
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[2] “vl53l1x - COMPENG 2DX3:Microprocessor Systems Project.”
https://avenue.cllmcmaster.ca/d2l/le/content/512368/viewContent/3979106/View (accessed Apr. 12, 2023).
[3] “Pololu - VL53L1X Time-of-Flight Distance Sensor Carrier with Voltage Regulator, 400cm Max.”
https://www.pololu.com/product/3415/specs (accessed Apr. 15, 2023).