2DX4: Microprocessor Systems Project
Final Project

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Link to Project Video:
https://drive.google.com/file/d/1M4hMZrSyL4qWo8YAiPFcAzn5hO8RpulY/view?usp=sharing

Device Overview

Features

- This device is a measurement tool that uses distance data to plot the surrounding areas
    - Its uses ToF sensor and that information is sent to microcontroller
- ToF sensor used is the VL53L1X
    - Connected to 28BYJ-48 stepper motor
- Microcontroller used is the MSP432E401Y
- Python Open3D package used to display 3D model
- PySerial is used to store distance and displacement data from microcontroller to PC
- ToF sensor takes a 5VDC input
- Stepper motor takes a 5VDC input
- Push button is connected to 3.3V input
- 12-bit ADC uses successive approximation method
- The bus speed is 96 MHz
- Total cost of approximately $100
- Serial Communication Details
    - serial communication baud rate = 115200
    - Terminator is stop bit in UART; default set to 1

General Description

The system is a measurement tool using ToF to map the surrounding area. A stepper motor is used to spin the sensor 360º. The data obtained is then converted into graphical representation. The microcontroller then transfers the data from the ToF sensor to your computer, in turn creating a 3D model with Python. The motor then starts after a push button is pressed.

A laser pulse is used on the ToF sensor to create distance measurements. The sensor measures how long it takes for the pulse to reach something and return back. The largest distance the sensor could measure is 4m. Interrupts are triggered when ranging data is obtainable.

Serial communication is used to send data from the sensor to your computer. A serial object is created, using PySerial library. The aforementioned serial object opens a serial port. The data can then be transmitted from microcontroller to your computer with an UART program.

Device Characteristics Table

The ToF sensor has to be connected to the stepper motor so that it can measure a full rotation of 360º. The pins of the time-of-flight sensor have to be connected to the right pins on the microcontroller.
The pins I used were PF4 for Distance Status and PL3 for Displacement status. The bus speed I used for this project was 60MHz. The serial communication between microcontroller and PC is PySerial. The communication speed is 115.2kbps.

Detailed Description

Distance Measurement

The ToF sensor VL53L1X does most of the processing within the device. Using functions the microcontroller delivers data to the PC. The function BootState checks to see if the sensor has booted. The ClearInterrupt function is used to enable next interrupt. To initialize the sensor, SensorInit function is called. To enable sensor ranging and start measurements StartRanging function is called. Rotations are made when the push button is pressed, and the sensor makes a distance measurement at a certain interval of degrees. A laser pulse is used on the ToF sensor to create distance measurements. The sensor measures how long it takes for the pulse to reach something and return back. To get distance measurement in millimeters GetDistance is called, and the value is transferred to PC. ClearInterrupt function is then called. The obtained measurements are transformed to the xyz plane.

$Y_{COORDINATE}$ = distance * sin(angle)
$Z_{COORDINATE}$ = distance * cos(angle)

These are done for every measurement throughout the 360º rotation. StopRanging is called when the rotation is complete.

Displacement

Using the MPU-925 IMU you can measure the displacement. The inertial measurement unit has accelerometers to measure displacement among the 3 axes. Acceleration on a certain axis cause the proof mass to have displacement. The capacitive sensors, then in turn detect displacement. I2C is used by the IMU to transfer the data to the microcontroller

Visualization

My computer:

- HP Desktop with Intel(R) Core(™) i5-6400T CPU @ 2.20GHz 2.21GHz
- The OS is Windows 10
- Programming language I used was Python
- The version I used was 3.6.8 because it supports Open3D package
- Data stored in xyz file and processed using Open3D
    - Opened as cloud array

Application Example

1. You need a python program to detect the correct port
    a. Change the baud rate to 115200
2. When you have correct port, change “s = serial.Serial("COM#",115200)” to port number. Install the right python libraries to run the program.
3. Make sure the right pins are connected to the right ports
4. Open Keil project
5. Load code
6. Press reset button
7. Run the file
8. Click the onboard button on the side of the board. The motor should start moving
9. Python program will now display

Limitations

1. The Cortex-M4 processor core cause the limitations of microcontroller floating point capability. Single precision floating point operations are supported by the CPU’s floating-point unit. The floating point capability is 32 bits because it’s single precision. This affects microcontroller’s use of trigonometric functions because they typically expect/return double floating point values.
2. Maximum quantization error is $V_{FS}/2^m$

    V_{FS} = 5.5V

    8-bit ADC

    Maximum quantization error = 0.0215

    For IMU model:

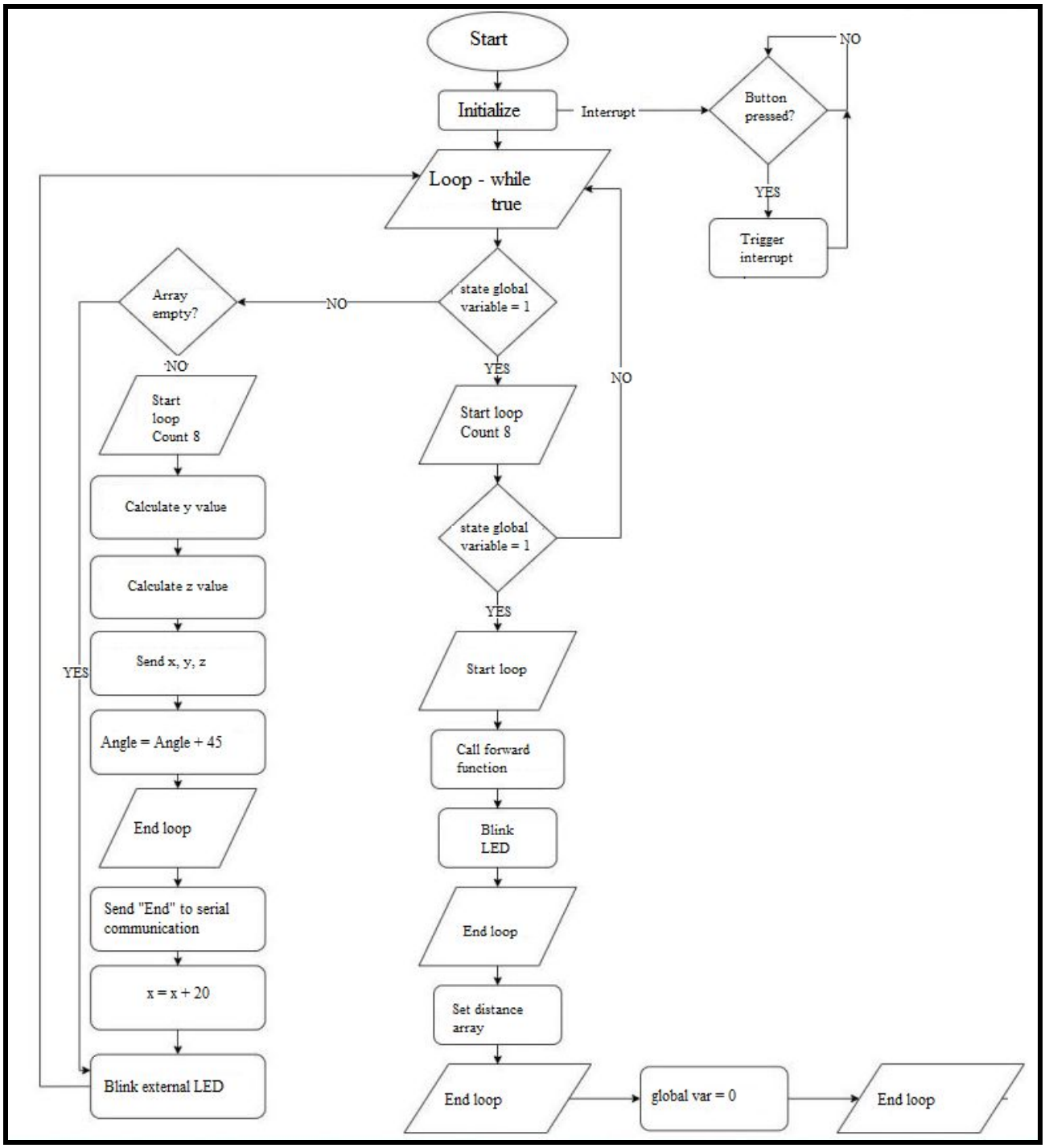
    V_{FS} = 3.6V

    16-bit ADC

    Maximum quantization error = 0.00005493164
3. Maximum standard serial communication rate you can implement is 115200 bps. It is possible to verify by speeding up the microcontroller to faster than 1.2Mb/s. You do that by checking the microcontroller bus speed > 1.2MHz. Once this is done, the computer misses most of the data.You then estimate the delay to be around 0.025s. Then you can see with the delay it gets most of the data, and with less it misses most of the data.
4. The communication method between the microcontroller and ToF through Inter-Integrated Circuit method. The bus speed between microcontroller and ToF module and microcontroller is 400kbit/s
5. The time of flight module is the primary limitation on speed. It takes time for the sensor to boot up and start taking measurements. The ToF module limits speed more than the motor because the rotation speed of the motor is adjustable.

Programming Logic Flowcharts

Figure 1.1



Sources

https://www.pololu.com/file/0J1506/vl53l1x.pdf