ENEL 387

Project Functional Specification

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Table of Contents

1 System Information

1.1 Description

This project is being created for the purpose of fulfilling the lab component of our ENEL 387 university class. The project is a mobile robot that will be capable of navigating a course, interacting with targets, and returning to its home position. The robot will be based around our 384 Lab Boards, and the STM Discovery Board that is mounted on the 384 board.

The robot includes several components that it will use to navigate, display information about, and make sense of the course around it. The usage of these components are covered in more detail in Section 2 of this document.

The project is intended to provide an opportunity for us to apply our learned knowledge about sensors and microcontroller operation to build a system that accomplishes a more complicated task. This task is the traversal of the course. This involves taking in many inputs into our control functionality, and deciding on the best action to take.

1.2 Description of Course

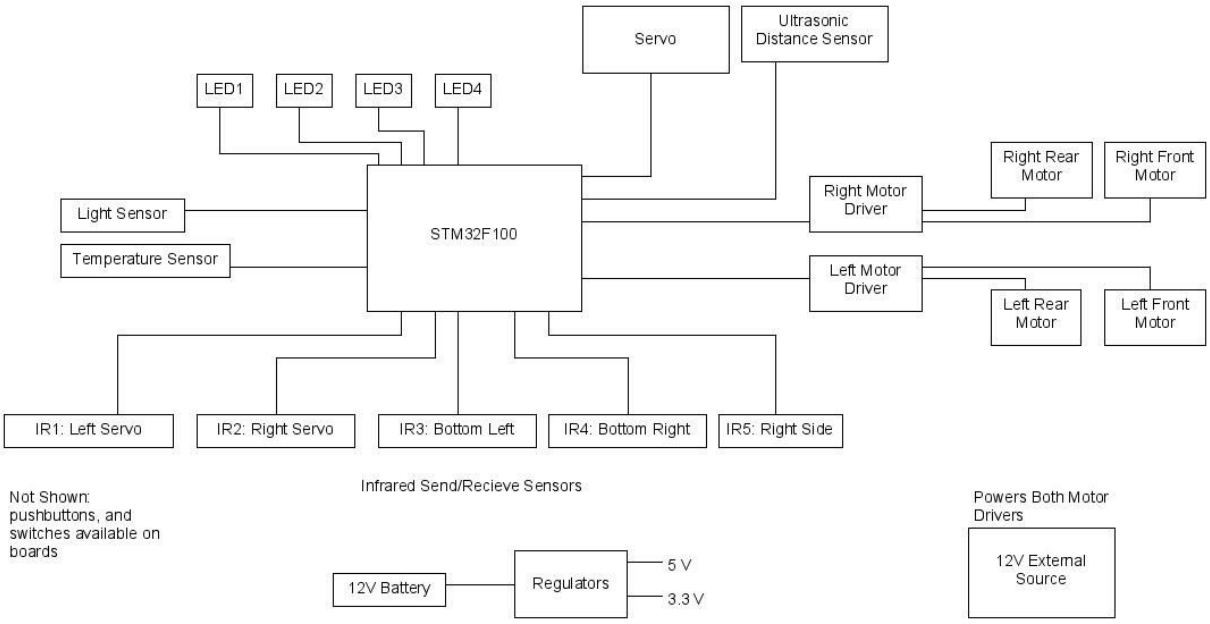
The course will involve the robot moving through hallways and entering rooms. The course floor will be black and have white navigation lines in the middle of the hallways. These lines are approximately 20mm wide. The course will include four rooms. Each room will be at least 50cm in every direction. These rooms will be connected via hallways with a minimum width of 46cm. Doorways will also have a minimum width of 46cm. Any of the walls will have a minimum height of 30cm. Rooms will be marked by narrow strips on the ground across their entrance. Room one will be marked with one strip, room two with two strips, and so on.

The robot will start and end the course from a Home Location (HL) that will be a white circle approximately 30cm in diameter. This HL will be located near an exterior wall in one of the hallways.

The robot will be expected to interact with several obstacles within the course. These obstacles include an incandescent lightbulb that the robot will need to identify; the aforementioned navigation lines on horizontal surfaces, which will allow the robot to navigate the course; and a panel on the wall of the room that will have vertical white lines used to identify it.

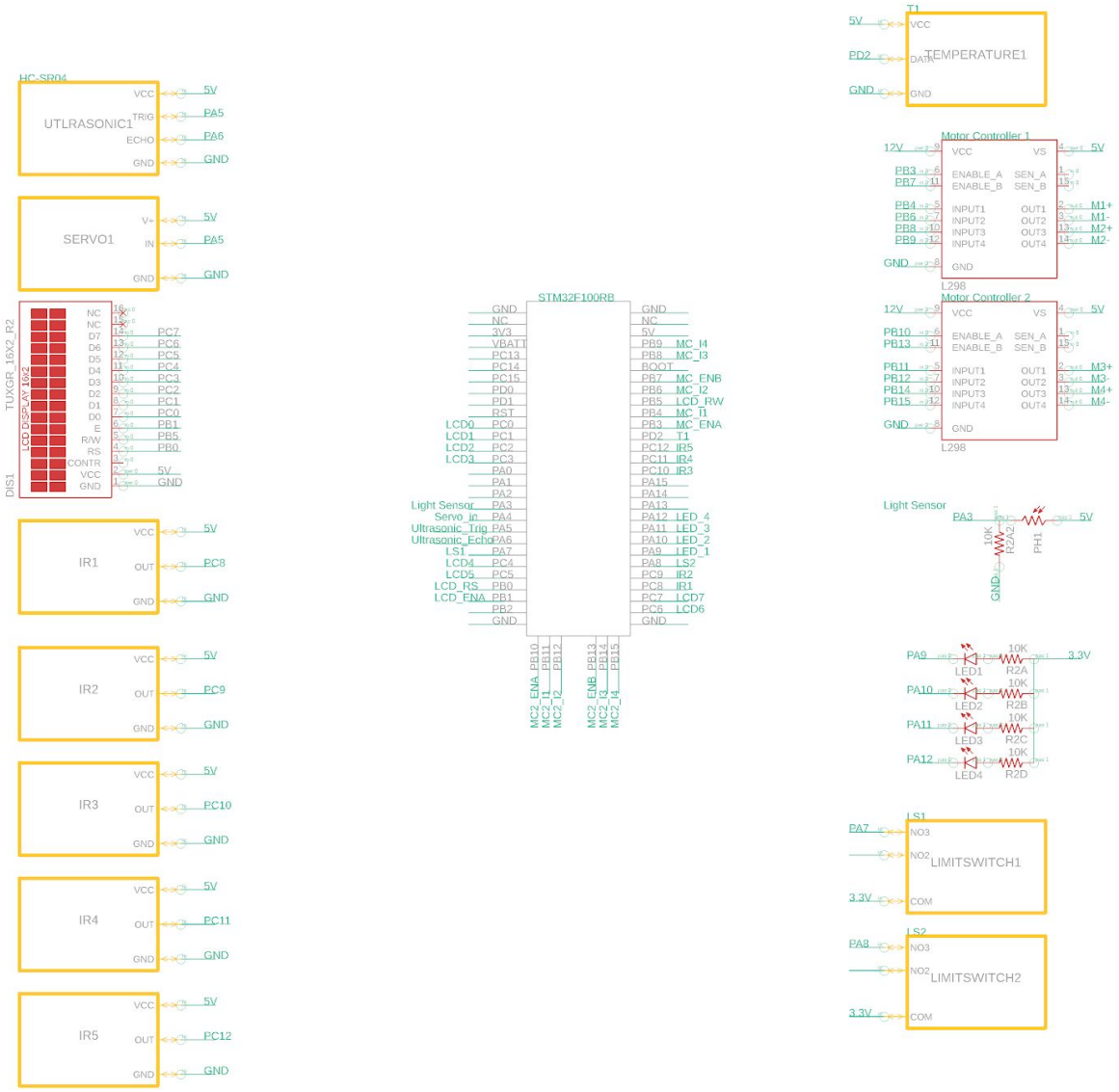
1.3 Block Diagram

A simple block diagram of our system is given below:



1.4 Schematic

Schematic with port mappings follows:

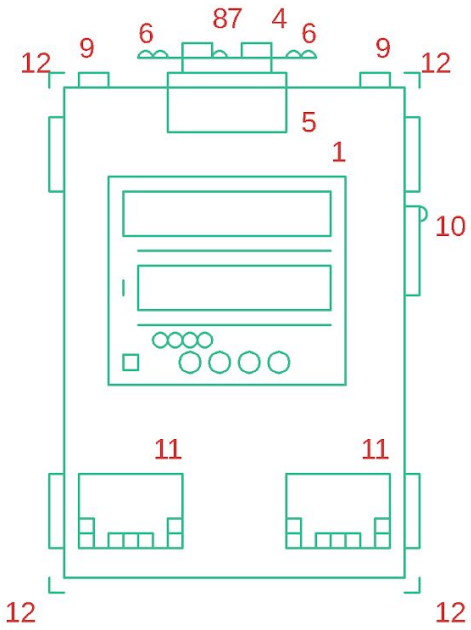


Project: ENEL 387 Robot Schematic	
Title: Robot Connections	

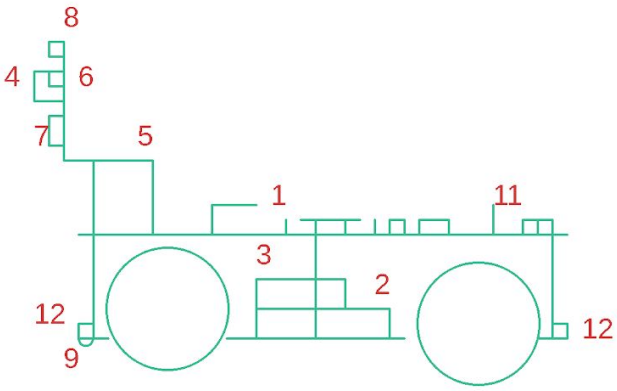
1.5 System Sketch

1	384 Board
2	Motor Battery
3	Board Battery
4	Ultrasonic
5	Servo
6	IR1 & 2
7	Temperature
8	Light Sensor
9	IR3 & 4
10	IR5
11	Motor Driver
12	Limit Switch

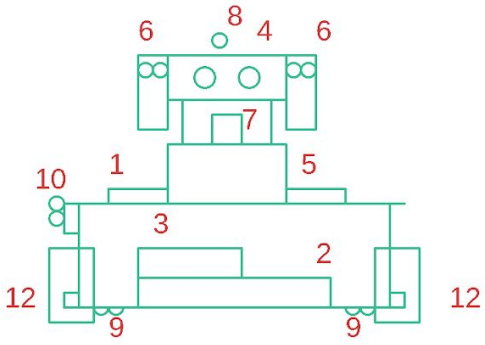
Top View



Side View



Front View



Author:	Avery Cameron
Title:	System Sketch
Disclaimer:	Not to scale

1.6 User Interface and Indicators

The robot is meant to operate entirely autonomously once it has begun the course. The user will simply have to start the machine using the start-up sequence documented in section 2.1. Therefore there are not very many inputs available to the user.

In terms of indicators, the robot contains several devices that will be used to communicate operating conditions or other information to a viewer. If a detectable internal error occurs, the four red LEDs on the 387 board will light up with a 0x0-0xF code corresponding to the given error. The LCD screen will be used to print information to the user. The LCD will be used during the start-up sequence to verify that components are functioning correctly, and will also be used to indicate when the robot has found an object in a room.

1.7 Input/Output

The board has several other components that function as inputs and outputs. Five IR sensors are used on the board: two on the servo with our one ultrasonic sensor that will scan to determine distance, two on the bottom of the car that will allow the robot to follow navigation lines, and one on the mid-right side of the car that will detect when the robot is next to an open door. The board has a light sensor and heat sensor which will both be used to detect an incandescent lightbulb within one of the rooms. The last remaining inputs to our board are the four limit switches that are located on the four corners of our board. These will be used to detect any collisions with walls that our robot may experience.

Outputs from our board are the two motor drivers, controlling the right two wheels and left two wheels respectively, the Servo that allows us to rotate our mounted sensors, our four red LEDs and the LCD screen.

1.8 Electrical Ratings

System	Parameter	Rating	Units
Motor Driver	Voltage	50	VDC
Motor Driver	Current(Max)	2	A
STM Board	Voltage	5	VDC
STM Board	Current(Max)	150	mA

2. Operation

The robot will go through the various operating modes listed below during the course of normal operation. The general functionality is that after being powered on, the robot will exit the Home Location and begin navigating according to the white navigation lines. If it encounters a room on its right side, it will enter the room. The robot will stay in the room until it has identified either a block with a number on it, or the incandescent light bulb. After identifying the object in the room it will leave the room, turn right, and begin navigating on the white lines again. The robot only enters rooms on the right, and leaves rooms to the right, so eventually the robot will have visited all four rooms, identified all four targets, and will return home. Once the robot enters the Home Location again, it will go through a shutdown sequence before powering off.
More in-depth descriptions of the modes of operation follow:

2.1 Start-Up

Switch on the power switch for the motors located on the larger of the two onboard battery packs. Then switch on the power switch on the smaller onboard battery pack. This turns on the robot.

The robot will run a short startup which will turn on LED indicators, move the robot forward and back, turn the servo and a print hex code corresponding to which sensors are working to the LCD.

2.2 Operating Modes

2.2.1 Line Following

The normal operating mode of the robot is line following. Starting in the home circle, the robot drives forward and uses an IR line follower using send and receive to follow the line as it drives down the hallway. The starting direction of the motors is forward.

The line following operation gets interrupted when the robot reaches the end of the hallway, detects a room to enter, or returns to the Home Location.

2.2.2 Turning Around

When the robot detects a wall in front using the ultrasonic sensor and does not detect any possible rooms beside it, the robot has reached the end of the hallway and turns around. The robot turns around by driving the left hand motors in reverse and the right hand motors forward until the line is detected again and it returns to line following mode.

2.2.3 Room Entering

When the robot detects a room, using irregular values detected from the IR sensors and confirmed with the ultrasonic sensor, it leaves the line and enters the room. The robot only scans the right side of the hallway for rooms and will therefore only enter rooms on the right. The robot turns and drives towards the room, using an IR sensor on the bottom of the chassis to detect the navigation strips across the entrance. A count of these navigation strips is stored in memory so the robot can ‘know’ which room it is in. After the robot passes these navigation lines, it switches to room traversal mode.

2.2.4 Room Traversal

Room traversal mode uses the ultrasonic sensor, IR send and receive and servo on the robot to scan for the panel or light. The robot will go along the wall of the room scanning for the panel to identify or the light source located in the room. The robot will scan the wall to identify the panel using the IR send and receive module. The object is scanned with an IR module which will determine the number of white vertical lines on the object. Once the object is scanned, the object’s number as well as the room number will be printed to the LCD. As the robot goes around the room, the robot will use the IR sensor, light sensor and temperature sensor to search for the incandescent lightbulb in the corners of the room. The robot will move in the room continuing to scan until an object, the panel or lightbulb, is detected and identified. The robot then enters room exit mode.

2.2.5 Room Exit

In room exit mode, the robot searches for the hallway opening to return to the line and follow the course, the robot will turn to the right as it exits the room and detects the line to follow again and returns to line following.

2.2.6 Return Home

As the robot goes through the course and follows the line, it will keep track of the number of rooms traversed and when all rooms are completed it will return to the Home Location.

2.2.7 Shut-Down Sequence

The Robot shutdown sequence involves all of the same steps as the Start-Up Sequence, except instead of printing a hex code representing the operating conditions of sensors, it will print a goodbye message before shutting off.

3. Troubleshooting

3.1 Error Indicator

The four red LEDs on the board below the LCD and microcontroller will be used to indicate error events. When an error is detected, the corresponding LED will turn on. When the error subsides, the LED will turn off. A list of all codes is given in section 3.3.

3.2 Troubleshooting Problems

3.2.1 Internal

Internal problems will be displayed externally through the use of the four LEDs on the board. Internal problems are the result of error values being detected from the input sensors. The sensors included in this internal check are the ultrasonic sensor, the IR send receive sensors, temperature and light sensors. Internal problems may resolve themselves in the case as a result of a single outlier in data reading. However, when internal errors persist:

1. Reboot the robot by turning off power to the robot, waiting, and turning the robot back on.
2. If errors still persist, check the troubleshooting table to determine which component is faulty.

3.2.2 External

External problems with the Robot present themselves externally, with the controlling of the motors and operation of line following, and object detection. When accompanied with an internal error indication, external errors can be attributed to faulty sensor readings and the internal error should be resolved first.

1. Reboot the robot and battery pack turning both off, waiting and turning them back on.
2. Check the troubleshooting table.

3.3 Troubleshooting Table:

3.3.1 Internal Errors

For the purpose of our error codes, an off LED will represent a zero. Therefore a code of 0001 would be shown with the three leftmost LEDs off, and the LED on the right on.

Error Code(s)	Problem	Possible Causes	Solutions
x000	Invalid IR1 Value	- Connection cable disconnected or damaged - The component is damaged	- Ensure cable is connected properly - Reboot robot - Replace component
x001	Invalid IR2 Value		
x010	Invalid IR3 Value		
x011	Invalid IR4 Value		
x100	Invalid IR5 Value		
x101	Invalid Ultrasonic Value		
x110	Invalid Temperature Sensor Value		
x111	Invalid Light Sensor Value		

3.3.2 External Errors

Problem	Possible Causes	Solutions
Motors do not drive	- Battery pack is out of power - Connection cable is disconnected or damaged - Motor driver connection error	- Ensure cable is connected properly - Reboot robot - Replace component
Servo does not turn	- Connection cable is disconnected or damaged	- Ensure cable is connected properly - Reboot robot - Replace component
Robot does not follow line	- Connection cable is disconnected or damaged - Invalid IR sensor data values	- Ensure cable is connected properly - Reboot robot - Replace component

4. Service Notes

Revision Date	Description of Change	Author of Change
2020-03-03	Initial writing.	Avery Cameron, Raymond Knorr
2020-03-05	Updated course description and room traversal for panel change.	Avery Cameron

5. Warnings

Be wary of sporadically moving parts. Robot includes exposed electrical wires.