ENEL387 Final project

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Contents

1. System Design

1.1 Description of project

The project is to construct a rover controlled by an STM32F103 microcontroller. This rover will navigate its orbit by following both fixed walls and black navigation lines. In this case, navigation lines are used to interact with the microcontroller to change its direction while the rover is in front of the wall. There will be three indicating patterns for the observer if the rover finds three types of floor targets that are painted black. When the rover reaches the DEAD End location, it will stop and turn around to navigate toward the START/END point. To achieve all the functionalities, the robot will be equipped with one line sensor with three color sensors. Additionally, one ultrasonic distance sensor is also required to detect the START/END position and detect the obstacles(walls). To navigate its pathway and also detect the floor targets and Endpoint, the sensors should collaborate with others. To complete the whole project, an STM32F103 microcontroller is also necessary as a CPU, LEDs as indicators, two motors and one motor driver to drive the rover forward and turn its direction, one battery with corresponding supply voltage based on the motor, one switch to control the circuit and, a chassis with wheels on it and one breadboard is also needed. The physical connections are in Figure 1.2.1. And the logical block diagram is shown in Figure 1.2.2.

1.2 System Diagrams

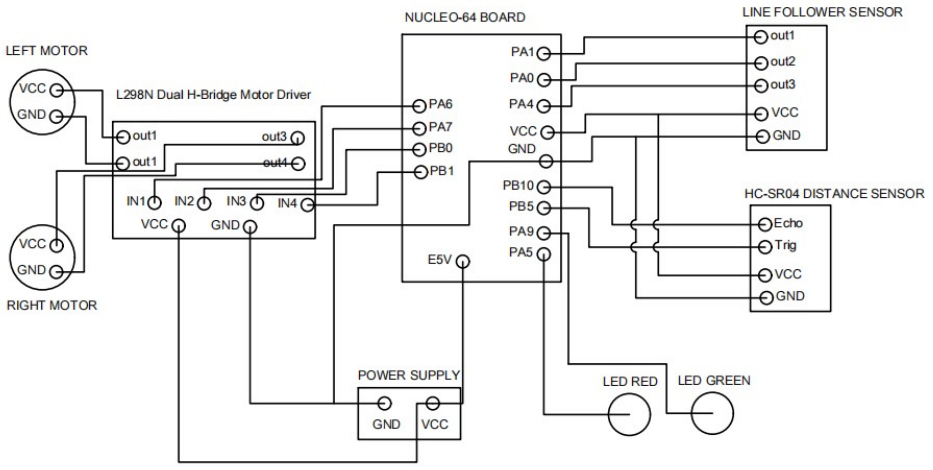

Figure 1.2.1 Physical Connection

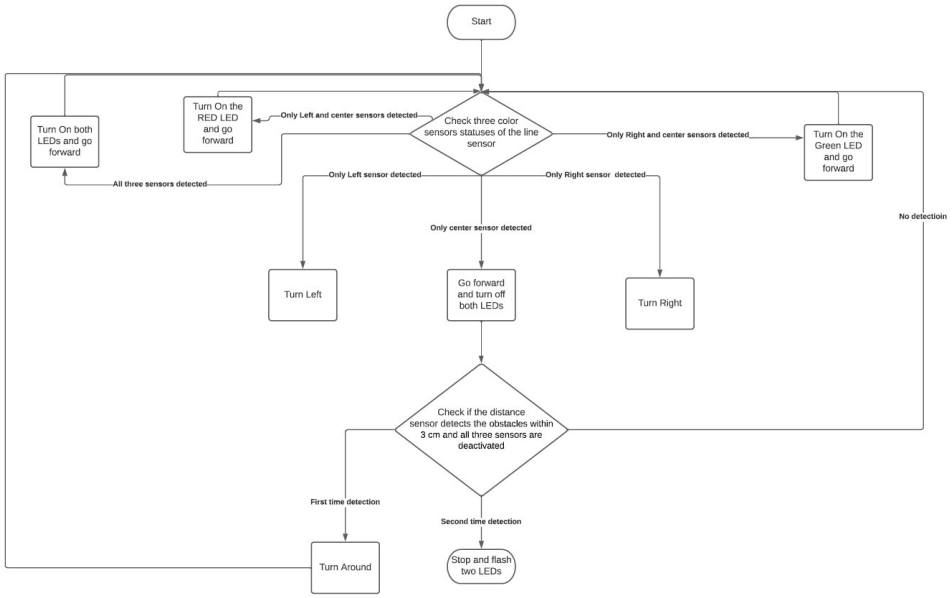

Figure 1.2.2 Logical Diagram

1.3 System Electrical Components

	Input voltage	Output voltage	Supply voltage	Working current
Line Sensor	5V(Nominal)	0-5 V Analog voltages	_____	75mA
Distance sensor	5V(Nominal)	Digital output	_____	15mA
LEDs(Green/Red)	3.3(Nominal)	_____	_____	_____
Motors	3-6V	_____	_____	200-400mA
Power Supply		_____	5V	1A
Nucleo board	5V	_____	3.3V/5V	300mA
Motor driver	3.2V-40V	_____	5V-35V	Peak: 2A

Table 1.3 Electrical Components

1.4 Functionalities

1.4.1 Navigating the pathway and Changing direction

As a rover, the basic function is to navigate the pathway. To achieve this task, two drive motors for left and right side wheels, one line sensor are necessary. The line sensor consists of three color sensors which will produce three analog signals. The line sensor connects to ADC pins(PA0, PA1, PA4) on the Nucleo board, and read by the microcontroller. When the center color

sensor is activated, and both two side sensors are deactivated, the rover is considered to have found the pathway. Then the micro-controller will produce a PWM signal to both motors and navigate on the pathway. While only the left sensor is detecting the pathway, the rover turns to the left. The same concept also would be applied to the right sensor to turn right. With this navigation functionality, the rover can turn to both left and right without any extra coding and functions.

1.4.2 Turning Around

When the rover reaches the dead-end of the course, it would turn around and start to navigate again from the end toward the START/END point. To initiate the state of turning around, one line sensor and one front distance sensor are used. When all of the three color sensors are deactivated, the distance sensor is activated(within 3 cm) and the “counter” in the program is 0, the rover would shift to the turning around state and turn its direction for 180 degrees.

1.4.3 Finding the floor target and START/END point

The floor targets are placed away from the wall and they are painted black. Due to this condition, one line sensor is needed to find the floor targets. While the right and center output signals of line sensors are activated, it means the first type of floor target is found, then the indicator/LED Green will light. After that, when the left and center produce active signals, it indicates that the second type of floor target is found and the Red LED will be turned on. The third type of floor target is found when all of the three sensors are activated, and both Red and Green LEDs would be turned on to indicate that state.

In addition to three types of targets, finding STRAT/END points will rely on the distance sensor and line sensor. When all the output signals of the line sensor are deactivated and the front distance sensors are active(within 3 cm) and the “counter” in the program equals 1 which means that the rover has reached the dead end, then the rover is on the START/END point, stop forever, and the both Red and Green LEDs would flash to indicate that state.

2. Testing Strategies and Procedures

2.1 Power Source Testing

In the project, a 2800 mAh power bank which can supply 5 VDC and 1A is equipped as the power source. As an external power supply, the Nucleo-64 board needs a special pin (CN7 Pin8) to connect the power, from the range of 4.75V-5.25V. Meanwhile, the jumper JP5 also needs to set to E5V. After all, wires are connected and JP5 set up properly, the LD1 is flashing and LD3 is turned on, which indicates that the Nucleo-64 board is ready to be used as a Micro-controller.

Another component that needs to be connected directly to the power source is the motor driver, to assure that the motor driver has enough input current to activate the motor. After the +12V and GND pin are connected properly to the power source, the LED on the driver is turned on and then, it is ready to operate. All the power supplies are measured and verified by the ADALM2000 before connecting to any component.

Instead of the Nucleo-64 board and motor driver, the other components, distance, and line sensor, are connected to the 5V and GND on the Nucleo board that produces 5VDC and smaller current.

2.2 Components Testing

Before connecting all the components in this project, the input voltages are measured by the ADALM2000 device to ensure that they are in the acceptable range for corresponding components.

2.2.1 Nucleo-64 board output pins Testing

One LED is required to test the output pins of the board. To assure that all output pins, PA5, PA9, PA6, PA7, PB0, PB1, are enabled, the LED needs to be connected to each output pin and turn on and observe the LED. And each input pin testing is embedded in the corresponding section.

2.2.2 Motor and PWM speed control Testing

To test the motor with the motor driver, only one jumper wire is needed. Connecting the power source to in1 on the driver, and then observe the reaction of motor and wheels. The same action is applied for all the remaining three input pins. After repeating 4 times, the movement patterns are concluded, in1 controls the left motor and moving forward, in2 controls the same motor and moving backward, in3 controls the right motor and moving forward, in4 is for the right motor and moving backward.

2.2.3 Distance Sensor Testing

One LED, one ruler, and a block are used to test the distance sensor. In the process of testing, the LED is connected to the enabled output pin of the Nucleo board(PA5), and the Trig and Echo pins on the distance sensor are constructed properly, connected to PB5 and PB10 respectively. Because this sensor produces digital output, so the signal can be directly used by the board. Then, set the condition, turning on the LED when the distance value is less than 5 cm, turning off otherwise. The final stage of this testing is to use the ruler and block to check if the distance sensor operates in the desired way. And continuously changing the value in the formula of calculating the distance until it works properly.

2.2.4 Line Sensor Testing

To test the line sensor, black tape, two LEDs are required. After the LEDs are connected properly to the Nucleo board, PA9 and PA5, the line sensor is the only part that needs to be tested. When the sensor detecting the black color, it will produce around 4 analog voltage in the corresponding output pin, then the ADC pins PA1, PA0, PA4 are used to convert the analog voltage to a digital output and give these signals to the micro-controller. Then, at the logical level, only turn on the Green LED when just the right sensors are activated. While the left sensors are detecting black, the Red LED would be turned on. Both two LEDs should turn on when only the center sensor is detecting black color. By using this logical strategy, all the three outputs of the line sensor can be tested and verified. Finally, the line sensor should be placed close enough to the surface to detect the colors.

2.2.5 Logical Level and Course Testing

Based on the testing cases above, all the outputs and inputs in this project will be working properly, the only test left is logical level and course testing. To ensure that this rover can fully functional, the course has to be set up, in this aspect paper, black tape, regular tape, glue, cardboard, and box are needed.

The course should be built on paper to ensure that all movements and actions of the rover have proceeded on the same condition. Because the rover is too light, the coefficient of friction of different surfaces could influence the movement of the rover. The black tape is used as the pathway to be navigated by the rover. Box and cardboard are used as walls and obstacles. Then, using the regular tape and glue to construct all the material together. Finally, using the ruler to measure the width and length of the course and adjust the location of boxes and cardboard to build the same course as the top view provided in the deliverable document.

After the course is built, the logical level testing could progress. In the program, set the corresponding conditions to achieve the desired functionalities, navigation, turning around, stop, detecting targets, and giving the corresponding signals to the observer, more detailed information is in section 1.4 and Figure 1.2.2.

In this final stage, only two LEDs would be used as the troubleshooting indicators and emphasize the tester which states the rover is in. Based on the course, the tester should observe each movement and action of the rover more carefully, because the factors would be broad. Location of the pathway, width of the targets, the location of the dead-end, the gap between each paper, all the external factors of the course can fail the test. In the program testing, all of the logic are listed and LEDs are more important to indicate the rover current state. Continuously testing the rover

reactions at different conditions, duty values, delay values to make sure that the rover can perform proper functionalities on this course.

3. Division From Functional Specification

3.1 Components Division

Based on the actual demonstration and constructing process, I realized that only one distance sensor is needed to cooperate with the line sensor and then detect the dead-end and START/STOP point. Other movements and reactions of the functionalities can be performed rely on the line sensor alone. Meanwhile, instead of three LEDs, two are enough to express all the states of the rover, details are shown in section 1.4. The motor driver is an extra component for functional specification. The driver is necessary to use PWM control signals from the board to change the motor's directions and rotating speed.

3.2 Logic Division

The first change is the finding and indicating targets functionalities. Instead of detecting one target, the rover should distinguish and indicate three different targets. The details are shown in section 1.4. Meanwhile, instead of pausing for a while and indicate the light signal to the observer, the rover would only should the LED indication and continue moving. The reason why deleting the pausing reaction is that the motor driver has some problems activating the right motor, once the rover stop, the right motor never rotates again unless giving it an external force.

Another division is the functionality of turning around when the rover reaches the dead end. Because the only line sensor is equipped in front of the rover, so the

rover is better to turn around and reuse the same functions of navigation and finding targets rather than reverse back and construct new functions.

The third division is changing the direction of the rover. When the navigation function is constructed, the rover can smoothly follow the line to move along any direction, so the changing direction function becomes unconsidered.

The last change is the finding STRAT/STOP point function. When the line sensor is deactivated and the distance sensor detected the wall within 3cm, the rover will stop and flashing the two LEDs as an indication permanently. Because the third target activates all three color sensors and due to the physical constraints, it is close to the dead end, which could result in the initiation of stop function at the dead endpoint, not START/STOP pint. And when the rover reaches the STOP point again, it will stop forever, because it completes its mission, not go back and forth again.

4. Summary

To complete the project, building the course is the fundamental requirement, then all the demo testing and adjusting are performed based on it. This project used one ultrasonic sensor, one line sensor, two motors, one battery, one chassis, one Nucleo board, one breadboard, motor driver, and two LEDs. As a scenario of operating the rover, turning the switch to activate the rover, then it will detect the path where it should navigate from START point. After finding the different floor targets, it turns on the corresponding LED/LEDs. Finally, when it reaches the dead endpoint, the rover turns around, and starts navigating back again and then repeating the same reactions while it meets relative conditions.