Final Report

# 

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# Overview

### Theory

Since the winner of the competition is based on the team that can acquire the most points by traversing the path, our team has decided to implement a design that focuses on traversing the track. The design will be based on a mostly defensive strategy and build that will allow our robot to traverse the track efficiently while avoiding contact with other robots. The robot will be controlled and directed using the IR sensor that will keep it on the path. The main components of the robot (the microcontroller, wires, board) will be protected by an enclosed shell around those components. The additional sensor that will be used in our design is a range detector. This detector will allow for our robot to scan the field in front of it, and detect if there is another bot nearby. Using this information we can decide on what course of action to take next (slow down to avoid contact, try to speed past the other bot, etc.). The overall design will incorporate defensive techniques, paired with a protected robot, in order to maximize the number of points earned.

### Design Summary

The design will consist of four infrared transmitters and receivers mounted onto the bottom of the robot in a Y shape, having a sensor at each end at the intersection. This pattern will allow for us to detect if the robot is on the line, in addition to any upcoming junctions. In order to decide which way the robot will go at a junction the side sensors will be used to control which way the robot spins until the middle IR sensors detect a black line. Then the distance sensor will be used to determine whether a path is taken or not. The distance sensor will be mounted on the front of the robot so that the field directly in front of the robot can be scanned.

# Hardware Design

### Additional Part description

Table 1

Parts added to lab

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Part Name** | **Part Number** | **Cost** | **Source** | **Manufacturer** | **Purpose** |
| 1M Potentiometer | A0013 | $1.00 | Stock Room | China | To adjust sensitivity of the infrared arrays |
| Ultrasound Distance Sensor | HC-SR04 | $10.00 (2 pack) | Amazon | Sunfounder | Object distance detection |
| 300 Ω resistor | n/a | $0.00003 | Stock room | No one really knows | To regulate current flow through the IR LEDs |
| 15 kΩ resistor | n/a | $0.000031 | Stock room | Certainly not the Borg | To regulate current flow through the phototransistors |

### Pin Assignments and Pin Usage Descriptions

Figure 1

PIC32MX470F512L Pinout

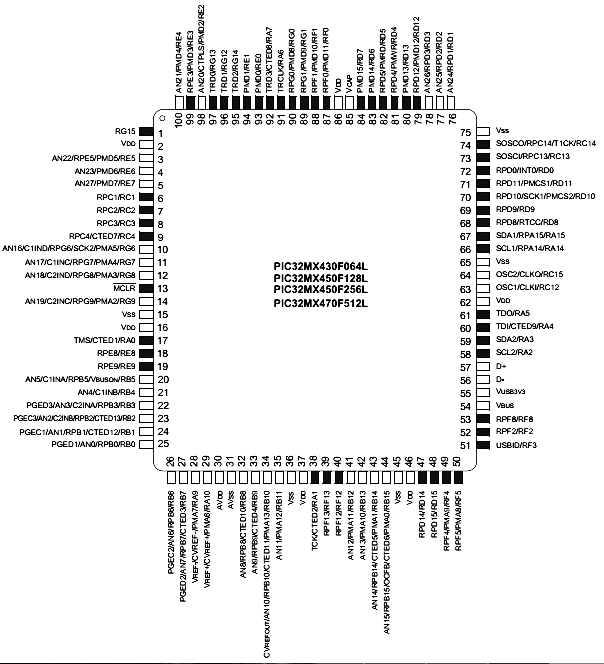
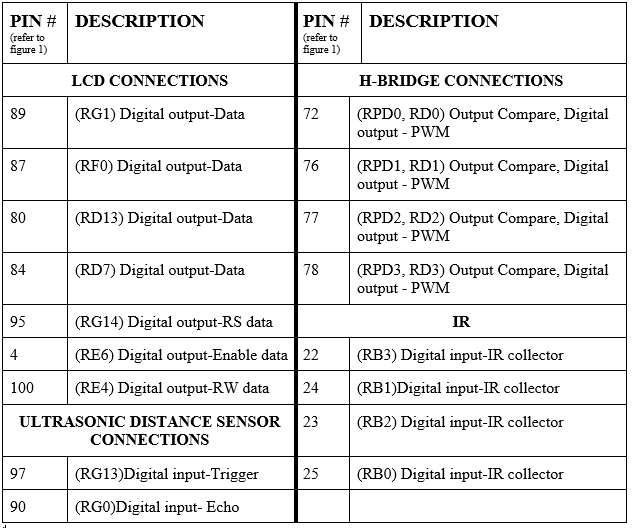


Table 2

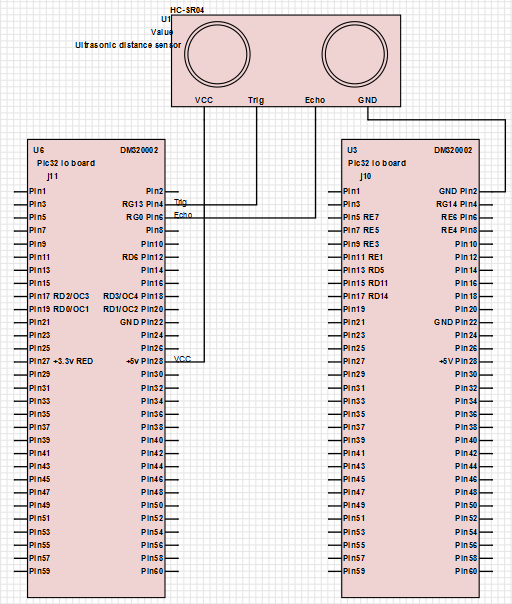


### Circuit Diagrams

Ultrasonic Distance Sensor Circuit Diagram

Figure 2

Ultrasound distance sensor circuit diagram



IR Circuit Diagrams

Figure 3a

IR circuit diagram (connections to expansion board)

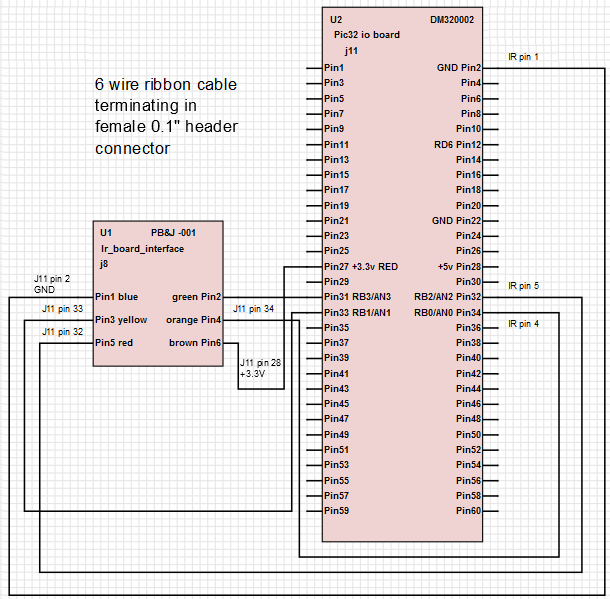
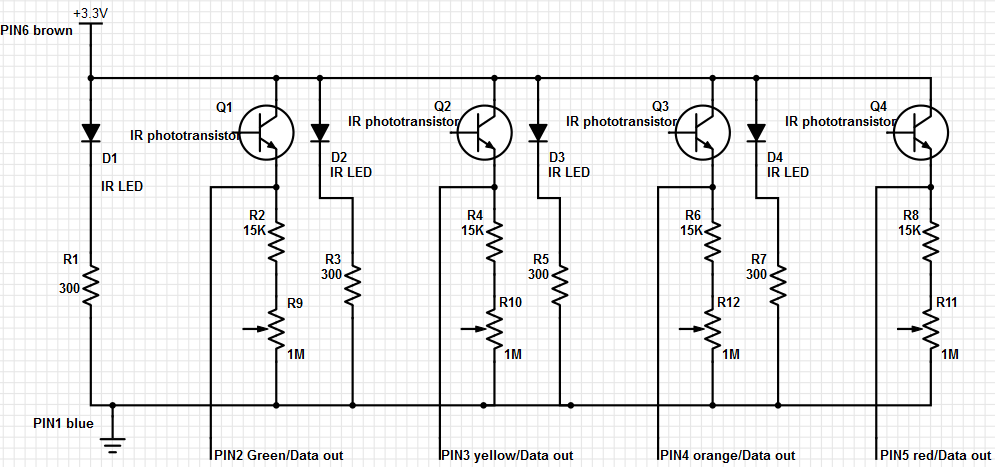


Figure 3b

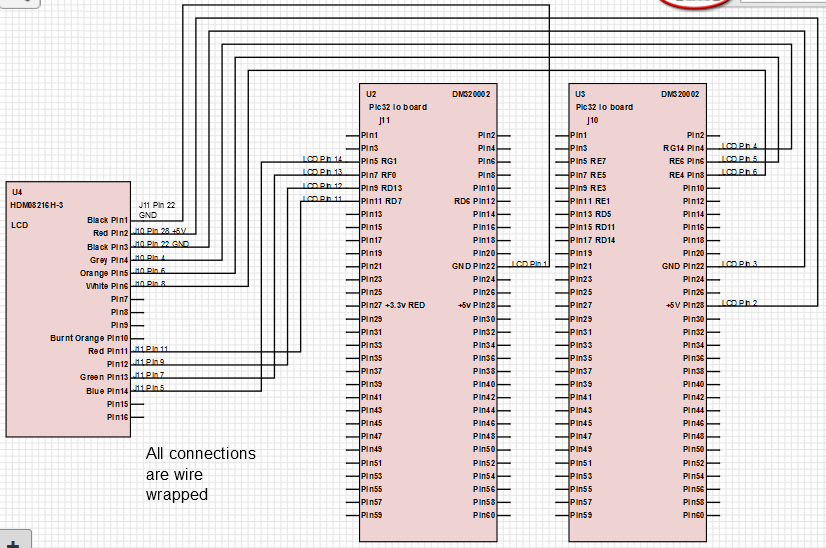
IR circuit diagram (internal connections)



LCD Circuit Diagram

Figure 4

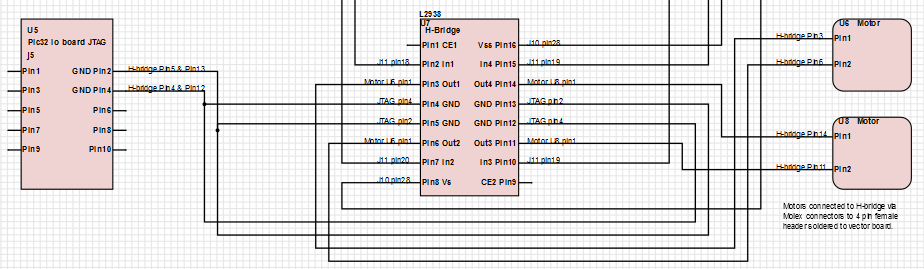
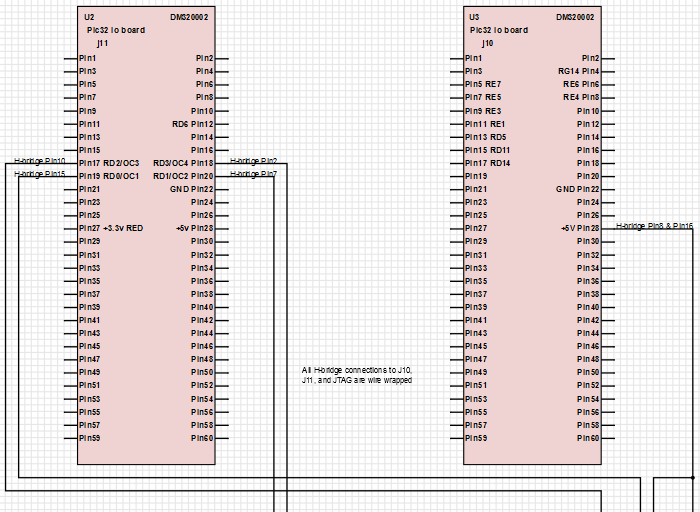
LCD circuit diagram



Motor/H-Bridge Circuit Diagram

Figure 5

H-bridge and motors circuit diagram (supposed to be one diagram, but SchemeIt sucks)



# Software Design

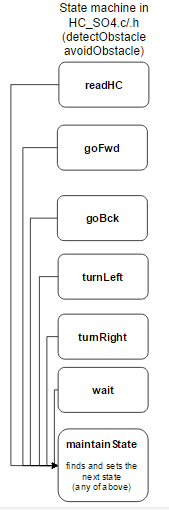
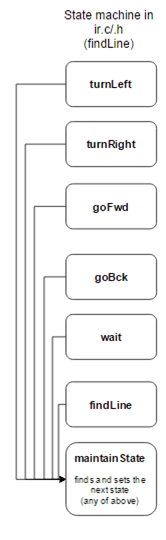
### Overview

Given the additional complexity of this project when compared to previous labs, the focus of the software design for the final is on scalability. The software is built in a way that enables both easy isolation of the robot subsystems and allows for easy modification of robot behavior at a high level. ‘main.c’ implements a state machine that carries out high level tasks while lower level tasks controlled by sub-state machines. This structure should make for simpler debugging.

This being said, the high level state machine will have states that that run tasks similar to the following: track line, check for robot, avoid obstacle etc. These tasks will then be defined as their own state machine in their corresponding .h and .c file.

The rightmost state machine below describes the high level state machine that we will be implementing in main.c. As described previously in this document, the states findLine, handleCollision, avoidObstacle, and detectObstacle in the main.c state machine will be located in separate files. The descriptions of these state machines are depicted by the diagrams below. Additionally, the diagram shows files that the state machines are in will be listed in. Each state will call a function that carries out an action. For example: the turnLeft state will call a function turnLeft() that makes the robot turnLeft. The readHc state will call a function readHc() that reads from the sensor. The same goes for all of the other states.

### Block Diagram



### Function Descriptions

Functions in pwm.c/.h

void initPWM();

Initialize the PWM for the motors and configure the pins for the robot.

void setMotorsIdle();

Sets motors to Idle.

void setMotorsBackward(int s);

Sets the motors to move in reverse with a speed of s.

void setMotorsForward(int s);

Sets the motors to move forward with a speed of s.

void setMotorsLeft(int s);

Sets the left motor to move forward with a speed of s, and right motor to stop.

void setMotorsRight(int s);

Sets the right motor to move forward with a speed of s, and left motor to stop.

void motorPiviotLeft(int s);

Sets the left motor to move forward with a speed of s, and the right motor to move backward with a speed of s.

void motorPiviotLeft(int s);

Sets the right motor to move forward with a speed of s, and the left motor to move backward with a speed of s.

void motorFindLine(int s);

Makes the robot move in a pattern that attempts to find a line.

Functions in ir.c/.h

void initIR();

Initialize the IR sensors and configure the pins for the robot.

void printIR();

Read from the IR sensors and write to the LCD.

int readIR();

Read from the IR and return an integer that can be decoded into the values read from each IR sensor.

int trackLine();

A state machine, as described above, that enables the robot to track a line.

irStateType parseIRData(int data);

Parse the data returned from the readIR() function, and return a state that the trackLine() state machine can use.

Functions in HC\_S04.c/.h

int readHC();

Read data from the hc-S04 sensor, return an int with the read information.

void initHC();

Initialize the hc-S04 sensor and the pins it connects to.

handleHC();

A state machine that controls the operations related to reading from the hc-S04 sensor.

hcStateType parseHCData(int data);

Parse the data returned from the readHC() function, and return a state that the handleHC () state machine can use.

# Testing Design

### Overview

The testing for this design will be done in a modular and step-wise fashion. In doing so we can assure all the parts that will be connected to the robot work individually. Once the robot starts to be assembled more tests can be performed to ensure parts work when implemented together.

### Tests

TEST 1: IR Sensors:

The purpose of this test is to ensure the functionality of the IR sensor and the pins that it will be connected to.

The first part of this test involves determining if the pins that the IR sensor will be connected to are functioning properly. In order to do this each pin was first mapped as an input. Then, the functions: printIR(), testIR() were used to read the values on the four IR pins and display those values onto the LCD. When nothing is connected to the pins the expected output on pins 31,32,33,34 respectively is “0000” since all the pins are reading logic low. In order to test each pin, the pins were individually connected to logic high using a jumper. When the pin is connected to high a 1 should be displayed onto the LED. For example, when pin 32 is connected to logic high the LCD should display “0100”.

The second part of the test is to ensure the IR sensor itself works. Since the pins and the LCD display function were tested for correctness in the previous part of the test, the functionality of the IR sensor will be able to be tested fully now. In order to do this the IR sensor was connected to pins 31,32,33,34 and first pointed at an all-white surface. The expected reading display on the LCD for this setup is “1111” since the IR sensor should be causing the pins to be logic high. The next step is to face the IR sensor at an all-black surface. The expected reading display on the LCD for this setup is “0000” since the IR Sensor should not be causing the pins to be logic high.

TEST 2: IR Potentiometer Tunning

The purpose of this test is to tune the potentiometers so that the values read by the IR sensor are as close to logic low (1.0V) and logic high (3.75V) as possible. In doing so the IR sensor will not have to use the ADC converter.

The first step in performing this test is to connect power to the input of the IR board and connect the oscilloscope to the output of the IR board. The oscilloscope is setup to read the voltage coming off the of IR board output, this voltage is what needs to be as close as possible to logic low and logic high given a white or black surface respectively. The process of tuning the potentiometer involved flashing the black and white surfaces in front of the IR sensor and adjusting the potentiometer so that the voltage readings were close to logic high and logic low. The value of the potentiometer was read and recorded using the Digital Multi Meter. This process was chosen as opposed to working out the resistance value by hand because it provides more accurate results that can be seen on the oscilloscope.

Attached images show the voltage readings for black and white IR sensor readings.

Test 3: Testing Motor Functions

The purpose of this test is to ensure that all the different motor functions are properly controlling the motors. The reason this test is needed is because several different motor functions have been written that all serve a different purpose in terms of controlling the movement of the robot, and since any can be used for the competition every function needs to be tested.

In order to test the motor functions (setMotorsRotate, setMotorsSweepForward, setMotorsSweepBackwards, setMotorsForward, setMotorsBackwards) the functions were called with different hardcoded values for the input (ADCBufferValue). The robot was then programmed using these hardcoded values and the results of the motors were observed. For example the setMotorsSweepForward function was tested by calling it with an input of 400. The expected result is for the right motor to move forward at full speed while the left motor moves forward at about 80% speed. The code for testing this function can be found in the testMotorFunctionality() function.

Test 4: Testing the Range Detector

The purpose of this test is to ensure that the newly acquired sensor (the range detector) works properly. The reason this test is necessary is because the range detector will be used to control the states of the motors and it must be tested independently of the motors to ensure it is working correctly.

In order to perform this test the range detector will be connected to the microcontroller and the values will be read in via digital pins. An object will be moved in front of the sensor and then the distance the object is from the sensor will be varied. The values being read from the sensor will then be displayed onto the LCD using a previously tested function for printing onto the LCD. The values will be tested against an actual measurement of the distance from the object to the sensor using a measuring tape so the accuracy and precision of the sensor can be obtained.

There will be up to a ~40 ms delay for the sensor to return distance readings. We will hook up an oscilloscope to the TRIG pin and the ECHO pin and measure the time intervals for TRIG output to see if it matches 10µs as specified in the datasheet; for ECHO to see if it matches the 38ms as specified in the datasheet.

Final Project Device Proposal

# Summarized Proposal

The device that has been chosen to improve performance in the competition is the Ultrasonic Module HC-S404 Distance Sensor. This sensor will aid in controlling which path on the track is taken by the robot. The distance sensor will allow for the robot to scan the field in front of it and detect if there is another robot on the path. When the robot comes to a corner where it needs to make a decision on which direction to go, the distance sensor will aid in making that decision. The robot detects that it has reached the end of a path it will spin until a black line is found. Once that black line is found the distance sensor will send out a pulse to detect if there is another robot on that path. If another robot is found on the path, our robot will continue to spin until a new black line is found. This process will be repeated until a black line is found that contains no other robots, in which case our robot will move forward down that path in order to earn points. This strategy is a purely defensive one and should allow for the maximum number of points to be earned while avoiding potential collisions.

# Part Details

|  |  |
| --- | --- |
| Device Name | Ultrasonic Module HC-SR04 Distance Sensor |
| Product Number | SN-HC-SR04 |
| Price | $5.99 |
| Distributor | Sunfounder |
| Communications Interface | N/A |
| Hardware Interface | 4 Pins, Vcc, Echo Trig, GND  Mounted onto a vector board |



# Summarized Use

The operation of the Ultrasonic sensor is fairly simple. Four pins from the sensor are connected to the microcontroller (Vcc, Trig, Echo, GND). The sensor works by sending a pulse of high voltage to the Trig pin for 10us, this will initiate the sensor to transmit out 8 cycles of ultrasonic burst at 40kHz and wait for the reflected ultrasonic burst. When the sensor detects ultrasonic burst from the receiver, It will set the Echo pin to high voltage for a certain period of time proportional to the distance. The distance the sensor is from the object can then be calculated based on the time. If no object is found the Echo pin will be set to high voltage for 38ms. In order to find the time that the Echo pin is high a timer will be started once the Echo pin first goes high. A while loop will then be started and will end once the Echo pin is low. Once the while loop exits the timer will stop and the time will be read and used for calculating the distance. Example software for the device is shown below.

# Proposed Tasks

Task 1: The first task that will be performed with this device is to output the distance being read from the sensor onto the LCD. In order to do this the value being read from the sensor will be converted into a distance using the following formula: (Duration of high level)\*(340)/2, which will give us the distance in cm. Once this value has been read in and converted it will be passed into a function that prints values onto the LCD. We can compare this value with the actual distance measured from the sensor to the object.

Task 2: The second task will be to interface the distance sensor with motors. The objective of this task is to use the distance sensor in order to control the direction of the robot. The distance sensor will sense weather there is an object in the direct path of the robot. Using this information the motors can be adjusted in order to spin the robot until it finds a clear path and then continue forward.

Task 3: The final task is to interface the distance sensor, motors and the IR sensor. The purpose of this task is to keep the robot on the black lines during the competition whilst avoiding other robots. The distance sensor will be used in order to scan the field in front of the robot when the robot detects that it has come to a corner of the track, it will spin and scan the field in front of it. In order for the robot to continue moving forward it will need to find a black line that contains no other robot on it. In terms of software, the distance sensor will be returning NULL and the IR sensor will detect black.

#include "Arduino.h"

#include "Ultrasonic.h"

Ultrasonic::Ultrasonic(int TP, int EP)

{

pinMode(TP,OUTPUT);

pinMode(EP,INPUT);

Trig\_pin=TP;

Echo\_pin=EP;

}

long Ultrasonic::Timing()

{

digitalWrite(Trig\_pin, LOW);

delayMicroseconds(2);

digitalWrite(Trig\_pin, HIGH);

delayMicroseconds(10);

digitalWrite(Trig\_pin, LOW);

duration = pulseIn(Echo\_pin,HIGH);

return duration;

}

long Ultrasonic::Ranging(int sys)

{

Timing();

distacne\_cm = duration /29 / 2 ;

distance\_inc = duration / 74 / 2;

if (sys)

return distacne\_cm;

else

return distance\_inc;

}

/\*

Ultrasonic.h - Library for HR-SC04 Ultrasonic Ranging Module.

Created by ITead studio. Alex, Apr 20, 2010.

iteadstudio.com

\*/

#ifndef Ultrasonic\_h

#define Ultrasonic\_h

#include "Arduino.h"

#define CM 1

#define INC 0

class Ultrasonic

{

public:

Ultrasonic(int TP, int EP);

long Timing();

long Ranging(int sys);

private:

int Trig\_pin;

int Echo\_pin;

long duration,distacne\_cm,distance\_inc;

};

#endif