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Abstract

As a part of the course module EN1093 Laboratory Practices-1, we were given with firefighting robotic challenge. The goal of the project is to develop the skills related with electronic as well as programming area, to empower the team work and to make students to develop the skills regarding decision making, logical thinking etc. In our firefighting challenge, we had to build a line following robot which can navigate through the lines on the bi-colored arena, detect the lit candles which are arbitrarily kept on the ends of the branches and extinguish them with the minimum time

We were instructed to use PIC micro controller for MCU and were given set of instructions regarding the arena, the robot and the criteria we have to complete. Based on the instructions given we built the robot that can complete the desired task. The robot would take 25-30 seconds to complete the entire task. The robot has the capability finishing the task with 95.4±0.1% accuracy.

This documentation written in order to explain the functionality, how we approach and implement to achieve the desires task, results we found, issues that we often faced of our firefighting robot

1.0 Introduction

The robot design consists of various sub systems, which linked with each other through the PIC microcontroller. The subsystem of the robot includes: Infrared line detecting sensor (Pololu QTR-8A), Ultra sonic sensor(HRC04), Motor controller circuit (build with L298), fan and microcontroller installing circuit. With the system assembled, microcontroller communicate with each subsystem to complete the desired task.

The designing group consist of 4 people, and the work was carried by ourselves based on our strong interest. The group is intended to build a solid design of the robot that could detect the fire and extinguish it with least time. The following is the detailed report which includes all the necessary descriptions, schematics and algorithm relating each subsystem to run the robot2

2.0 Procedures

2.1 Chassis Setup

The chassis profile of the robot is solid and stable. The aluminium L bar is used to design the skeleton of the body which is light and strength material. The skeleton is designed in accordance with the contest rules. In order to maintain the stability of the robot the center of gravity of the body is lowered by mounting heavy components like LiPo battery and 12V DC motors to the lower side of the body. The body includes two main wheel which can be controlled by circuit, which is about 4cm diameter [See Fig.2.1.1]. In addition to that the body had to be supported by use of two caster wheel to ensure the stable balance while making sharp turns and also avoiding the robot tipping forward.

The white line detecting sensor was mounted bottom of the front frame and the ultra-sonic sensors were mounted don either side of the robot a sufficient height to detect the candle holders[See Fig.2.1.2]. On the front of the robot e mounted the CPU cooling fan. The fan is power supplied through relay switches. By designing the skeleton with adequate space we could be mount the components securely and in an easy way for adjustments and false checking requirements, also have clean appearance and with enough potential for the task.

Figure 2.1.1

Motor and wheel assembly

Figure 2.1.2

Motor and wheel assembly

2.2 Subsystems

2.2.1 Power Systems

The main power supply of the robot is rechargeable 11.1V; 3 cell, LiPo, 4200mAh battery. The 12v motors were powered directly LiPo battery, for powering to the micro controller voltage regulator circuit module is used. The module was prepared by ourselves which is step down the voltage to 5V. The module contains regulator IC with headers and heat sink to prevent any possible overheating problems. The regulator circuit consist of main switch by which we were able to have safe and control interconnection with hardware components. In addition to that having the switch ensure that the only power that was drawn from battery is used at the given time. So that we could eliminate unwanted power dissipation.

For the PIC micro controller, we had a separate circuit build by ourselves in accordance with datasheet for PIC16Fxxx and PIC18Fxxx provide by microchip. The circuit contains headers to the relevant ports of the PIC, in addition we had used an LED to ensure that the microcontroller has been programmed. The designing of a separate circuit board for the micro controller with required pins had eased us to use needed components depending on tests during calibration time. The battery was able withstand about 4 hours during calibration time. Since the battery is old one we had a trouble of getting inconsistent current with the drop in battery charge. Any how the effect of the change could be neglected.

2.2.2 White Line Sensors

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The most important sub system of this robot is the white line sensor. For sensing the white line, we had used POLOLU QTR-8A sensor array module []. The module contains 8 pairs of IR emitter and receiver which ae evenly spaced at intervals of 0. 95cm.Although the output of each pair is independent, the pairing reduces the consumption of power. The LED pairs are controlled by the MOSFET gate. Each LED current consumption is about 20-25 mA [See Fig.2.2.2.a][1]

QTR-8A sensor Outputs:

Each pairs in the module gives an independent analog voltage between 0V to Vcc (which is 5V in our circuit). when the sensor is over the white line, the reflectance will be strong, the output voltage will tend to 0V. With weak reflectance the output will tends to Vcc. In order to get a good range of values the sensor board was mounted at about 1.25 cm above the surface. The analog output values are then sent to PIC, the ADC library(reference) **convert** it to digital values by which the motion of the motor is controlled.

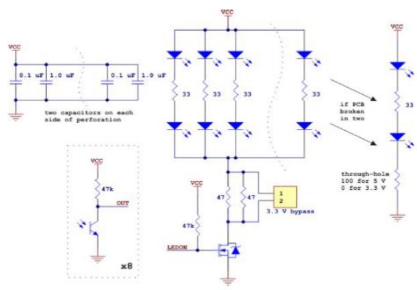

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Figure 2.2.2.a

Schematic of QR-8A array

In the calibration process each pair is tested with all possible reflective surface in the arena it will encounter

2.2.3 Distance Sensor

In our arena the candles will be kept on a holder made up of PVC pipe. The holder will be in a branch at 15cm from the junction if the candle is light up. So to extinguishing purpose we used to detect the base of the holder. For this purpose, we have used HC-SR04 Ultrasonic Distance Sensor module. It is most convenient non contacting distance measuring sensor. It can detect the object distance in a range of 2cm to 400 cm. The module includes ultrasonic transmitter, ultrasonic receiver and its control circuit [See Fig.2.2.3.a][2][3].

Figure 2.2.2.a

HC-SR04 sensor module

The module includes four pins:

- **VCC**: 5V
- **TRIG:** Trigger pin
- **ECHO**: echo pin
- **GND:** Ground pin

TRIG and ECHO pins can be used to connect the module to the PIC.

Functioning of the Module:

WhenTRIGGER is activated it sends eight 10µs pulse of 40kHz ultra sonic burst.If there is obstacle in front of the module ,the burst will be reflected whch is then received bythesensor,If the sensor receivedthe burst back,the ECHO pin will be in HIGH state[See Fig.2.2.2.a].The High state voltage input by the sensor defines the successive motion o f the robot through the PIC.To check the availability of candle holder we had used two module on either side of the robot. At each junction we activated the ultrasonic sensor,depends on the out put the robot make the next decision;to move to the branch or continue the motion.

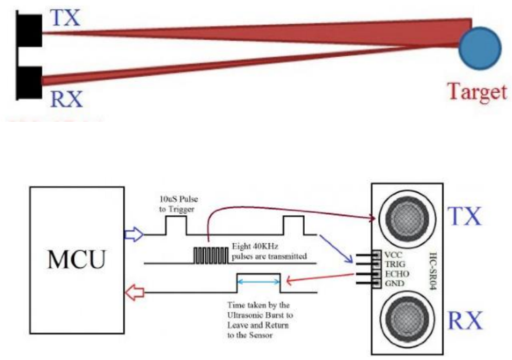


Figure 2.2.2.a

HC-SR04 module working

2.2.4 H-Bridge Motor Driver

To drive the motors, we used the L298 motor controlling IC [See Fig.2.2.4]. The sub circuit was designed using Software and the PCB was obtained manually. The relevant components were manually soldered and a heat sink is attached with the IC to avoid the overheating when the amount of current drawn through IC is high. The PCB circuit is then connected to the Main Circuit Unit through appropriate pins. According to the outputs of the white line sensor and ultra-sonic sensor, the PIC controls the motors.

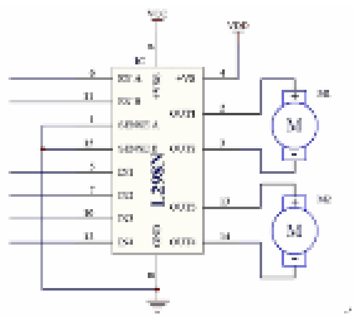


Figure 2.2.4

Motor Controller Circuit Schematic

The dual H driver can dive to DC motors simultaneously. In order to run the relevant motor, we need to enable the motors. The following table shows the response of a motor inaccording to the inputs given[See Table 2.2.4].

Although we can able to control the motion of the motor using the bridge, there is a problem we had in bindings. Since the IC supplies High or LOW current, in turning the robot is tending to turn with respect to the vertical axis gone through the wheel to which LOW voltage has been supplied, as result when taking turnings, the robot tends to move to the dark surface completely. In order to rotate the body with respect to its central axis and to provide better turning we have used pulse signal to enable the motors. The CCP1 and CCP2 pins of the PIC is responsible to the generation of the pulse voltage. The periodic increase and decrease of voltage level rhythmically Turn ON and OFF the motors at proper places

Enable	L1	L2	Response
0	0	1	Clockwise rotation
0	1	0	Anti-clockwise rotation

Table 2.2.4

Motor Controller Response

2.2.3 DC Motors and Wheels

DC motors:

We had used a pair of 12 V,3000 rpm motors for the main motion control. Although 6V motors is enough for the motion of the robot we have used 12V motor by which we could be controlled a solid motion of the body. Also with the minimum effort the robot could move for a long distance as he motor provides a power which give large momentum to the body. The motors are geared using the readymade gears available. The physical size of the motors was small enough to fit them into the body. Since motors have reasonable weight we used them to lower the center of gravity which would help to avoid unnecessary bugged motion of the robot.

Wheels:

The wheels we used were 55mm plastic wheel with 10mm Rubber Tire which is used for RC cars. Since the wheel base is small width and the wheel is wrapped perfectly with the rubber part, we were able to move the body on any terrain and also it increase the speed of turning compare to the large width base wheels.

2.2.6 Fire Extinguishing System

Once the robot successfully identifies the candle holder, turns to the relevant branch and stopped front of the candle holder, now the time is to extinguish the flame. To complete our ultimate task, we have used a 12V chassis attached computer fan about 3”x3” dimension. We selected this fan considering many aspects listed follows:

1. The rotational speed of the fans large enough to extinguish a candle flame. Also the resistance is very much low, thus it didn’t need a much current, even after switch of the fan, the fan is rotating which was assisted us in extinguishing strong flame.
2. Since almost all parts of the fan are made up of plastic materials, it is a light weight subsystem attach to the body.
3. This fan has enough static pressure to force the air flow and give adequate air pressure in the blow direction.
4. The ire extinguishing fan module available in the market is about five times the price of this fan. Using this fan save us a lot

Figure 2.2.6

Fan

2.3 PIC Microcontroller

The Microchip PIC 18F452 microcontroller[4] is the brain of this robot. The robot works according to each of the command send through the PIC microcontroller to the subsystems and from the subsystems. We built a separate PCB board manually for the MCU [See Fig.2.3][Appendix 2]. Then the necessary components for programming the PIC microcontroller was soldered and silicon wax was applied to the copper area to prevent the oxidation**.**

Figure 2.3

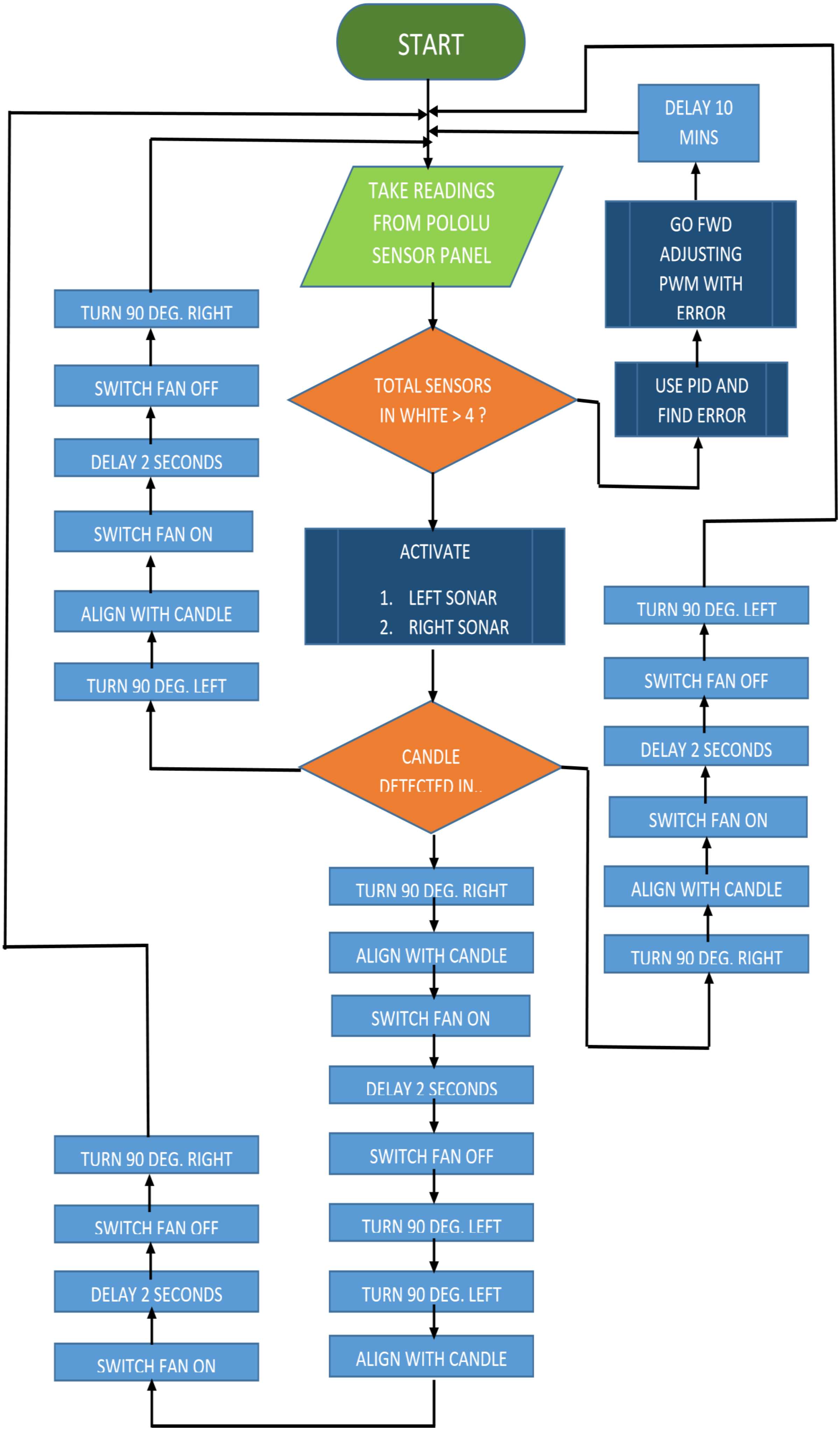
PIC Microcontroller PCB

The board was fixed at to the body of the robot such that it can easily connect with the supply circuit and other sub systems. Then by proper commanding through programs the Pic was controlled.

2.4 Program Development

With completing all the needy hardware stuffs the ultimate task by which the simulation is done is by the code programmed. Before code anything related to the robot control we had drafted algorithms and pseudo codes. In the algorithm and the pseudo code we had targeted to the basic functionality that we have to do. Based on the pseudocode we developed codes using mikro C pro 2011.Our code is mainly based on the PID algorithm[5]. The PID algorithm commonly uses to waddling of robot during line following motion. In that algorithm, the error caused when the robot leaves the line, is integrated and the subsequent motion is decided by the previous error. The algorithm then operates the turning of the robot proportional to the error occurred.

On subsequent calibration we adjusted the code according to the hardware parameters of different subsystems that affect the motion of the robot. After each trial and checking of our code we drafted the issues that we faced with the previous code and the almost all the possible worst cases that each subsystem may undergo. Our final code modified as much as fit to the working parameters of each of the sub systems. For uploading the ‘. hex’ file to the microcontroller we have used locally made PIC kit2 with the help of the PIC_KIT2 programming software.


START
DELAY 10 MINS
TAKE READINGS FROM POLOLU SENSOR PANEL
GO FWD ADJUSTING PWM WITH ERROR
TURN 90 DEG. RIGHT
SWITCH FAN OFF
TOTAL SENSORS IN WHITE > 4 ?
USE PID AND FIND ERROR
DELAY 2 SECONDS
SWITCH FAN ON
ACTIVATE
1. LEFT SONAR
2. RIGHT SONAR
TURN 90 DEG. LEFT
ALIGN WITH CANDLE
SWITCH FAN OFF
TURN 90 DEG. LEFT
DELAY 2 SECONDS
CANDLE DETECTED IN..
SWITCH FAN ON
ALIGN WITH CANDLE
TURN 90 DEG. RIGHT
TURN 90 DEG. RIGHT
ALIGN WITH CANDLE
SWITCH FAN ON
DELAY 2 SECONDS
TURN 90 DEG. RIGHT
SWITCH FAN OFF
SWITCH FAN OFF
TURN 90 DEG. LEFT
DELAY 2 SECONDS
TURN 90 DEG. LEFT
SWITCH FAN ON
ALIGN WITH CANDLE

3.0 Observations

3.1 Average time taken to travel from starting point to end point

Trial	Time Taken (S)
1	20
2	21
3	18
4	25
5	19
6	21
7	23
8	20
9	19
10	19

Average Time Taken to travel = **20.5 S**

Chart 3.1

Time taken for a trial

3.2 Average time taken to travel from starting point to end point

Trial	No. of junctions detected
1	9
2	9
3	9
4	9
5	9
6	9
7	9
8	9
9	9
10	8

Average No. of junctions detected

= **8.9 ~ 9** junctions

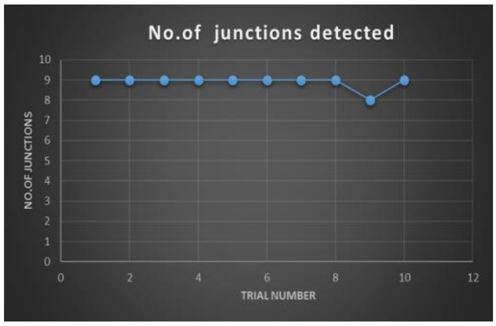


Chart 3.1

No. of junctions detected

Trial	No. of candles extinguished (out of 4)
1	4
2	4
3	3
4	4
5	4
6	3
7	3
8	4
9	4
10	4

Average no. of candles extinguished = **37 out of 40**

Accuracy = **(37/40) *100**

= **92.5%**

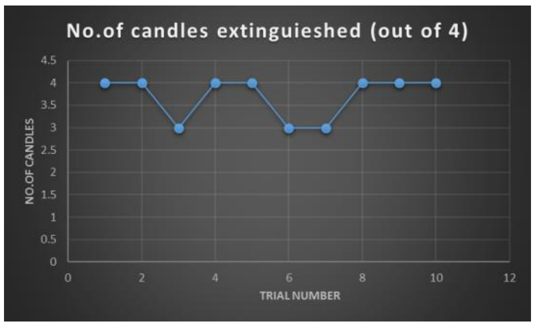


Chart 3.3

No. of candles detected

3.4 Observations and Issues

During the calibration time and demonstration time we encountered some sort of issues regarding the hardware as well as software aspects. The issues and the solution that we have taken is described below

3.4.1 MikroC IDE and the PIC kit

Since the IDE we had used to program was a trial version, the code memory that can compile by the program is limited.so we need to reinstall older versions of the IDE, which are bit of different in syntax.

For uploading the program, we had use the local built PIC Kit, where we have to plug in the PIC for programming each time, to avoid wasting time on plugging the PIC, we've used 5 wires from the pins (Vdd, Vss, PGM, PGC, PGD) which are used to program the PIC micro controller.

3.4.2 Motor Controller circuit

For motion control of motors, we have built a H-dual bridge motor control circuit manually, but most of the time the L298IC was burnt due to overheat and the circuit quickly damaged by the oxidation. As a result, most of the time we had use the motor control module for the calibration, we were forced to use the module instead of our circuit.

3.4.3 LiPo battery Issue

Most of the time we have used Lipo battery at about 70% of charge. The calibration was done almost at that charge level. During the calibration time we were in the idea that the momentum gained by robot will be enough for turning purpose. Our code was fully based in the idea of momentum of the body. During the final demonstration we have charged the battery fully. Since the current supplied by the fully charge battery is high, the turning became hectic to us. The robot tend to turn more than the calibrated value. This may be due to increase of momentum of the robot. So that we have to change some delay values in the code. As result during the final demonstration, the turning effect was not good as our calibrated effect.

3.4.4 Fan Controlling

For extinguishing purpose, we decided to use the computer fan as it is cheaper and efficient enough. We had the problem of operating the fan as it required 12V 100mA for optimum operation. Since we have to operate fan through the PIC and the supply voltage is not enough for its operation, we used a BJT transistor which can roughly increase the Ic current up to 100mA by the base current supplied by the PIC controller. Then the Ic current and 5V supply from the PIC is send to a relay switch which switches 5V to 12V.

4.0 Acknowledgement

Although this robotic competition gave us lot of experience, completing the task was not an easy task k for us as we were newbies. Many personals from the department as well as outside the department helped us to accomplish this firefighting robot.

First and most important personal we would like to thank is our supervisor Mr. Sudaraka Mallawaraachchi (sudaraka@ent.mrt.ac.lk) who supported us to learn the basic concepts of robotics and boosted us to self-learn the required stuffs needed for the robotic challenge. The weekly meetings conducted by him were very helpful to clear the problems and doubts we had faced and also gave us new notions to complete our task.

Also we willing to pay our gratitude to all the lecturers, instructors and other academic staffs who were intimately welcomed us to share their knowledge and experiences regarding these type of competitions. We are very much grateful to the personals who are in charge of laboratories and electronic workshop for allowing us to use the labs when needed and supported to solve the technical problems.

The most important is our department, the support from the ENTC family to conduct and complete this robotic completion successfully is inevitable one. Each one of our batch willing to share what they knew apart from the competition.

Further, we would like to thank all the people who supported us to complete our robotic challenge successfully at the due time

5.0 Appendices

5.1 Appendix-1 Competition Rules and Regulations

Summarized Objective

Develop a line-following robot that can navigate, detect and extinguish several arbitrarily positioned, lit candles on a bi-colored arena. The robot must be designed, calibrated and optimized in order to extinguish all lit candles within a minimum amount of time

Robot Specifications

- Only <u>one</u> robot is allowed per participating team. The robot **cannot separate during operation**.
- <u>Maximum</u> dimensions of the robot are $26 \times 26 \times 26\ cm^3$.
- There is no weight requirements for the robot, however, lighter robots perform better!
- The robot must be battery powered. External power sources and cables are not allowed.
- The robot must <u>follow lines</u> in order to navigate on the arena.
- The robot **must be completely autonomous**! All manual interventions will be heavily penalized.
- The robot **must not harm the arena** during operation. Carefully select the materials of the robot.
- The robot **must not physically touch the flame** in order to extinguish.
- Contestants are allowed to decorate their robots in any manner of their preference. .

Arena Specifications

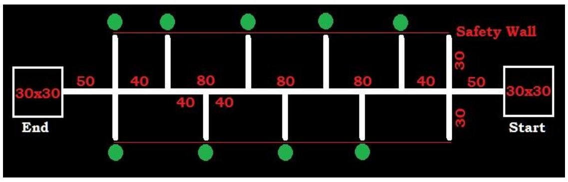


Figure 1 - Drawing of the Proposed Arena.

- **Building of the arena is the responsibility of the contestants.** o The sooner you have the arena, the sooner you can start preparing for the game
- Please refer Figure 1 for the proposed schematic of the arena.
  - All dimensions are shown in red are <u>measured in centimeters.</u>
- All components shown in white and green must be drawn or pasted.
  - White regions are for **navigation**. Make sure they remain 'white' for the final competition!
    - Please refer standard schematics and sensor dimensions to decide the path width.
  - Green dots are for **candle placement**. The diameter of each circle is *5cm*.
    - Please align them perfectly with the vertical grid lines.
- The safety wall is an <u>optional</u> component, separating the candles from the navigation region.
  - Wall height should be less than *2.5cm*.
- The dimensions of the proposed arena are $\sim 4.8 \times 0.6 m^2$
- Contestants are <u>not allowed to customize the final arena</u> under any circumstances, regardless of the effects the customization may have upon the arena.
- Contestants can discuss and make alterations to the proposed schematic before constructing it!

Candle Specifications

- The arena supports placement of up to <u>nine</u> (9) candles as shown in figure 1.
  - Only <u>four</u> (4) of these slots will be utilized during each competition round.
- These 4 candles can be placed on any of the 9 locations according to the preference of the judges. o Only one candle will be placed at a single location.
- All candles must be mounted on a black cylindrical base with *5cm diameter and 7cm height*.
  - Participants must build these
  - cylinders using a suitable material, such as wood.

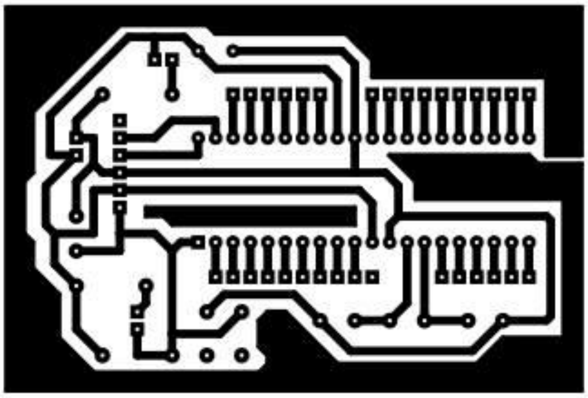
- Bases used for the competition cannot be used for trial or calibration purposes.

- Proposed candle type is shown in figure 2.
  - **Participants must purchase a sufficient number of candles for the competition.**

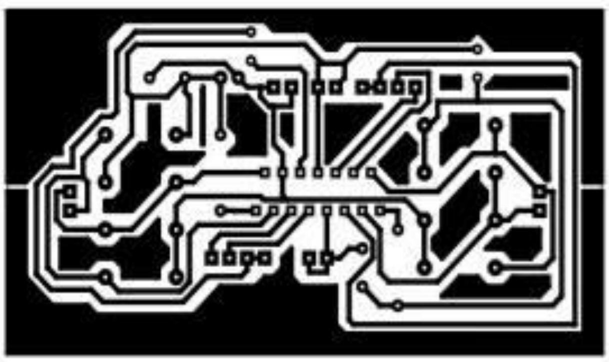
Figure 2 - Proposed candle type

- The circular candle placement region must clearly be marked on top of each cylinder!

5.5 Appendix-2 PCB diagrams for the circuits used



PCB diagram for Main Circuit Unit



PCB diagram for Motor Controller Circuit

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