LABORATORY PROJECT

Line & Wall Following Robot

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EN1093 Laboratory Practice I

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Abstract

A robot that follows a line and then follows wall is designed using ATMEGA32A microcontroller. Three HC-SR04 ultrasonic distance sensors was used to follow walls and 2 IR sensors (designed by us) was used to track the line. 4 IR sensors was used to identify the start points and end points. Two 180650 batteries was used series to power the circuits. LM7805 based circuits (designed by us) was used to regulate voltage. For controlling the motor L293D IC based motor controller was designed by us. For the locomotion of the robot two N20 DC 6V gear motors was used. Finally algorithm was implemented to ATMEGA32A microcontroller using Atmel Studio. Chassis of the robot was designed by us.

Contents

Introduction

Description

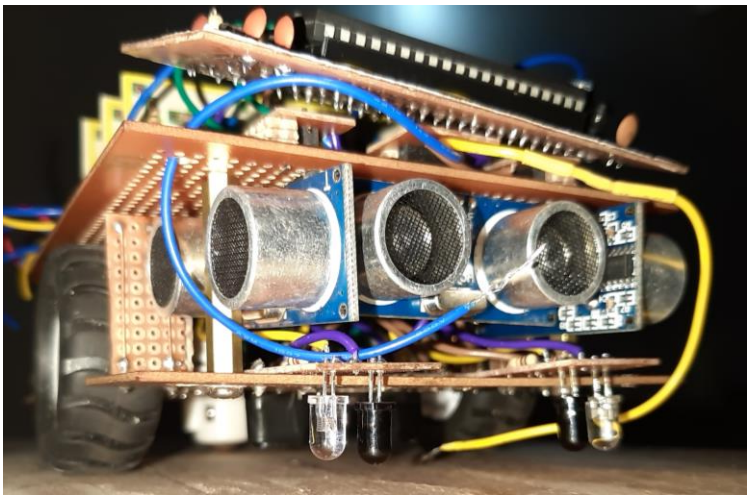
There were basically three sides of designing the robot as

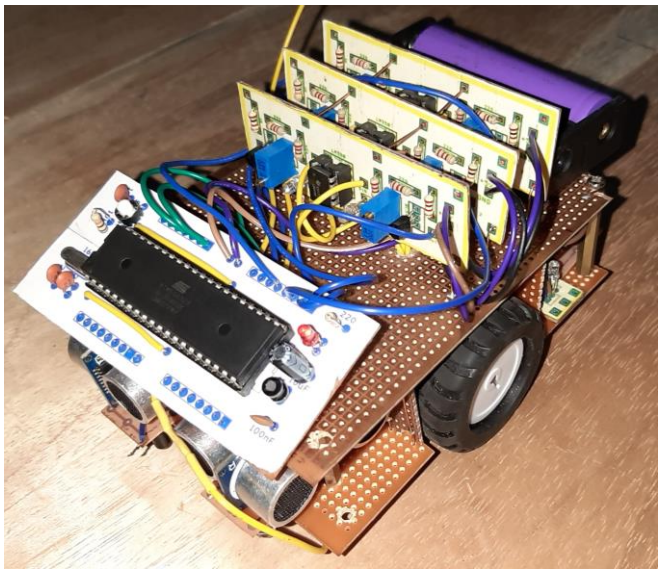
1. Designing the Hardware (electronic circuits)
2. Designing the algorithm and coding
3. Designing the chassis

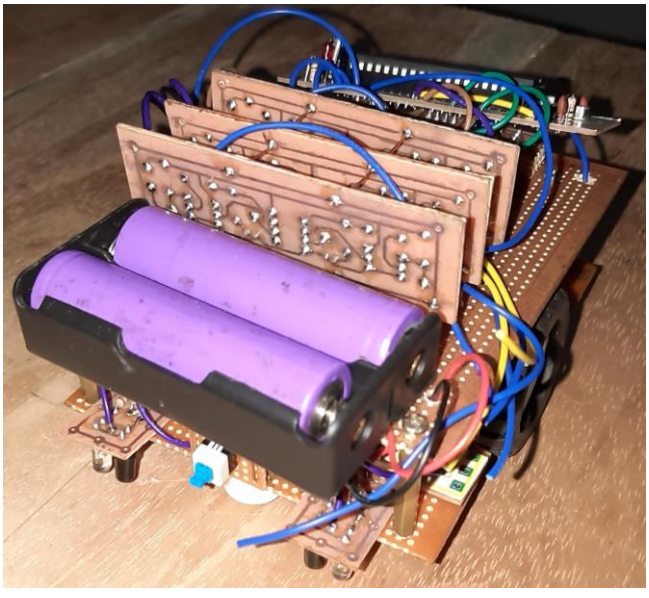
First we designed the electronic circuits needed for the robot and then designed the algorithm for functions and tested the functioning of the robot. After that we manufactured the PCBs with the smallest possible sizes and tested the circuits. Then we designed the chassis of the robot.

First robot should complete the line following by identifying start and end points. Then it should follow the wall and finally stop at the destination. Robot should be capable of following curved turns and taking 90^0 turns at wall following path.

Size of the robot should be within the given dimensions.







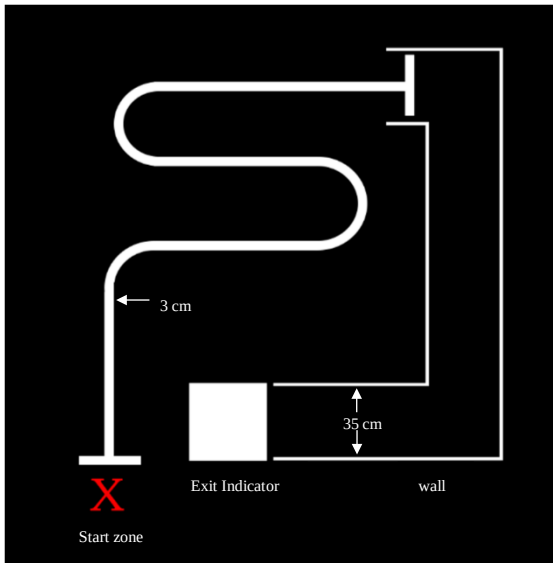
Robot Specifications

1. Only one robot is allowed per one team. The robot cannot separate during operation.
2. Maximum dimensions of the robot are 20 x 20 x 20 cm^3.
3. The robot must be battery powered. External power sources and cables are not allowed.
4. The robot must be completely autonomous. Manual interventions are not allowed.
5. The robot must not harm the arena during operation.

Design rules

1. Teams have the autonomy to select off the shelf structures or self-designed structures.
2. Arduino or any electronic development boards will not be allowed. However, teams are free to use any microcontroller (PIC, ATMEL) in making the robot.
3. Arduino IDE is not allowed for programming.
4. All PCBs should be designed and manufactured by members of each team. (Off the shelf motor control boards, line following sensor panels are not allowed)
5. Teams are allowed to use any type of proximity sensors, motors.

Task



- **Start zone:** Marked with a red "X" in Figure 1. The robot always starts from this location
- **Line following zone:** Each line segment should have a width of 3cm. Note that, the line following part of the arena will not contain 90^0 turns. (There will be curved lines instead).
- **Wall following zone:** Inner width between two walls is approximately 35cm. The wall will be made by white color wall segments of length 35 cm and height 10 cm. Wall segments are not fixed to the arena. It should be possible to change the traversing path by rearranging the wall segments.
- **Exit Indicator:** A white square with 35 x 35 cm^2.

Method

Methodology Description

1. Tracking the white line

   Two IR sensors was used to track line.
   When the difference of two outputs is identified by the microcontroller, particular motor is driven for 2mS to make the robot follow the line.
   When reflection from both sensors is identified by microcontroller both motors are driven for 2mS.
   When no reflection is identified, none of the motors are driven.
   A loop is used to follow line continuously.

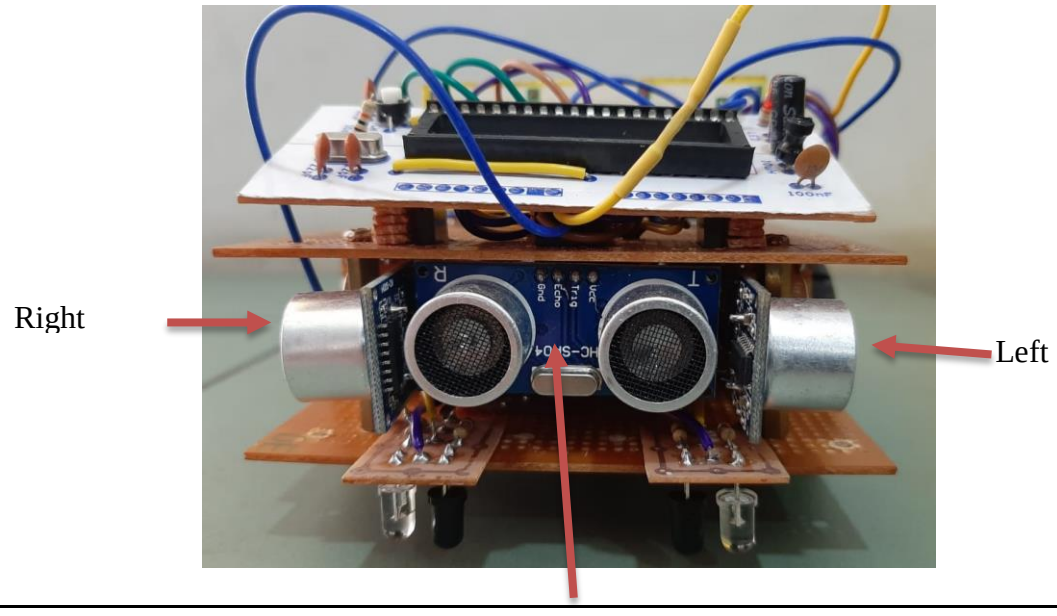
2. Identifying Start and End points

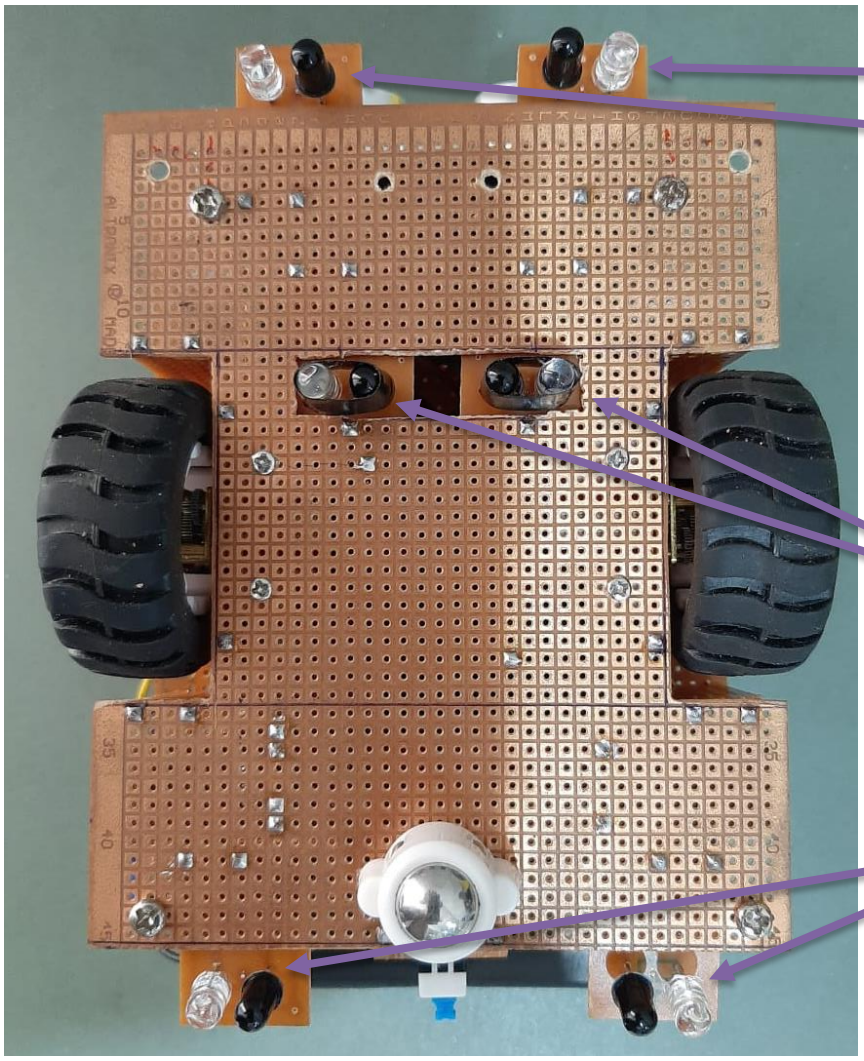
   Four IR sensors was used for this. Two at the front of the robot and two at the rear of the robot.
   When reflection from both front sensors was identified by microcontroller, robot identify the line perpendicular to path.
   Stopping at final destination is identified by the two sensors fitted at rear of the robot.

3. Following wall

   Three HC-SR04 sensors was used to accomplish this task.
   Sensors were fitted at
   - Front side
   - Left side
   - Right side

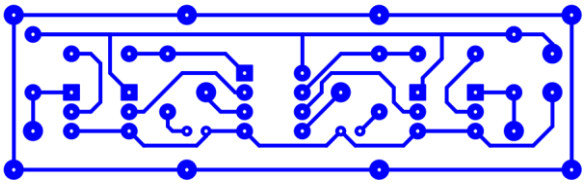
   If the microcontroller identifies an obstacle in 5cm distance infront of robot, then it make the turn to the side where there is no obstacle.

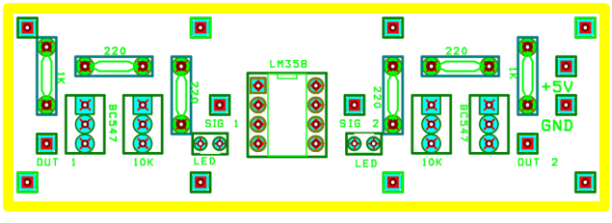




Circuits and Components used

1. Three IR sensor panels
   One sensor panel consist of one LM358 package which consist of two operational amplifiers and two IR modules (IR module - one IR Transmitter diode & one IR receiver diode) are connected. The comparator circuit identifies the condition and signal the microcontroller circuit. BC547 transistor converts the analog signal to a digital signal. Threshold point can be adjusted by the 10K variable resistor. PCBs are manufactured by us. Components in a sensor panel
   i. LM358 package * 1
   ii. 3mm red LED * 2
   iii. 10K variable resistor * 2
   iv. 220 resistor * 4
   v. 1K * 2
   vi. BC 547 transistor * 2

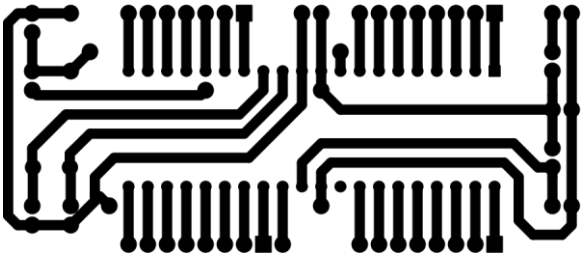


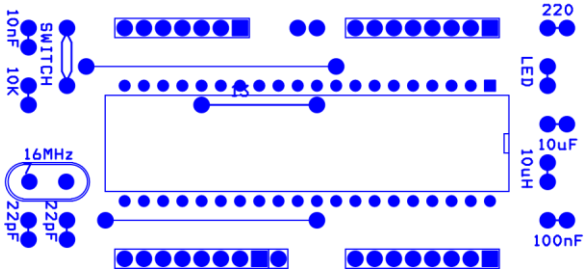


2. Three Ultrasonic sensor panels
   Factory manufactured HC-SR04 modules were used as the given instructions.

3. Microcontroller circuit
   40 pin ATMEGA32A microcontroller was used. PCB was manufactured by us. Components used are

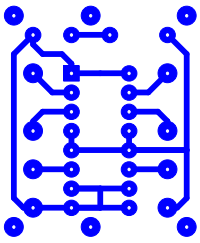
   i. ATMEGA32A IC * 1
   ii. 10K resistor * 1
   iii. 220 resistor * 1
   iv. 3mm red LED * 1
   v. 10nF non-polar capacitor * 1
   vi. 100nF non-polar capacitor * 1
   vii. 22pF non-polar capacitor * 2
   viii. 10uF polar capacitor * 1
   ix. 10uH inductor * 1
   x. 8MHz crystal * 1
   xi. Push button switch * 1

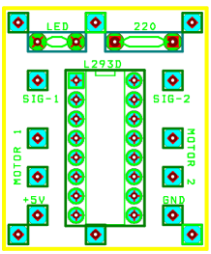




4. Motor Driver circuit
   L293D motor controlling IC based circuit was designed by us. As the IC consists of internally attached diodes, circuit is very simple. IC is capable of unidirectional driving of 4 motors independently. As two N20 motors are to be driven, pins of IC is connected two drive two motors bidirectional. PCB was manufactured by us. Components used are

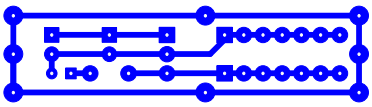
   i. L293D IC * 1
   ii. N20 gear motor * 2
   iii. 220 resistor * 1
   iv. 3mm LED * 1

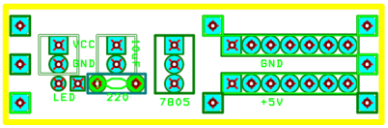




5. Two voltage regulating circuit
   LM7805 voltage regulator based circuit was designed. As motors consume comparatively high amount of power, one regulating circuit is dedicated to drive two motors, motor driver circuit and IR diodes. Other circuit supply power to all other circuits. So overloading one regulator is prevented. As we use two 3.7V 18650 batteries in series to power up the robot V_{in}-V_{reg} is comparatively low and smaller heat sinks are adequate. PCB was manufactured by us. Components used in a circuit

   i. LM7805 *1
   ii. 10uF * 1
   iii. 220 resistor * 1
   iv. 3mm LED * 1
   v. Heat sink * 1





Atmel code

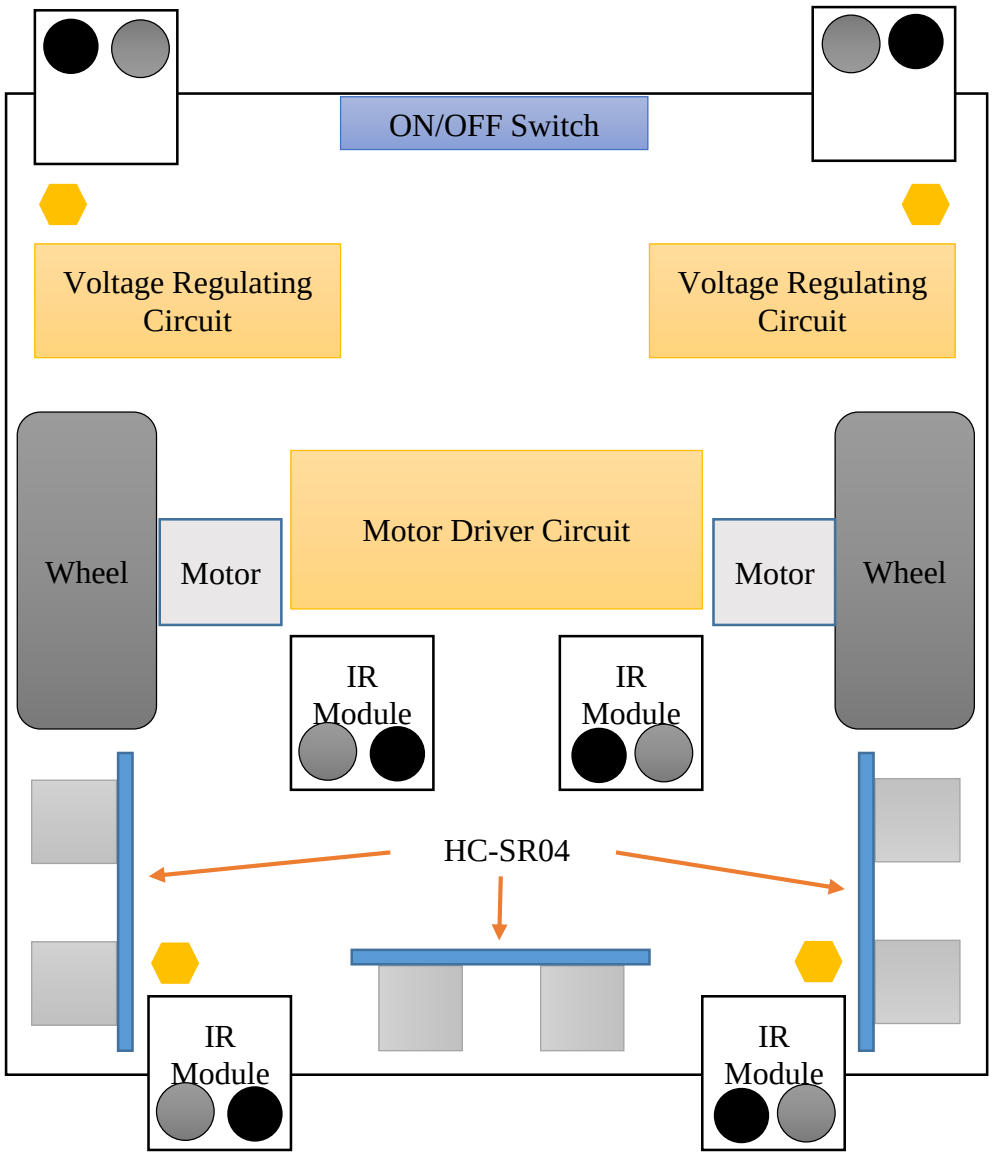
For coding we used Atmel studio 7.0 and the used code is

```
#ifndef F_CPU
#define F_CPU 1000000UL
#endif

#include <avr/io.h>
#include <util/delay.h>

int main(void)
{
	DDRB = 0b00000000;
	DDRD = 0b11111111;

	int ls1, rs1,fl,fr,bl,br;
	while (1)
	{
		ls1 = PINB & 0b00000001;
		rs1 = PINB & 0b00000010;
		fl  = PINB & 0b00000100;
		fr  = PINB & 0b00010000;
		bl  = PINB & 0b00100000;
```

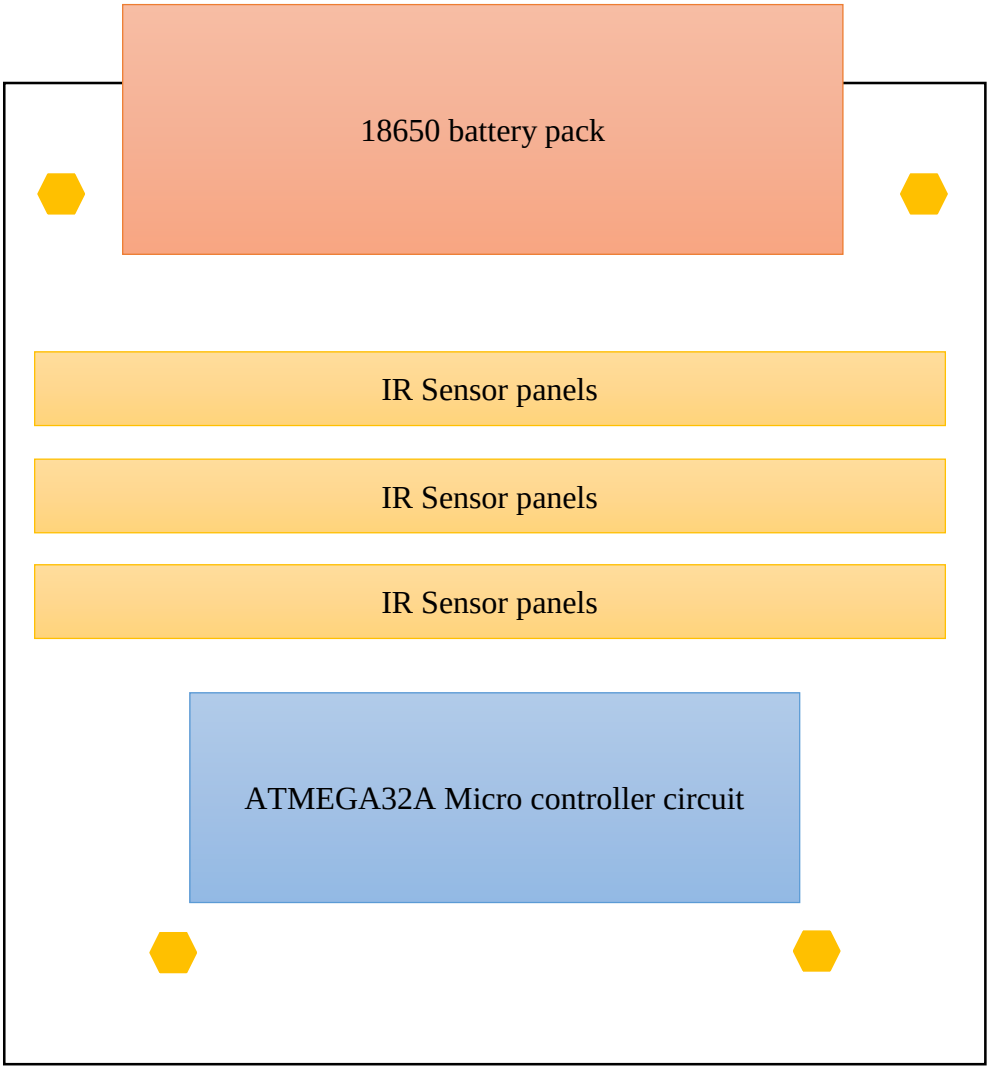
```
            br  = PINB & 0b01000000;


            if ((ls1 == 0b00000001)  && (rs1 == 0b00000010))
            {
                  PORTD = 0b00001001;
                  _delay_ms(10);
                  PORTD = 0b00000000;

            }

            else if ((ls1 == 0b00000000)  && (rs1 == 0b00000000))
            {
                  PORTD = 0b00000000;
                  _delay_ms(10);
                  PORTD = 0b00000000;
            }

            else if ((ls1 == 0b00000000)  && (rs1 == 0b00000010))
            {
                  PORTD = 0b0000001;
                  _delay_ms(10);
                  PORTD = 0b00000000;
            }

            else if ((ls1 == 0b00000001)  && (rs1 == 0b00000000))
            {
                  PORTD = 0b00001000;
                  _delay_ms(10);
                  PORTD = 0b00000000;
            }

      }
}
```

Structure and chassis

Robot is two storied. Platforms are made of fiberglass boards. Four spacer pillar screws are used to separate two platforms. Locomotion of the robot is accomplished by two rubber tired wheels and one universal wheel. All circuits are oriented saving space such that robot is very compact. Dimensions of the robot are 15cm*10cm*8.5cm.



Bottom platform



Top platform layout

Engineering Aspects

- Ultrasonic sensors give comparatively accurate readings when the distance is higher than 5cm. Width of the wall following path is 35cm. Width of the robot is 10cm. Therefore if we assume robot travel in the middle of the path, sensors have a distance of 12.5cm to take readings.
- Except two voltage regulating circuits, there 5 circuits and 9 module which work on 5V. So if we use high voltage batteries, when regulating lot of energy so wasted. When considering rechargeable batteries, least cost effective & lesser weight type is 18650. So we decided to use two batteries in series which will give 7.4V of total voltage as to minimize the power wastage.
- When choosing the motors we choosed N20 motors as it can be operated with 4V-6V range the batteries have a maximum of 7.4V. As the torque of N20 motors are comparatively less and RPM is high, we chose N20 reducer gear motors.
- When supplying power to motors, we decided to use 5V from the same regulating circuit for the safe guard of the motor.
- For IR sensor panel circuits we needed 6 operational amplifiers. For the ease of manufacturing PCBs and reduced size we used LM358P package with two operational amplifiers other than LM324N package which have 4 operational amplifiers.
- For the motor driver circuit we chose L293D package as it can be operated without a heat sink and consist of internal diodes. So we could design very simple motor driver circuit with very lesser size. If we chose L293 package, we have to add external diodes. If we used L298N we should use a heat sink and may cause damage to wires which touch the heat sink from thermal energy.
- When manufacturing chassis we used perforated fiberglass boards as the weight is negligible and have adequate strength. And mounting components and circuits was easy as the board is uniformly perforated in a matrix.
- In IR sensor panel circuit operational amplifiers output an analog signal. To convert it to a digital signal we used a BC547 transistor as we can reduce the number of steps in Atmel program so the robot will work efficiently.
- We decided not to use PID for line following part as
    i. the surface was even
    ii. width of the line is fixed at 3cm
    iii. Line is continuous.

  So the code for line following part is very simple and efficient. And the design is cost effective.
- We added a reset switch in microcontroller circuit to reset program without interrupting power.

Results

Out of the two tasks, line following and wall following, we could complete only the line following part due to an error occurred in the code segment for ultrasonic sensors.

Conclusions

- For line following in even surfaces PID is not essential. With two IR sensors line can be followed accurately.
- In chassis manufacturing perforated fiberglass board is a good substitution for Perspex boards.
- When taking readings delays are important.
- Using IC bases in PCBs for the ICs we use, increase the replaceability.
- Using indicator LEDs for circuits ensure the functioning and easy to troubleshoot.
- Adding a reset switch in microcontroller circuits makes easy to restart program without power interrupts.
- In the same IC there are different versions with slightly different configurations (L293 & L293D). Choosing most versatile configurations will reduce the complexity of circuit and cost.
- When voltage regulating, difference between input voltage and output voltage should be minimum in order to reduce the power wastage.