Design and Implementation of the Line Follower Robot Based on Single Pole Double Through Relay by Using Microcontroller

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A B S T R A C T

The aim of this work is to achieve an efficient control design for the line follower robot based on Single Pole Double Through (SPDT) relays by using PROTEUS professional software and its practical implementation. It followed a white line on the black background, detects turns or nonconformities, and operates the motors very efficiently by using the microcontroller. Infrared (IR) sensors are used to sense the white line (path). Differential directing was utilized to turn ON the robot. In this article, we have the voltage from the comparator by using the IR sensors. Microcontroller AT89C51 reads the voltage from comparator and operates the relays and these relays further operate the Direct Current (DC) motors. Each rear wheel has a dedicated DC motor while the front wheel is free to rotate. The design and hardware implementation with microcontroller are presented in this paper. Multiple tests were carried out on the robot for validation of the ability to follow the white line by adopting the accurate path and successfully achieving the target. It is worth mentioning that the robot has successfully achieved the target by using the AT89C51 microcontroller.

Keywords: IR Sensors, Comparator LM324, Microcontroller AT89C51, Single pole double through SPDT Relay, DC motor, Proteus professional software

1. Introduction

Embedded systems regularly incorporate the advancement of the technology such as the interfacing of different modules hardware and software, microcontroller-coding having different techniques, for achieving the better accuracy and all various sensors working knowledge. In the field of embedded systems, project-based learning is very important for deep understanding, interest, and motivation for the students. By the design and implementation of the line follower robot, students can grasp the knowledge of schematics, hardware, software as well as the utilization of the same on the large-scale system [1].

In the past robots were used in the nuclear reactors, accelerators, X-rays generating machines to avoid the radiation because these rays are very harmful for the human being. AT89C51 may be an exceptionally great microcontroller dependent on the coding technique that is utilized for controlling the robot to take after the precise line position. Robot is logically programmed using a microcontroller to follow the specified path and perform multiple tasks in the military, building construction, fabricating units and especially in industries where the hazardous environment for the human [2].

Nowadays robots are being used by the industries for various applications. In industries, the function of the robot is to deliver various products from one position to another, where other options like gantry systems, conveyer and rail are not appropriate option. Line follower robot is an automated robot that follow a specific path on the floor. The path may consist of a white line on a black surface or a black line on a white surface.

The control system utilized must be able of sensing a line and move the robot to remain online, by using the feedback system robot will always follow the line. Mobile robots may be designed by using microcontrollers. It uses various sensors and technologies to recognize and move all around its surroundings. Whereas creating a mobile robot, it gets to be vital to explore it freely and energetically within the workspace [3]. In the modern environment or the development of new products comes the requirement for new sensors or controllers, human body is a mobile robot and having various sensors and controllers [4]. To identify the line, which is to be followed, multiple sensing techniques can be utilized they may vary from the high-cost vision system to low-cost circuits [5]. The work is being done to improve the quality and function of the robotic system by the various researchers [6].

This paper describes the design and implementation of a line follower robot, which would be able to follow a given composite path.

2. Basic Principle of Line Follower Robot

The important principle included, as it follows the path with the use of IR sensors that are mounted at the front of the robot [7]. The combination of phototransistor and IR LEDs is used for accurate sensing and the same is called the optocoupler. The line sensing procedure requires higher resolution and robustness. With the help of steering mechanism, it must steer robot to follow the line. To attain this, we utilize two IR sensors for the detection of line and two motors for the movement of the wheels. The proposed block diagram of the line follower robot is shown in Fig. 1. The IR transmitter-receiver senses the line and the analog output received from the receiver is shared with the comparator and the same will produces 1s and 0s. These 1s and 0s are the input of the microcontroller, based on these inputs microcontroller chooses the next movement depending on the programming. The output of the microcontroller, which will operate the

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SPDT relays and the same relays will operate the DC motors [8]. When both IR sensors are online and indicate "1" the robot will move forward and follow the path. Similarly, when both IR sensors are offline and indicate "0" the robot will stop and move reverse in direction.
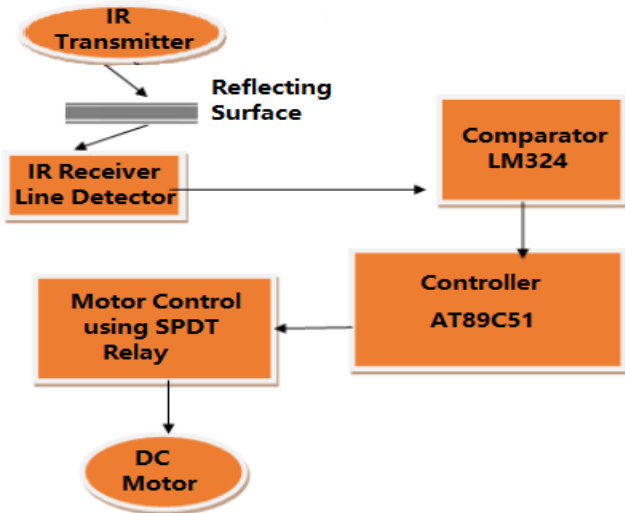

Fig. 1:   Proposed block diagram of line follower robot.

3.   Procedure for Proposed System

3.1   IR Sensors

The infrared sensor is used to detect a white line over a black surface [9]. This consists of an IR transmitter and IR receiver. When the supply voltage (V_{cc}) is applied, IR transmitter continuously transmit IR light. Hence, the IR led is working as a transmitter and the photodiode is working as a receiver. When the IR transmits the radiation, it will be reflected from the surface. The IR receiver receives this reflected radiation. The output of IR sensor is the input of the comparator [10].

3.2   Comparator

In our proposed system, operational amplifier is used as a comparator in the open-loop configuration. We have used LM324 comparator having two inputs, inverting (V-) and non-inverting (V+). When the input voltage is applied to the noninverting terminal (V+) and it is higher as compared to the input voltage of the inverting terminal (V-), high (1) will be received at the output of the operational amplifier. High (1) shows led will glow at the output of the comparator as shown in Fig. 2. Similarly, when the input voltage is applied to the inverting terminal (V-) and it is higher as compared to the input voltage of the non-inverting terminal (V+), low (0) will be received at the output of the operational amplifier. Low (0) shows led will not glow at the output of the comparator as shown in Fig. 3. The output of the comparator is the input of the microcontroller. The controller will perform the precise activity based on the signal received from the comparator [10].
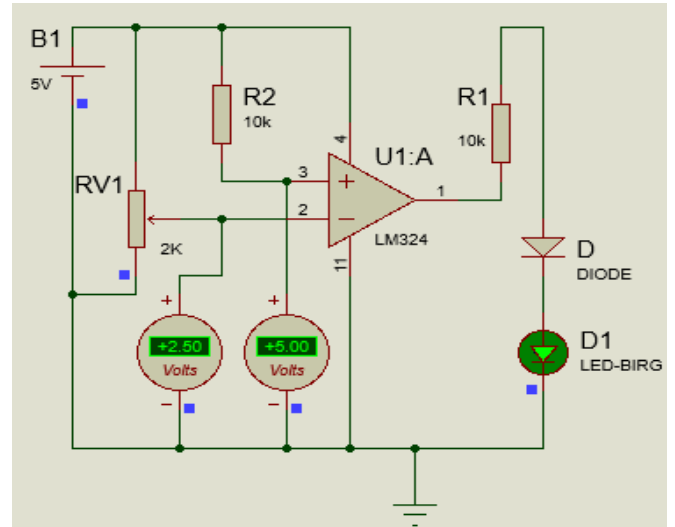

Fig. 2:   High output of the comparator is dependent on the inverting and non-inverting input.
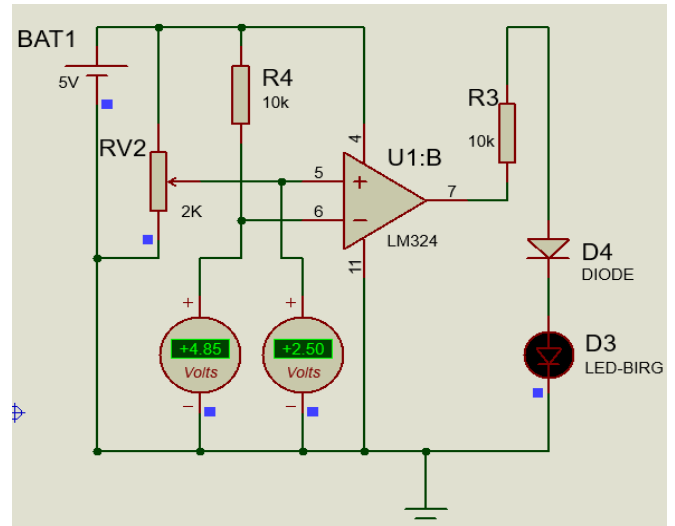

Fig. 3:   Low output of the comparator is dependent on the inverting and non-inverting input.

3.3   Microcontroller

Two sensors S1 and S2 are used and attached in the front of the robot. These two sensors sense the white line and generate the output to the comparator. The output of the comparator is the input of the microcontroller as mentioned above. A microcontroller (AT89C51) is used for the persistence of controlling and managing the movement of the robot [12]. The microcontroller will generate four outputs (P2.0, P2.1, P2.2, P2.3) and that is dependent on the two inputs (P1.0 and P1.1) which were given from the comparator. These outputs are used for controlling the DC motors. By using the formula of number of combinations 2^n, where n is number of inputs, it gives the maximum possible number of combinations [13]. In our case n=2 and the maximum number of combinations are 4. As shown in table1, following cases should be kept in mind before write the code for the microcontroller.

Case 1: If the microcontroller will receive "0" for both the inputs at P1.0 and P1.1, which reflect the output of the sensor as well as the position of the robot. Both the sensors S1 and S2 are offline as shown in Fig. 4, now controller needs to be turned ONN both the motors M1 and M2 in the reverse direction. The output pins will be as P2.0 = 1, P2.1 = 0, P2.2 = 1 and P2.3 = 0
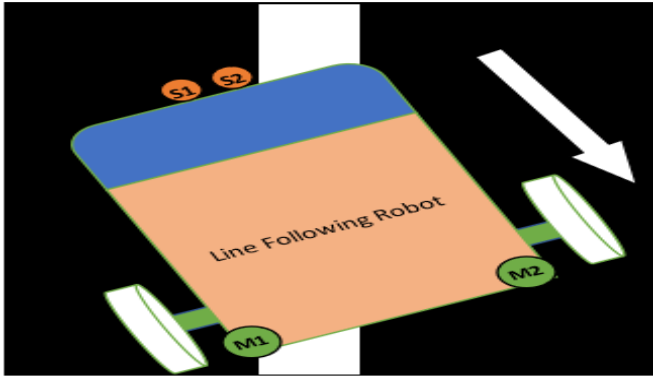
Case 3: If the microcontroller will receive "1" at P1.0 and "0" at P1.1, which reflect the output of the sensor as well as the position of the robot. The sensor S1 is online and sensor S2 is offline as shown in Fig. 6, now controller needs to be turned ONN motor M2 in forward direction and motor M1 in the reverse direction. The output pins will be as P2.0 = 1, P2.1 = 0, P2.2 = 0 and P2.3 = 1

Fig. 4:   Case 1 for reverse direction.

Fig. 6:   Case 3 for M2 in forward and M1 in reverse direction.

Case 2: If the microcontroller will receive "0" at P1.0 and "1" at P1.1, which reflect the output of the sensor as well as the position of the robot. The sensor S1 is offline and sensor S2 is online as shown in Fig. 5, now controller needs to be turned ON motor M1 in forward direction and motor M2 in the reverse direction. The output pins will be as P2.0 = 0, P2.1 = 1, P2.2 = 1 and P2.3 = 0
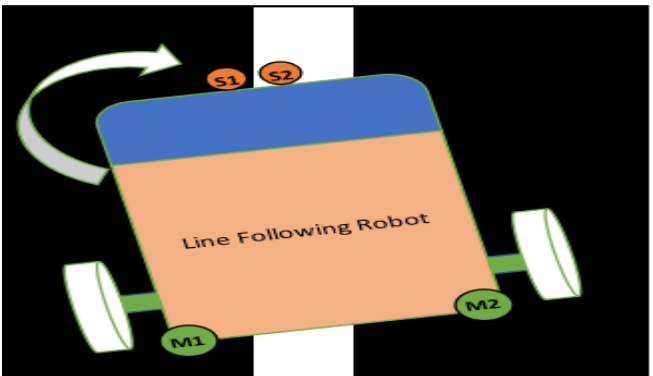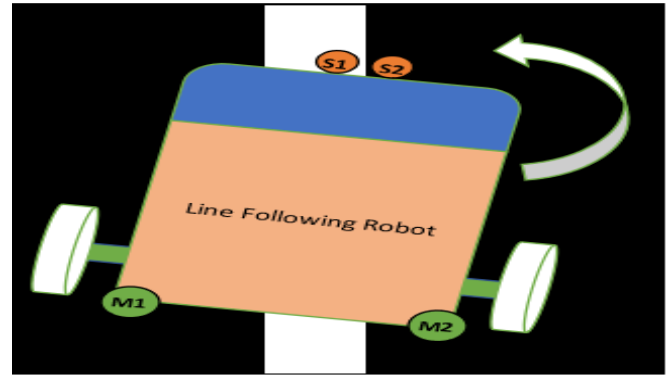
Case 4: If the microcontroller will receive "1" for both the inputs at P1.0 and P1.1, which reflect the output of the sensor as well as the position of the robot. Both the sensors S1 and S2 are online as shown in Fig. 7, now controller needs to be turned ONN both the motors M1 and M2 in the forward direction. The output pins will be as P2.0 = 0, P2.1 = 1, P2.2 = 0 and P2.3 = 1
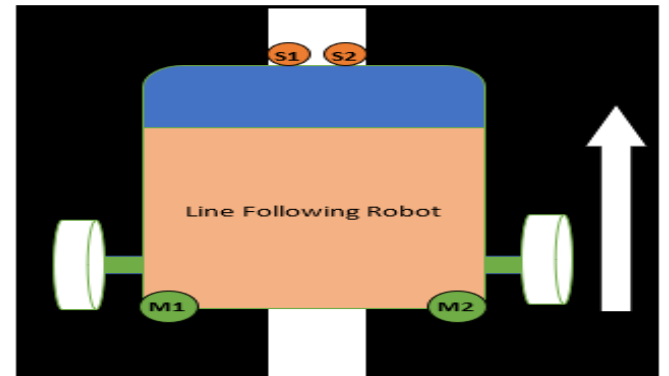

Fig. 5:   Case 2 for M1 in forward and M2 in reverse direction.

Fig. 7:   Case 4 for forward direction.

Table-1: Different cases and movement of robot

Type	Input		Output				Movement of Robot
	P1.0	P1.1	P2.0	P2.1	P2.2	P2.3	
Case 1	0	0	0	0	0	0	Motor 1 Stop
							Motor 2 Stop
Case 2	0	1	0	1	1	0	Motor 1 Forward
							Motor 2 Reverse
Case 3	1	0	1	0	0	1	Motor 1 Reverse
							Motor 2 Forward
Case 4	1	1	0	1	0	1	Motor 1 Forward
							Motor 2 Forward

3.4 Relay (SPDT)

Relay is a switch and is used for close or open the circuits electronically or electromechanically. Relay contains a coil, normally close (NC) terminal, normally open (NO) terminal and a common terminal. When the coil in the relay is energized, common terminal is in contact with the normally open (NO) terminal. Similarly, when the coil in the relay is de-energized, common terminal is in contact with the normally close (NC) terminal [14]. There are multiple types of relays but in our case, we have used SPDT (single port double through) relay just to avoid the complexity of the circuit.

In our proposed system, four outputs of the microcontroller will operate the four bipolar junction transistors (BC548). These transistors will further operate four relays (single pole double through) and the same are used to operate two DC motors in the forward and reverse direction to meet the requirement as shown in Fig. 8. Freewheeling diode is used to prevent voltage spikes when the relay is going to be turned off. Therefore, freewheeling diode would be attached with the reverse polarity from the given supply voltage and the same is parallel to the inductance coil. Light emitting diodes (Led's) have been used just for demonstrating the condition of relay either ON or OFF.
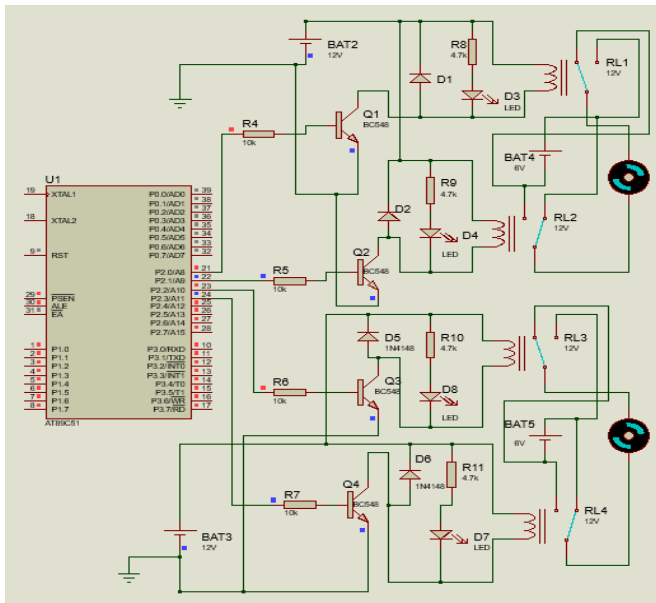

Fig. 8: Four relays operate two DC motors in forward and reverse direction.

3.5 DC Motors

For following the white line DC motors have been selected, these motors are bi-directional motors and having the ability to move in both directions [15-16]. In our proposed system, two DC motors are used in the robot. By controlling these DC motors, we have used microcontroller, transistors, and relays in the mentioned system. The output of the controller will decide either motor will be moved in a forward direction, reverse direction, or in the stop position. The proposed motors having the specification of 6 volts, 35 rpm and they draw a maximum of 6-amp current. Current may

vary according to the load faced by the motor. Current may be reduced if it will be separated from the base of the robot. The same may be increased but not more than 6 amps, depending on the weight of the base, batteries, relay inductance coil, discrete components etc. The overall efficiency of the system is also dependent on the efficiency of the DC motor. There will be two steps of load test, which will be performed for measuring the efficiency of the DC motor.

Steps are mentioned below.

i. Output Power

$$\text{Output Power} = \frac{2 * pi * n * T}{60}$$

$$n = \text{speed (rev/s)}$$

$$T = \text{time taken}$$

ii. Input Power

$$Input\ Power = V * I_L$$

$$I_L = Load\ current$$

iii. Efficiency

$$\text{Efficiency} = \frac{Output\ Power}{Input\ Power}$$

3.6 Voltage Regulator

We have used two batteries of 6 volts and combine them in series because we need 12 volts to operate the relays as well as the motors. As we know that microcontroller will be operated on 5 volts, and we also need 5 volts for power up the sensors and comparator. Voltage regulator is required whose input voltage will be of 12 volts, and the output voltage will not be more than 5 volts [17]. Voltage regulator LM7805 have been selected for getting the constant output voltage of 5 volts depending on the input voltage as shown in Fig. 9. LM7805 having the ability to get the input of 7 volts to 36 volts and maintain the output voltage of 5 volts [18]. It consists of three terminals first one is the input terminal; second one is the ground terminal and the third one is the output terminal. The output of LM7805 will be connected to microcontrollers, sensors, and comparators.
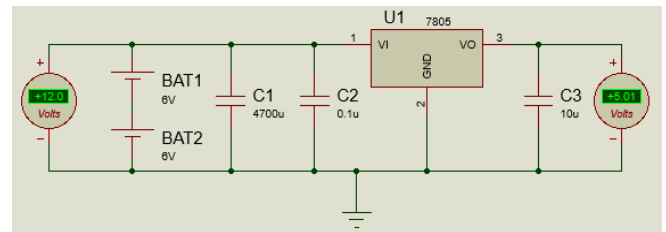

Fig. 9: Schematic diagram of voltage regulator.

3.7 Programming Description

Varying output of the sensors (S1 and S2) depending on the white line and the movement of motors accordingly as discussed in four cases and the same has been implemented in the programming flow chart diagram as shown in Fig. 10. In our proposed system, AT89C51 microcontroller has been

selected [19]. We need a programming code that will have to cater all the conditions and follow the white line automatically. We have implemented programming code in "C" language by using mikroC PRO for 8051 v.3.5.0 software. Fig. 11 represents the programming code for the line follower robot.
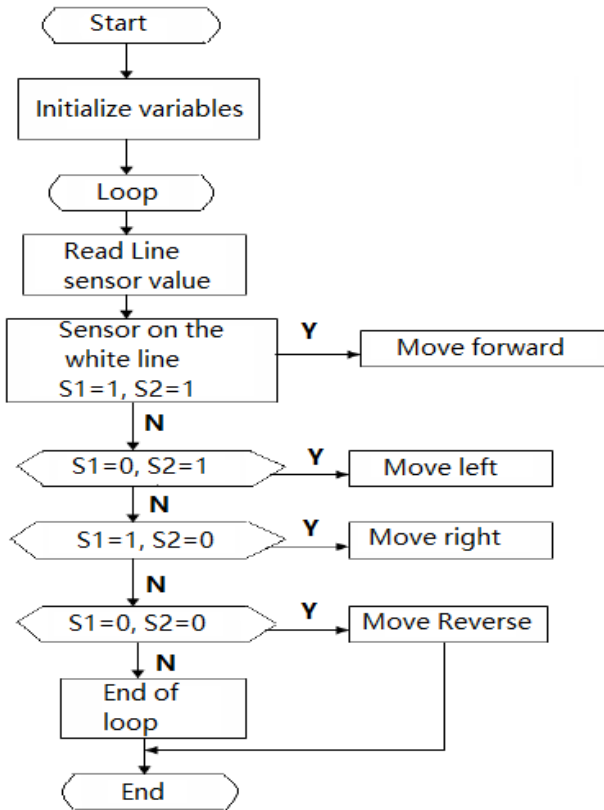

Fig. 10: Programming flow chart for the line follower robot.

```
1   // LINE FOLLOWING ROBOT // mikroC PRO for 8051 v.3.5.0
    void main()
    {
    p2.b0=0; p2.b1=0; p2.b2=0; p2.b3=0; p1.b0=1; p1.b1=1;
    while(1)
    {
    while (p1.b0==0 && p1.b1==0)    // Case 1 : M1 Reverse , M2 Reverse
    {
    P2.b0 = 1;P2.b1 = 0; P2.b2 = 1; P2.b3 = 0; delay_ms(1000);
10  p2.b0=0; p2.b1=0; p2.b2=0; p2.b3=0; delay_ms(500);
    }
    while (p1.b0==0 && p1.b1==1)    // Case 2 : M1 Forward , M2 Reverse
    {
    P2.b0 = 0; P2.b1 = 1; P2.b2 = 1; P2.b3 = 0;delay_ms(1000);
    p2.b0=0; p2.b1=0; p2.b2=0; p2.b3=0; delay_ms(500);
    }
    while (p1.b0==1 && p1.b1==0)   // Case 3 : M1 Reverse , M2 Forward
    {
    P2.b0 = 1; P2.b1 = 0; P2.b2 = 0; P2.b3 = 1; delay_ms(1000);
20  p2.b0=0; p2.b1=0; p2.b2=0; p2.b3=0; delay_ms(500);
    }
    while (p1.b0==1 && p1.b1==1)    // Case 4 : M1 Forward , M2 Forward
    {
    P2.b0 = 0; P2.b1 = 1; P2.b2 = 0; P2.b3 = 1; delay_ms(1000);
    p2.b0=0; p2.b1=0; p2.b2=0; p2.b3=0; delay_ms(500);
```

	Message No.	Message Text
	125	Project Linked Successfully
	128	Linked in 328 ms

Fig. 11: Programming code for the line follower robot.

4. Prototype Implementation

Before implementation of the hardware, it is very important to verify the design by using the Proteus professional software for simulation. This will help us to identify the silly faults that may be present in our design. Furthermore, we can remove those faults identified by the simulator. This will increase the overall efficiency of the system [20]. In our proposed system, we are using Proteus professional software for the design and implementation of comparators, microcontroller, SPDT relays, DC motors drive, and the verification of the programming code. Fig. 12 shows the complete design for analyzing the output voltage and current at different nodes. Fig. 13 shows the prototype implementation.
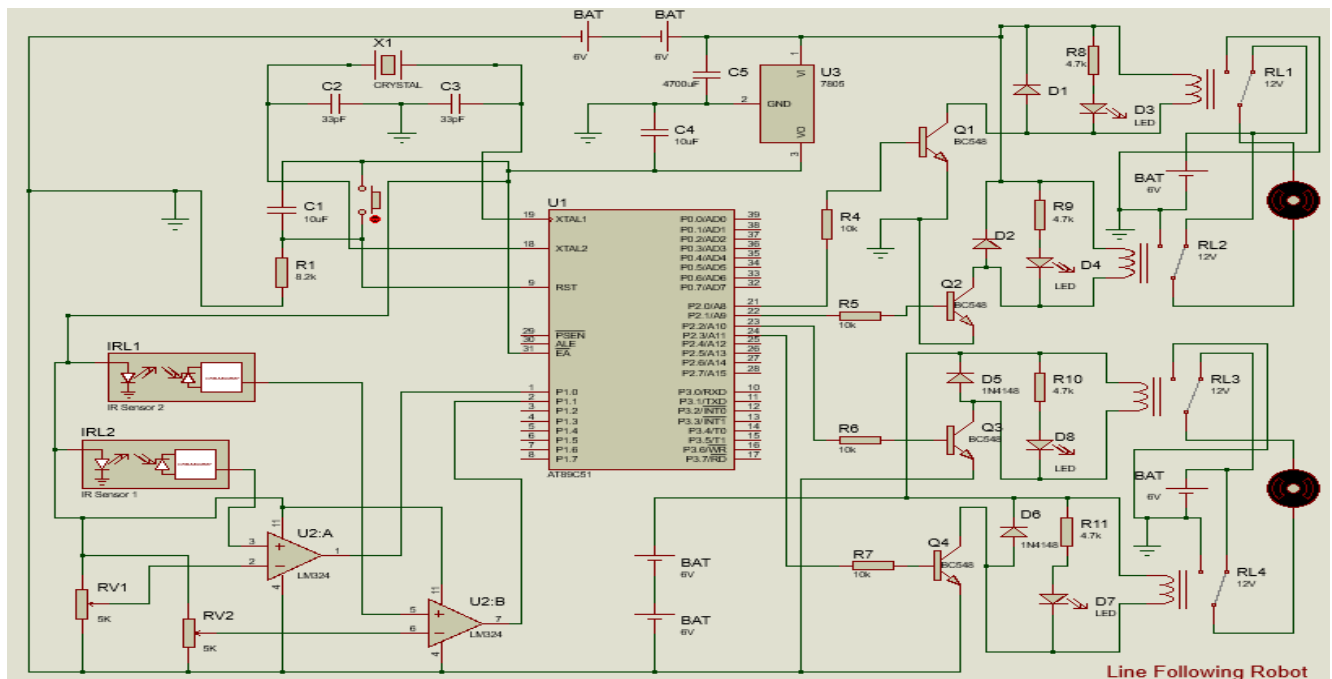

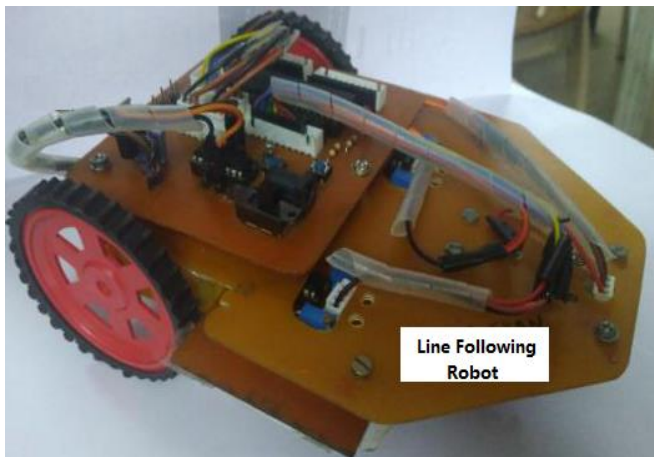Fig. 12: Schematic diagram for the line follower robot.

Fig. 13:   Hardware of the Proposed System.

5.   Useful Application

The robot will follow the desired path automatically once proper instructions have been set to the controller [21]. Furthermore, if the simulation has been successfully done, that shows the robot (prototype model) will perform all the duties that have been assigned to the controller. The proposed model is based on the microcontroller and the same is very cost-effective due to the uniqueness and the simplicity of the design. It is a unique design to operate different specifications of the DC motors. There are many applications of the proposed system, which we got if slightly change in the programming code and the base of the existing system [22]. Few are mentioned below.

- These types of robots may be used at the time of seed insertion in the farms, to reduce the manpower of the farmers [23].
- These types of robots may be used for supplying materials to the construction building [24].
- These types of robots may be used at the time of food serving, to reduce the manpower of the waiters.
- These types of robots may be used in motels, who may guide the new customers in finding the allocated room.
- These types of robots may be used in hospitals for supplying the medicines to the patients [25].
- These types of robots may be used in offices for supplying the food to the workers [26].

6.   Conclusions

The schematic diagram of the "line follower robot" was designed by the Proteus Professional software and successfully achieved the desired result, which is beneficial for accurately recognizing the white line. It was found that simulation results and hardware-tested results are synchronized with each other. We successfully designed and implemented the line follower robot based on single pole double through relays by using a microcontroller with the locally accessible components. The test results and successful implementation showed that the same approach can efficiently work for designing the line follower robot.

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