Line Follower Robot: Fabrication and accuracy measurement by data acquisition

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***Abstract*— The line follower robot has great importance in industrial manufacturing process, automation, carrying cartage in a specific direction etc. Importance is given in this paper in investigating efficiency of the robot, response of the sensor, getting actual data of the sensors, feedback of the central processing unit depending on this response, error correction of following line, future aspects of the line follower robot, providing some real time data of the robot and giving the preliminary steps on fabricating a line follower robot. This robot is the basic form of the line follower robots. Much more complex form of line following robot can be manufactured depending on this basic form of line follower robot. More specifically, efforts has been put on acquiring data during test runs so that robots can be manufactured in massive way under specific requirements of purpose.**

Keywords*— *Line follower, Sensor board, Motor driver, Code, Microcontroller, Geared motor, Data acquisition.

I. INTRODUCTION (*Heading 1*)

The line follower robot (LFR) is a specific purpose robot that can follow a path of white in color in the background of black (and vice versa). The robot is capable of avoiding obstacles, making sharp turns and climbing bridges and also can detect a specific object and able to carry and deposit the object at right position. Micro-controller PIC18F452 was used to control the robot in autonomous mood. And the loaded program controls the robot through the whole path giving proper command. It is able to maintain good speed balance depending on the shape of the path.

Roadmap:

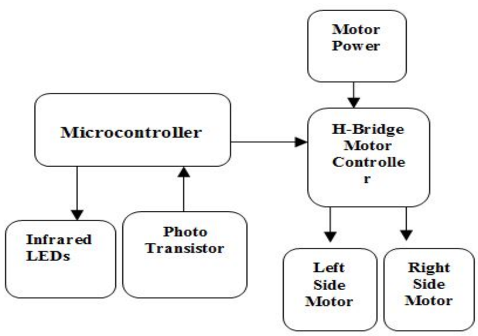

Fig. 1. Roadmap to the line follower robot

II. EQUIPMENTS

A. Line Follower

The line follower is a kind of robotic vehicle having the capability of following a line of specific color and it may include other functions also. The robots simply sense the line by measuring light intensity (converting it into voltage) reflected from the ground, where it is assumed that an ideal black floor reflects no light and the white line reflects almost the total incident light back.

The main task is sensing the line and bounding the robot to stay over the line, by continuously changing the wrong moves using an efficient program through microcontroller to achieve an optimum velocity for racing with time. The program is based on the characteristic of the light reflected by the different color of the path. Microcontroller receives the analogue signal of reflected light as a voltage relative to the color of the path and the voltage difference for different color ensures the correct way to go and loaded program commands the robot to go that way automatically.

B. Motors and Wheels

Normal motors of same power don't have enough torque to move the heavy robot bases properly. And there was also limitation of current flow due to the use of motor driver (L293D) to connect motor with micro-controller. Hence gear head motors with a very high torque and larger wheels to make up for the loss in RPMs are suitable for line follower robot. These relatively large wheels allowed the slower motors to move quickly at a large distance. Tire from wasted tires of car increases the grip quality of the wheels and helps the robot in slippery condition and to climb the bridges. It also helped the robot to climb inclined surface.

Since it needed to carry 6-7 kg in the robot where the battery was approximately 4 kg, we choose a motor with high torque (4.35 kg-cm). But the upcoming result of choosing high torque motor was its low rpm (revolution per minute), since the rpm is inversely proportional to the torque.

Motor specification was 17 watt, 12V. This means that the motor will draw a current of 1.41 Amp current at its maximum load torque. This means that if imposed more than 4.35 kg per motor it stalls. But, just below the mass, the motor will draw 1.41 Amp in an intention to rotate at 200 rpm. Measured stall current drew by motor was 1.45 Amp practically. But at low imposed mass, it will draw less current from battery.

C. Sensors

The most common sensors for a line following robot have been LDR (Light Dependent Resistor) and IR (infrared) LED (light emitting diode). But the IR LED is the most optimized sensor for line following robot. It comprises of IR-transmitter (Tx) and receiver (Rx). This special purpose LED transmits infrared rays of wave length 760 nm. These LEDs are made of gallium arsenide or aluminum gallium arsenide.

D. Sensor Architecture

IR transmitter connected to 5v dc source with a security resistor of 47ohm. Then this transmitter transmits infrared ray of 760-950 nm wavelength which is invisible. The receiver is again connected to 5V source. But it allows current to pass if only it receives the infrared rays at its base. Actually it acts as a switch which depends only upon the infrared ray. For line following robot, the line is generally made of black or white color. On white color track, infrared rays reflect the most and hence the receiver can conduct the maximum current and voltage. But for black track, IR rays reflect least, hence the receiver remains inactive. . The responses of the sensor for different color track in the scale of 10 bit analog to digital conversion value as found in experiments are shown here:
1. White 2.Blue 3.Green 4.Orange 5.Black 6.Yellow 7.Red 8.Dark blue 9.Purple tracks

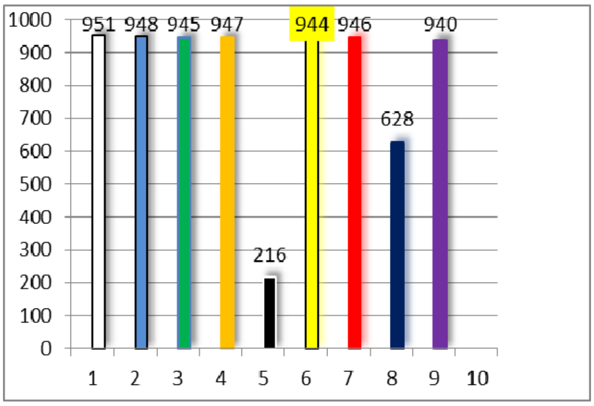

Fig. 2. Response of the sensors for different color track in terms of 8bit ADC value.

III. MICROCONTROLLER FEATURES

PIC 18F452 microcontroller (MCU), an 8 bit MCU having programmable memory up to 32 kilobytes has been used for this purpose. It operates under an external clock pulse like 8MHz, 16MHz, and 20MHz which is called crystal. The most important characteristic of this MCU is its Analog to Digital Converter Module. This module has 8 input pin to receive analog signal.

A. Analog to Digital Conversion (ADC) Module of MCU

The ADC pin of microcontroller receives the IR received signal if a wire just after the receiver is connected to the ADC pins. The ADC module converts the analog signal to a corresponding 10 bit digital number, which means 2^{10}=1024 (2^n, where n is no. of bits) digital number. Visualize this as a 10 bit resolution box where the received voltage is distributed. As per the MCU working limitation, the ADC pins can only receive maximum 5V. Hence, this voltage is distributed in the 1024 resolution box equally and each box receives 5/1024 = 0.00488 voltage. But, each box mandatorily has to fill up with 0.00488V, and then it goes to fill the next box. MCU measures only the number of boxes filled up.

For example, a small resistor like 47 ohm before the Rx has been put; there is drop of voltage in the resistor. Hence the ADC pin receive analog signal of less the 5V, such as 4.49V. This 4.49V corresponds to the (4.49×1024)/5 =920 resolution box in the 10 bit digital number in ADC module. MCU can only sense this number not the voltage. Coding is totally dependent on this number only.

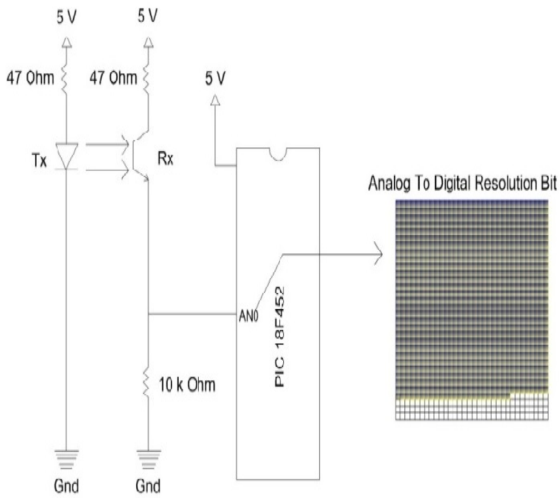

Fig. 3. Voltage division in 10 bit ADC module

B. Pulse Width Modulation (PWM)

This is another built-in architecture of the MCU. PIC 18F452 Microcontroller's RC1 and RC2 two pins are PWM pins. The current passing from this two pin is controlled by means of coding. For example,. This means, minimizing the time duration of voltage supply and hence the current supply. Library functions of PWM such as ‘pwm_set_duty ()’ has been used. This function is an 8 bit (2^8=256) phenomena and starts from 0. The function ‘pwm_set_duty (255)’ means the PWM pin will provide full time length (100%) voltage. This varying current is used to control the motor speed. Pulse of varying modulation can be generated at any pin by means of complex coding with help of Timer and Interrupt (two another inbuilt feature of MCU).

In figure, first one is providing 50% PWM signal and second one will provide 20% PWM signal.

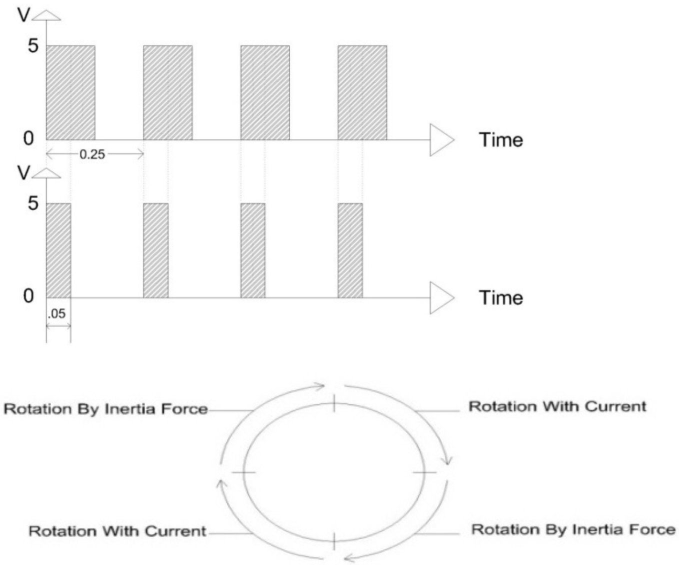

Fig. 4. Motor running process with pulse width modulation

C. Motor Controller

A DC Motor can't be driven directly with a Microcontroller, as DC Motors requires high current and high voltage than a Microcontroller can provide. Microcontrollers usually operates at +5 or +3.3V supply and it I/O pin can provide only up to 25mA current. Commonly used DC Motors requires 12V supply and 300mA current. Moreover, the back EMF of motor can affect the working of MCU. Hence, H-bridge motor controller named L293D was used for the robot. The benefit of this H-bridge is the direction of motor and speed can be changed by controlling 4 switches by means of coding.

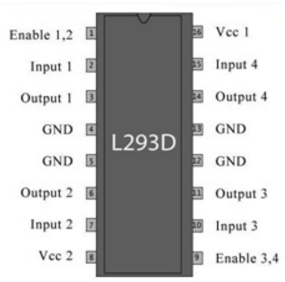

Fig. 5. Motor driver L293D

IV. HARDWARE DESIGN.

A. Conceptual Design

It is a two-wheeled differential-drive robot. Each wheel attached with a motor via axel and a bearing.

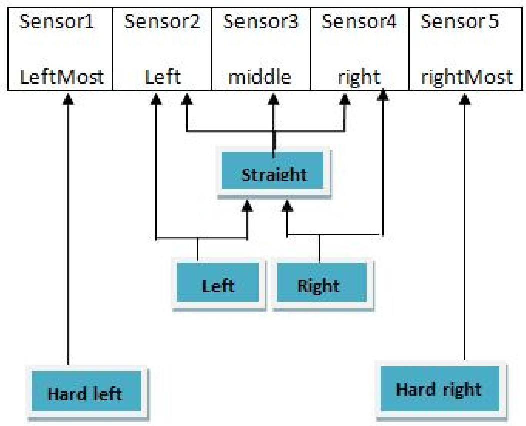

Fig. 6. Conceptual Design

At first it was designed in a paper then an AutoCAD design was prepared and after that, built up the robot according to the design after selecting the proper material.

B. Preliminary Design

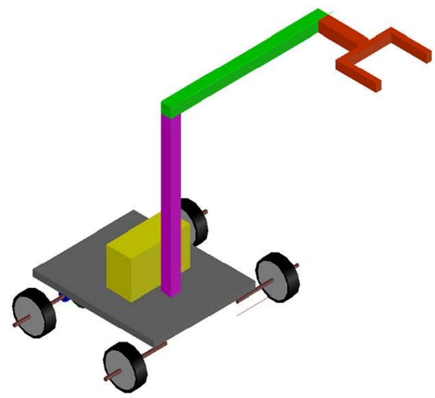

Fig. 7. Autocad preliminary design

C. Circuit Design

For the preparation of line follower robot, at first a sensor board containing a Vero board and 5 IR (Infrared ray) transmitter-receivers, suitable resistances and 1 LED was prepared. Each of the sensors has two major parts: infrared LED and a photo transistor. Main purpose was to draw light to the photo-transistor from the LED after bouncing from the ground. The environment light can affect the photo-transistor that is why the sensor board was set as near to the ground as possible. There an LED (yellow in color) was set to ensure that sensors were properly working. It enlightens when IR receiver receives emitted light from the infrared LED and otherwise remains off.

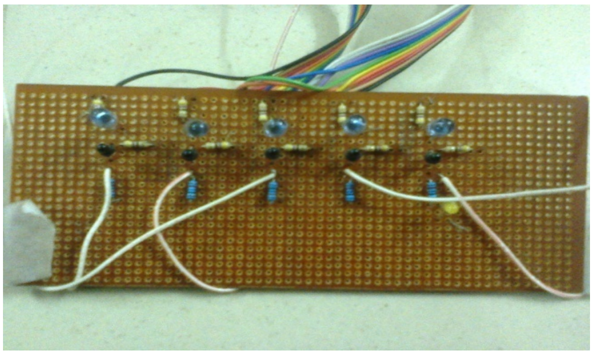

Fig. 8. Sensors circuit design in vero board

D. Final Design

A wooden board was taken according to the dimension of AutoCAD design. It was in the shape of (9*12) square inch. The thickness of the board has particularly no job but should be enough to carry the load of battery and other equipment's and the robotic hand. So it may vary from one material to other. Then according to the calculation of load distribution the battery and other equipment's were placed. Heavy loads were kept in the side of the wheels which were directly connected to the motors. Finally after assembling each parts and components required for the robot the shape was made suitable for running in the race.

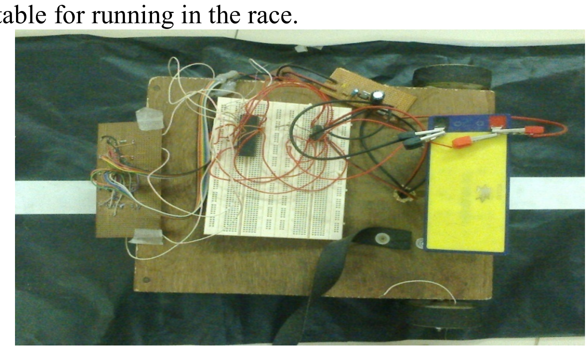

Fig. 9. Complete robot design

V. SOFTWARE DESIGN AND SIMULATION

A. Microcontroller Coding Methodology

Microcontroller only understands 0 and 1. Here 1 means any nonzero value. Whenever the IR receiver receives the infrared ray, it makes a path for current to pass and hence the ADC module gets some digital number for the analog signal. This digital number is used as the operating principal for the MCU coding. Such as, if the rightmost sensor receives such amount of infrared rays that it can send 4.49V to the AN0 pin of the ADC module then coding would be like this-

```
int sensor [5];
Void main ()
{
PORTD=0x00;     //configuring PORTD pins as low voltage
TRISD=0x00;  //configuring PORTD pins as output operation
PORTA=0x00;     //configuring PORTA pins as low voltage
TRISA=0xFF;  // configuring PORTA pins as input operation
PORTC=0x00;     //configuring PORTC pins as low voltage
TRISC=0x00;  //configuring PORTC pins as output operation
While (1)
{
Sensor [1] =ADC READ (0);          //Reading 10 bit digital
                         //number of ADC module from AN0 pin
If (sensor [1] >= 900)            //checking that the IR receiver
               //is not receiving infrared ray from other source
{
PORTD=0b 00000101;            //configuring the two motor in
//clockwise direction
RD7  RD6  RD5  RD4  RD3  RD2  RD1  RD0
0    0    0    0    0    1    0    1

PWM1_SET_DUTY (197);          //Setting the right motor at
                              // 75% pulse width modulation
PWM2_SET_DUTY (255);          //Setting the right motor at
                              //100% pulse width modulation
Delay_ms (50);
     }
   }
}
```

B. Simulation

A simulation was done by 'PROTEUS' software to be sure that the circuit design and the coding was correct enough to drive the LFR properly.

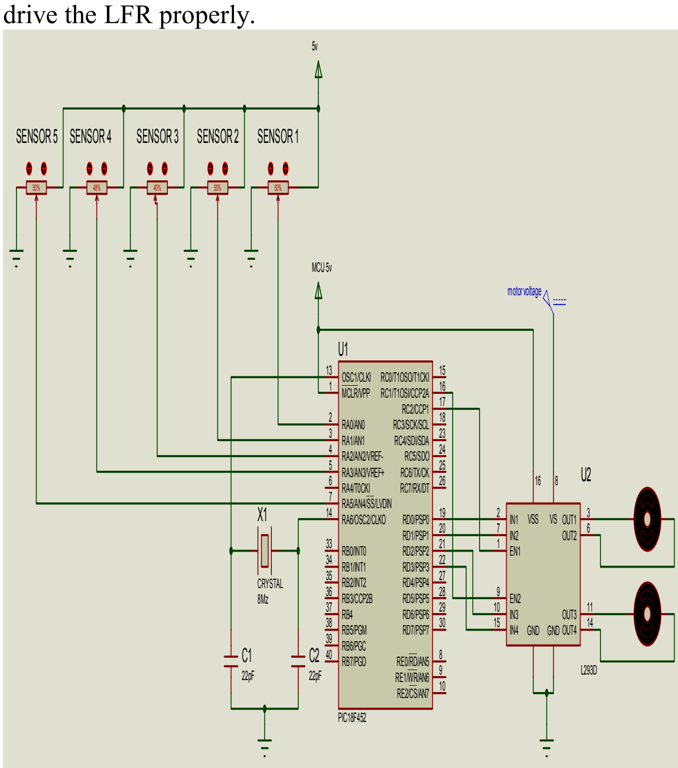

Fig. 10. Proteus simulation

VI. PERFORMANCE ANALYSIS

- The H-bridge motor driver L293D which has output current at each pin only 600 milliamps. That means, though the battery was of 7.2 Amph, only 600 milliamps was served to each motor which was almost half of the maximum current draw rating of motor at maximum allowable load torque. Hence, the result is that the motor was running at only 103 rpm, which was half of the motor RPM rating. This was basically architectural limitation of this robot.
- Due to noise in signal of IR sensor, there was a varying value of 10 bit digital number for which the ADC module was receiving greater varying analog signal. To minimize the effect, a limitation in the microcontroller was coded that the MCU should not use the ADC module data before reaching 900 digital numbers out of 1024 of the 10 bit digital number of ADC module.
- A 100uf 25V capacitor in the each ADC pin of microcontroller was used to reduce noise.
- Response of the five sensors (rightmost, right, middle, left and leftmost) during a test run in terms of their ADC value against cycle number and corresponding feedback from microcontroller in terms of pulse width modulation has shown here.

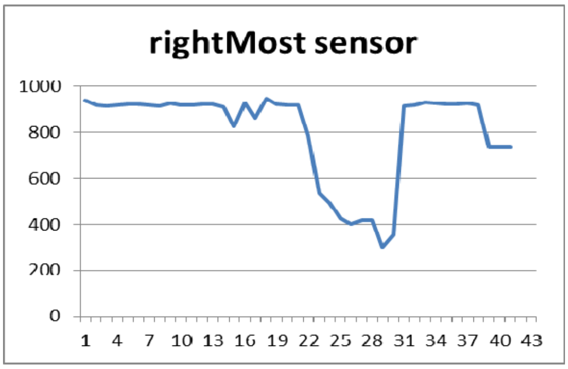

Fig. 11. RightMost sensors ADC value against cycle number (TIME)

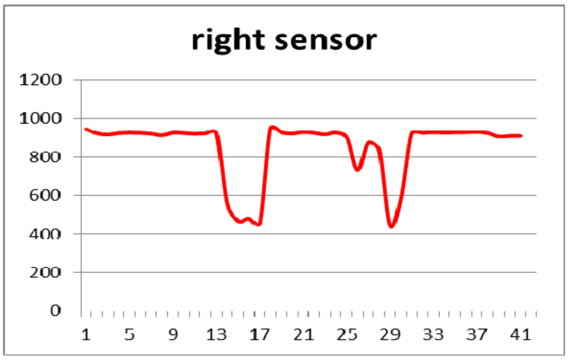

Fig. 12. Right sensors ADC value against cycle number (TIME)

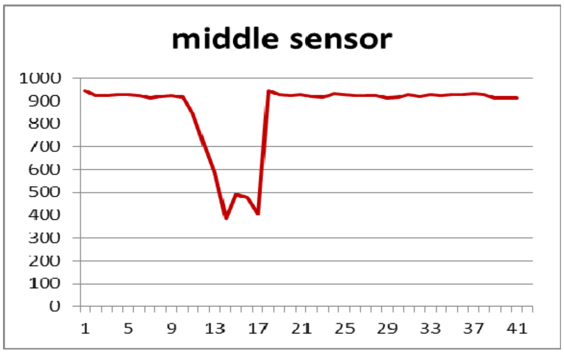

Fig. 13. Middle sensors ADC value against cycle number (TIME)

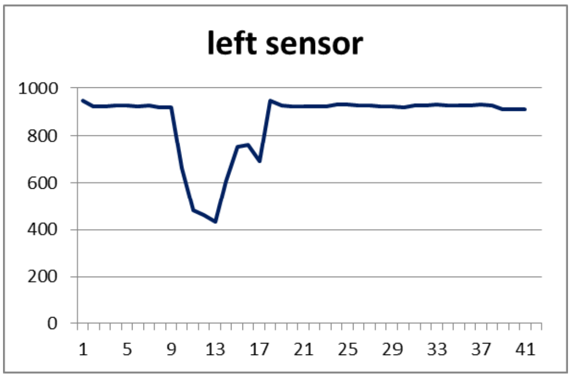

Fig. 14. Left sensors ADC value against cycle number (TIME)

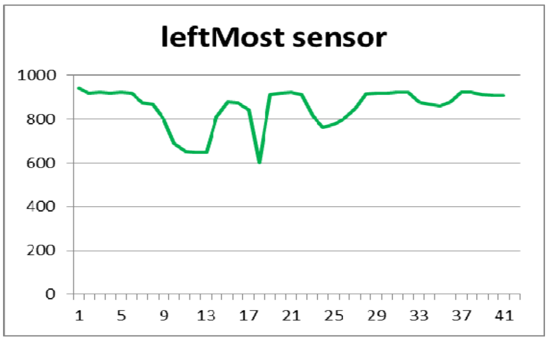

Fig. 15. LeftMost sensors ADC value against cycle number (TIME)

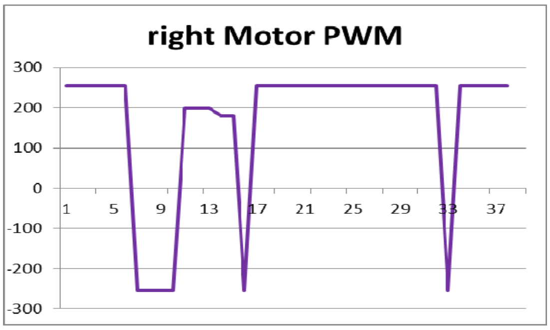

Fig. 16. Response of the right motor 8 bit(256) PWM against cycle

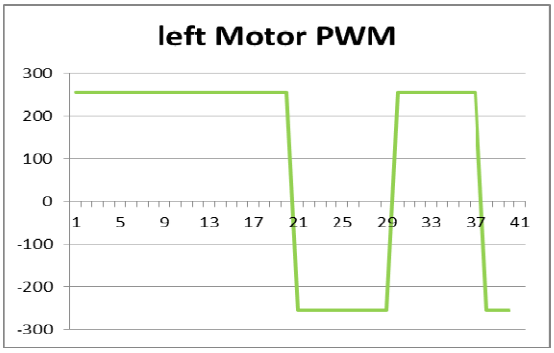

Fig. 17. Response of the left motor 8 bit(256) PWM against cycle

- Pulse width modulation is always in the range of 0 to 255. But in graph negative PWM has been shown, which actually means that at those times the motor was running reverse direction at that PWM and speed to correct their track.
- From the graph it is easily visible that as soon as the robot moves away from the track (sensor value less than 900) it tries to get back into the track (increase of sensor value above 900) automatically, which ensures its efficiency.
- PWM values became less than 255 when they were off the track to correct them.
- The robot covered 50 meter within 2 minute 45 seconds. Hence the speed of robot was 18.18 meter per minute.

VII. Cost Comparision

Cost of each and every part (like wheel-10 $, battery- 15 $, bearing- 5 $, axle- 10 $, base- 15 $, motor- 25 $ etc.) is same all around the world except the cost of microcontroller. There are microcontrollers and development boards of numerous companies. Among which PIC 18F452 is one of the cheapest-only 5 $. It is possible to make the robot within 100 $ if special features aren't added. If we add robotic arm, buzzer, signal transmitter and receiver, zigbee devices, some extra money requires to be added. But, overall cost of this robot is very less comparing with other robots which use Beaglebone, Arduino, Raspberry Pi, Hydra development board.

VIII. Conclusions

Massive use of this line follower robot is in the production line where autonomous carrying of the products from production to storage room. Another important use of this line follower robot is defining path for blind peoples in office or house incorporating some buzzer or vibrator. Motion detector sensors can be used to detect moving object near the car. After advanced modification it can be used in factories for loading and unloading and chemical industries to perform hazardous job. By adding robotic hand and object detector it can be used to pick up object where we cannot go.

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