UNIVERSITY OF NAIROBI

MAZE WANDERER ROBOT

PROJECT INDEX: PRJ 90

BY

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F17/23988/2008

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Project report submitted in partial fulfillment of the requirement for the award of the degree of

Bachelor of Science in Electrical and Electronic Engineering of the University of Nairobi

Submitted on 28th April 27, 2014.

DECLARATION OF ORIGINALITY

<u>FACULTY/ SCHOOL/ INSTITUTE:</u> Engineering

<u>DEPARTMENT:</u> Electrical and Information Engineering

<u>COURSE NAME:</u> Bachelor of Science in Electrical & Electronic Engineering

<u>TITLE OF NAME OF STUDENT:</u> KIBET MARITIM

<u>REGISTRATION NUMBER:</u> F17/23988/2008

<u>COLLEGE:</u> Architecture and Engineering

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Acknowledgement

I would first like to thank the Almighty God, for the life He gave me, the opportunities He has blessed me with and the strength to carry on, even when faced with impossibilities and despair got the better of me.

I am very grateful to my supervisor, **DR. HEYWOOD ABSALOMS OUMA** for his insight, his advice and his help towards the success of this project. He guided my ideas which were otherwise, boundless.

I would also like to take this opportunity to express my deepest gratitude to all those people who have provided me with invaluable help over the course of this project.

Finally I convey my gratitude to my classmates and to the entire Electrical Engineering Department body, more especially to the lecturers for the knowledge they imparted in me during my entire course duration.

ABSTRACT

This project is about a maze wanderer robot in which an RF toy car is adapted. The robot is expected to navigate through the maze, that is, the robot is expected to avoid the obstacles while trying to find its way out. This implies that the robot should be able to move forward, turn right, turn left and even move reverse depending on where the obstacles is. This is achieved by the use of the IR infrared sensors to enable the robot to sense the presence of an obstacle in its path. Most of the application systems in the industry are designed in such a way that they give outputs in accordance with the predefined conditions. They have no means of detecting the changes in their immediate environment and can't perform any corrective measures. This challenge gives one an opportunity to explore how to design and implement a Maze wanderer robot that can take commands from their immediate environment and respond to them accordingly. It typical consists of the drive system, an array of sensors, and the control system. The purpose of Maze wanderer robot is to find its way through any type of Maze. Design decisions involve power, sensing techniques, turning methods and programming. A wall follower logic algorithm was employed to solve the maze which was found to be simpler and much faster compared.

Dedication

I would like to dedicate this project to my loving Father and Mother, who, throughout the years they have seen to it that I received the best education. They have provided a more than sufficient environment for my learning and growing up and ensured that I lacked nothing.

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Abbreviations

ADC -	Analog to Digital Converter
ALU-	Arithmetic Logic Unit
CPU-	Central Processing Unit
IC-	Integrated Circuit
IR-	Infra-Red
I/O-	Input/output
LCD-	Liquid Crystal Display
LED-	Light Emitting Diode
MCU-	microcontroller
XMTR OR TX-	transmitter
RC-	radio control
RF amplifier-	radio frequency amplifier
AC-	alternating current
RAM-	Random Access Memory
ROM-	Read Only Memory
DC-	Direct Current

CHAPTER 1
INTRODUCTION

1.0 Introduction.

Robotics is a field which involves design, construction, operation, and application of robots. It also interfaces computer system for their control, sensory feedback and information processing to achieve the desired functionality.

Of particular interest in this project, is an autonomous robot programmed to have good path finding ability and obstacle avoidance. Sensors will be used to sense the direction and navigating the robot through predefined environs while constantly correcting wrong moves using feedback mechanism to form a simple yet effective closed loop system. As a programmer, he/she gets an opportunity to control a robot to navigate/ solve a maze thus mimic's lifelike movement which in its sense conveys a sense of intelligence or a thought of its own in that matter.

In order to successfully accomplish the objective of this project which is to navigate a robot through a maze, it is necessary to be conversant with or have knowledge of general electronics, microcontrollers, sensors, actuators, programming language and embedded systems.

Putting all the above together comes in handy in ensuring the success of the design and implementation of the system to control the robot to navigate through a given area while observing specified restrictions by taking commands from the environment and responding to them

1.2 Problem statement

Most of the application systems in the industry are designed in such a way that they give outputs in accordance with the predefined conditions or they are simply open loop systems. They have no means of detecting the changes in their immediate environment and even if they do they can't perform any corrective measures to ensure that the system gives the expected response. This challenge gives one an opportunity to explore how to design and implement closed loop systems that can take commands from their immediate environment and respond to them accordingly and also use the feedback mechanism to correct the response in accordance with any changes in the environment as detected by the system.

1.3 Objectives

1.3.1 Overall objective

To adapt a radio controlled toy car to make it capable of navigating through a maze.

1.3.2 Specific objective

In order to accomplish the overall objective of this project, the following are the specific objective:

a) To design obstacle sensor system.
b) To implement path tracking system for the robot.
c) Design control unit for the robot.
d) Integrate the above system into a maze wanderer robot.

1.4 Justifications

Robots are intelligent machines capable of doing tasks they are programmed to do. They have shown significance in decreasing human work load especially in industries. If there is one technological advancement that would certainly make living easy and convenient, robots would be the answer.

Robots are mostly utilized in the manufacturing industry. People who do the same thing for a long period of time tend to get bored and tired of what they are doing and might arrive in a position wherein they are unwillingly doing their job. The person who reached this point will not be as efficient and effective as when they first started working. Also, as human beings, we get exhausted so the length of time that we can work is limited. This is when the importance of robots is realized. They can be set to function for a long span of time producing the same quality product all throughout the production process. This results to an increase in the number of manufactured products of consistent quality and decrease in the production of defective goods.

Industries can gain a lot of benefits out of robotics. The company productivity will rise making businesses achieve more profits. Also, company losses will be reduced because flawed products are trimmed down to almost none. The importance of automation and robotics in all manufacturing industries is growing. Robots can replace human beings in a wide variety of industries. Robots outperform humans in jobs that require precision, speed, endurance and reliability. Robots safely perform dirty and dangerous jobs. Robots need no environmental comforts as compared to humans and can process multiple tasks simultaneously.

For repetitive tasks which use the same path in a factory to remove the need for a human operator, path can be used as a guide for a robot lawnmower. Smarter versions of path followers can be used to deliver mail within an office building and deliver medications in a hospital. The technology has been suggested for running mass transit systems within a factory/industry and may end up as part of autonomous cars navigating the freeway.

Rescue robots in development are being made with abilities such as searching, reconnaissance and mapping, removing rubble, delivery of supplies such as medical supplies or even evacuations of casualties.

From the above uses one can be convinced that indeed a robot is a very important device in our day-to-day operations. Thus, proper design and implementation of this instrument, taking into consideration safety, accuracy and precision, cost and efficiency has been an engineering concern to meet the ever growing demand of the device.

1.5 Project scope

The scope of this project entails designing, programming and implementing a robot that takes the commands to dictate its direction of motion based on the obstacle avoidance. A program is to be written to give the robot its intelligence. The project will as well be restricted to a motorized car which will be given the intelligence to be able to navigate through a given maze.

1.6 Report organization

This project documentation consists of 5 chapters;

***Chapter1*:** The project is introduced where the problem is identified and thus the project objectives are outlined.

Chapter 2: The literature review such as the different concepts employed in designing robot before hand, sensory part and controlling mechanism employed is discussed.

***Chapter 3*:** The methodology on hardware and software implementation of the project is discussed. It also includes the flow of the project development and flow of the programming used in the project.

Chapter 4: This chapter discusses the results of the project in form of simulation and its implementation.

Chapter 5: Conclusions and recommendation of this project is discussed. The overall project design is summarized and further future work suggestions are to be done.

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction.

Radio control (or simply R/C) is the use of radio signals to remotely control a device. Radio-controlled cars are self-powered model cars or trucks that can be controlled from a distance using a specialized transmitter. The term "R/C" has been used to mean both "remote controlled" and "radio controlled", where "remote controlled" includes vehicles that are connected to their controller by a wire, but common use of "R/C" today usually refers to vehicles controlled by a radio-frequency link. This review focuses on radio-controlled vehicles only.

The figure shown below shows the radio control toy car adapted for this project

2.1: principle of operation.

Radio-controlled cars use a common set of components for their control and operation. All cars require a transmitter, which has the joysticks for control, or in pistol grip form, a trigger for throttle and a wheel for turning, and a receiver which sits inside the car. The receiver changes the radio signal broadcast from the transmitter into suitable electrical control signals for the other components of the control system. Most radio systems utilize amplitude modulation for the radio signal and encode the control positions with pulse width modulation. Upgraded radio systems are available that use the more robust frequency modulation and pulse code modulation. The radio is wired up to either electronic speed controls or servomechanisms (shortened to "servo" in common usage) which perform actions such as throttle control, braking, steering, and on some cars, engaging either forward or reverse gears.

Electronic speed controls and servos are commanded by the receiver through pulse width modulation; pulse duration sets either the amount of current that an electronic speed control allows the flow into the electric motor or sets the angle of the servo. On these models the servo is attached to at least the steering mechanism; rotation of the servo is mechanically changed into a force which steers the wheels on the model, generally through adjustable turnbuckle linkages. Servo savers are integrated into all steering linkages and some nitro throttle linkages. A servo saver is a flexible link between the servo and its linkage that protects the servo's internal gears from damage during impacts or stress. The transmitter and receiver sections of the radio frequency controlled car functions as follows:

2.2 Radio Transmitters

A transmitter ("XMTR" or "TX") is used for radio communication of information over a distance. The information is provider to the transmitter in the form of an electronic signal such as an audio (sound) from a microphone or a wireless networking devices. The transmitter combines the information signal to be carried with the radio frequency signal which generates the radio waves, which is often called the carrier through the process called modulation.

The antenna may be enclosed inside the case or attached to the outside of the transmitter. In a more powerful transmitter, the antenna may be located on top of a building or on a separate tower, and connected to the transmitter by a feed line.

The block diagram given below consists of all the consisting parts of the radio transmitter:-

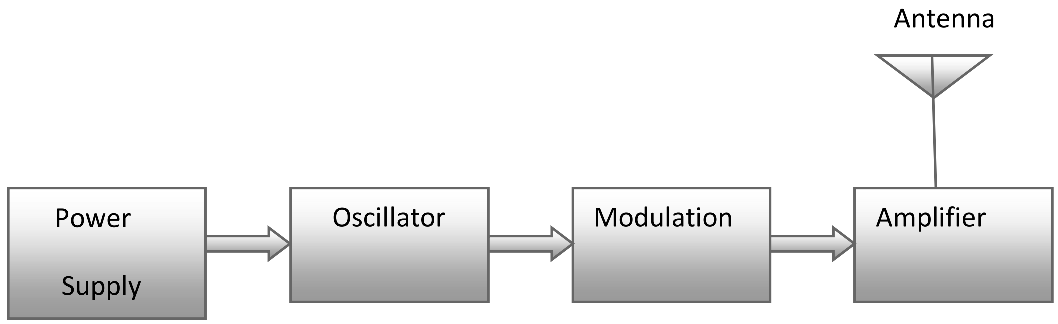


Figure 2.2: Block diagram of a radio transmitter.

2.3 Radio Receivers

A radio receiver uses an antenna to capture radio waves, processes those waves to extract only those waves that are vibrating at the desired frequency, extracts the information signals that were added to those waves, amplifies the information signals, and finally passes it out to be converted into suitable electrical control signals for the other components of the control system.

Radio waves are captured using antenna which is simply a length of wire. When this wire is exposed to radio waves, the waves induce a very small alternating current in the antenna. RF amplifier amplifies the weak signals from the antenna so that signals of a particular frequency can be extracted from a mix of signals of different frequencies using a tuner.

The tuner usually employs the combination of an inductor (for example, a coil) and a capacitor to form a circuit that resonates at a particular frequency. This frequency, called the resonant frequency, is determined by the values chosen for the coil and the capacitor. This type of circuit tends to block any AC signals at a frequency above or below the resonant frequency. The resonant frequency can be adjusted by varying the amount of inductance in the coil or the capacitance of the capacitor.

A detector is now employed to separate information signals from carrier wave and the weak signals which comes it is amplified using a simple transistor amplifier circuit called a signal amplifier. Below is the block diagram of a radio transmitter consisting of all the pertinent components:-

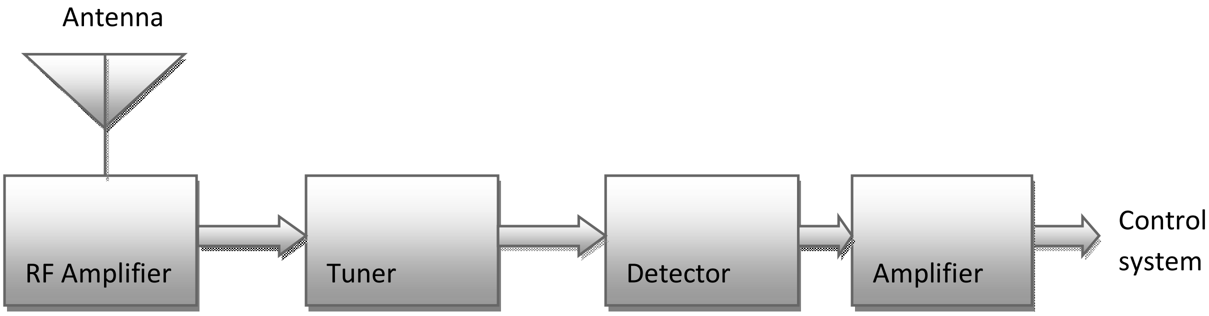


Figure 2.3 : block diagram of a Radio receiver.

3.0 Components and devices review.

Common electronic components and devices used in the design of a maze wanderer robot are discussed below.

3.1 Microcontrollers

A microcontroller can be considered to be a miniaturized computer mainly due to its size. Like any other computer out there, a microcontroller has a central processing unit (CPU), some RAM and a means of getting in input data and giving out data or output.

The main features of microcontrollers include;

a) They are embedded inside other devices
b) They are dedicated – programmed for only one specific purpose
c) They are often low power devices
d) They have a dedicated input device and often but not always an LED or LCD display for output.

Microcontrollers need to be programmed to be capable of performing anything useful. It then executes the program loaded in its flash memory – the code comprised of a sequence of zeros and ones. It is organized in 12-, 14- or 16-bit wide words, depending on the microcontroller's architecture. Every word is considered by the CPU as a command being executed during the operation of the microcontroller.

Over the years, programming microcontrollers has become progressively programmer-friendly. At the advent of microcontrollers, programming was done in its rawest form – in binary digits. However assembly languages were developed and it was hoped that this would make programming easier. Truth be told, it made the process of programming more complicated, but on the other hand, the process of writing programs was simplified. Programmers have always desired a language that is close to the human language, and as a result, higher programming languages have been created. One such program is C. The main advantage of these languages is simplicity.

A single microcontroller can be sufficient to control a small mobile robot, an automatic washer machine or a security system. Any microcontroller contains a memory to store the program to be executed, and a number of input/output lines that can be used to interact with other devices, like reading the state of a sensor or controlling a motor. Figure 3.1 shown below is an image of a microcontroller (Atmega328 in this case).

Figure 3.1: microcontroller chip.

3.2 Inside a Microcontroller

A microcontroller incorporates the following;

a) The CPU core

b) Memory (RAM & ROM)

c) Parallel digital input and output

Additional features include;

a) A timer module to perform time related tasks

b) A serial I/O port to allow data flow between the microcontroller and other devices

c) An ADC to allow the microcontroller to accept analog input data for processing.

The figure below shows the basic blocks of a microcontroller. The blocks are then discussed briefly below.

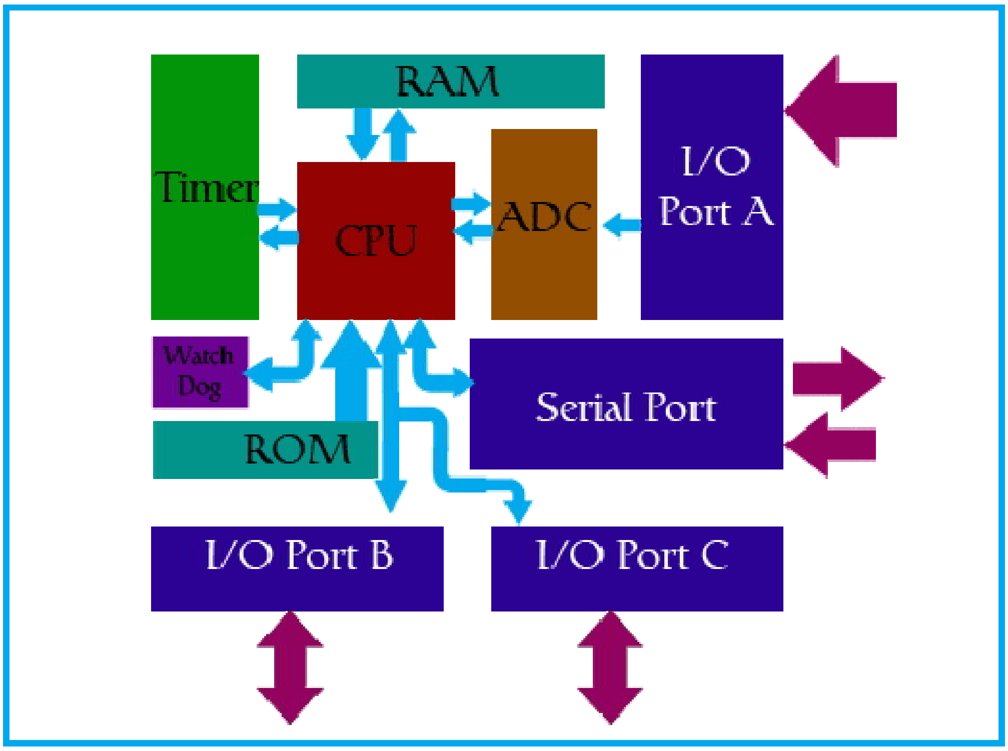


Figure3.2: Microcontroller architecture

Memory unit: this is the part of the microcontroller whose function is to store data. It consists of the RAM and the ROM.

Central Processing Unit: this is the block that performs arithmetic functions and movement of data.

Bus: this is a group of wires, typically 8 or 16. There are two types of buses; address bus and data bus. The address bus is as wide as the memory and is used for transferring the address of a register while the data bus is as wide as data and transmits data.

Input - output unit: these are locations called ports which are used when sending data into the microcontroller or reading data from the microcontroller. There are several types of ports: input, output or bidirectional ports.

Serial communication: Unlike parallel communication, data moves here bit by bit or in a series of bits. This is the so called full-duplex mode block.

Timer unit: this block gives us information about time, duration, protocol etc. The basic unit of the timer is a free-run counter which is in fact a register whose numeric value increments by one in even intervals. By taking its value during periods, the time elapsed can be determined on the basis of their difference.

Watchdog: this block is a free-run counter where the main program needs to writes a zero in, every time it executes correctly. In the event of incorrect execution, the zero won't be written and the counter alone will reset the microcontroller resulting in re-execution of the program correctly.

Analog to Digital Converter (ADC): this block performs the conversion of analog input to binary equivalents and follows the data through to a CPU block so that the CPU block can further process it.

3.4 Actuators

There needs to be in place, a system that facilitates the movement of the robot. Motors come in handy in executing this motion.

Magnetism is the basis for the operation of motors. They use permanent magnets, electromagnets, and exploit the magnetic properties of materials to facilitate motion. There are several types of electric motors out there. The two main classes are;

a) AC motors
b) DC motors

Ac motors require an alternating current or voltage source while dc motors require a direct current or voltage source. This being the case, the construction of motors in these two classes is different.

3.5 DC motors:

These are very commonly used in robotics. DC motors can rotate in both directions depending upon the polarity of current through the motor. These motors have free running torque and current ideally zero. These motors have high speed which can be reduced with the help of gears and traded off for torque. Speed Control of DC motors is done through Pulse Width Modulation technique, i.e. sending the current in intermittent bursts. PWM can be generated by 555 timer IC with adjusted duty cycle. Varying current through the motor varies the torque.

DC motors are generally more powerful than servos in terms of speed and torque. A microcontroller will not be able to accurately control DC motor without a motor controller, motor controller will be needed. An encoder can be used to get feedback from the DC motor.

Would be driven either through an arrangement of transistors known as an H-bridge, or using a dedicated motor driver IC. The figure 3.4.1 shows the image of DC motor:-

Figure 3.5: DC motor.

3.6: Motor controller.

The system uses RF to control the car by controlling DC motors through a motor driver IC L293D. Transmission is enabled by giving a low bit to pin14 (TE, active low) of encoder HT12E shown in Figure 2.4. The controls for motor are first sent to the encoder. Pins 10 and 11 (D0-D1) are used to control one motor while pins 12 and 13 (D2-D3) are used to control another motor. The data signals of this encoder work on negative logic. Therefore a particular signal is sent by giving a low bit to the corresponding data pin of encoder.

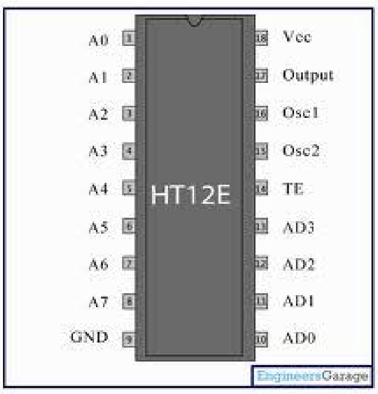


Figure 3.5.0: Pin configuration of HT12E encoder

The parallel signals generated at transmission end are first encoded (into serial format) by encoder HT12E and then transferred through RF transmitter. The same signals are acquired by RF receiver after which it is decoded by decoder HT12D.

Since the encoder/decoder pair used here works on negative logic, the decoded signals are fed to an inverter (NOT gate) IC 74LS04. The proper (inverted) signals are then supplied to L293D. L293D contains two inbuilt H-bridge driver circuits to drive two DC motors simultaneously, both in forward and reverse direction. Figure 2.5 is a circuit arrangement of an H-bridge.

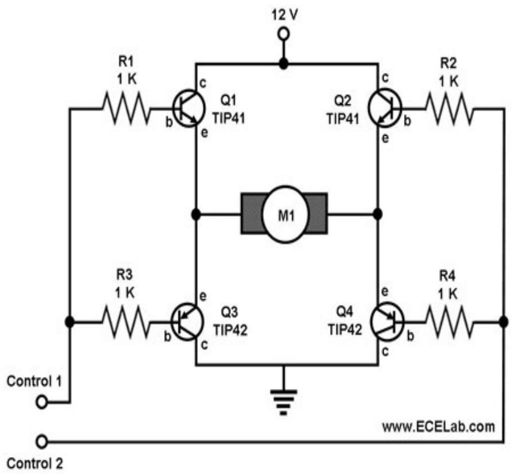


Figure 3.5.1: H-bridge configuration

The operations of the two motors can be controlled by input logic at pins 2 & 7 and pins 10 & 15 of the motor driver IC L293D shown in Figure 2.6. Input logic 00 or 11 will stop the corresponding motor. Logic 01 and 10 will rotate it in clockwise and anticlockwise directions, respectively. Thus, depending upon the signals generated at the transmission end, the two motors can be rotated in desired directions.

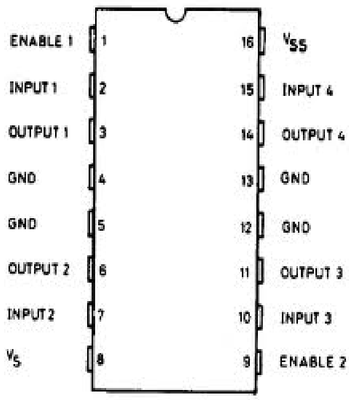


Figure 3.5.2: Pin configuration of IC L293D

3.5. Sensors.

3.5.1. Infra-red sensors

3.5.6.1 Elements of infrared detection system

A typical system for detecting infrared radiation is given in the following block diagram of Figure 2.14:

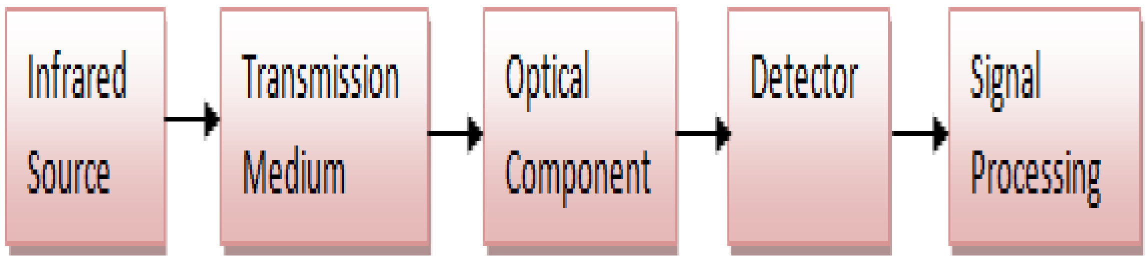


Figure 2.14 Infrared detection

Infrared Source: All objects above 0 K radiate infrared energy and hence are infrared sources. Infrared sources also include blackbody radiators, tungsten lamps, silicon carbide, and various others. For active IR sensors, infrared Lasers and LEDs of specific IR wavelengths are used as IR sources.

Transmission Medium: Three main types of transmission medium used for Infrared transmission are vacuum, the atmosphere, and optical fibers. The transmission of IR – radiation is affected by presence of carbon dioxide (CO_2), water vapour and other elements in the atmosphere. Due to absorption by molecules of water, carbon dioxide, ozone, etc. the atmosphere highly attenuates most IR wavelengths leaving some important IR windows in the electromagnetic spectrum; these are primarily utilized by thermal imaging/ remote sensing applications.

***Optical Components*:** Often optical components are required to converge or focus infrared radiations, to limit spectral response, etc. To converge or focus radiations, optical lenses made of quartz, CaF_2, Ge and Si, polyethylene Fresnel lenses, and mirrors made of Al, Au or a similar material are used. For limiting spectral responses, band pass filters are used. Choppers are used to pass or interrupt the IR beams.

***Infrared detectors*:** Various types of detectors are used in IR sensors. Important specifications of detectors are:

1. **Photosensitivity or Responsivity:** Responsivity is the Output Voltage or Current per watt of incident energy. The higher the better.
2. **Noise Equivalent Power (NEP):** NEP represents detection ability of a detector and is the amount of incident light equal to intrinsic noise level of a detector.
3. **Detectivity (D*: D-star):** D* is the photosensitivity per unit area of a detector. It is a measure of SNR (signal to noise ratio) of a detector. D* is inversely proportional to NEP. Larger D* indicates better sensing element.

In addition, wavelength region or temperature to be measured, response time, cooling mechanism, active area, number of elements, package, linearity, stability, temperature characteristics, etc. are important parameters which need attention while selecting IR detectors.

***Signal Processing*:** Since detector outputs are typically very small, preamplifiers with associated circuitry are used to further process the received signals.

2.5.6.2 Types of infrared sensors

- **Active infrared sensors**

Active infrared sensors employ both infrared source and infrared detectors. They operate by transmitting energy from either a light emitting diode (LED) or a laser diode. A LED is used for a non-imaging active IR detector, and a laser diode is used for an imaging active IR detector. In these types of IR sensors, the LED or laser diode illuminates the target, and the reflected energy is focused onto a detector. Photoelectric cells, Photodiode or phototransistors are generally used as detectors. The measured data is then processed using various signal-processing algorithms to extract the desired information. Active IR detectors provide count, presence, speed, and occupancy data in both night and day operation. The laser diode type can also be used for target classification because it provides target profile and shape data.

Two possible configurations for connecting active infrared sensors are:

✓ **Break Beam Sensors**

This type of sensors consists of a pair of light emitting and light detecting elements. Infrared source transmits a beam of light towards a remote IR receiver creating an "electronic fence". Once a beam is broken/interrupted due to some opaque object, output of detector changes and associated electronic circuitry takes appropriate actions. The block diagram of Figure 2.15 illustrates this.

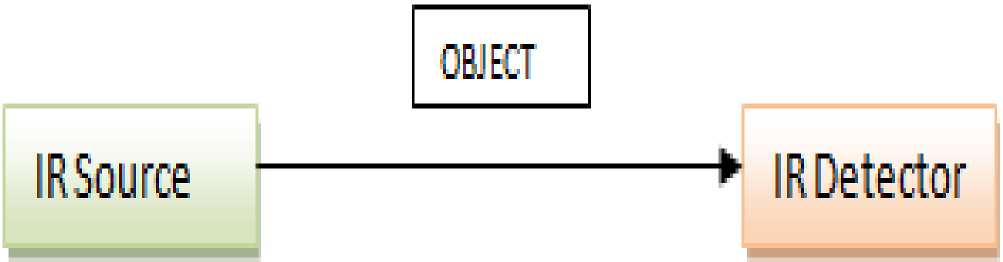


Figure 2.15 Break beam sensors configuration.

✓ **Reflectance Sensors**

This type of sensor houses both an IR source and an IR detector in a single housing in such a way that light from emitter LED bounces off an external object and is reflected into a detector. Amount of light reflected into the detector depends upon the reflectivity of the surface. This is shown in Figure 2.16 below. This principle is used in intrusion detection, object detection (measure the presence of an object in the sensor's field of view (FOV)), barcode decoding, and surface feature detection (detecting features painted, taped, or otherwise marked onto the floor), wall tracking (detecting distance from the wall), etc.

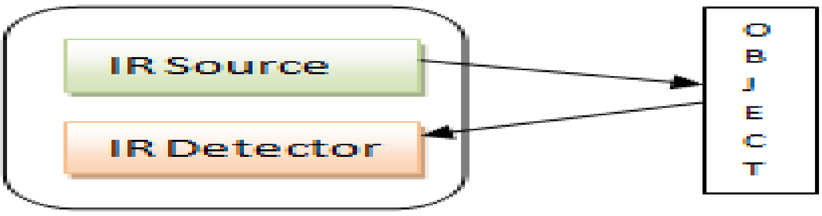


Figure 2.16 Reflectance sensors configuration.

- **Passive infrared sensors**

These are basically IR detectors; they don't use any IR source. These form the major class of IR sensors/detectors. A passive infrared system detects energy emitted by objects in the field of view and may use signal-processing algorithms to extract the desired information. It does not emit any energy of its own for the purposes of detection. Passive infrared systems can detect presence, occupancy, and count. Passive Infrared Sensors are of two types: Thermal and Quantum. Thermal type sensors have no wavelength dependence. They use the infrared energy as heat and their photosensitivity is independent of wavelength. Thermal detectors don't require cooling but have disadvantages that response time is slow and detection time is short.

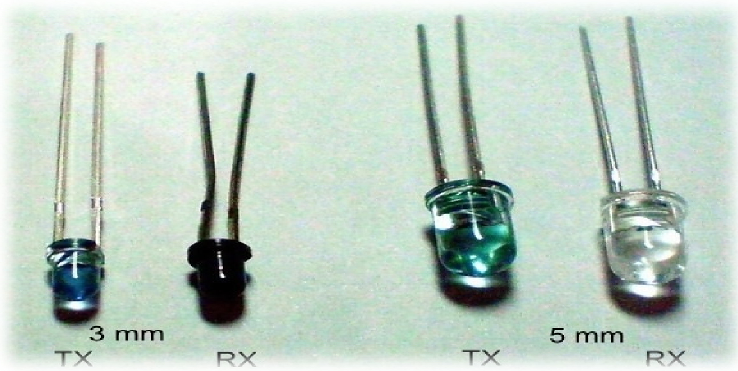


Figure3.5: Infrared transmitter (TX) and receiver (RX)

3.5.2 Ultrasonic

Ultrasonic sensors are a very common sensor type, used in robotics. They work by emitting a high frequency acoustic wave from the sensor. This frequency is usually 40 kHz, and is way above the range of human hearing. This sound wave travels through the air, and bounces off an object before returning to the sensor. The sensor counts until the sound wave returns, and calculates the distance, using the time from when the sound wave left, until when it returns. The advantage of using this type of sensor is that it does interfere with camera, or any form of light. The bad part of this sensor is that the speed at which sound travels is a function of temperature, therefore the calculated distance changes with temperature.

3.5.3 Laser

A laser distance sensor works by sending a laser beam out into the environment. This beam bounces off of an object, and is reflected back to the receiver portion of the sensor. The sensor measures the time which it takes to send and receive the beam. From the time, it calculates the distance at which the object is away. Because light travels so fast, this type of sensor can be very expensive, and not accurate.

3.6. IC Voltage Regulators

IC voltage regulators are three-terminal devices that provide a constant DC output voltage that is independent of the input voltage, output load current, and temperature. There are three types of IC voltage regulators: IC linear voltage regulators, IC switching voltage regulators, and DC/DC converter chips. IC linear voltage regulators use an active pass element to reduce the input voltage to a regulated output voltage. By contrast, IC switching voltage regulators store energy in an inductor, transformer, or capacitor and then use this storage device to transfer energy from the input to the output in discrete packets over a low-resistance switch. DC/DC converter chips, a third type of IC voltage regulators, also provide a regulated DC voltage output from a different, unregulated input voltage. In addition, DC/DC converters also provide noise isolation regulate power buses.

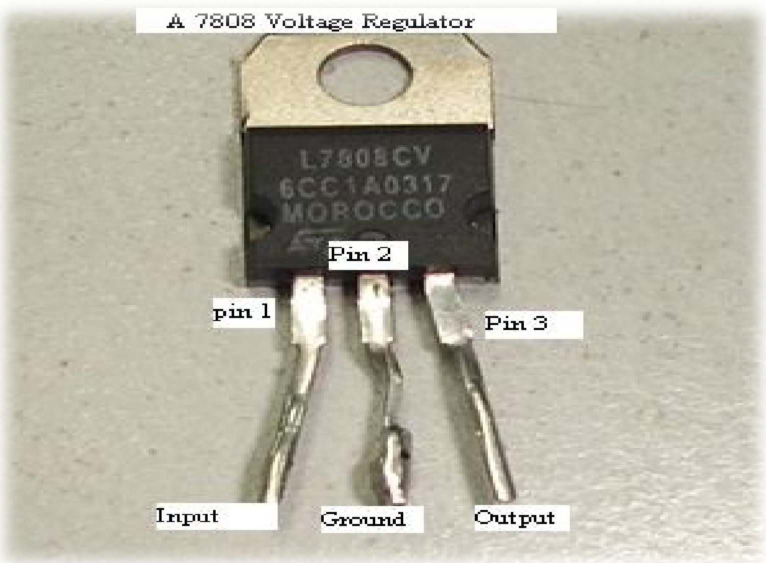


Figure 3.6: 3-pin IC voltage regulator

3.7. Resistors

Resistors are common elements of electrical networks and electronic circuits and are ever present in electronic equipment. Practical resistors can be made of various compounds and films, as well as resistance wire (wire made of a high-resistivity alloy, such as nickel-chrome). Resistors are also implemented within integrated circuits, particularly analog devices, and can also be integrated into hybrid and printed circuits.

There are basically two types of resistors; Fixed and variable resistors. Fixed resistors are classified into 4 types based on various factors like manufacturing style, resistance range, power rating etc. The four types of fixed resistors are Carbon composition, Carbon film, Metal film (again classified into thick film resistors and thin film resistors), Wire wound- which consists of power style type and precision style type. On the other hand variable resistors are used in electronic circuits to adjust the value of voltages and currents. The three types of variable resistors are; Potentiometer (classified into carbon potentiometer and wire wound potentiometer), rheostat and trimmer. Figures 3.7.1 (a,b) shows the various types of resistors available in the market.

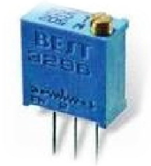


Figure 3.7.1 (a): trimmer (preset) resistor

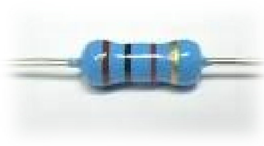


Figure 3.7.1 (b): fixed resistor

CHAPTER THREE
DESIGN

3.0 INTRODUCTION

The implementation of the system was broken down into several modules. Each module responsible for a specific role that when summed up would meet the objective of the project.

This chapter gives a detail explanation on the hardware and software development for this project. Hardware development is the construction of the project circuit, the method and how it is constructed will be explained. Meanwhile, the software development tells the programming part of this project.

3.1 HARDWARE DEVELOPMENT.

The hardware part is important in this project; it must be correctly design to ensure that the operation will work appropriately as desired. The main operation is to define how to control the DC motors using the H-bridge and the sensor and how to connect this combined circuit to the micro-controller circuit. The H- Bridge and the micro-controller are being control by the micro-controller program code. In this chapter, the hardware design for this program will be described.

This project circuit consists of a combination of 3 circuits; the power supply unit, sensory array module, central processing unit (controller) and the drive system which is the motor control unit. The figure below shows the block diagram for this project. The general block diagram of the robot is shown in figure 3.1 with the various parts of the system.

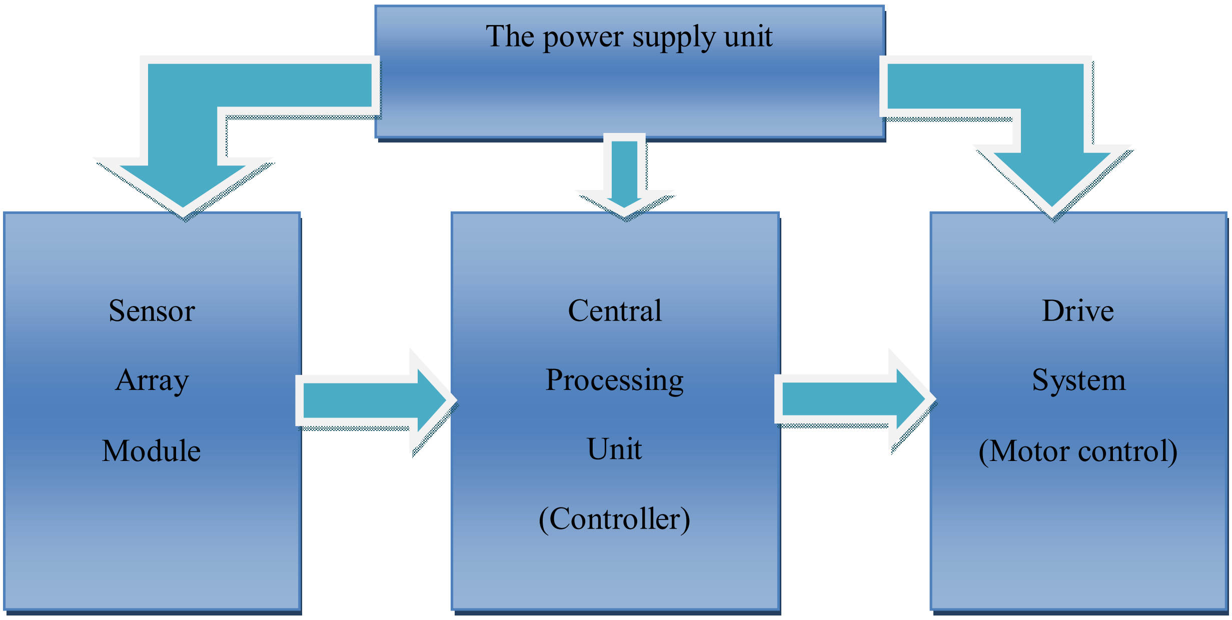


Figure 3.1 General control system's block diagram

3.1.1 Central processing unit (controller).

Control unit refers to an electronic system which takes inputs from the various sensors which collect data from the environment and can drive the output devices according to the conditions which are applied due to various constraints. The control unit consists of a programmable logic device called microcontroller. The microcontroller is a type of electronic device which can be pre-programmed according to our requirements. Every microcontroller has various input and output pins where different I/O devices can be connected. The microcontroller also has other peripherals like ADC, USART, PWM, etc. embedded inside the same chip. Therefore microcontroller is nothing but a microprocessor with all other peripherals embedded inside the same chip. Whenever we have to control the systems dynamically according to the conditions of system environment, we use a microcontroller as the control unit.

3.1.2 Design of the obstacle sensing unit

Each infrared range sensor measures the distance to an object by detecting reflected infrared light transmitted by its light emitter. This is illustrated in Figure 3-2. The electronics in the sensor enable it to measure the angle at which the reflected light enters the detector. When the sensor is close to an object, light enters the detector at a sharp angle. When the sensor is far from an object, light enters the detector at a slight angle. The sensor outputs an analog voltage that varies depending on the angle at which the reflected light enters the detector. This technique makes the sensor insensitive to ambient light and the reflectivity of the detected object, ensuring the output voltage is solely a function of the distance to the detected object

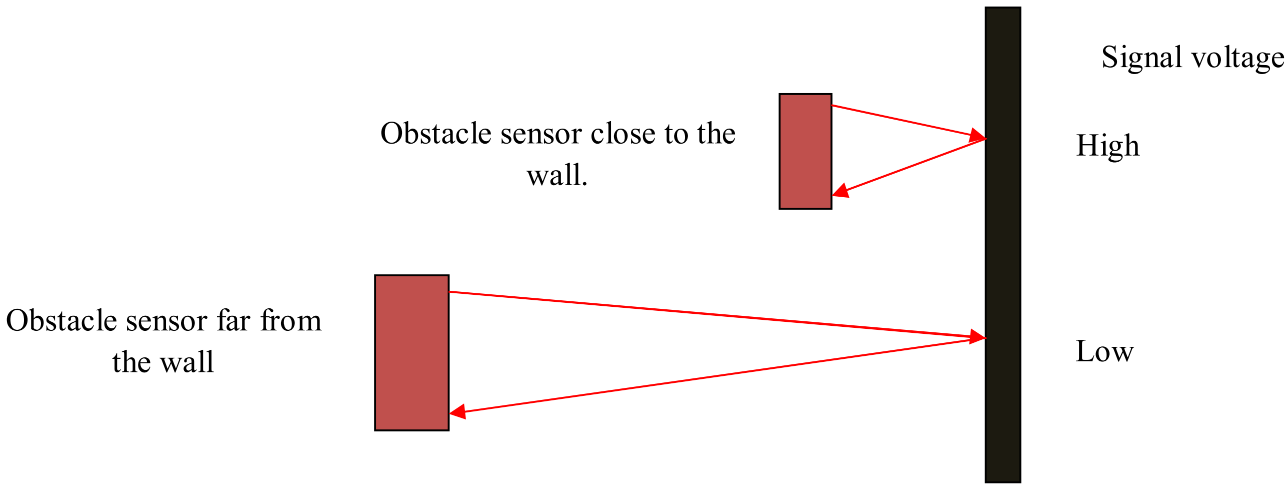


Figure 3.1.2 (a) sensing distance to the obstacle.

The infrared based object detector can be implemented using two configurations; Break beam sensors and reflectance sensors. The second configuration is very suitable for the portability of this robot where both the IR source and the IR detector need to be on the robot; hence it is going to be implemented in the control system of the robot. The infrared emitter-detector basic circuit is as shown in Figure 3.3.

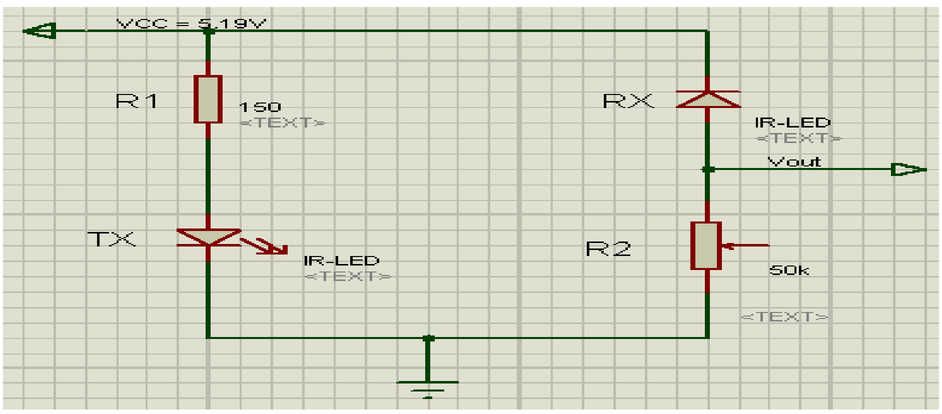


Figure 3.1.2 (b) the infrared emitter-detector basic circuit.

R1 is to prevent the emitter LED from melting itself. The emitter specification sheet is used to find maximum power, then the value of R1 is chosen such that $Vcc^2/R1$ < Maximum Power specification. Therefore,

$$R_1 > \frac{V_{cc}{}^2}{\text{Maximum Power\_specification}} \tag{3.4}$$

From the specification sheet of the transmitter infrared diode, the voltage and current requirements are 1.8V and 100mA respectively. From these figures,

$$\text{Maximum power speci ication} = V * I = 1.8 * 0.1 = 0.18W \tag{3.5}$$

For V_{cc} = 5.19V the resistance value of R_1 can be computed as follows,

$$_1 > \frac{5.19^2}{0.18} > 149.645\Omega \tag{3.6}$$

Hence in this case R1 is chosen to be 220Ω.

The resistance value of R2 determines the sensitivity of the robot in terms of the distance between the robot and the obstacle. For R1 = 220Ω, R2 = 22KΩ and V_{cc} = 5.19V, if no obstacle is in front of the sensor then the value of V_{out} is around 2.05V and when an obstacle comes to about 15cm from it, the value goes up to 3.78V, and when the obstacle comes nearer than 5cm the value saturates to 5.06V.

Similarly, six units of the obstacle detector circuits designed above are going to be used, two for detecting left wall obstacles during the forward motion, two for detecting front obstacles and turning right if there is an obstacle in front. One on the right to determine when to move forward when there a reverse initially and one on the rear part in order to turn when reversing.

All the outputs from the sensors are analogue in nature and since the microcontroller to be used has only six pins that can do analogue to digital conversion. In addition to the microcontroller that is going to do the analogue to digital conversion, it also performs the signal processing.

3.1.3 Design of the control signals processing unit

Output signals from the obstacle detection unit are used as inputs to the control signals processing unit. These include the six inputs from the other six inputs from the obstacle detector circuits. Hence the control signals processing unit will have six inputs from the obstacle detection unit which are all digital in nature.

Since the input signals are analogue signals, the first step is to convert them to digital signals using the analogue to digital conversion feature of the microcontroller. Next step is to perform logical operations on the digital signals; for the obstacle detection circuits, the one with the highest value (meaning receiving the highest value due to complete obstability) is determined to indicate the direction of motion of the robot and for the obstacle sensors, their values are used to determine whether the motion to a given direction can be permitted.

The robot will have a total of six IR infrared sensors, all oriented strategically to determine the motion of the robot. Orientation of the sensors is as shown in figure 3.1.3

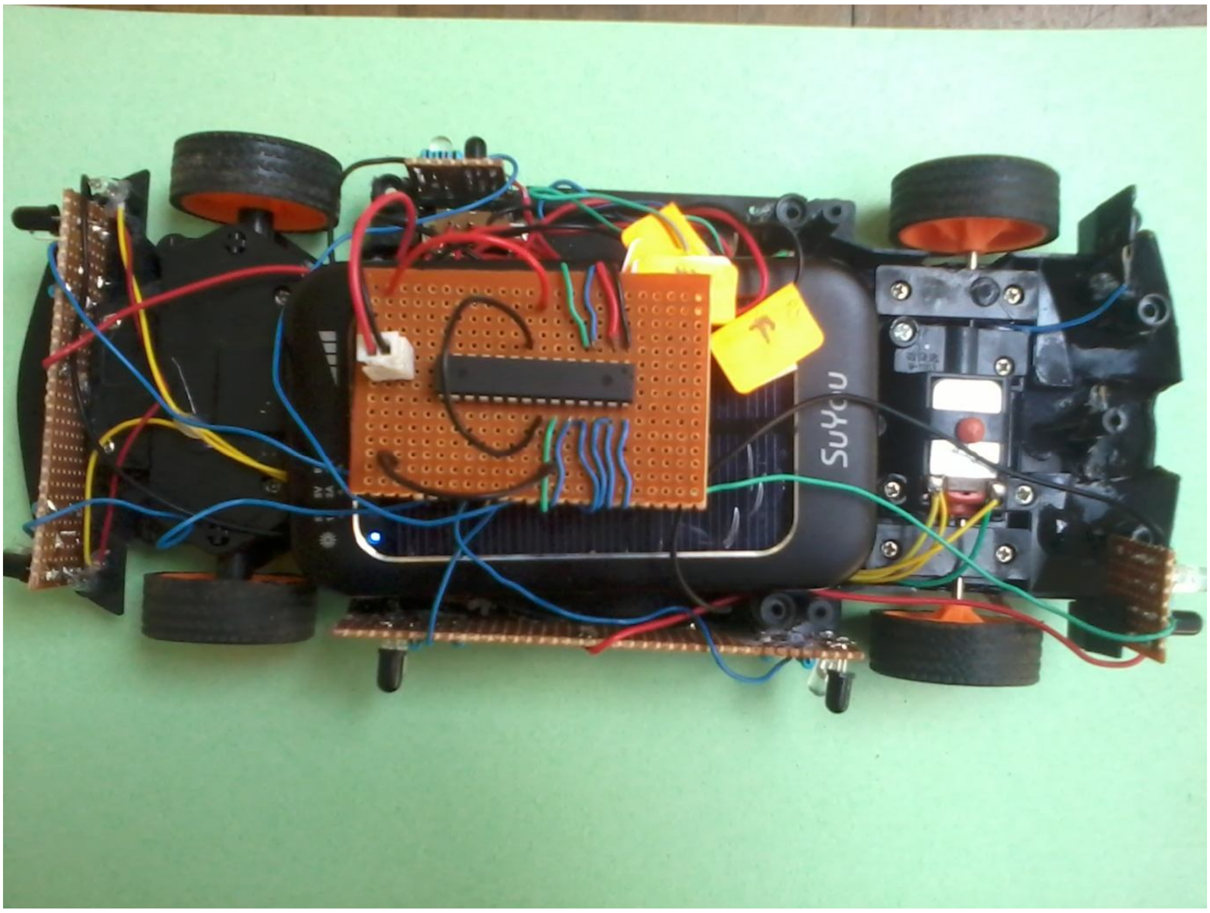


Figure 3.1.3. Orientation of the IR infrared sensors

The total number of sensors that the robot is expected to use are six. This implies that there will be a number of combinations as the various sensors will be giving different readings at any instant of time

3.2. SOFTWARE DEVELOPMENT

The primary purpose the software is to maintain control over the hardware at all times and determine where to move by solving the maze. Controlling the hardware consist of reading the sensors; setting the motor speed and communicating with any external peripherals.

3.2.1. Algorithm

The principal goal of a robot is to solve the maze and find its end. To accomplish this task, the robot uses a particular maze searching algorithm. A vast amount of research on searching techniques already exists and is currently being undertaken. As a result robots generally use some variation of the following three searching algorithms: Wall following, Depth First search and Flood Fill

3.2.2 Wall follower algorithm

The wall follower, the best-known rule for traversing mazes, is also known as either the *left-hand rule* or the *right-hand rule*. If the maze is *simply connected*, that is, all its walls are connected together or to the maze's outer boundary, then by keeping one hand in contact with one wall of the maze the robot is guaranteed not to get lost and will reach a different exit; otherwise, the robot will return to the entrance having traversed every corridor in the maze at least once.

Another perspective into why wall following works is topological. If the walls are connected, then they may be deformed into a loop or circle. Then wall following reduces to walking around a circle from start to finish. To further this idea, by grouping together connected components of the maze walls, the boundaries between these are precisely the solutions, even if there is more than one solution.

If the maze is not simply connected (if the start or endpoints are in the center of the structure or the pathways cross over and under each other), this method will not be guaranteed to help the goal to be reached.

Wall-following can be done in 3D or higher-dimensional mazes if its higher-dimensional passages can be projected onto the 2D plane in a deterministic manner. However, unlike in 2D, this requires that the current orientation be known, to determine which direction is the first on the left or right.

The figure3.2.2 below shows a simple maze which it was use for the basis of illustration how the robot will navigate around it until it exits.

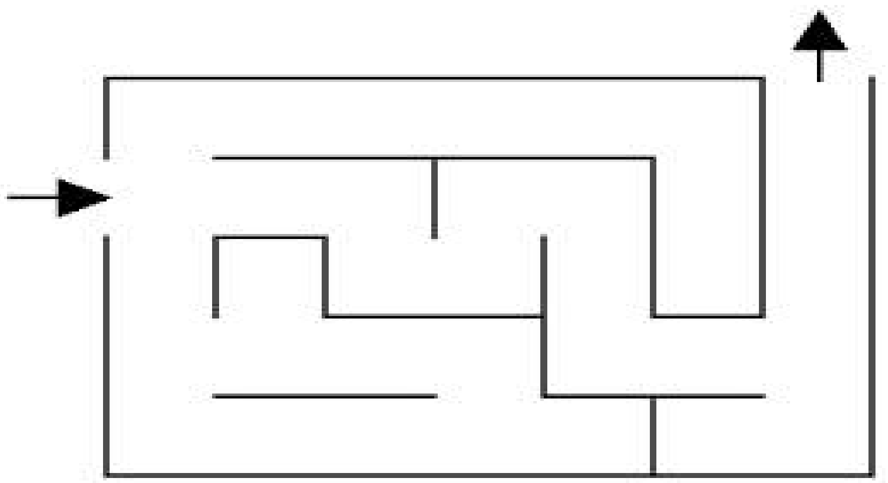


Figure: 3.2.2 simple maze for wall follower algorithm.

the final design implementation was done with the complete system incorporating sensors, the central processing unit and the power supply then couple with the radio controlled toy car was finally done as shown in figure 3.2.3 below;

3.2.3 Programming environment

Arduino is a single-board microcontroller, intended to make the application of interactive objects or environments more accessible.[1] The hardware consists of an open-source hardware board designed around an 8-bit Atmel AVR microcontroller, or a 32-bit Atmel ARM. Current models feature a USB interface, 6 analog input pins, as well as 14 digital I/O pins which allow the user to attach various extension boards.

It comes with a simple integrated development environment (IDE) that runs on regular personal computers and allows writing programs for Arduino using C or C++ to the atmega 328 then the chip was transferred to the robot's board. The figure below shows the Arduino Uno board and the pin mapping for the chip.

Figure 3.1.3 arduino Uno board

Figure 3.1.4 Atmega pin mapping

Program flowchart

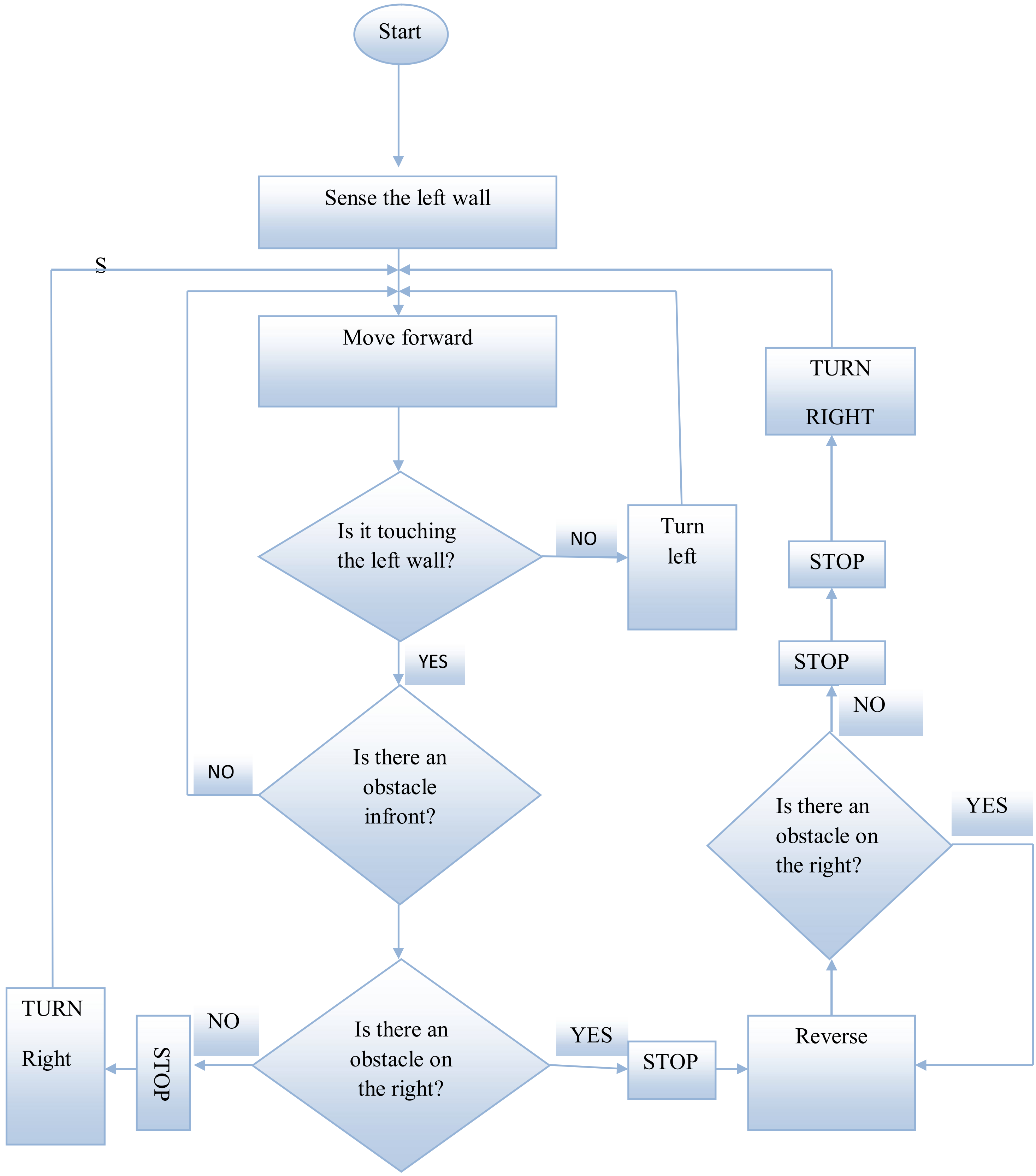


Figure 3.1.5 flowchart for the maze robot

CHAPTER FOUR

4.0 Simulation of results

4.1 Simulation of the obstacle sensors

Six obstacle sensors were used to detect the presence of an obstacle in the path of the robot. All of the sensors were similar (they had approximately equal output voltage for a given distance from the obstacle) hence they were having the same response. Figure 4.1 is the circuit diagram of the obstacle detector designed for the robot.

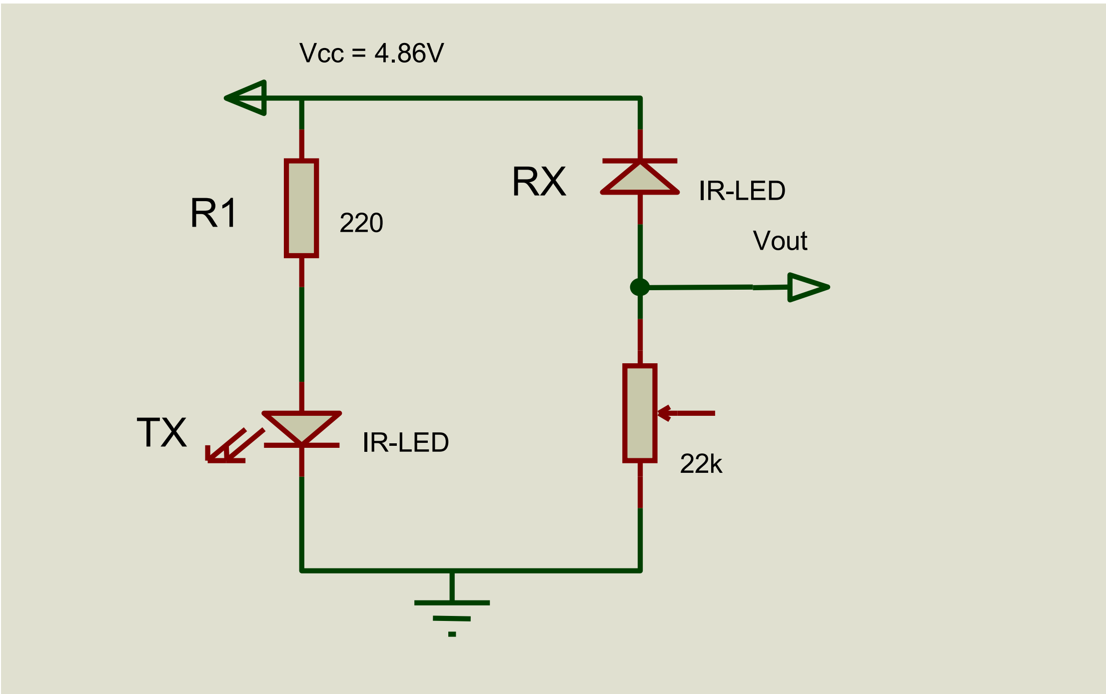


Figure 4.1 Obstacle detector circuit diagram

For V_{cc} = 4.86V, R1 = 220Ω and R2 = 22KΩ, the obstacle was moved in a straight line along the direction of the obstacle sensor. The corresponding values of the distance of the obstacle from the obstacle sensor (d), and the obstacle sensor's output voltage (V_{out}) were measured and recorded in table 4.1.

Number	Distance, d (cm)	Output voltage (volts)
0	No obstacle	1.73
1	35	2.30

2	30	2.41
3	25	2.57
4	20	2.77
5	15	3.03
6	10	3.44
7	5	4.12
8	4	4.35
9	3	4.53
10	2	4.69
11	1	4.70

Table 4.1 Results of the obstacle sensors

The plot of the output voltage of the obstacle sensor in volts against the distance of the light source from the sensor in centimeters is as shown in figure 4.4.

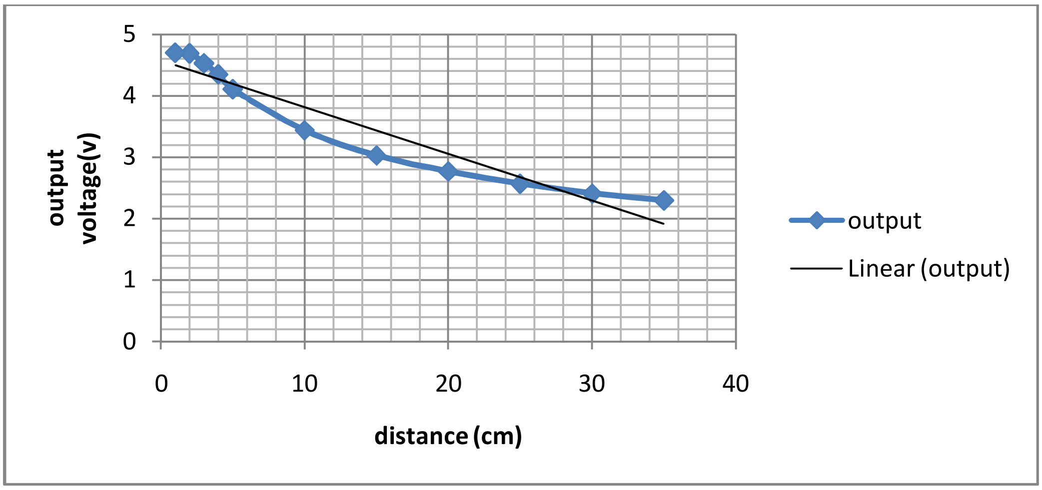


Figure 4.2 Variation of voltage with distance for obstacle sensors

From the plot of the output voltage of the obstacle sensor in volts against the distance of the light source from the sensor in centimeters, it is seen that there is a 1/d^2 variation of distance and the output voltage, with d (cm) being the source distance from the sensor. Therefore as the distance of the obstacle (in the path of the robot) from the sensor decreases the output voltage also increases.

4.3 Simulation of the signal processing unit

Output signals from the obstacle detection unit are the inputs to the control signals processing unit. These include the six inputs from the obstacle detectors, which are digital in nature. This implies that the control signals processing unit has six inputs of which are digital in nature.

The test done on the signal processing unit where each one of all of the input signals from all the sensors gave particular instructions as the output of the signal processing unit. Indicated below in table 4.3 are the various possible states of the robot and the corresponding control action is also suggested.

Number	Sensor	Instruction
1	Left _forward sensor	Move forward
2	Left _reverse sensor	Move forward with a left turn if left _forward sensor is clear.
3	Forward _left sensor	Move forward with a right turn if the left _forward is blocked
4	Forward _right sensor	Move forward with a right turn if it's not clear, else reverse with left turn until it's clear if all other options are not clear
5	Reverse sensor	Move reverse with left turn until forward right is clear.
6	Right _forward sensor	Move forward with right turn if it's clear and front and left not clear.

Table 4.3 States of the robot and the corresponding instructions

CHAPTER FIVE

5.0 DISCUSSION

The robot was designed to navigate through a maze and find its exit. It has six IR infrared sensors positioned at, the front side (extreme left and extreme right), the left side (extreme forward and extreme back), the back (extreme left) and the right (extreme forward) .Based on the obstacles which falls on any of the IR infrared sensors, the robot will move to the desired direction.

This idea of giving control commands to a robot wirelessly has very many industrial applications which when put into practice can definitely help to advance the technology. Some of these applications are:

- Robots can be used for repetitive tasks which use the same path on the floor of a factory.
- Lines of metal or magnetic strips placed under lawns can be used as a guide for a robot lawnmower to replace the human operators.
- There are cases where smarter versions of wall followers are used to deliver mail within an office building and deliver medications in a hospital
- The technology has been suggested for running buses and other mass transit systems, and may end up as part of autonomous cars navigating the freeway.

A robot is a robust system that takes into account and overcomes inaccuracies and imperfections; in summary, a valid engineering approach to a typical (industrial) problem. Robotics has come a long way, especially for mobile robots, a similar trend is happening as we have seen for computer systems: the transition from mainframe computing via workstations to PCs, which will probably continue with handheld devices for many applications.

In the past, mobile robots were controlled by heavy, large, and expensive computer systems that could not be carried and had to be linked via cable or wireless devices. Today, however, we can build small mobile robots with numerous actuators and sensors that are controlled by inexpensive, small, and light embedded computer systems that are carried on-board by the robot.

There has been a tremendous increase of interest in mobile robots. Not just as interesting toys or inspired by science fiction stories or movies, but as a perfect tool for engineering education. A number of mobile robots have developed including wheeled, tracked, legged, flying, and underwater robots. The simplest case of mobile robots is wheeled robots. Wheeled robots comprise one or more driven wheels and have optional passive or caster wheels and possibly steered wheels. Most designs require two motors for driving and steering a mobile robot.

One disadvantage of all wheeled robots is that they require a street or some sort of flat surface for driving. Tracked robots are more flexible and can navigate over rough terrain. However, they cannot navigate as accurately as a wheeled robot. Tracked robots also need two motors, one for each track. Legged robots are the final category of land-based mobile robots. Like tracked robots, they can navigate over rough terrain or climb up and down stairs, for example. There are many different designs for legged robots, depending on their number of legs. The general rule is: the more legs, the easier to balance.

This device forms a sub-section to a lot other bigger and more useful applications where a robot is needed to move. This forms a lot of industrial applications where Controlling the movement of a robot is necessary for almost all type of robots, thus the device serves as a basic necessity accomplished while designing any high level robots. The device also has precise control, fast processing, reduced error rate and the most important being cost-effective.

In my project I have demonstrated the use of the interfacing of microcontrollers with other devices such as I.C.TLMX12O8. Where four pins of microcontroller are connected to the four input pins of the driver I.C. The software can be used to send any sequence of voltage pulses to the interfaced circuit.

In this project I have created simple controls for the movement of the robot. The instructions are already loaded into the microcontroller using universal burner are fed to the driver I.C. which is connected to the motors that starts rotating on the reception of the signal.

Interfacing electrical and electronic circuits with the microcontroller gives lots of advantages and scope for extended as well as extension purposes. Using this technique we can design a circuit for the higher level robots too. Even the usage of different simulators as well as emulators gave us a lot of knowledge about the working of the embedded system devices.

In a nutshell, it may be said that this project can be used very well elsewhere i.e. in other applications and lays the basic foundation for interfacing external circuits using the microcontroller

5.2 LIMITATION AND FURTHER DEVELOPEMNTS

There are several limitations that exist in the current system which should be addressed in further developments.

The sample maze considerer has one entry and one exit hence the robot navigate through the maze to its exit.

The maze wanderer robot has information only about its local environment and does not localize itself in a global environment. Thus it is impossible to introduce a define goal for the robot to reach in global environment.

The robot scans through the IR infrared sensors only in six predefined directions. Thus it is assumed that any obstacle detected lies in those directions only. This effect can be minimized by incorporating probabilistic models to the system which is somewhat difficult in a microcontroller.

Also sometimes some obstacles are not detected when the obstacle surface isn’t in an angle to sufficiently reflect the waves sent by the IR infrared sensor.

The receiver infrared diode is sensitive to light; hence when the ambient light is high it interferes with the obstacle sensing unit of the robot hence limiting my project to indoor application.

A proper attention should be paid to the above matters in a further development of this project.

CONCLUSION

In this paper, a maze wanderer robot was designed and implemented using wall follower algorithm technique. Controlling the movement of a robot is necessary for almost all type of robots, thus the device serves as a basic necessity accomplished while designing any high level robots. It was also established that wall follower algorithm has precise control, fast processing, reduced error rate and the most important being cost-effective as compared to depth-first and flood fill algorithms.

My overall experience making the maze robot was a great learning opportunity. I made several mistakes and was able to correct some of them. If I were to design and build that robot again I would do the design and implementation section very early in the semester because that was the most time consuming portion of the entire robotic project. As far as enhancements go, overall, it was a great learning experience and this project has helped me further realize the importance of good time management. The control system of the robot was successfully designed and was tested yielding successful results.

Appendix A: time schedule.

Table 1: time schedule.

Start date	End date	Duration (weeks)	items	scope
22/11/2013	5/12/2013	2	introduction	Project objective, requirements and scope specification
5/12/2013	30/12/2013	3	Literature review	Detailed description of various methods of achieving the required control system.
1/01/214	27/01/2014	4	Design implementation and program development.	Designing the required circuit and algorithm development
28/01/2014	14/02/2014	3	simulation	Analyzing the designed hardware developed program and their operation
15/02/2014	02/03/2014	3	Final implementation	Correcting and fixing all the problem all in the hardware and the program
03/03/2014	21/03/2014	3	Final presentation	Presentation of the project final review
22/04/2014	05/04/2014	2	Report finalization and submission	Review of the objective and preparation of presentation slides.

Appendix B: The program

```
/*******************************************************************************
************************/

 /*maze_wandarer_robot

 /*created: 4/20/2014

 /*AUTHOR: MARITIM KIBET

/
*********************************************************************************
************************/

int input = A5;

float value = 0;

int SPEED = 7;

//float input_voltage = 0;


int buffer_size = 6;

double light_sensors_buffer[6] = {};

int buffer_position = 0;

float input_voltage;

float v_ref = 2.0;//considerable distance from the obstacle (distance from the left wall)

float v_ref_lower = 0.5;//a bit far from the obstacle (distance from the forward obstacle before turning
right)

float v_ref_higher = 4;//a bit close to the obstacle


int motion1 = 2;  //FORWARD-REVERSE MOTION CONTROL PIN.

int motion2 = 3;  //FORWARD-REVERSE MOTION CONTROL PIN.

int turning1 = 4;  //LEFT-RIGHT MOTION CONTROL PIN.

int turning2 = 5;  //LEFT-RIGHT MOTION CONTROL PIN.

void setup()

{

  Serial.begin(9600);

  //SETTING THE MOTION CONTROL PINS AS OUTPUTS.
```

```
  pinMode(motion1,OUTPUT);

  pinMode(motion2,OUTPUT);

  pinMode(turning1,OUTPUT);

  pinMode(turning2,OUTPUT);

}


void loop()

{

  clear_light_sensors_buffer();

  read_and_store_sensor_values();

  if (light_sensors_buffer[0] < v_ref && light_sensors_buffer[1] < v_ref && light_sensors_buffer[2]
> v_ref)// && light_sensors_buffer[3] > v_ref)

    {

      Serial.println("moving forward");

      forward_motion();

      delay(SPEED);

      digitalWrite(motion1,LOW);

      digitalWrite(motion2,LOW);

    }

    else if (light_sensors_buffer[0] < v_ref && light_sensors_buffer[1] < v_ref &&
light_sensors_buffer[2] < v_ref && light_sensors_buffer[3] > v_ref)

            {

              while(light_sensors_buffer[2] < v_ref)

                {

               Serial.println("moving forward left");

               clear_light_sensors_buffer();

               read_and_store_sensor_values();

                     forward_left();

               delay(SPEED);
```

```
            digitalWrite(motion1,LOW);

            digitalWrite(motion2,LOW);

             }

          }

  else if (light_sensors_buffer[0] > v_ref_lower && light_sensors_buffer[1] > v_ref_lower &&
light_sensors_buffer[2] > v_ref && light_sensors_buffer[3] > v_ref && light_sensors_buffer[5] <
v_ref)

          {

            while(light_sensors_buffer[1] > v_ref_lower)

            {

          Serial.println("moving forward right");

          clear_light_sensors_buffer();

          read_and_store_sensor_values();

              forward_right();

          delay(SPEED);

          digitalWrite(motion1,LOW);

          digitalWrite(motion2,LOW);

            }

          }

   else

          {

            Serial.println("stopping");

        stop_motion();

          }


}


 void calculation(void)

 {
```

```
        input_voltage = (((value) * 5) / 1024);
}
//FUNCTION FOR CLEARING THE LIGHT SENSOR BUFFER

void clear_light_sensors_buffer(void)
{
        for (int x = 0; x < buffer_size; x++)
        light_sensors_buffer[x] = 0x00;  //initializing the data array to null
}

//FUNCTION FOR READING AND STORING THE ADC SENSOR VALUES

void read_and_store_sensor_values(void)
{
  input_voltage = analogRead(A0);
  light_sensors_buffer[0] = ((input_voltage * 5) / 1023);
  input_voltage = analogRead(A1);
  light_sensors_buffer[1] = ((input_voltage * 5) / 1023);
  input_voltage = analogRead(A2);
  light_sensors_buffer[2] = ((input_voltage * 5) / 1023);
  input_voltage = analogRead(A3);
  light_sensors_buffer[3] = ((input_voltage * 5) / 1023);
  input_voltage = analogRead(A4);
  light_sensors_buffer[4] = ((input_voltage * 5) / 1023);
  input_voltage = analogRead(A5);
  light_sensors_buffer[5] = ((input_voltage * 5) / 1023);
}
```

```
//FUNCTION FOR FORWARD MOTION.
void forward_motion()
{
  digitalWrite(motion1,HIGH);
  digitalWrite(motion2,LOW);
  digitalWrite(turning1,LOW);
  digitalWrite(turning2,LOW);
}

//FUNCTION FOR REVERSE MOTION.
void reverse_motion()
{
  digitalWrite(motion2,HIGH);
  digitalWrite(motion1,LOW);
  digitalWrite(turning1,LOW);
  digitalWrite(turning2,LOW);
}

//FUNCTION FOR FORWARD-LEFT MOTION.
void forward_left()
{
  digitalWrite(turning1,HIGH);
  digitalWrite(turning2,LOW);
  digitalWrite(motion1,HIGH);
  digitalWrite(motion2,LOW);
}

//FUNCTION FOR FORWARD-RIGHT MOTION.
```

```
void forward_right()
{
  digitalWrite(turning2,HIGH);
  digitalWrite(turning1,LOW);
  digitalWrite(motion1,HIGH);
  digitalWrite(motion2,LOW);
}

//FUNCTION FOR REVERSE-LEFT MOTION.
void reverse_left()
{
  digitalWrite(turning1,HIGH);
  digitalWrite(turning2,LOW);
  digitalWrite(motion1,LOW);
  digitalWrite(motion2,HIGH);
}

//FUNCTION FOR REVERSE-RIGHT MOTION.
void reverse_right()
{
  digitalWrite(turning2,HIGH);
  digitalWrite(turning1,LOW);
  digitalWrite(motion1,LOW);
  digitalWrite(motion2,HIGH);
}

//FUNCTION FOR STOPPING THE MOTION.
void stop_motion()
```

```
{
  digitalWrite(turning2,LOW);
  digitalWrite(turning1,LOW);
  digitalWrite(motion1,LOW);
  digitalWrite(motion2,LOW);
}
```

Appendix C: datasheet for high power Emitting diode.

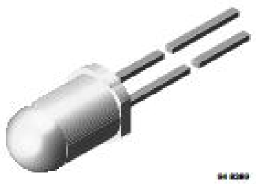
VISHAY.

www.vishay.com

TSAL6100

Vishay Semiconductors

High Power Infrared Emitting Diode, 940 nm, GaAlAs/GaAs



FEATURES

- Package type: leaded
- Package form: T-1¾
- Dimensions (in mm): Ø 5
- Peak wavelength: λ_p = 940 nm
- High reliability
- High radiant power
- High radiant intensity
- Angle of half intensity: $\varphi = \pm 10°$
- Low forward voltage
- Suitable for high pulse current operation
- Good spectral matching with Si photodetectors
- Compliant to RoHS Directive 2002/95/EC and in accordance to WEEE 2002/96/EC

RoHS COMPLIANT

GREEN (5-2008)**

Note

** Please see document "Vishay Material Category Policy": www.vishay.com/doc?99902

DESCRIPTION

TSAL6100 is an infrared, 940 nm emitting diode in GaAlAs/GaAs technology with high radiant power molded in a blue-gray plastic package.

APPLICATIONS

- Infrared remote control units with high power reqirements
- Free air transmission systems
- Infrared source for optical counters and card readers
- IR source for smoke detectors

PRODUCT SUMMARY				
COMPONENT	I_e (mW/sr)	φ (deg)	λ_p (nm)	t_r (ns)
TSAL6100	130	± 10	940	800

Note

- Test conditions see table "Basic Characteristics"

ORDERING INFORMATION			
ORDERING CODE	PACKAGING	REMARKS	PACKAGE FORM
TSAL6100	Bulk	MOQ: 4000 pcs, 4000 pcs/bulk	T-1¾

Note

- MOQ: minimum order quantity

ABSOLUTE MAXIMUM RATINGS (T_{amb} = 25 °C, unless otherwise specified)				
PARAMETER	TEST CONDITION	SYMBOL	VALUE	UNIT
Reverse voltage		V_R	5	V
Forward current		I_F	100	mA
Peak forward current	t_p/T = 0.5, t_p = 100 µs	I_{FM}	200	mA
Surge forward current	t_p = 100 µs	I_{FSM}	1.5	A
Power dissipation		P_V	160	mW
Junction temperature		T_j	100	°C
Operating temperature range		T_{amb}	- 40 to + 85	°C
Storage temperature range		T_{stg}	- 40 to + 100	°C
Soldering temperature	t ≤ 5 s, 2 mm from case	T_{sd}	260	°C
Thermal resistance junction/ambient	J-STD-051, leads 7 mm soldered on PCB	R_{thJA}	230	K/W

Rev. 1.7, 24-Aug-11 1 Document Number: 81009

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