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**SENSBOT:
4 LEGGED AUTONOMOUS ROBOT**

MOHAMAD FADZLI BIN HANIFF

**Project Report Submitted as Partial Fulfillment of
the requirement for the award of the
Bachelor Degree of Electrical Engineering (Mechatronics)**

**FACULTY OF ELECTRICAL ENGINEERING
UNIVERSITI TEKNOLOGI MALAYSIA**

MAY 2011

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ABSTRACT

4 legged robot is a very common thing in engineering today. It even catches the attention of university students, where there are so many final year projects that are using this robot as the topic. As we all know, robot are used for entertainment from toy companies to films. It is very common to see robot in commercials on television. This project deals with the development of autonomous 4 legged robot. Autonomous means the robot can adapt to the environment without being controlled by human or user. There is no remote control needed in this project. This project's idea occurs from the inspirations caused by Sony AIBO and WowWee Robopet. The objective of this project is to build an autonomous 4 legged robot that can detect the movement of object in front of it, SensBot. SensBot will be programmed to do movements such as walking, wiggle tail, barge to the front, and wiggle without the aids of human. The robot will be able to react differently to moving and non moving object. Lastly, SensBot will be the ability to use its waist in obstacle avoiding movement sequence.

ABSTRAK

Robot berkaki empat adalah sangat umum dalam bidang kejuruteraan masa kini. Ia juga menarik minat mahasiswa-mahasiswa universiti dimana terdapat banyak projek tahun akhir yang menggunakan robot ini sebagai topik. Seperti yang kita tahu, robot digunakan untuk hiburan, dari permainan hingga filem. Ia adalah sangat biasa untuk melihat robot di dalam iklan di televisyen. Projek ini berkaitan dengan pembuatan robot automasi berkaki empat. Automasi bermaksud robot itu mampu menyesuaikan diri dengan persekitaran tanpa dikawal oleh manusia. Tiada panel kawalan di dalam projek ini. Idea untuk menjalankan projek ini adalah timbul dari inspirasi yang disebabkan oleh Sony AIBO dan WowWee Robopet. Objektif projek ini adalah untuk membina robot automasi berkaki empat yang boleh mengesan pergerakan object yang berada di depanannya, SensBot. SensBot akan deprogram untuk melakukan pergerakan seperti berjalan, menggoyangkan ekor dan menggoyangkan ekor tanpa pertolongan dari manusia. Robot ini akan mampu member reaksi yang berbeza kepada objek bergerak dan object tidak bergerak. Akhir sekali, SensBot akan mempunyai kebolehan menggunakan pinggangnya dalam urutan pergerakan mengelak objek.

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LIST OF ABBREVIATIONS

IR	-	Infra Red
PIR	-	Passive Infra Red
PC	-	Personal Computer
PWM	-	Pulse Width Modulation
ISP	-	In System Programmer
LPT	-	Line Print Terminal

LIST OF APPENDIX

- Appendix A** – Program For Attiny2313 A
- Appendix B** – Program For Attiny2313 B

CHAPTER 1

INTRODUCTION

1.1 The Development Of Animal Robots

Nowadays, there are so many robots created resembling the characteristic of animal such as dog, cat and even dinosaur. These robots are just the incomplete resembles of those real animal. Even though there are many robots created based on one animal, but each of the robots have its own functions and specialties. The functions are based on the reaction of the real animal in term of movements and also sound.

These animal robots are used as pet, security guard, military purpose and also research purposes. As pet, these robot needs to be built as close as possible to the real animals in term of reactions. A pet must be able to react to its master in friendly way, it also should be able to differentiate between living things and non living things so that it can give specific reactions to each one. If not, the robot cannot be considered as a pet.

These robots must be able to operate by its own or can operate automatically. Remote control is not necessary to control the movements or behaviors of the robots. These robots must be built to be intelligent to control its own reactions depending on the surrounding conditions. These reactions may be complex but it is necessary to improve the current animal robot. But it is not necessary to build all the reactions at the same

time because a detail study must be done on the real animal. Everything should be done one by one so that the reactions truly resembles the real ones.

From day to day, these incomplete resembles of real animals are developed to be more advance, complex and detail so that it will become more closer in resembling the real animals. The developments of the animal resembling robots will always exist because there are some complex functions that are being left out from the past project. As long there are behaviors of real animal that can be implemented in robots, the development will keep on happening.

1.2 Objectives

The objectives of this project are as below:

1. To build an animal robot or 4 legged robot that able differentiate between human and obstacles(non living things) and react differently to both.
2. To build a 4 legged robot that only have basic functions such as can produce sounds, walking, avoid obstacle, sitting, standing and moving its ears and tail.
3. To build a 4 legged robot that use a different way of obstacle avoidance sequence.

1.3 Scope Of Project

The scope of project will give the brief image of the outcome of the project and also giving the direction of what has to be done to fulfill the objectives. The scopes are as stated below:

1. SensBot will be totally autonomous and microcontroller based with a small easy to carry size.

2. SenseBot will be a robot that resembles a dog.
3. SensBot will ONLY be able to perform the simple walking locomotion like a dog
4. SensBot will has several basic canine characteristic like producing sounds, obstacles avoidance, ducking and sitting down .
5. SensBot will be able to give different reactions to human and obstacles
6. SenseBot will resembles the stray dog and explore the environment by its own.

1.4 Summary Of Works

The schedule of the tasks and works done for this project are illustrated in the form of Gantt charts in Table 1.1 and Table 1.2 below

Weeks	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15
Proposal			■	■	■	■	■								
Background Study				■	■	■	■	■	■						
Circuit Designing								■	■						
Part Purchasing										■					
Component Study											■	■			
Circuit Construction													■	■	
Mehcanical Design															■
Report Writing														■	■
Presentation														■	

Table 1.1: First semester Gantt Chart

Weeks	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15
Program Flow Design	■														
Program Writing		■	■												
Testing Program				■											
Modification /Fine Tuning					■	■	■	■	■	■					
Demo Preparation										■	■				
Report Writing										■	■	■	■	■	■
Presentation													■	■	
Thesis Compilation														■	■

Table 1.2: Second Semester Gantt Chart

1.5 Outline Of Thesis

The remaining contents of this thesis are organized as follow:

- Chapter 2: Theory and literature review that have been done for robot pets
- Chapter 3: Methodology for component selections
- Chapter 4: Mechanical design of the robot from the sketches, actuators, leg design, body design and head attachment. The movement design of the robot will also be discussed in this chapter.
- Chapter 5: Circuitry design and software development for main circuitry system, infra red, PIR and analog distance sensors and software used for programming purpose.
- Chapter 6: The experimental results and discussions
- Chapter 7: Discussion of conclusions, future works.

CHAPTER 2

LITERATURE REVIEW

2.1 Sony AIBO

Sony AIBO is the first robot act as entertainment pet robot. The AI part of its name comes from the term Artificial Intelligence and the BO taken from the syllabus of ROBOT. In Japanese, AIBO also means partner.

Toshitada Doi, the creator of AIBO,
“AIBO is equipped with six emotions (joy, sadness, anger, surprise, fear, and discontent) and four instincts (the desire to interact with people, to search for favorite objects, to move around, and to re-charge its battery)...”



Figure 2.1: Sony AIBO

AIBO is equipped with 20 motors located at the neck, ears, legs, tail and mouth. These motors enables the robot to produce as many as 250 types of movement including walking, sitting, lying down and also the most relevant functions, flapping ears and

wagging tail. AIBO expresses its emotions with a wag of his tail or by changing the color and shape of his eyes or by his body movements.

AIBO has several senses that allow AIBO to interact with people such as touch (on his head, chin and back), hearing (stereo microphones) and sight (a camera in his head) and balance. It also has an infrared distance sensor, an acceleration sensor, and a temperature sensor. These allow AIBO to adapt to its surroundings, to interact with people - and to grow and learn from both.

The pressure sensors on AIBO's body make it react exactly when it is touched by any object, living beings. Meanwhile in real situation, animal gives different reaction to living beings and non living objects and react right before any object touches it. This is the weakness of AIBO.

2.2 WowWee Robopet

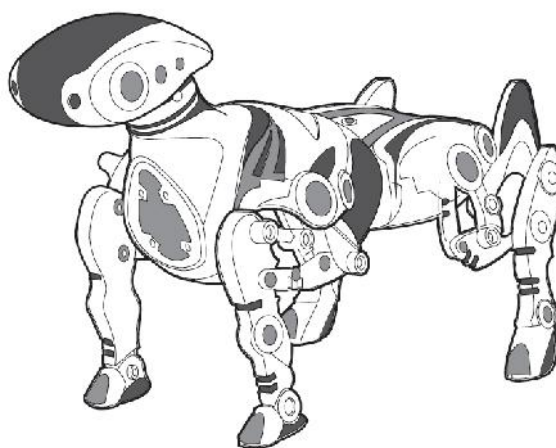


Figure 2.2: WowWee Robopet

This robot is a naturally active robot that have personality and a mind of its own. It will automatically explore environment and perform actions and tricks as it wanders around. The behavior can be train using the training buttons on the remote controller.

There is also a motor on its waist adding the extra degree of freedom to do some movements such as rolling.

AIBO is equipped with several sensing systems that allow it to explore its environment and respond to human approach. The sensing systems are like the following:

2.2.1. Sound Sensing

- Detecting loud and sharp sound with sensor located at the front of its body.
- When this robot hears a noise, it will stand up, walk forward or even able to perform some trick.

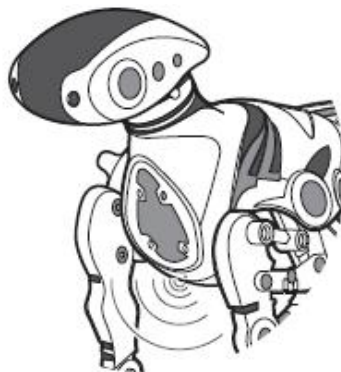


Figure 2.3: WowWee Robopet's Sound Sensing

2.2.2. Infrared Vision Sensing

- Sensors located at the head that enable it to detect movement to either side.
- It will either walk towards the movement present a paw to the side that it senses the movement.

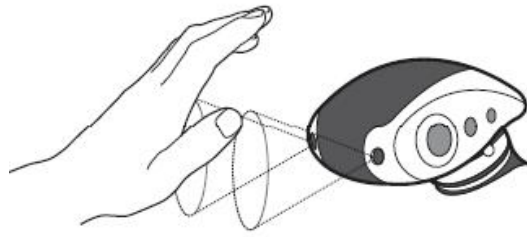


Figure 2.4: WowWee Robopet's Infrared Vision Sensing

2.2.3. Obstacle Avoidance

- It will stop and walk backward when there is obstacle.
- While walking Robopet will not be able to detect movement so it will treat human as an obstacle.

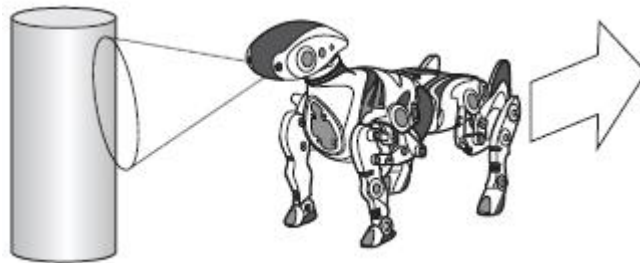


Figure 2.5: WowWee Robopet's Obstacle Avoidance

2.2.4. Edge Detection

- Additional sensors to detect the edge of table when it is walking.
- When it arrives to the end of table top, it knows that it cannot walk forward anymore because there is no floor to walk on.

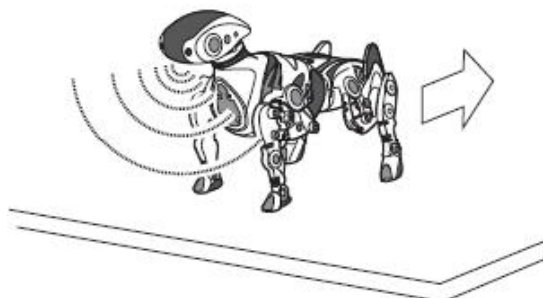


Figure 2.6: WowWee Robopet's Edge Detection

This robot is able to detect the motion in front of it and also do obstacle avoidance. The problem is, it will not be able to detect the motion while walking, so it will treat moving living things in front of it as obstacle and will avoid it. In real situation, if there is living beings such as human or other animal in front, animal will look and stare. This is the main problem of Robopet. The waist motor of this robot enabling it to do unique movements but is not used during walking movement just like real animal does.

2.3 I-Dog

This is the final year project of FKE, UTM student, Ng Hock Yuan, year 2008 inspired by AIBO and Robopet. I-Dog is able to perform the standing, sitting, running and walking actions other than obstacles avoidance

This robot takes the characteristic from Robopet which is the degree of freedom on the waist so that it can perform some extra task such as rolling and doing peeing position. I-Dog also able to response to word recognition for voice commands. It also has voice synthesizing ability such as barking, talking, singing and making some puppy noise.

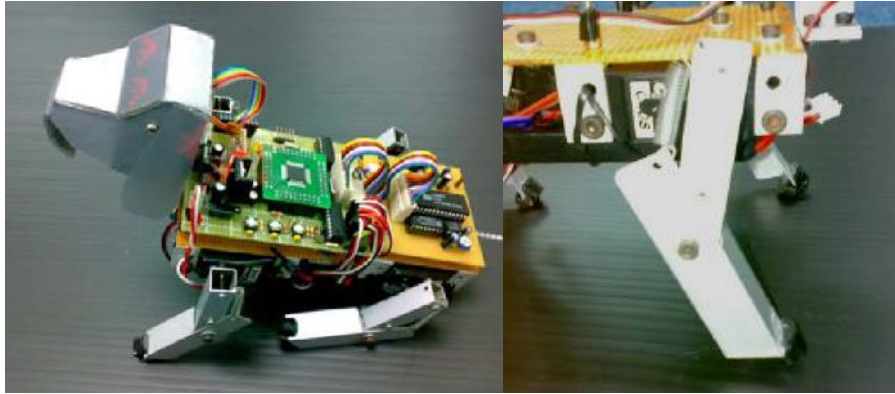


Figure 2.7: I-Dog

The most unique part is how the developer of I-Dog improved the robot's one degree of freedom legs. The robot's legs only have one degree of freedom for each one, but the developer modified the legs so that each leg has one actuator and a passive springy joint. The spring will act to absorb impact shocks from complicated bending movements in the joints. With this, the movement of the robot will be smoother.

2.4 Summary Of Literature Review

Nowadays, there are lots of similar and identical projects that can be found across the internet and reference books motivated by the autonomous 4 legged pet robot technology. So in this chapter, the important characteristics of autonomous 4 legged pet robots such as Sony Aibo, WooWee Robopet and I-Dog which is useful for the project title are discussed.

2.5 Problem Statements

From the three robots stated in the Literature Reviews part, some problem statement had been developed such as:

1. The ability of Sony AIBO to react to human touch is helped by using pressure sensors but it cannot differentiate if the one that touches it is living beings or any non living things object that fell on it.
2. WowwWee Robopet and UTM's I-Dog gives the same reaction to living things and obstacles because their inability to tell if its living beings or non living things.
3. In WowwWee Robopet and UTM's I-Dog, the waist degree of freedom is only used to perform special task such as peeing position, and rolling but not during walking action.

From the problem statement concluded from the literature reviews, a 4 legged autonomous robot with ability to sense movement, using its waist for moving and react differently to moving and non moving object named SensBot are built.

CHAPTER 3

METHODOLOGY OF COMPONENTS CHOSEN

3.1 Component Selections

Many components are used for this project, 3 types of sensors, 2 types of servo motors, controller, and comparator. The descriptions of the component will be discussed in the next subtopics.

3.2 SN-IRS-02 - IR Sensor Set With Socket

This component contains IR(Infrared) transmitter and an IR receiver mounted side by side. Both of the sub components are covered by a rectangular socket to minimize the influence from the environment This sensor can be used as a reflective type IR sensor for mobile robot It can detect the object up to 5cm distance, so it is good for close range detection such as reaction to human touch.

3 units of this type of sensor product will be used to

1. Detect the human touch on the head of the 4 legged robot
2. Detect the wall/object at its both sides.

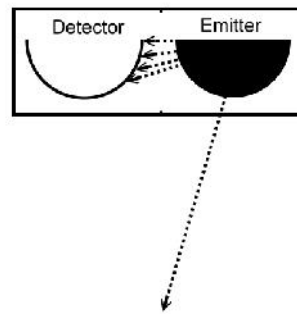


Figure 3.1: Effect of no socket on IR

Without Socket Detector will keep on receiving the infrared pulse beam from the emitter
Wall because of both emitter and detector are located next to each other.

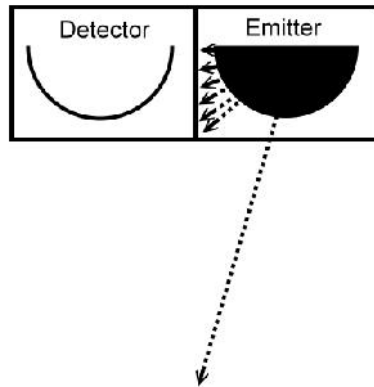


Figure 3.2: Emitting Infrared Pulse With Socket

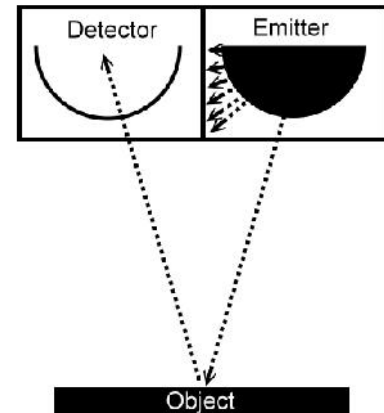


Figure 3.3: Detecting Infrared Pulse With Socket

With Socket By having the socket wall between emitter and detector, the detector wont
Wall able to receive any pulse from infrared emitter from other direction except
front. The wall blocks the pulse from to be detected by detector from side.

3.3 SN-GP2Y0A21 - Analog Distance Sensor

This is a distance measuring sensor unit, using the integrated combination of PSD (position sensitive detector), IRED (infrared emitting diode) and signal processing

circuit. The environmental temperature and the operating duration are not influenced easily to the distance detection because of adopting the triangulation method.



Figure 3.4: Analog Distance Sensor

This sensor 's range of detection is from 10cm up to 80cm. The best thing about this device is the outputs where the output voltage corresponds to the detection distance. The closer the object detected, the higher the output voltage of this sensor. So this sensor can also be used as a proximity sensor.

It is good to be used when a moving robot needs to react to blocking object before it become too close with the object such as other animal, human or wall. With the advantage stated before, the detection distance of the robot can be fixed by using potentiometer.

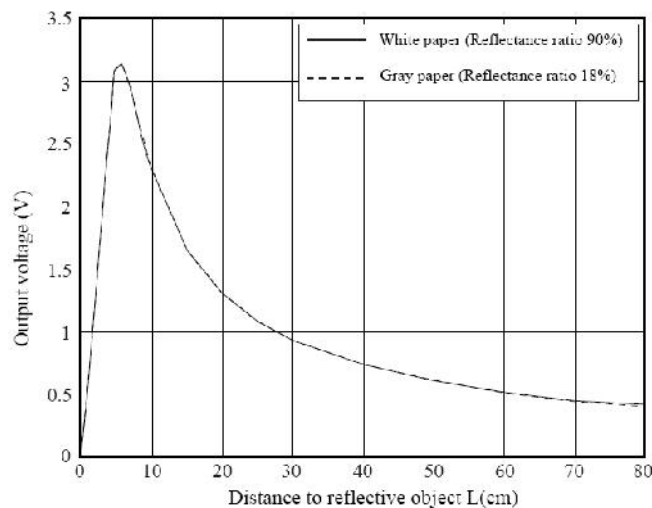


Figure 3.5: Characteristic Of Analog Distance Sensor Output (Output voltage versus distance)

3.4 PIR Sensor(Passive Infrared Sensor)

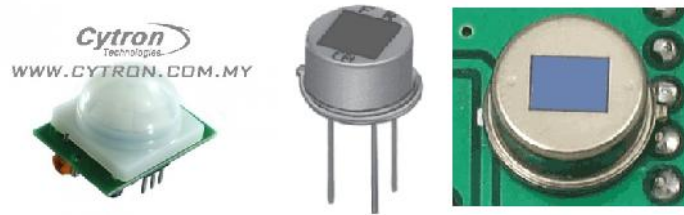


Figure 3.6: PIR Sensor

This component is a pyroelectric device that detects motion by measuring changes in the infrared levels emitted by surrounding objects. This motion can be detected by checking for a high signal on a single I/O pin.

The product features include:

1. Single bit output
2. Small size makes it easy to conceal
3. Compatible with all types of microcontrollers

The sensor can sense the change in the amount of infrared energy within small distances, approximately up to 10 inches. For detecting movements at longer distance, infrared radiation has to be focused. This focusing is done by a Fresnel lens which focuses the infrared signals onto the elements made of a crystalline material that generates an electric charge when exposed to infrared radiation. The Fresnel lens condenses light, providing a larger range of IR to the sensor. With the lense, the PIR Sensor has a range of approximately 5 meters.

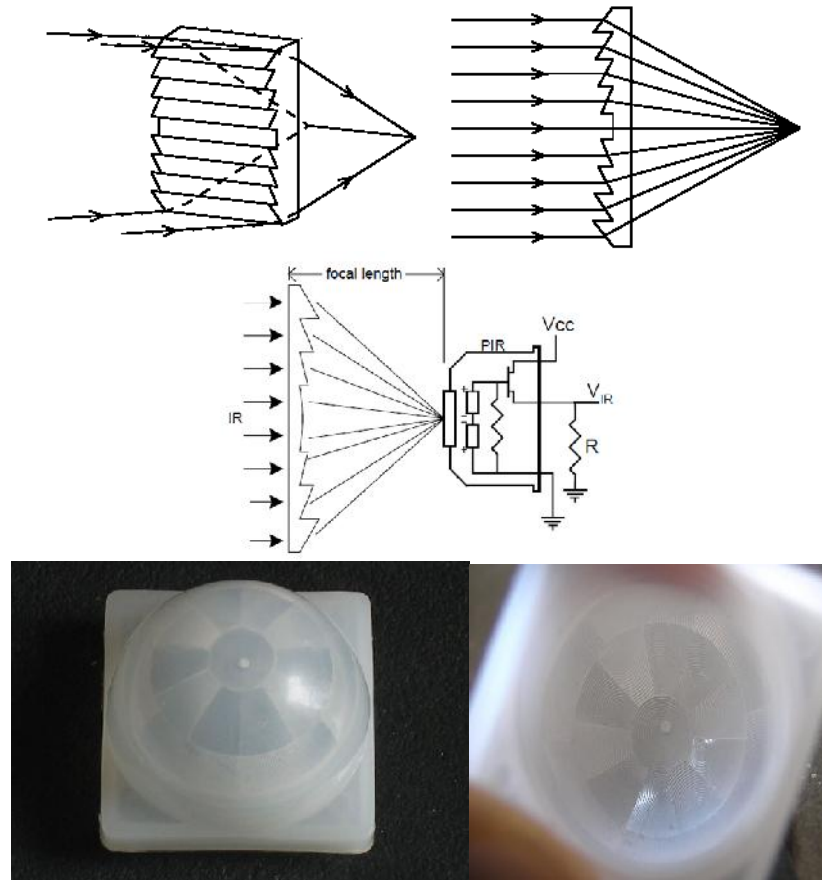


Figure 3.7: Frensel Lens

3.5 RC Servo C36R

RC servos are become more popular in robotics, creating humanoid robot, biologically inspired robot, robotic arm and etc because its' ability to rotate and maintain and certain location, position or angle according to control pulses from a single wire.

Features:

1. Control position through Pulse Code Modulation
2. Pulse width range: $\sim 0.5\text{ms} - 2.5\text{ms}$
3. Come with servo horn and screw accessories



Figure 3.8: RC Servo

The angle is determined by the duration of a pulse that is applied to the signal wire. This is called Pulse Width Modulation. So the motor can be connected directly from the processor. The position pulse must be repeated to instruct the servo to stay in that position. The same pulses must be provided along the time during the position or else the position will change

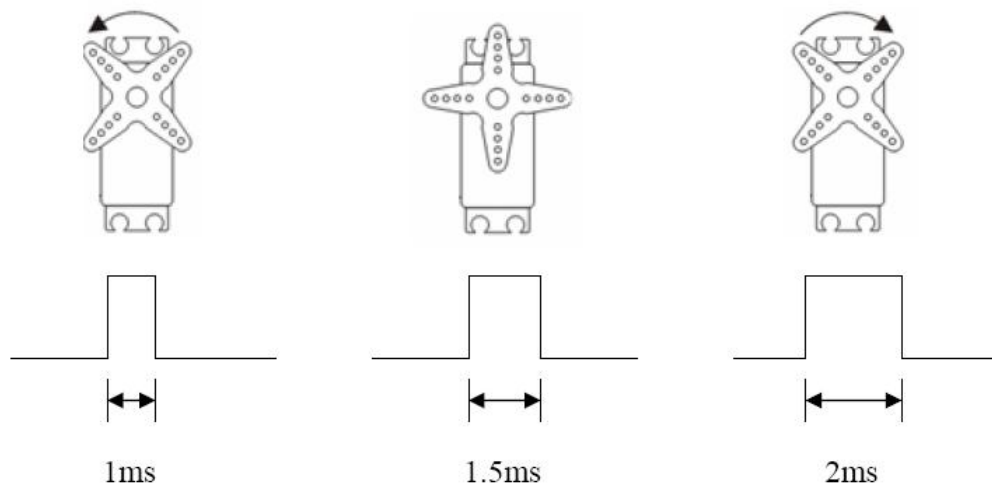


Figure 3.9: The Effect of PWM on RC Servo

3.6 RC Micro Servo Motor

This motor works just like the previous servo motor stated. The different is the size and power. The features of this motor are such as:

1. Micro size servo Speed (sec/60deg): 0.12/4.8V, 0.11/6.0V
2. Torque (Kg-cm): 1.50/4.8V, 1.60/6.0V
3. Size (mm): 22.8x11.8x20.6 Weight (g): 10



Figure 3.10: RC Micro Servo

3.7 Comparator LM358

LM358 is a Low Power Dual Operational Amplifiers that contain two independent, high gain, internally frequency compensated operational amplifier which were designed specifically to operate from a single power supply for over a wide range of voltage. The advantages of this component are like below:

- Two internally compensated op amps
- Eliminates need for dual supplies
- Allows direct sensing near GND and VOUT also goes to
- GND
- Compatible with all forms of logic
- Power drain suitable for battery operation
- Wide power supply range:
 - Single supply: 3V to 32V
 - or dual supplies: $\pm 1.5V$ to $\pm 16V$
- Very low supply current drain (500 μA)—essentially independent of supply voltage

- Low input offset voltage: 2 mV
- Differential input voltage range equal to the power supply voltage
- Large output voltage swing

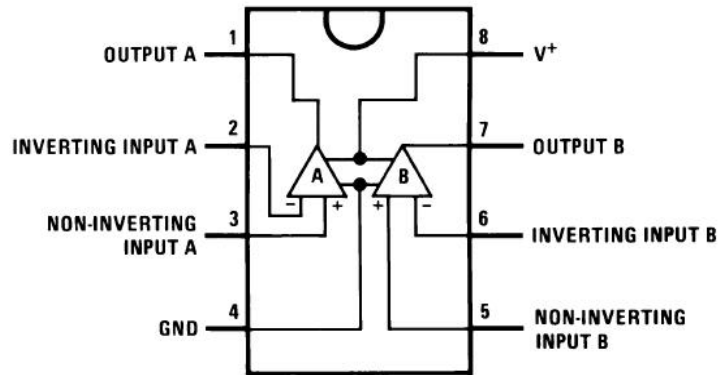


Figure 3.11: LM358 Architecture

3.8 ATMEL ATTINY2313

Recently Atmel controllers are widely used and the application of Atmel can be found all over the internet. This controller is selected for the project because of the PWM (Pulse Width Modulation) pins that it have. Controllers like PIC does not have such pins, programmers have to use delay on and delay off instruction, 4 lines of instructions just to sent the PWM value. With this controller, PWM can be set by one line of instruction only. PWM is important to control servo motors, this is the main reason why Atmel is suitable for this project.

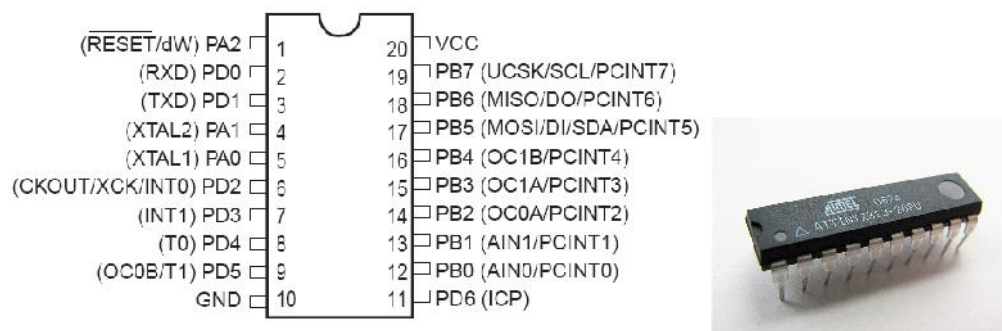


Figure 3.12: Attiny2313 Architecture

Characteristics of ATTINY2313

1. Data and Non-volatile Program and Data Memories
 - 2K Bytes of In-System Self Programmable Flash
Endurance 10,000 Write/Erase Cycles
 - 128 Bytes In-System Programmable EEPROM
Endurance: 100,000 Write/Erase Cycles
 - 128 Bytes Internal SRAM
 - Programming Lock for Flash Program and EEPROM Data Security
2. Peripheral Features
 - One 8-bit Timer/Counter with Separate Prescaler and Compare Mode
 - One 16-bit Timer/Counter with Separate Prescaler, Compare and Capture Modes
 - Four PWM Channels
3. I/O and Packages
 - 18 Programmable I/O Lines
 - 20-pin PDIP, 20-pin SOIC, 20-pad QFN/MLF
4. Operating Voltages
 - 1.8 – 5.5V (ATtiny2313V)
 - 5.5V (ATtiny2313)

CHAPTER 4

MECHANICAL DESIGN

4.1 Sketch

The sketch of the robot had been done by using Google Sketch Software. Below are several views of the robot sketch

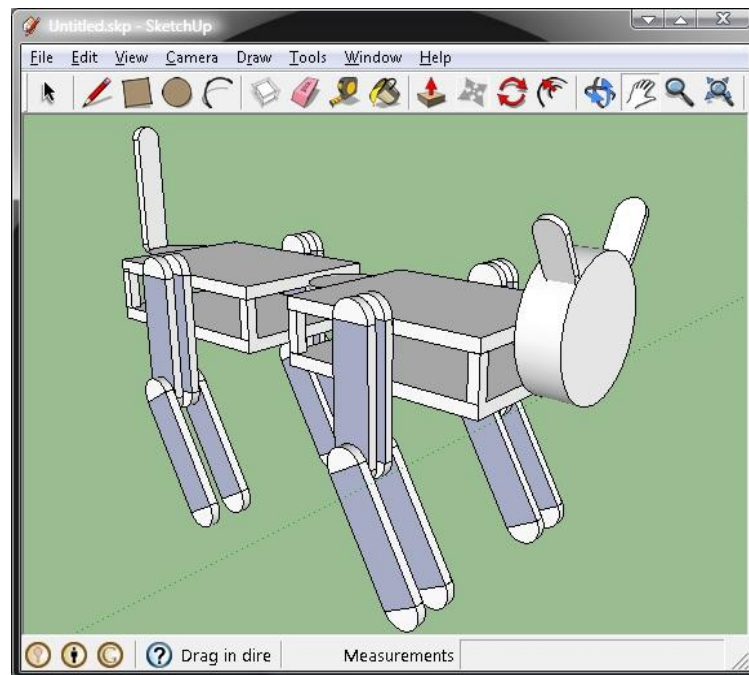


Figure 4.1: Sensbot's Sketch - Full View

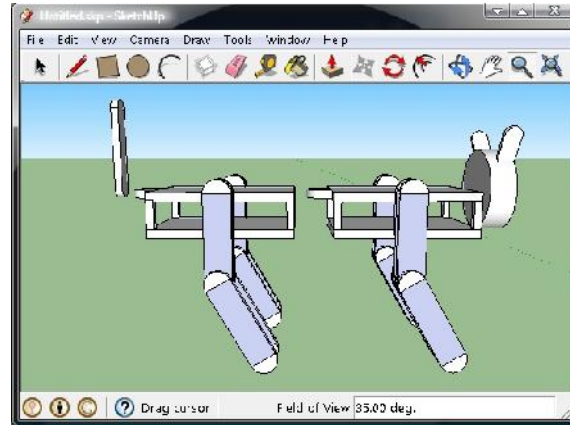


Figure 4.2: Sensbot's Sketch - Side View

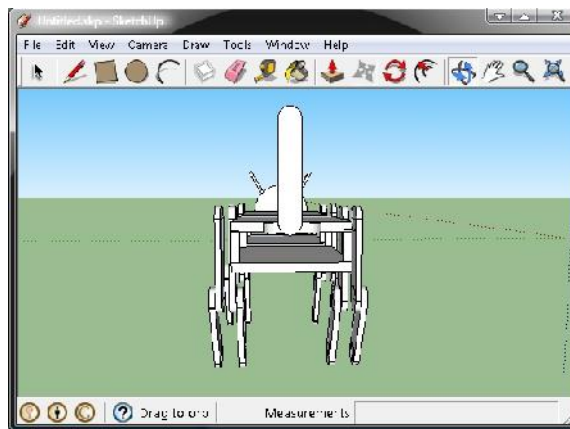


Figure 4.3: Sensbot's Sketch - Back View

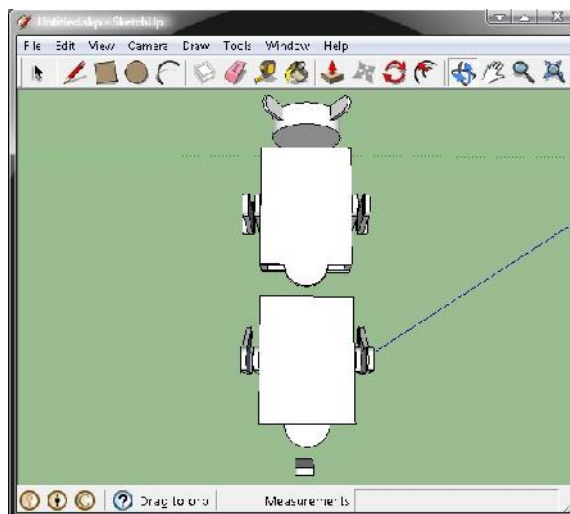


Figure 4.4: Sensbot's Sketch - Top View

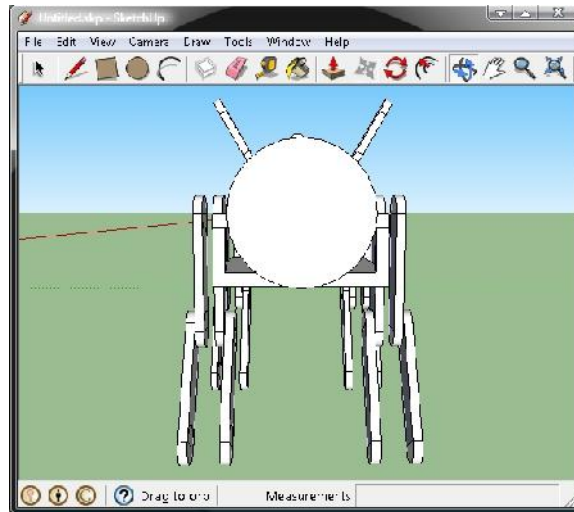


Figure 4.5: Sensbot's Sketch - Front View

4.2 Design and Attachment of Tail, Ears, Head, Body Parts and Legs

As shown below, it can be seen that the robot is divided into two 2 parts, front and back. These two parts will be connected by a servo motor. The motor will be placed at the circled position. The moving part of the motor will be connected to the extended part of the front body. By doing that, the robot will have an extra degree of freedom which is its waist.

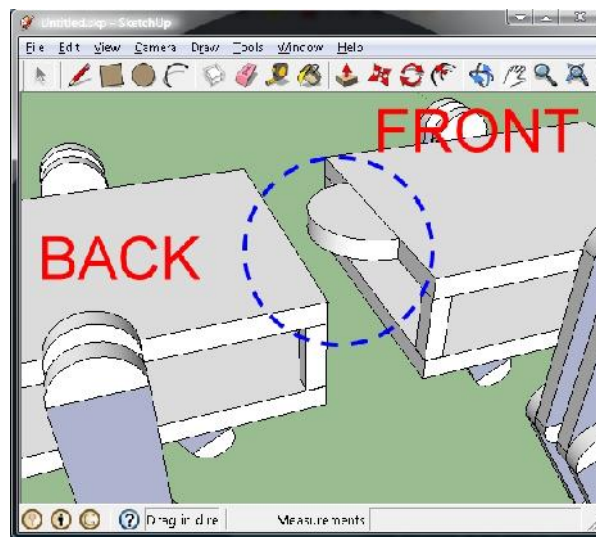


Figure 4.6: Sensbot's Sketch - Design and Attachment of Body Parts

The tail of the robot will be positioned at the back of back part of the robot as the figure below. The tail and the back body will be connected together by attaching the moving part of a servo motor to the tail and the motor itself to back part of the robot. As shown in the figure below, the circled area is the area that the servo motor will be located.

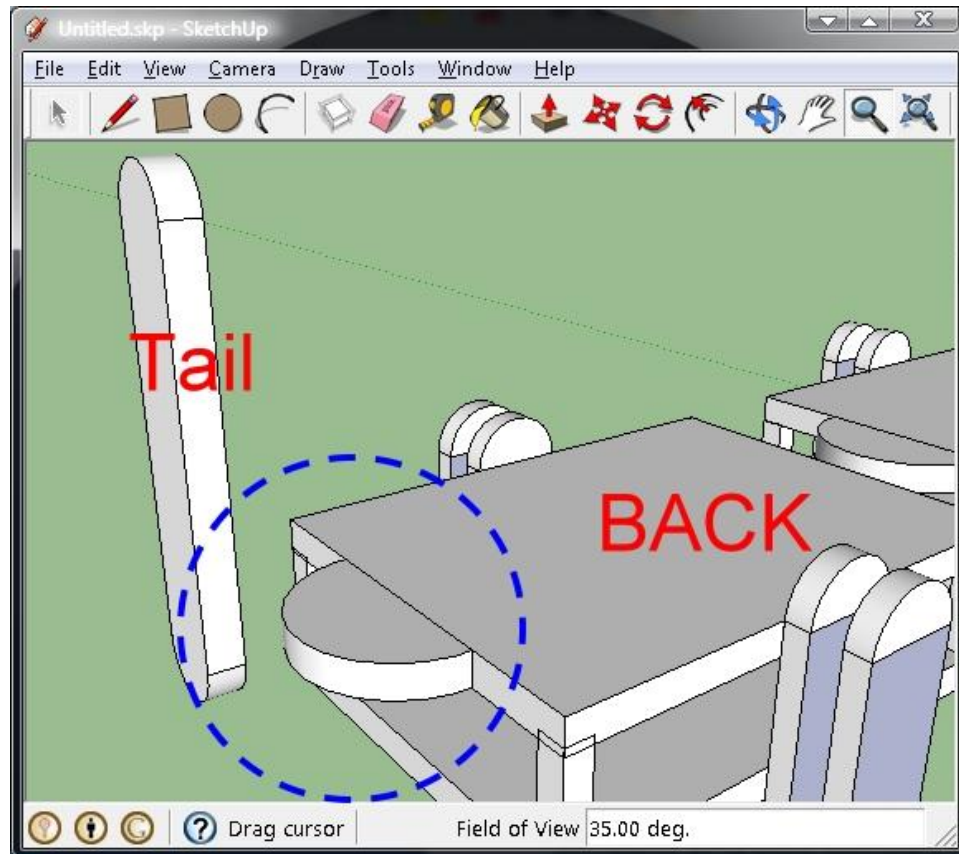


Figure 4.7: Sensbot's Sketch - Design and Attachment of Tail

Meanwhile, the head and ears will be attached to each other. The head will be fixedly attached to the front body. The ears will be connected to the two micro servo motors moving part while the motors itself will be attached to the head. The circled areas are the position where the motors will be located.

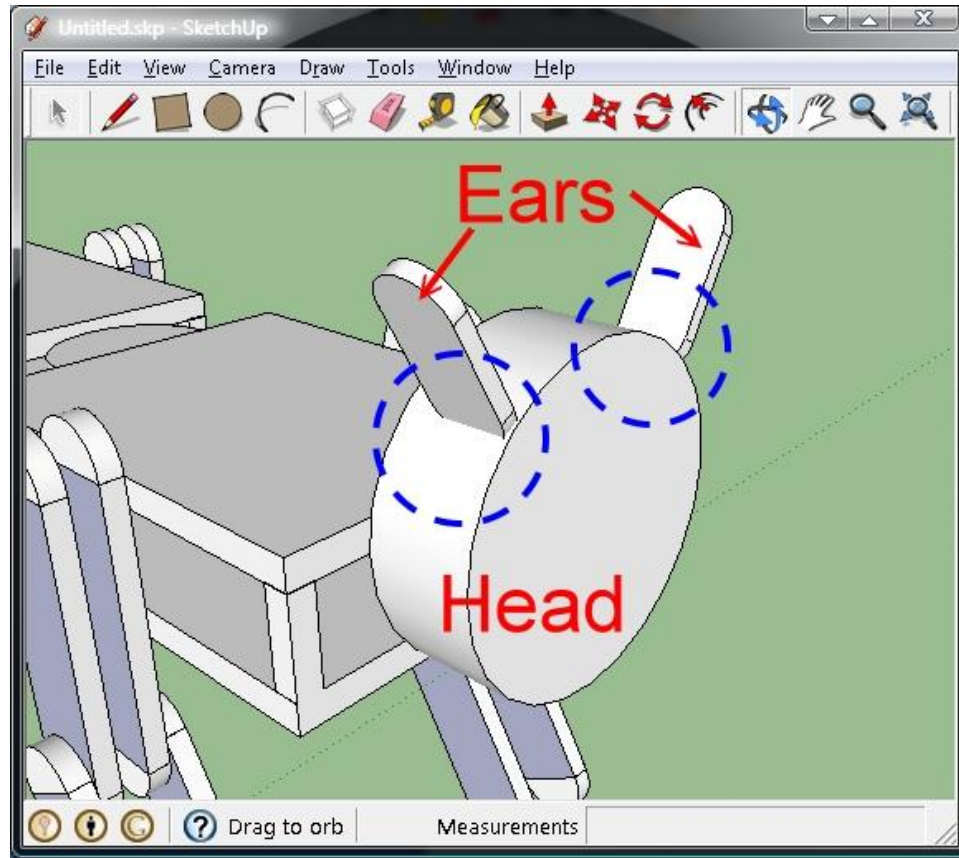


Figure 4.8: Sensbot's Sketch - Design and Attachment of Ears and Head

As in for the legs, each leg will be divided into two parts like shown below. The two parts will be connected by a screw and nut so that the angle between the parts can be change if needed. The green circled areas are where the screw and nut will be located. Each leg will be connected to the prospective body part by servo motor. Each leg will be attached to the moving part of servo motor and the motor itself will be attached to the body. As shown in the figure below, the blue circled areas are where the motors will be located.

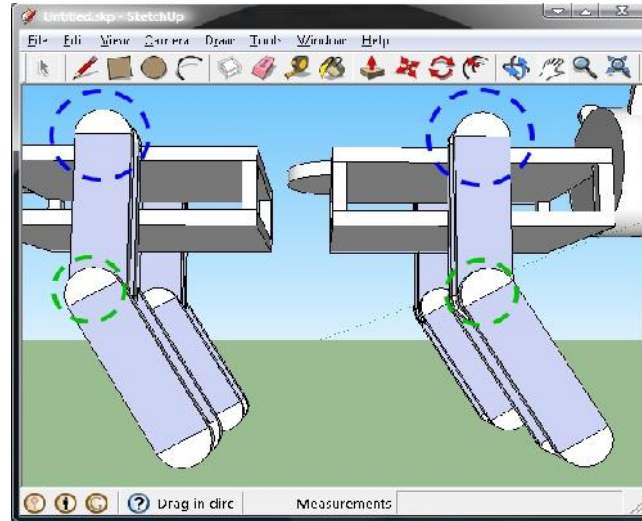


Figure 4.9: Sensbot's Sketch - Design and Attachment of Legs

4.3 Detail Drawing on Dimensions of Robot Mechanical Parts

Below is the drawing that indicated the dimensions of legs, tails and ears. Since each legs are divided into two, so there are 8 parts just for the legs. The dimensions of the legs will be the same just like the tail. The dimensions are in inches.

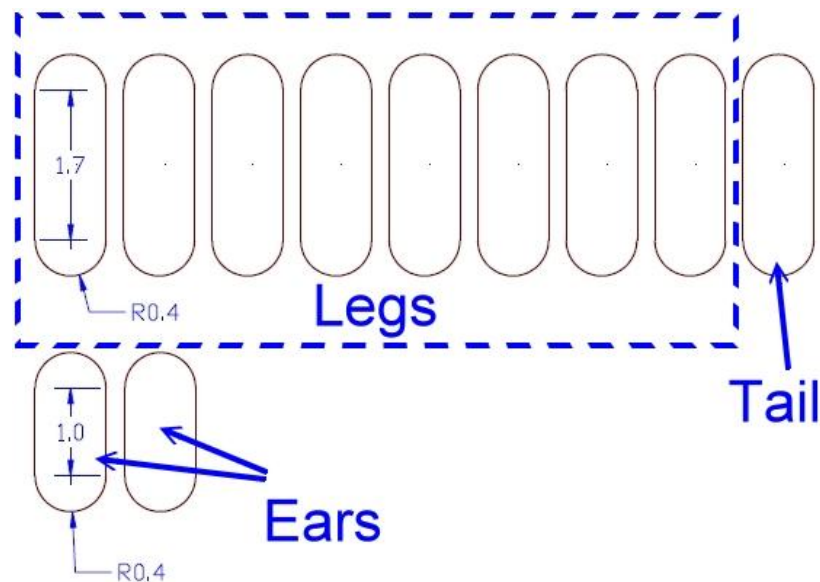


Figure 4.10: Sensbot's Sketch - Dimensions for Ears, Legs and Tail

As in for the body parts, the figure below shows that the design had been change from using semi-round extended parts into simple square extended parts. Also, now the moving part of the motor waist will be attached to the back extended part of back body part. The head of the robot will be attached at the extended part of the front body. The parts without extended part are used to be the platform of the circuitry part. The circuits will be combined together on the platforms and the platform will be attached on the parts that have extended part.

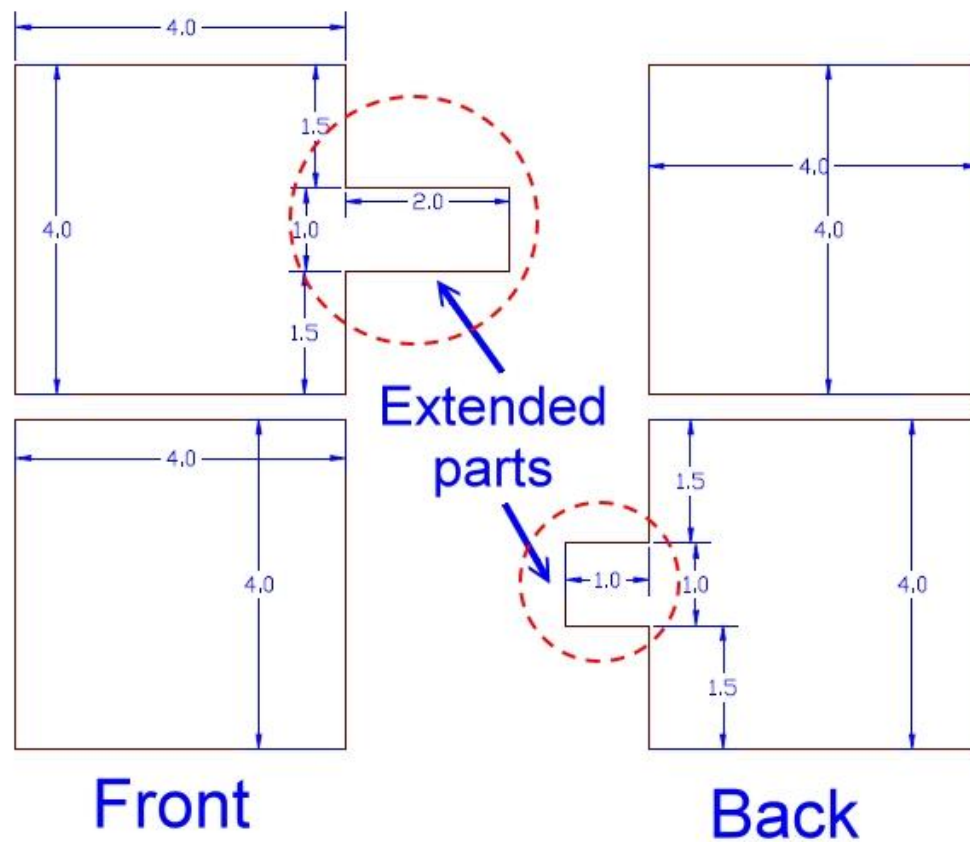


Figure 4.11: Sensbot's Sketch - Dimensions for front and back body parts

4.4 Actual SensBot Mechanical Parts

The figures below shows the actual robot after the attachments is done. The legs, tail, ears, and body are covered by jeans to cover the circuits and to make it look tidy.

The basic robot body is the robot without the circuits, head, ears and tail attachment. The circuits will be attached first on two pieces of prospect used as platform and the platform will be attached on the basic robot body.



Figure 4.12: SensBot's Basic robot body without circuits



Figure 4.13: Completed SensBot's Full view



Figure 4.14: SensBot's Top View



Figure 4.15: SensBot's Leg



Figure 4.16: SensBot's Tail



Figure 4.17: SensBot's Ears and Head

4.5 Movement Design

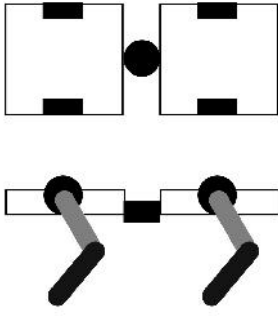
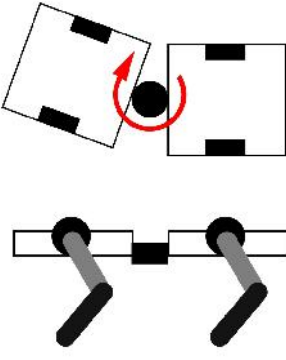
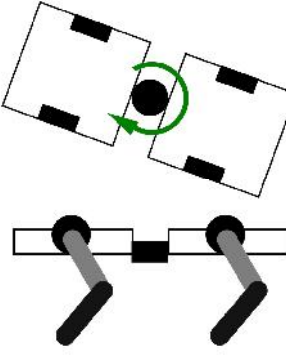
There are 3 other functions designed other than walking, which are obstacle avoiding, reaction to touch on head and reaction to moving and non moving object.

The explanations of each will be discussed in sub topics.

4.5.1 Obstacles Avoiding

Using the motor on the waist to “curves” the body of robot to turn left or right. Inspired by Robopet, instead of using the waist to make twisting movement, the degree of freedom will be used for turning right and left sequence. The sequence will be explained below by considering the robot detects wall on its left side.

Table 4.1: Obstacle Avoiding Sequence

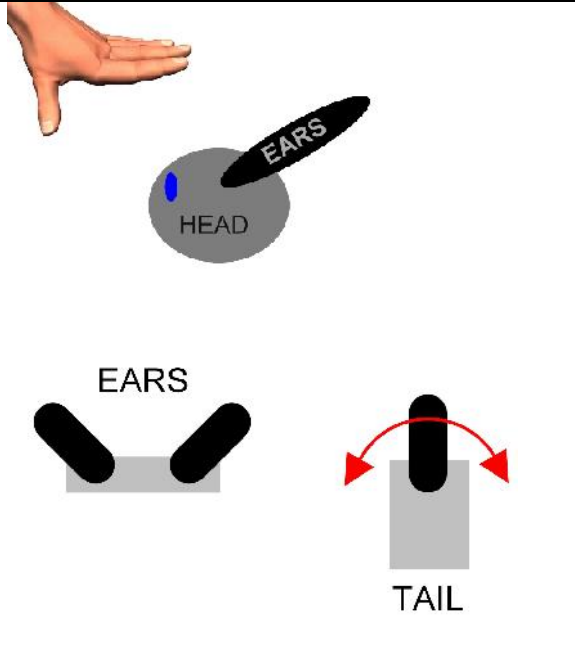
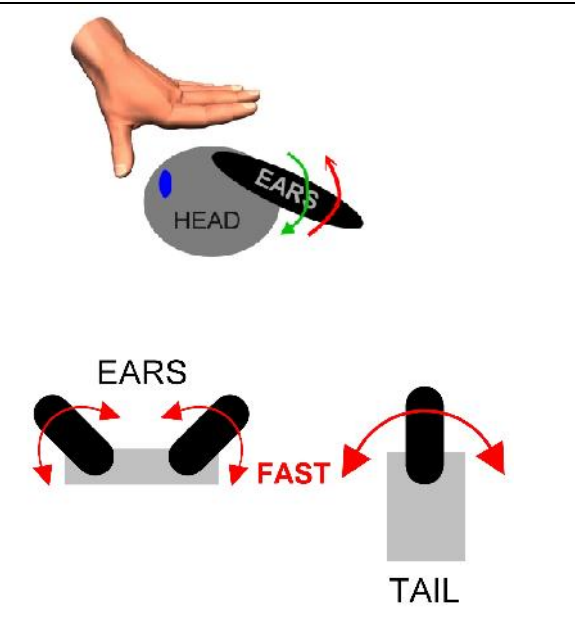
State	Top and Side View	Explanation
1.		<p>This the state where the robot is walking where there is not detection at all</p>
2.		<p>If it detects that object at its left/right in this case left, the motor at the waist will move the front body to the opposite direction of object detected, in this case, it moves to right direction. This process happens while the robot is walking.</p>
3.		<p>The robot will stay in [2] position while walking until a certain time, then it the motor will return to original position making the front and back part of body return to the same line.</p>

4.5.2 Reaction to Human Touch on Head

In real situation, the ears of animal will start to be lowered down not when human touches its head but when the hand is approaching its head. The PIR sensor will

help the robot to differentiate between non living objects and living beings. If it is just a ceiling or non living object it will duck.

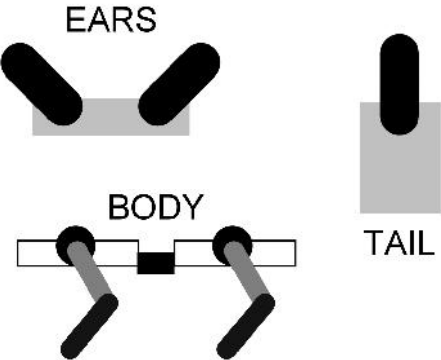
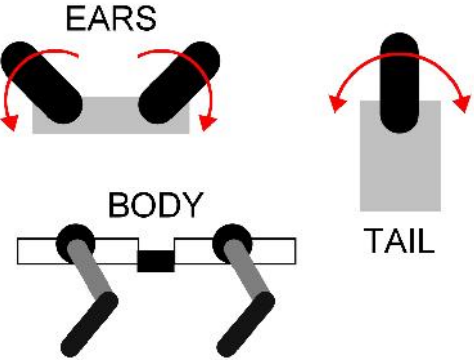
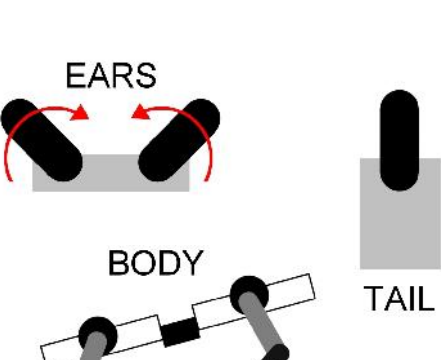
Table 4.2: Reaction To Touch On Head

State	Image from Side View	Explanation
1.	 <p>The diagram shows a hand reaching towards a robot's head. The robot's head has a blue IR sensor and a black ear labeled 'EARS'. Below, the robot's ears and tail are shown. The ears are tilted downwards, and the tail is moving left and right, indicated by red arrows.</p>	<p>At certain distance the IR sensors cannot detect the human hand. So the ears will stay like it was. Meanwhile, the tail moves left and right while the robot is walking.</p>
2.	 <p>The diagram shows a hand reaching towards a robot's head. The robot's head has a blue IR sensor and a black ear labeled 'EARS'. Below, the robot's ears and tail are shown. The ears are moving up and down, and the tail is moving left and right, indicated by red arrows. The word 'FAST' is written in red.</p>	<p>When the IR sensor on the head detects the hand, the robot will stop walking and the ears will turn up and down several times, same goes for the tail. Both moves at higher speed than the tail's speed before detecting object on the head.</p>

4.5.3 Reaction to Moving and Non-Moving Object

The reaction to the moving and non moving object will be explained in the table below.

Table 4.3: Reaction to Moving and Non-Moving Object

State	Top and Side View	Explanation
1.	 <p>The diagram shows a top view of a robot with two black, angled 'EARS' on a grey base. Below it is a side view of the robot's 'BODY' with two legs and a small black square in the center. To the right is a side view of the 'TAIL', a black vertical bar on a grey base.</p>	<p>When robot detects object at the front, the robot will stop and wait for a moment to detect if it is moving object or non-moving object.</p>
2.	 <p>The diagram shows the robot's top and side views. Red curved arrows indicate the 'EARS' turning downwards and the 'TAIL' moving left and right.</p>	<p>If it is a non-moving object, the robot will turn down it ears and moves it tails left and right several times. Then if the robot still detects object in front of it, it will repeat [1]. If there is no object, the robot will continue walking.</p>
3.	 <p>The diagram shows the robot's top and side views. Red curved arrows indicate the 'EARS' moving upwards and the 'BODY' tilting forward. The 'TAIL' remains vertical.</p>	<p>If it is a moving object the robot will change it body posture and move its ears upward. The tail will remain stop. Then if the robot still detects object in front of it, it will repeat [1]. If there is no object, the robot will continue walking.</p>

CHAPTER 5

CIRCUITS DESIGN

5.1 Schematic

5.1.1 Circuit For IR Sensors

Four IR sensors will be used on this robot. Each of this IR will be located at different location: HEAD, BACK OF BODY, LEFT OF BODY and RIGHT OF BODY

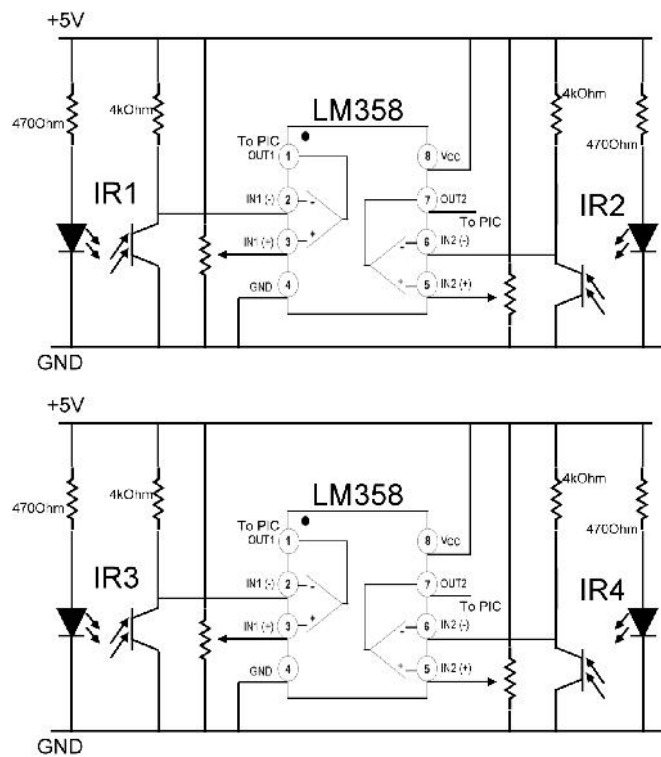


Figure 5.1: Circuit for 4 IR Sensors

The outputs of the comparator LM358 will be connected to controller directly to be used as input signal. These inputs will determine how the robot will react.

5.1.2 Circuit For Front Detection

In this circuit, PIR and Analog distance sensors are used to detect if the object in front of the robot head is living things or not. The output of the comparator will be connected to microcontroller. The output voltage of comparator is 5V, that is why it can be connected directly to the controller.

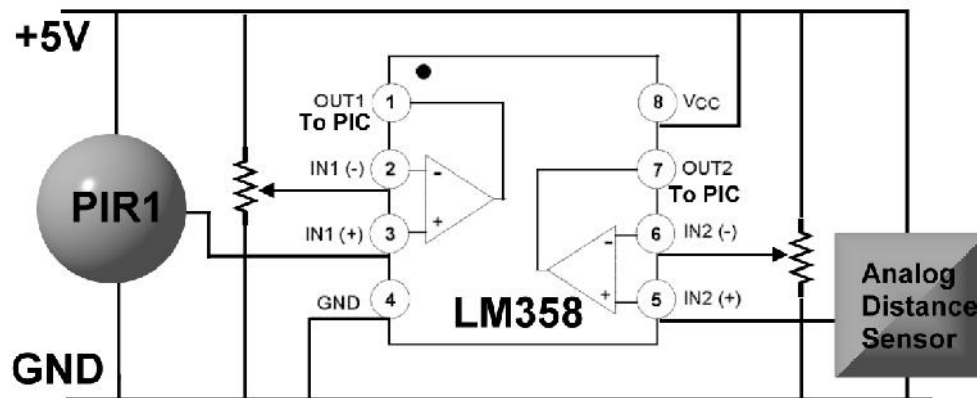


Figure 5.2: Circuit For Front Detection

5.1.3 Circuit For Attiny2313

This circuit is used in Problem Based Laboratory program in Fakultas Kejuruteraan Elektrik for final year students. The designer of this circuit is Dr Rosbi Mamat, the faculty's lecturer. This circuit is designed so that it can be directly programmed using BASCOM AVR IDE.

Two sets of this circuit will be used to control 8 servo motors; first circuit will send control outputs to second circuit as control inputs. Two sets is used because of

there is only 4 PWM pins on Attiny2313, other commercialized Atmel controllers have up to only 6 PWM pins or a bit costly. The simple solution is to use two sets of 4 PWM pins.

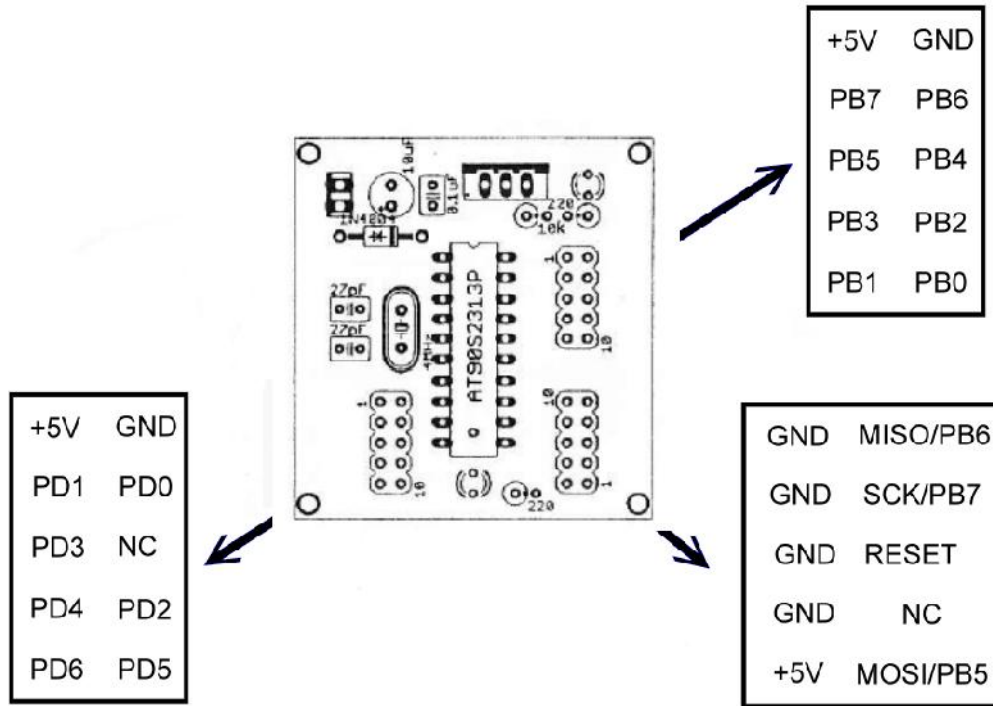


Figure 5.3: Attiny2313 Circuit Pins Locations

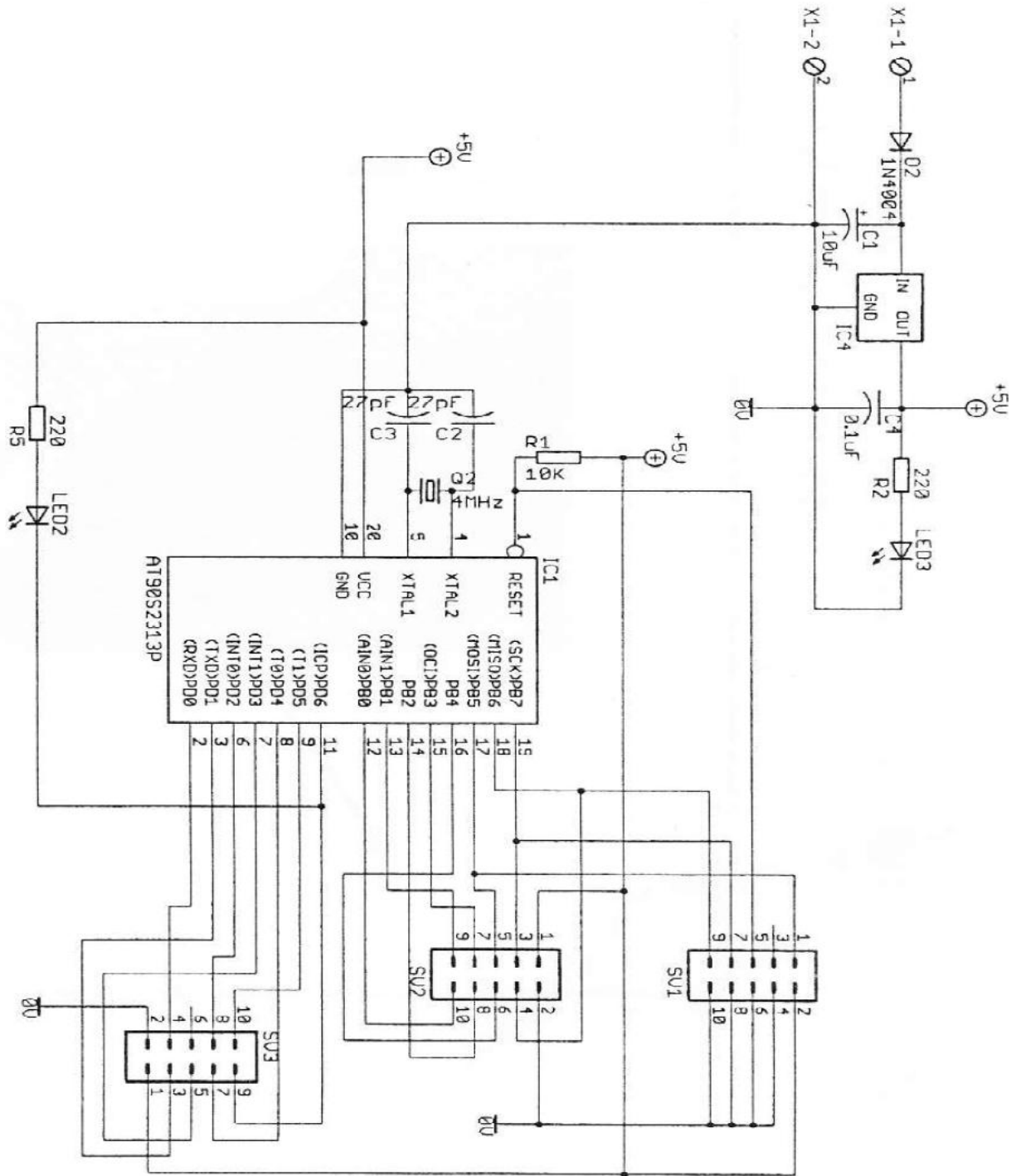


Figure 5.4: Circuit Attiny2313

5.1.4 Circuit For ISP cable

The Attiny2313 circuit must be connected to PC using ISP cable and DB25 Male Printer Port Connector. Usually this connection only can be used on desktop, because notebook and laptop nowadays do not have the LPT. The ISP schematic is like below.

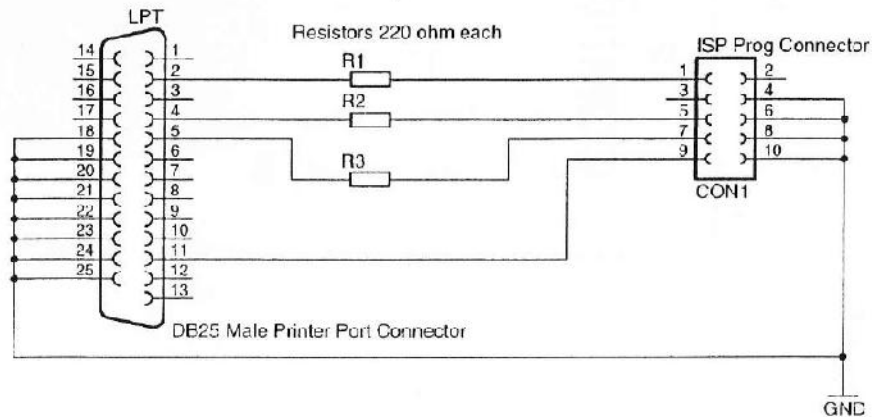


Figure 5.5: ISP cable circuit connection.

5.2 Actual Circuits

5.2.1 Circuits For Sensors' Location

As shown below in the figure, the PIR, analog distance sensor and IR sensors circuits are combined on one board. The red rectangle area is PIR and analog distance sensor area meanwhile the blue rectangle is the area for the IR sensors circuit.

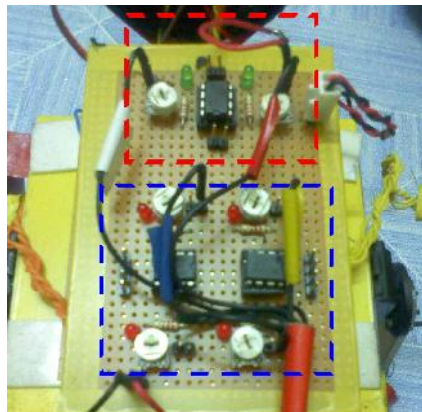


Figure 5.6: Circuits For Sensors' Location

Meanwhile the allocations of the sensors are shown in figures below. The IR sensors are located at the left, right and front sides of front body part. The IR at the front side is attached to the head.

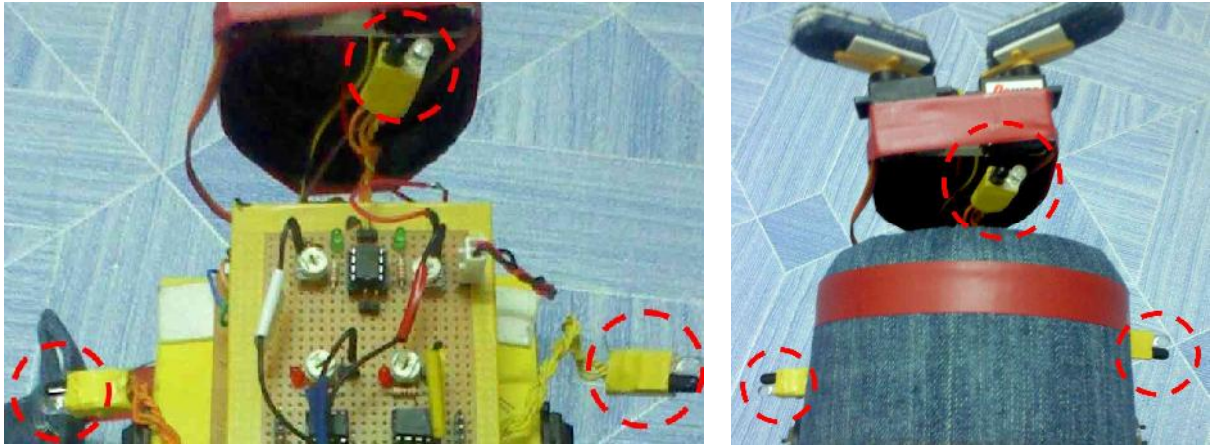


Figure 5.7: IR sensors' locations

For the PIR sensor and analog distance sensors, both are located at the head of SensBot just like in the figure below. The analog distance sensor is located on the face of SensBot meanwhile the PIR is located at the bottom part of the head.



Figure 5.8: PIR and Analog Distance Sensors Location

5.2.2 Attiny2313 Circuit's Location

Meanwhile figures below shows the Attiny2313 circuit. The size of the Attniy2313 circuit is 3x3 inch squares

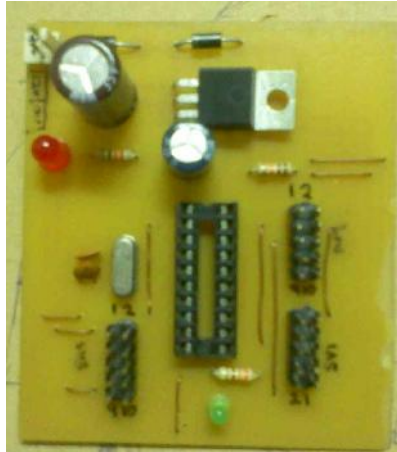


Figure 5.9: Attiny2313 Circuit

Figure below shows the location of the two Attiny2313 circuits on the Sensbot. The circuits are located at the back part of the robot body next to each other. Each circuits will handle different inputs and outputs. Both circuits operate at frequency 1MHz and the PWM frequency is 50Hz since servo motors operate at that frequency rate. The functions of the two Attiny2313 circuits are listed in the table below.

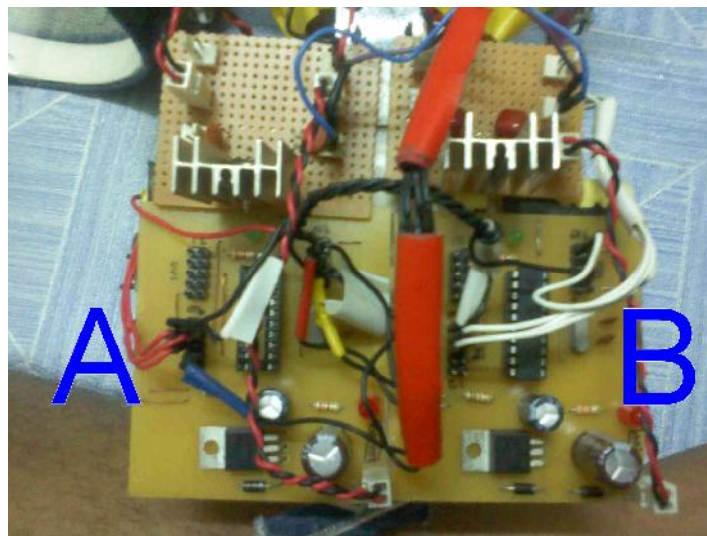


Figure 5.10: Position of Attiny2313 Circuit on Sensbot.

Attiny2313 Circuit	Functions
A	Receives 5 sensors circuits output as its input and process it to control the 4 legs servo motors. This Atmel's circuit also sends 3 control outputs to control Attiny2313 circuit B.
B	Receives 3 control output from circuit A as input and process it to control 4 motors for tail, ears and waist.

Table 5.1: Functions of Attiny2313 circuits

Figure below shows the attachment of all circuit to the robot body. The circuits are attached first to two plates of prospect and the attached to the basic robot body.

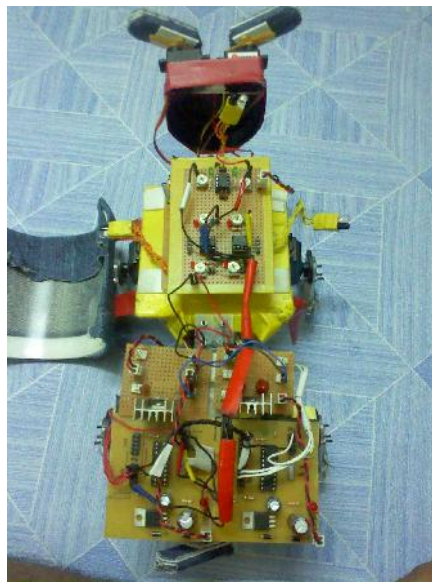


Figure 5.11: Full Circuit view of SensBot

5.2.3 Connection between Attiny2313 and PC using ISP cable

Figure below shows the connection between Attiny2313 circuit and PC using the ISP cable. Connection also can be made to notebook or laptop, but not all of it have the ISP port. The circuit does not have to be supplied with any supply voltage since the PC will supply the voltage through ISP cable. Advantages of using this method is, the

program can be directly written into Attiny2313 with the same software used to write the program unlike PIC that have to use different software to write the program and to program the chip.

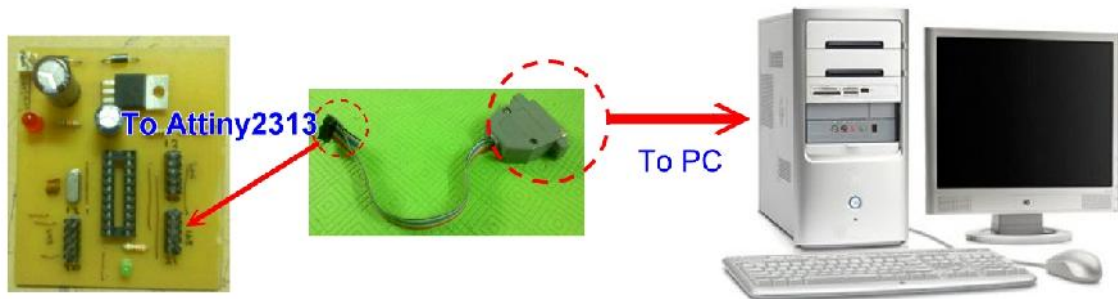


Figure 5.12: Connection between Attiny2313 and PC using ISP cable

5.3 Software For Programming Attiny2313

BASCOM AVR IDE is used to program the Attiny2313 for this project. This software is very simple software and it can directly write program into the Attiny2313 without having to use another software just like PIC does. The programming is using C language, which is very familiar in engineering field.

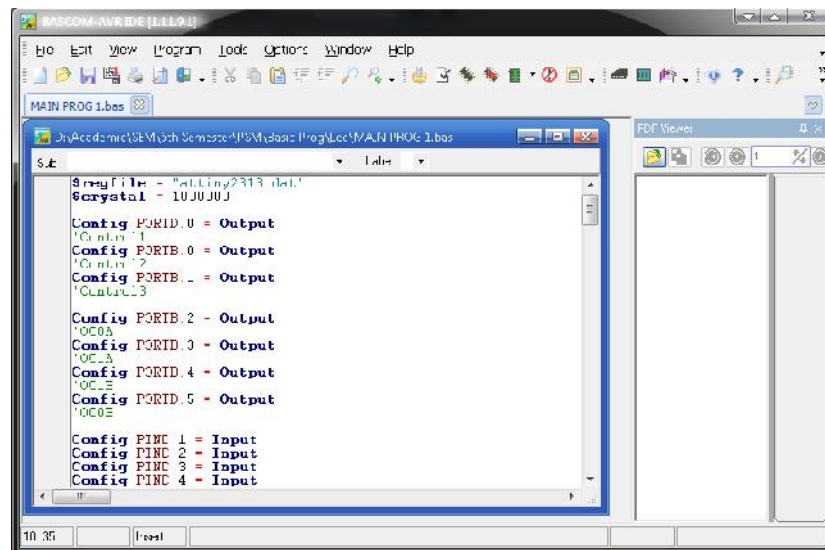


Figure 5.13: Bascom AVR

CHAPTER 6

RESULTS OF EXPERIMENTS

6.1 Distance Of IR Sensors Detection

When voltage supply of 5V was used for the sensors circuit, it is found that the range of distance of detection of the sensors were very small, the range of detection can be observed by tuning the variable resistors on the circuits. Each sensors have its own variable resistor, the distance of detection can be varies by tuning the potentiometers.

An experiment on the maximum detection of IR sensor's circuit had been done. Instead of just using 5V voltage supply, it can be increased into up to 7V. It is found that the maximum distance of the IR sensors is affected by the input supply of the circuit. But too high supply voltage may ruin the sensors.

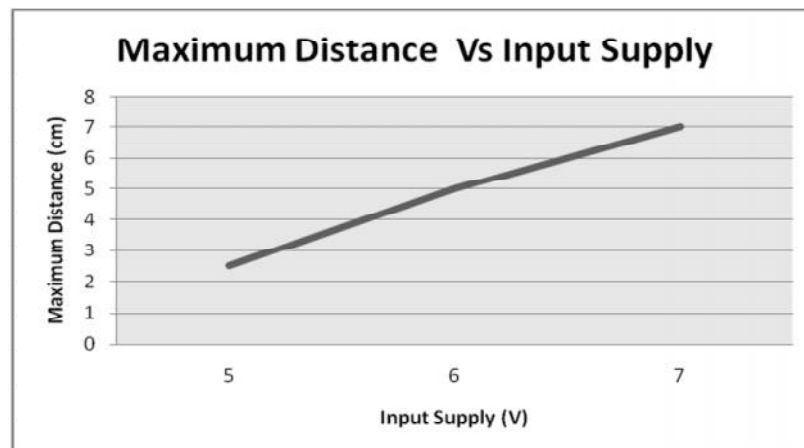


Figure 6.1: Maximum Distance Of IR Detection Versus Input Supply

Since the robot needs to detect wall or object for left and right obstacle avoidance, it is better to use a high range detection but yet safe for the circuit. So supply input of 6V is chosen to operate the IR sensors' circuit. The distance is not quite enough but this supply voltage value is safe enough and this range is enough for this project just to show the reaction of robot to the object at left or right.

6.2 Output Voltage of Analog Distance Sensor

The distance sensor is the advance version IR sensor. It may have a great range of detection which is 80cm. But it is not necessary to use 80cm as the distance where the SensBot will detect object in front of it. For this project a smaller distance will be used so that during demo, SensBot wont be needing large space to operate at.

The output become greater as the object getting closer, but the circuit is designed so that, comparator will produce high output when analog distance sensor detects object at certain distance and distance closer than that. This is done by using the potentiometers.

A test had been done on the sensors at certain range or distance, to figure out the actual output response. 20cm is chosen as the distance where the object will be detected, so what was left is to find the output voltage the distance. This output voltage is needed as the inverting input of the comparator of sensors' circuit will follows this value.

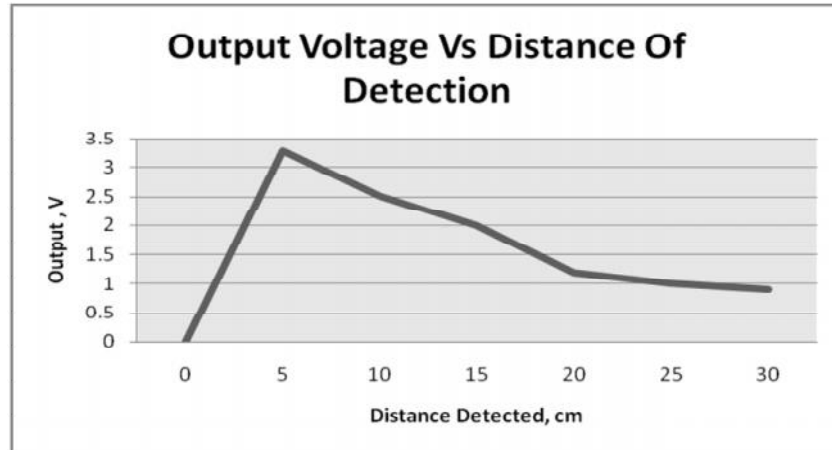


Figure 6.2: Output Voltage Vs Distance Of Detection

6.3 PIR Sensor's Reaction

An experiment had been done to observe the behavior of the PIR sensor. A problem is found after that. The output of the sensor will always be HIGH which is one fixed value no matter the distance of the moving object as can be seen in the figure below. The maximum distance it can detect movement from is 5m, and it can detect as wide as 120 degree angle area. This is because of the fresnel lense as the casing of the sensor.

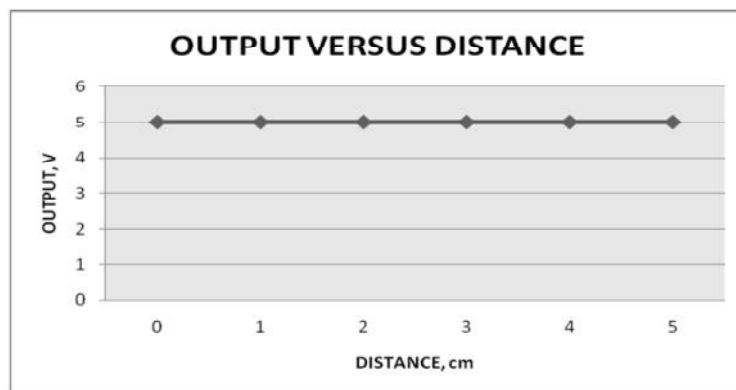


Figure 6.3: PIR response, Output Versus Distance

The another problem with PIR sensor is where it needs some time to calibrate itself with the environment condition before it can detect again. Meaning, the

surrounding area must be in stay during that calibration time, unless the sensor cannot function in a desired way. So SensBot need to give some time to the sensor so that it can calibrate itself to the environment condition.

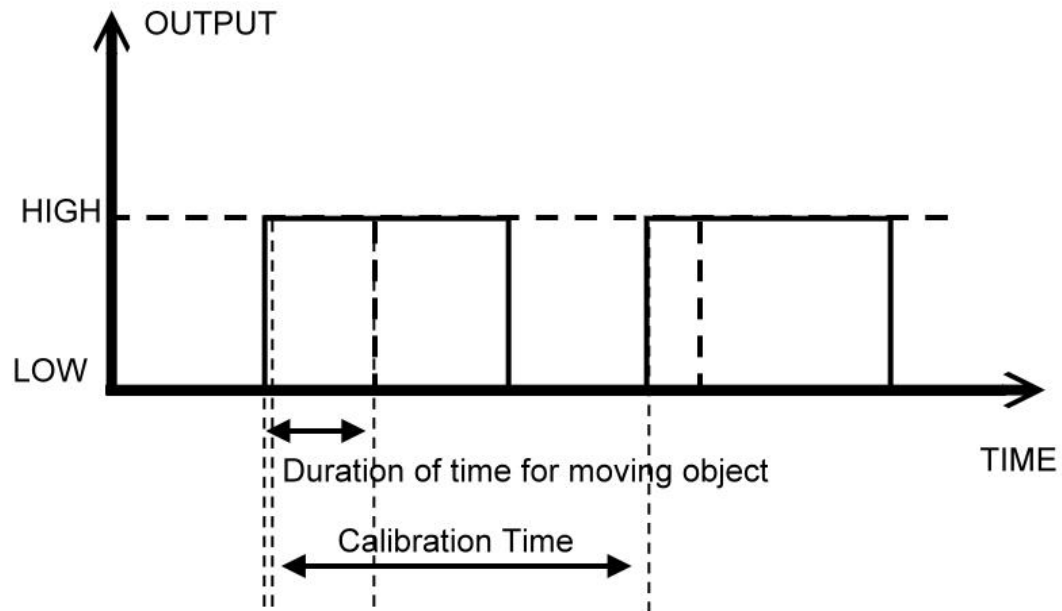


Figure 6.4: PIR Response: Output Versus Time

6.4 Combining Analog Distance Sensor And PIR To Detect Movement At Certain Distance And Giving Time To PIR To Calibrate To Environment

The problem of PIR sensor, where output does not correspond to distance can be overcome by combining it with analog distance sensor. We do not want SensBot to detect object as far as 5m, it will become un-practical during the demo due to space problem. The problem can be solved by looking at the figure below.

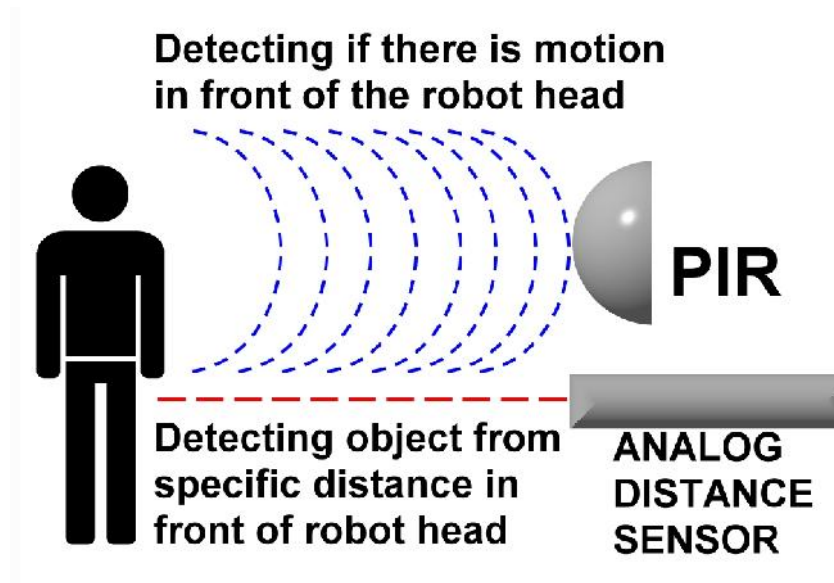


Figure 6.5: Combining PIR and Analog Distance Sensor

Firstly, the distance sensor will detect the object in front, then controller will read the input from PIR sensor. In other words, SensBot will detect object in front first, then it will 'see' if the object is moving object or not. The calibration time will be the delay time used before the controller process the PIR's output. After distance sensor detected, SensBot will wait for several seconds to give time for PIR and then it will process PIR's output.

By doing this, the movement can be detected at close distance considering the object is the only thing in front of the robot. The response of PIR and analog distance sensor circuit when detecting a moving object can be seen in figure below.

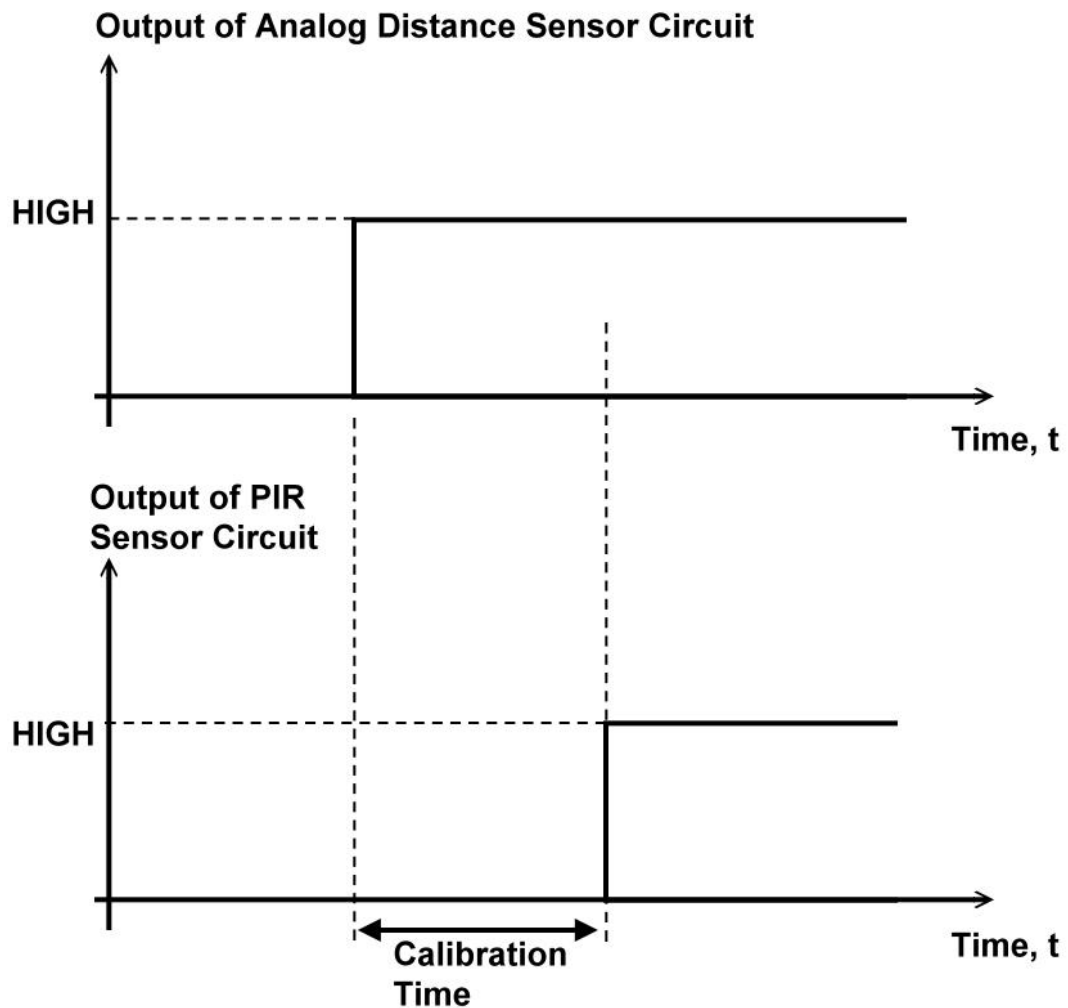


Figure 6.6: PIR and Analog Distance Detecting Moving Object In Closer Distance

6.5 Servo Motor's Response

In SensBot, servo motors are used as the actuators for legs, ears, waist and tail.. The angle position of the moving part of servo motors can be determined with the value of pulse. But first, the full angle range of the servo motor need to be known. The actual pulse width modulation signal range also should be determined.

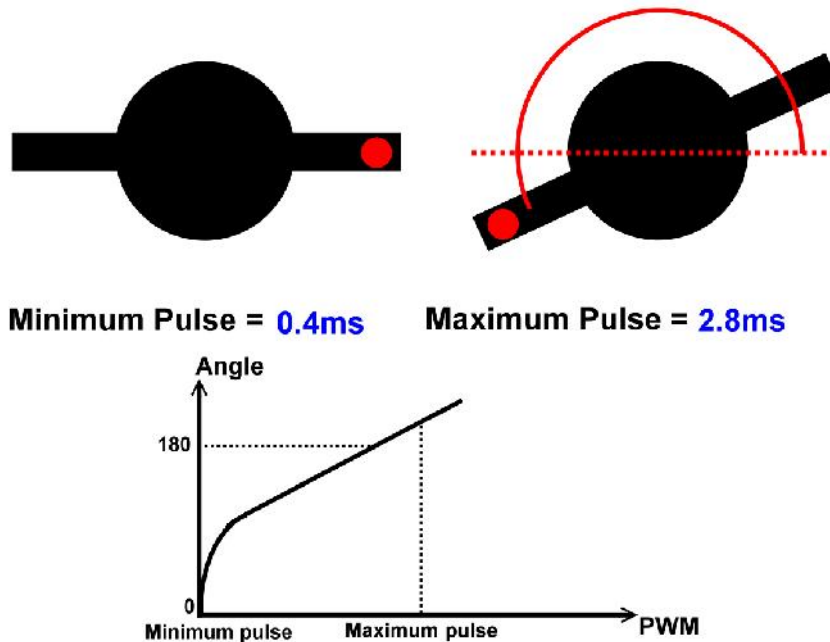


Figure 6.7: Servo Motor's Response

After some experiment, it is found that the full angle range of the motor is not 180 degree, but more than that, it is about 190-200 degree. This means, the actual pulse range is also bigger. This is not a problem for building SensBot. The problem is where the response of the motor where it is not linear, to be exact, the rate of increase of angle is not fixed. The motor suppose to be linear.

When a linear increasing pulse is supplied to the motor, at first the motor will jump to higher angle than the calculated angle it should go to. The calculation is done by using the formula:

$$\text{ANGLE}_{\text{expected}} = (\text{PWM}_{\text{supplied}} - \text{PWM}_{\text{min}} / (\text{PWM}_{\text{max}} - \text{PWM}_{\text{min}})) * 180$$

It is found that the motor moves at higher rate at first, for angle less than 45 degree. For angle higher than 45 degree, the motor moves at lower rate which is follows the real rate even though the values of angle is different.

6.6 SensBot System Flow

Since Sensbot contain 2 Attiny2313 controllers, each of it will have different program. The flowchart of the program for each Attiny2313 can be seen in figures below.

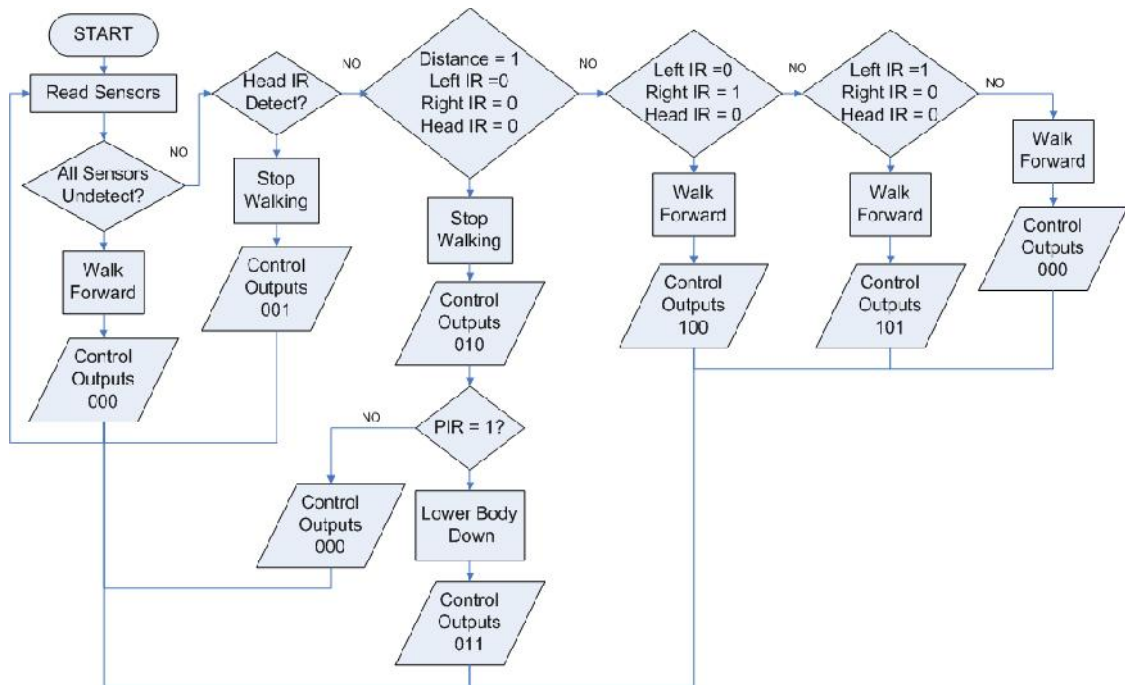


Figure 6.8: Program Flow Chart ATTINY2313 A – Controls 4 Legs

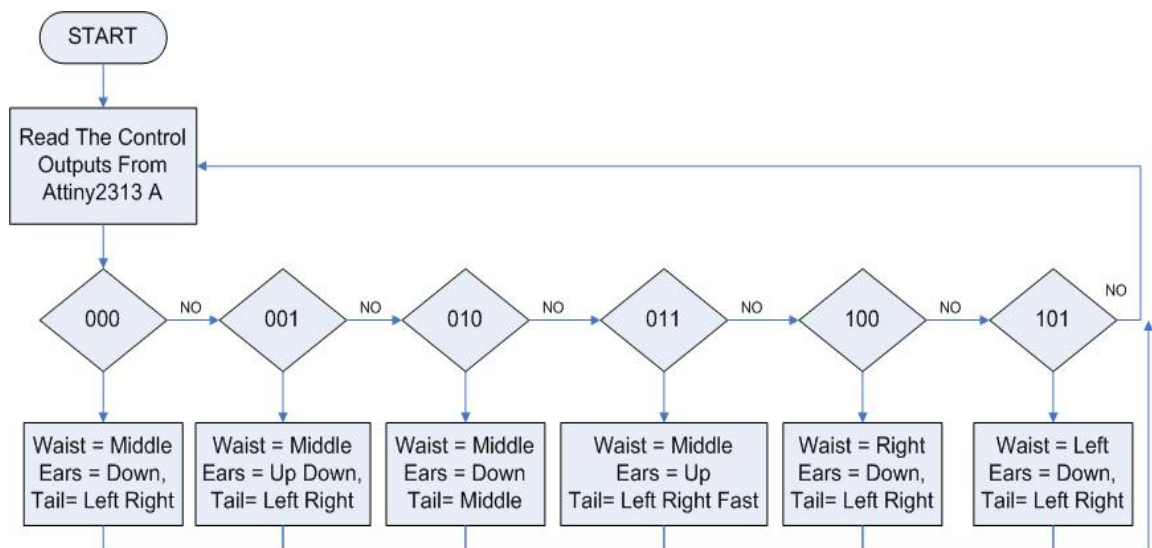


Figure 6.9: Program Flow Chart ATTINY2313 B – Controls Ears, waist and tail

SensBot initially set in walking function. It walks forward until it gets the right sensors' detection combinations that are in the system. If the combination is not in the system, Sensbot will keep on walking. All the sensors circuits' output are connected as Attiny2313 A inputs meanwhile Attiny2313 B gets input which are 3 control outputs from Attiny2313 A.

The robot has several highlights in its functions which are:

1. Walking

- Walking while moving tail left and right.



Figure 6.10: Walking Sequence 1



Figure 6.11: Walking Sequence 2



Figure 6.12: Moving tail Sequence 1



Figure 6.13: Moving tail Sequence 2



Figure 6.14: Ears in walking mode

2. Stop/Standing

- When there is detection on head and front, it will stop walking



Figure 6.15: Standing/Stop position



Figure 6.16: Ears in Standing/Stop position

3. Reaction to touch on head

- Moving ears and tail fast in specific standing position

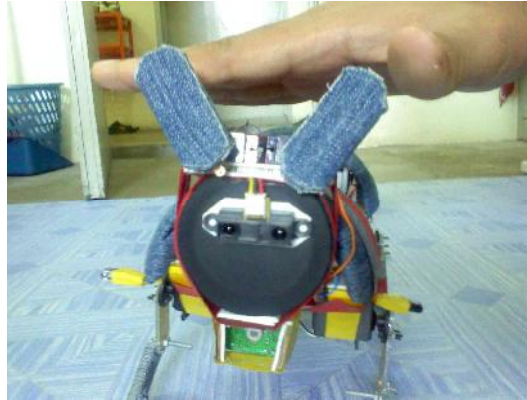


Figure 6.17: Moving Ears Sequence 1



Figure 6.18: Moving Ears Sequence 2

4. Reaction to Moving objects

- Turn ears up and tail straight in specific standing position

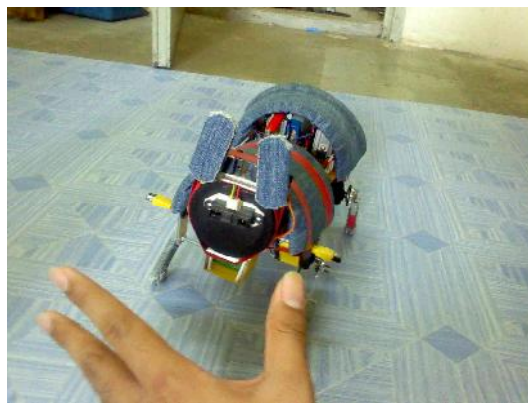


Figure 6.19: Ears up for moving object

5. Reaction to Non Moving objects

- Moves tail and turn ears down while in stop position



Figure 6.20: Ears lower for non moving object

6. Left and Right Obstacle Avoidance Using Waist

- Waist will move to the side with no obstacle detection while walking.



Figure 6.21: Turn left when object at right



Figure 6.22: Turn right when object at left

CHAPTER 7

CONCLUSION AND FUTURE WORKS

7.1 Conclusions

This final year project able to archive the expected goals which are to design and to build an autonomous robot that can react differently to moving and non moving object. This project is inspired by the real animal behavior and is implemented using the controller, sensors, motors and other components as stated before.

As the conclusion, SensBot, an autonomous robot that resembles a dog that have the features such as below are successfully completed

- Walk
- Stop when there is object in front
- React differently to moving and non moving object
- Move waist for Left and right obstacle avoidance
- React to a touch on the top of its back by wiggling tail and ears

This robot can fill the empty space in FYP idea of doing 4 legged where animal robot must react differently according to some important condition and in this case is the

object's movement, also some of body part of waist are important to make me robot movement more realistic.

7.2 Future Works

1. The robot could use more than one degree of freedom leg, so that the movement truly resembles the movement of walking animal. By using one degree leg, the robot's movements are very stiff and the movement types are limited.
2. More flexible and efficient sensors other than PIR should be used to detect movements around the robot. The PIR seems to need some time to give reactions, real animals do take time to figure out the environment but the PIR features that need it to calibrate to the environment seem to take longer time.
3. Robot could be equipped with system that can produce sound according to the animal the robot resembles. Instead of just keep quiet, the robot may bark when there is moving object in front of it.

If the three works above can be done, then the robot may resemble real animal reaction in terms of movements and sounds.

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APPENDIX

Appendix A – Program For Attiny2313 A

\$regfile = "attiny2313.dat"

\$crystal = 1000000

Config Portd.0 = Output

'Control1

Config Portb.0 = Output

'Control2

Config Portb.1 = Output

'Control3

Config Portb.2 = Output

'OC0A

Config Portb.3 = Output

'OC1A

Config Portb.4 = Output

'OC1B

Config Portd.5 = Output

'OC0B

Config Pind.1 = Input

Config Pind.2 = Input

Config Pind.3 = Input

Config Pind.4 = Input

Config Pinb.7 = Input

Config Timer0 = Pwm , Compare A Pwm = Clear Down , Compare B Pwm = Clear Down , Prescale = 64 'timer 8 bit

Config Timer1 = Pwm , Pwm = 8 , Compare A Pwm = Clear Down , Compare B Pwm = Clear Down , Prescale = 64 'timer 16 bit

'prescale 256 means the clock counts till 156.25 , $f(\text{pwm})=f(\text{xtal})/(\text{prescale}*2*\text{topcount})$

Frontleft Alias Portb.2

'OC0A

Frontright Alias Portd.5

'OC0B

Backleft Alias Portb.3

'OC1A

Backright Alias Portb.4

'OC1B

Control1 Alias Portd.0

Control2 Alias Portb.0

Control3 Alias Portb.1

Frontpir Alias Pind.1

Frontdistance Alias Pind.2

Lefttir Alias Pind.3

Righttir Alias Pind.4

Headir Alias Pinb.7

Main:

Do

Frontpir = 0

Frontdistance = 0

Lefttir = 0

Righttir = 0

Headir = 0

'No detection at all

If Frontpir = 0 And Frontdistance = 0 And Leftir = 0 And Rightir = 0 And Headir = 0

Then

'Waist = original, Ears = down, Tail= left right

Control1 = 0

Control2 = 0

Control3 = 0

'Walk normal

Pwm0a = 11

Pwm0b = 11

Pwm1a = 7

Pwm1b = 7

Waitms 800

Pwm0a = 7

Pwm0b = 7

Pwm1a = 11

Pwm1b = 11

Waitms 800

'Touching the head

Elseif Headir = 1 Then

'Waist = original, Ears = up down, Tail= left right

Control1 = 0

Control2 = 0

Control3 = 1

'Lower body down

Pwm0a = 11

Pwm0b = 7

Pwm1a = 11

Pwm1b = 7

Wait 2

'Detect object front

Elseif Frontdistance = 1 And Lefttir = 0 And Righttir = 0 And Headir = 0 Then

'Waist = original, Ears = down, Tail= stop

Control1 = 0

Control2 = 1

Control3 = 0

'Stand

Pwm0a = 7

Pwm0b = 11

Pwm1a = 11

Pwm1b = 7

Wait 3

'Moving object in front

If Frontpir = 1 Then

'Waist = original, Ears = up, Tail= left right faster

Control1 = 0

Control2 = 1

Control3 = 1

'Lower body down

Pwm0a = 11

Pwm0b = 7

Pwm1a = 11

Pwm1b = 7

Wait 2

'No moving object

Elseif Frontpir = 0 Then

'Waist = original, Ears = down, Tail= left right

Control1 = 0

Control2 = 0

Control3 = 0

'Stand

Pwm0a = 7

Pwm0b = 11

Pwm1a = 11

Pwm1b = 7

Wait 2

End If

'Right side object detection

Elseif Lefttir = 0 And Righttir = 1 And Headir = 0 Then

'Waist = right, Ears = down, Tail= left right

Control1 = 1

Control2 = 0

Control3 = 0

'Walk normal

Pwm0a = 11

Pwm0b = 11

Pwm1a = 7

Pwm1b = 7

Waitms 800

Pwm0a = 7

Pwm0b = 7

Pwm1a = 11

Pwm1b = 11

Waitms 800

'Left side object detection

Elseif Lefttir = 1 And Righttir = 0 And Headir = 0 Then

'Waist = left, Ears = down, Tail= left right

Control1 = 1

Control2 = 0

Control3 = 1

'Walk normal

Pwm0a = 11

Pwm0b = 11

Pwm1a = 7

Pwm1b = 7

Waitms 800

Pwm0a = 7

Pwm0b = 7

Pwm1a = 11

Pwm1b = 11

Waitms 800

'Other than that, just walk

Else

'Waist = original, Ears = down, Tail= left right

Control1 = 0

Control2 = 0

Control3 = 0

'Walk normal

Pwm0a = 11

Pwm0b = 11

Pwm1a = 7

Pwm1b = 7

Waitms 800

Pwm0a = 7

Pwm0b = 7

Pwm1a = 11

Pwm1b = 11

Waitms 800

End If

Loop

End

Appendix B – Program For Attiny2313 B

\$regfile = "attiny2313.dat"

\$crystal = 1000000

Config Pind.0 = Input

'Control1

Config Pinb.0 = Input

'Control2

Config Pinb.1 = Input

'Control3

Config Portb.2 = Output

'OC0A

Config Portb.3 = Output

'OC1A

Config Portb.4 = Output

'OC1B

Config Portd.5 = Output

'OC0B

Config Timer0 = Pwm , Compare A Pwm = Clear Down , Compare B Pwm = Clear Down , Prescale = 64 'timer 8 bit

Config Timer1 = Pwm , Pwm = 8 , Compare A Pwm = Clear Down , Compare B Pwm = Clear Down , Prescale = 64 'timer 16 bit

'prescale 256 means the clock counts till 156.25 , $f(\text{pwm})=f(\text{xtal})/(\text{prescale}*2*\text{topcount})$

Ear1 Alias Portb.2

'OC0A

Ear2 Alias Portd.5

'OC0B

Waist Alias Portb.3

'OC1A

Tail Alias Portb.4

'OC1B

Control1 Alias Pind.0

Control2 Alias Pinb.0

Control3 Alias Pinb.1

Main:

Do

'Waist = original, Ears = down, Tail= left right

If Control1 = 0 And Control2 = 0 And Control3 = 0 Then

Pwm0a = 15

Pwm0b = 4

Pwm1a = 7

Pwm1b = 5

Waitms 300

Pwm1b = 9

Waitms 300

'Waist = original, Ears = up down, Tail= left right

Elseif Control1 = 0 And Control2 = 0 And Control3 = 1 Then

Pwm0a = 15

Pwm0b = 4

Pwm1a = 7

Pwm1b = 5

Waitms 150

Pwm0a = 8

Pwm0b = 10

Pwm1b = 9

Waitms 150

'Waist = original, Ears = down, Tail= stop

Elseif Control1 = 0 And Control2 = 1 And Control3 = 0 Then

Pwm0a = 11

Pwm0b = 7

Pwm1a = 7

Pwm1b = 7

'Waist = original, Ears = up , Tail= left right faster

Elseif Control1 = 0 And Control2 = 1 And Control3 = 1 Then

Pwm0a = 7

Pwm0b = 11

Pwm1a = 7

Pwm1b = 5

Waitms 150

Pwm1b = 9

Waitms 150

'Waist = right, Ears = down, Tail= left right

Elseif Control1 = 1 And Control2 = 0 And Control3 = 0 Then

 Pwm0a = 11

 Pwm0b = 7

 Pwm1a = 9

 Pwm1b = 5

 Waitms 300

 Pwm1b = 9

 Waitms 300

'Waist = left, Ears = down, Tail= left right

Elseif Control1 = 1 And Control2 = 0 And Control3 = 1 Then

 Pwm0a = 11

 Pwm0b = 7

 Pwm1a = 5

 Pwm1b = 5

 Waitms 300

 Pwm1b = 9

 Waitms 300

End If

Loop

End