NUST COLLEGE OF ELECTRICAL AND MECHANICAL ENGINEERING

Six legged all terrain unmanned ground vehicle

A PROJECT REPORT

DE-34 (DEE)

Submitted by

NS Abdullah Lodhi

NS Ahmer Ali

NS Salman Haider

NS Shanza Munir

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PROJECT SUPERVISOR

DR. FAHAD MUMTAZ MALIK

COLLEGE OF

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YEAR 2016

Declaration

We hereby proclaim that this project neither as a whole nor as a section there has been replicated out from any source. It is further proclaimed that we have built up this project and the accompanied report altogether on the premise of our own endeavors made under the sincere guidance of our supervisor. No portion of the work introduced in this report has been submitted in backing of whatever other degree or qualification of this or any other University or Institute of learning, if found we shall stand responsible.

Dedication

This project would be incomplete without mentioning of bolster given to us by our parents, family members and friends to whom this project is dedicated. They kept our spirits up and lifted us up when this project seemed interminable. Without their consolation and bolster we doubt it should ever have been completed.

Acknowledgements

Above all else, on account of Allah Almighty, who gave us the capacity and mettle to comprehend these things, by the grace of Whom each deterrent was determined in the fulfillment of this arduous undertaking.

Apart from the endeavors of the group, the success of any project depends to the great extent on the encouragements and guidelines of others. We wish to express our gratitude to out supervisor, Dr. Fahad Mumtaz Malik who was abundantly helpful and offered invaluable assistance, support and guidance.

We are also thankful to Mr. Salman Qadir who offered us great deal of help and assistance. He helped us hit the ground running and carry forward the project.

In the end, we would like thank our department, Department of Electrical Engineering, for providing us knowledge and helping us to excel in our field. We are really thankful to all faculty members and the staff; we have played their roles impeccably in ensuring that we are provided with best facilities.

Table of Contents

Chapter 5

Hardware implementation and cost estimation

Chapter 6

PID implementation

Chapter 7

Radio control

Chapter 8

Limitation and furure work

APPENDICES

Abstract

We have fabricated a UGV (Unmanned Ground Vehicle) Hexapod a six-legged robot with inherently high mobility. It is capable of moving in rock fields, mud, sand, vegetation, railroad tracks and up inclines and stairways. Due to its small size and weight, it is capable of exploring areas where existing walking robots cannot go. Its structure has been intended to be lightweight, without compromising its robustness. The UGV (Unmanned Ground Vehicle) is one of its kinds in the sense that it employs half-circle leg morphology. We have worked on the design and development of a hexapod (six legged) robot with a single motor per leg intended for real-world mobile applications. Hexapoad is a redesigned adaptation of the RHex platform, intended to offer significant improvements in power, run-time, durability, and terrain navigation, with a smaller physical volume and a comparative impression and weight. Furthermore, Hexapod is designed to be easier to build and maintain. Hexapod supports a variety of sensor suites on a small, mobile robotic platform proposed for broad, general use in exploration, defense, and search and rescue applications. It consists of six legs as a part of its design (three on each side). Owing to its six legged morphology, the Hexapod can recover from a vertically flipped position.

CHAPTER 1

INTRODUCTION

Chapter 1

1.1Thesis organization:

- **Chapter 1** is the introduction the report. It includes introduction to each chapter, key points of each chapter and working idea of the project
- **Chapter 2** explains the detailed summary of the project and goals of the project
- **Chapter 3** refers to literature review.
- **Chapter 4** explain the software simulation, it includes CAD model design and its simulation, its gait study, and analysis of the model.
- **Chapter 5** Hardware implementation. It includes detail discussion on the selection of each component and its fabrication.
- **Chapter 6** software system coding it includes the PID implementation.
- **Chapter 7** deals with Radio control interface with our module.
- **Chapter 8** deals with limitation of the project and future work.

1.2 Motivation:

The engineering technique for enhancing the parcel of mankind is two dimensional: building applications and formulating speculations that add to our comprehension of our surroundings. These two aspects of designing are connected; hypothesis can prompt applications, however it is hard to evaluate the estimation of hypothesis in apply autonomy without building and testing a genuine robot. At the College of Electrical and Mechanical engineering, we strive to work in both spheres.

All the team members of this project had keen interest in robotics and controls systems we also studied related subjects like Microprocessors, machines and electronics. So we were looking for the project where we can apply our current knowledge and experience on a wider scale, grow professionally so we thought of this project.

This robot can be utilized as a part of defense purpose. It will upgrade our defense system since will be equipped for reaching the places where human's access is bit difficult. It can also be used for spying and ground surveillance purposes. Can comparably be used for rescue operations.it will likewise have advantage of conveying payloads and also for mine detection purposes. In Pakistan no work has been done on this venture so it will be revolution in robotics and defense of the country.

1.3 INTRODUCTION

In recent years, with the progression of electronic and control innovations, robots are being outlined to perform dangerous or computerized assignments, which a normal human being cannot perform, as well as to serve in different fields, for example, instruction, diversion, cleaning, security, visit controlling, and natural investigation. Among the different sorts of robots

Hexapod robots are mechanical vehicle that strolls on six legs. Since a robot can be statically steady on three or more legs, a hexapod robot has a lot of adaptability by the way it can move. On the off chance that legs get to be debilitated, the robot may in any case have the capacity to walk. Besides, not the greater parts of the robot's legs are required for stability; different legs are allowed to achieve new foot positions or control a payload.

Hexapod is a six-legged robot with inalienably high portability. Capable, freely controlled legs produce specific strides that devour harsh landscape with insignificant administrator input. Hexapod can moves in rock fields, mud, sand, vegetation, railroad tracks, and phone shafts and up slants and stairways.

Hexapod has half circle morphology with make it very suitable for rough terrains.it has cockroach like locomotion morphology. Where three legs provide support and other three provide locomotion. There is motor attached to each leg these motor has more torque relative to speed to make it suitable for rough terrains. PID control is implemented on each motor which help to track the motor position. Leg angle is gathered from motor encoders present on each hip of the leg. Encoders are reliable, and simple to use. They are the most important sensors on the robot. Forward backward or left right motion of the pod is controlled with radio control. A normal toy RC is used to control the pod.

We achieved our goal in steps shown in the flow diagram:

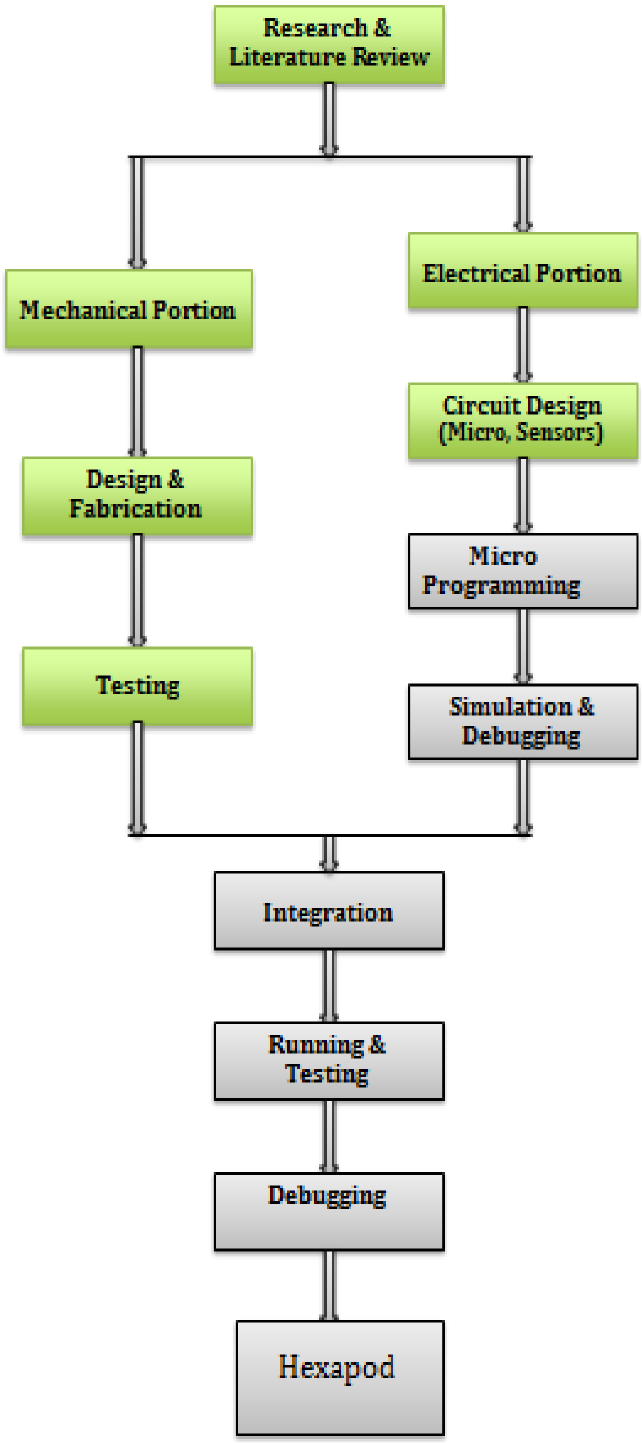

Figure1.1 flow diagram

CHAPTER 2

SUMMARY

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PROJECT GOALS

Chapter 2

2.1Summary of project:

Hexapod has half circle morphology with make it very suitable for rough terrains.it has cockroach like locomotion morphology. Where three legs provide support and other three provide locomotion. There is motor attached to each leg these motor has more torque relative to speed to make it suitable for rough terrains. PID control is implemented on each motor which help to track the motor position. Leg angle is gathered from motor encoders present on each hip of the leg. Encoders are reliable, and simple to use. They are the most important sensors on the robot. Forward backward or left right motion of the pod is controlled with radio control. A normal toy RC is used to control the pod.

2.2 Goals and aims:

- All terrain capability so that it can moves in rock fields, mud, sand, vegetation, railroad tracks, and phone shafts and up slants and stairways.
- Small, robust and light weight so that it can go anywhere to perform exploration purposes.
- Remotely controlled so that we can control it and send to long distances.
- Position control of the motors.
- Motors should b of high torque to overcome obstacles more efficiently
- Its use has to be user friendly so that user can operate it easily.
- Selecting components to minimize overall expenditures.
- Reduce the cost to as much extent as possible without affecting it working.
- Development of mathematical model & control algorithm.

CHAPTER 3

LITERATURE REVIEW

Chapter 3

3.1 Literature review:

3.1.1 Background of Hexapod:

In the course of the most recent two decades the innovative work of legged locomotion robots has become relentlessly. Legged frameworks present real points of interest when contrasted and wheeled "traditional" vehicles, since they permit motion in difficult to reach territory as compared to vehicle with wheels. Hexapod have various types of function some involve simple controller operations or complex control designs.

One of the innovations that has high pace progression, for example, the innovation of hexapod robot which has expanded from a straightforward capacity, size and weight to a different capacities, greater size and weight. LAURON is the case, a six-legged robot which has been produced at the Forschungszentrum Informatik Karlsruhe (FZI) in Germany. The main LAURON venture was begun in mid 90s and persistently enhanced until the most recent task called as LAURON IV

3.1.2 Literature review of Hexapods:

The framework outlines of hexapod robots from every diary have their own disparities. RHex created by [1] is an alternate robot contrasted with other hexapod robot since it is impelled by brushed DC engine. The engines that are utilized at this robot are Maxon sort engine with a 33:1 planetary gearhead controlled by a 24V NiMH battery. The configuration of the leg is one degree of flexibility and half-circle. As per the creator, the strategy is anything but difficult to manufacture and keep up the robot and no sliding grinding amid spring relocation. This configuration is most appropriate for stair ascending.

Hexapod robot, Bill-Ant-P robot done by [2] is made of 6061 aluminum and carbon fiber sheets. It utilizes MPI MX-450HP distraction engines for its unwavering quality, high torque, and reasonableness development. The engine have 8.37kg-cm of torque, can turn around a 60 degree in 0.18sec, and has a little inner dc engine expends 1125mW of force at slow down torque.

In the diary done by [3], a robot called as Gregor has been created. The Gregor robot advancement model has Autodesk Inverter 9.0 to characterize properties of parts, for example, mass. Rhinocerus 2.0 programming is utilized to organize of the imperatives and model the robot that can be effectively sent out into the dynamic recreation environment which is likewise utilized the same programming.

MSR-H01 hexapod created by Micromagic System is worked from 26 accuracy laser-cut 5053 aluminum body and leg segments. It is controlled by utilizing a p.Brain-HexEngine and utilized eighteen servomotors from three diverse sorts of servomotors. The connection for the robot is Bluetooth with quality 99.2% from 17215 bundles sent, 17083 parcels are recognized [4].

Hexapod robot created by [5] Devantech SD-21 board to control 18 servo motors by interfaced with the favored microcontroller, which is Arduino Decimilla board. The programming that is utilized to control the servo controller is Matlab. In other to control the robot leg, Jacobian reverse lattice technique is utilized to characterize the edges and leg position.

The hexapod robot's diary done by [6] states that the hexapod utilized shrewd actuator module Dynamixel RX-28 by ROBOTIS as joint actuators. The control board taking into accounts the 16-bit AVR ATmega128 and capable speaks with outer PCs by RS232. The fundamental controller spoke with the robot by sending and getting information parcels to the engines and sensors

The strolling robot Ragno created by [7] is 33 cm long and 30 cm wide and 2.15 kg weights. It has four layers control engineering where the first is at off-board to process the proper control signal for all leg's joint and send control orders to robots. The second layer is ready control layer that deciphers orders from first layer and sends to leg controllers. There are six leg controllers that work at the same time and control the inputs send to them. The robot has a twofold hub accelerometer and a spinner to gauge the storage compartment introduction in a 3D space. The on-board and off-board parts of the control framework convey by method for a Bluetooth association.

CHAPTER 4

MECHANICAL DESIGN

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SIMULATIONS

Chapter 4

4.1 CAD Model design:

We have used solid works for our CAD (computer aided design) model design. Solid works is a software use to make 3D mechanical designs of objects. We can design an object in solid work and test its working.

We used this software for designing our bot and test its working. We made each component step by step and then assembled them together.

4.1.1 Leg:

We designed the leg of the pod in the solid works. We have designed half circle legs reason of this is explained in the next topic with detail.

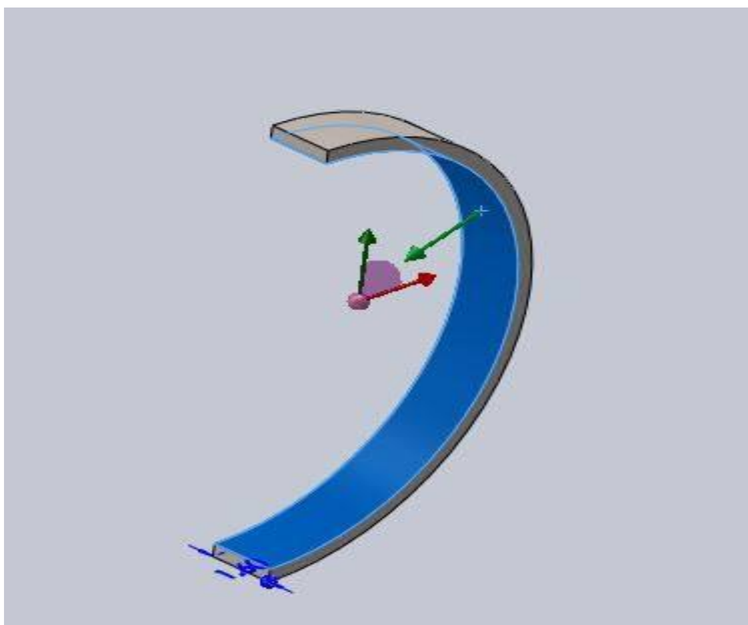

Figure 4.1: Leg of the pod

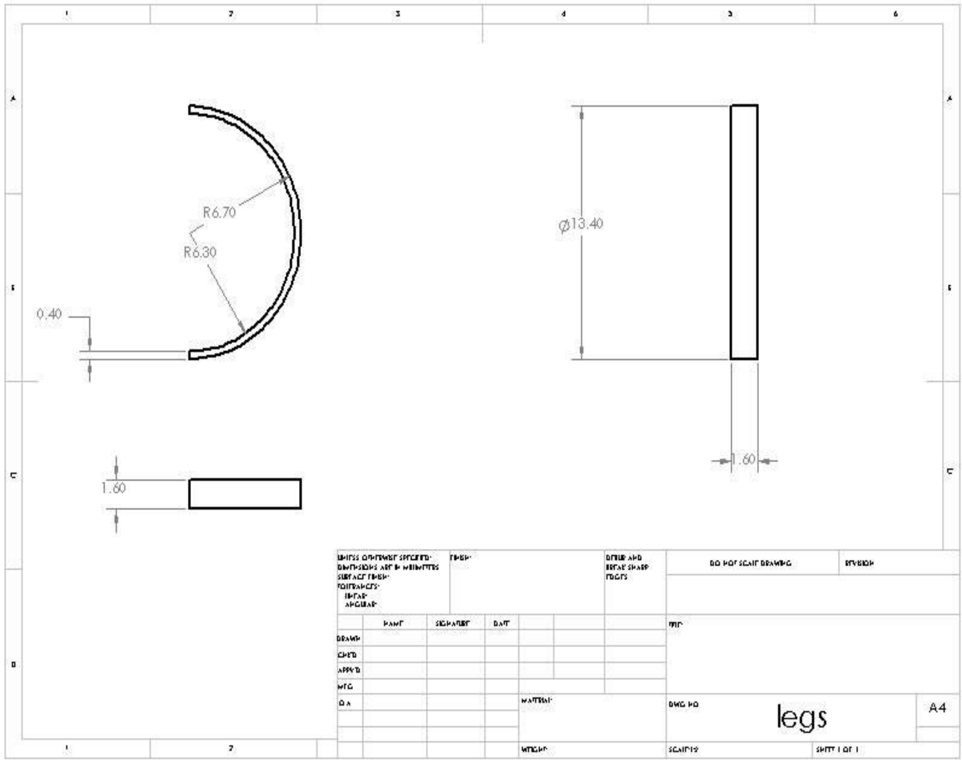

Figure 4.2: Specifications of leg

4.1.2 Motor mount

We have designed motor mounts in the solid works these mounts provide support to the motor and keep it fixed at it place.

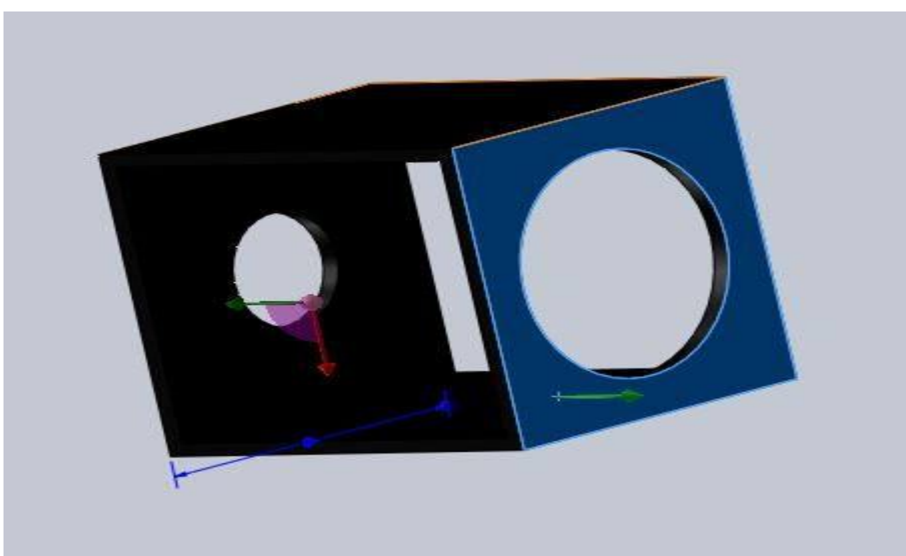

Figure 4.3Motor mounts

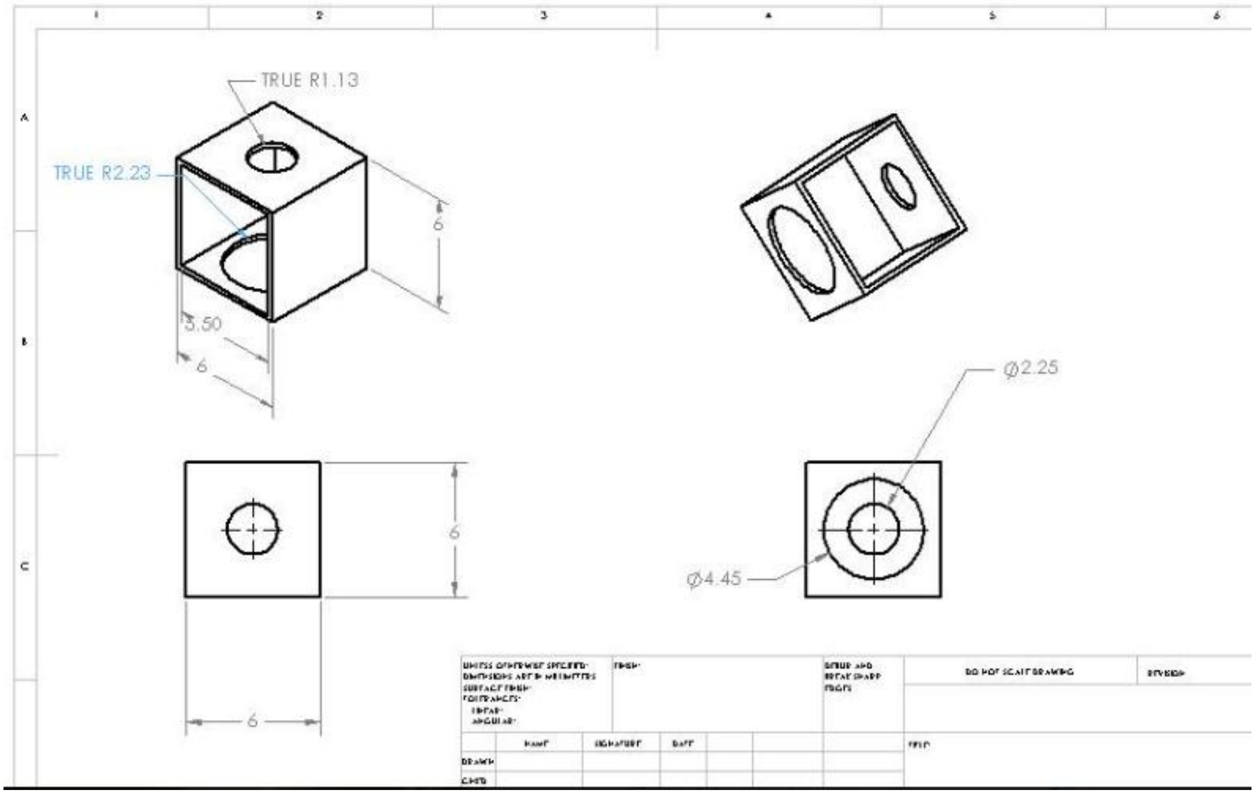

Figure 4.4: Motor mount specifications

4.1.3 Motor:

We designed the motors according to the specification given by the manufacturer.

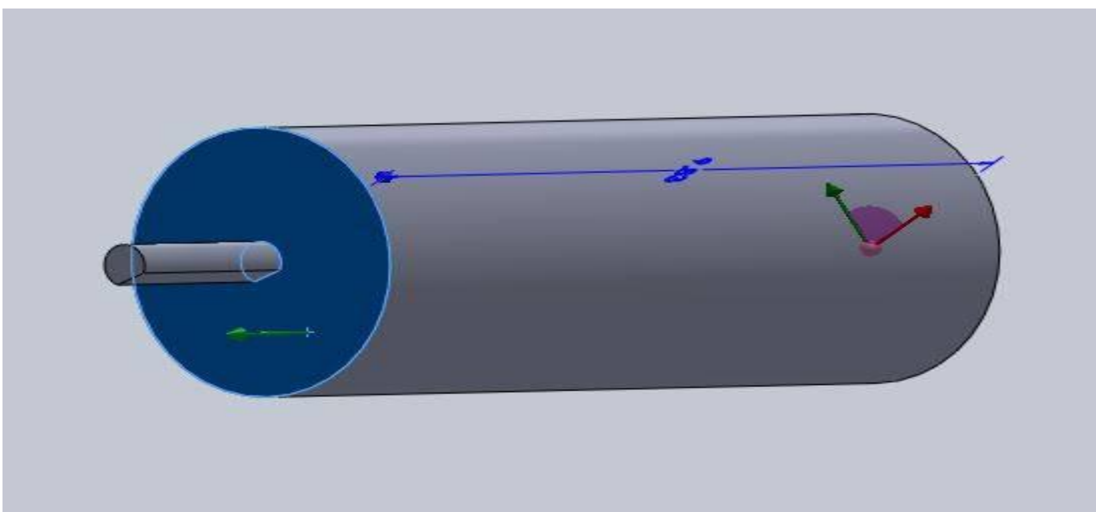

Figure 4.5: Motor design

4.1.4 Top and bottom platform:

We designed the platform of our bot according to requirements.

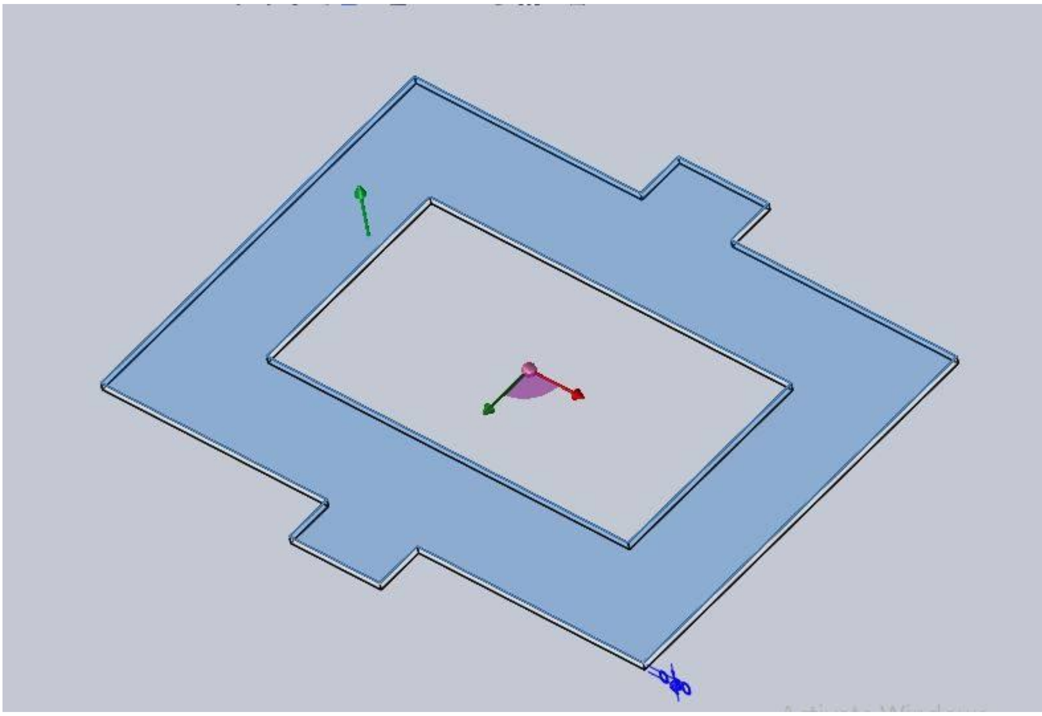

Figure 4.6: platform

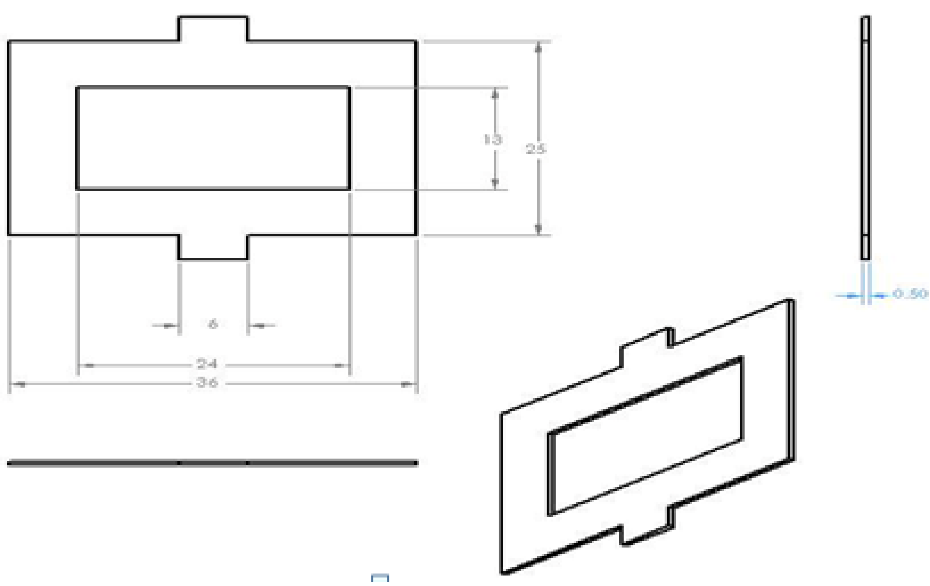

Figure 4.7 Platform specification

4.1.5 Assembling:

We joint each discrete component to form the full design of the bot.

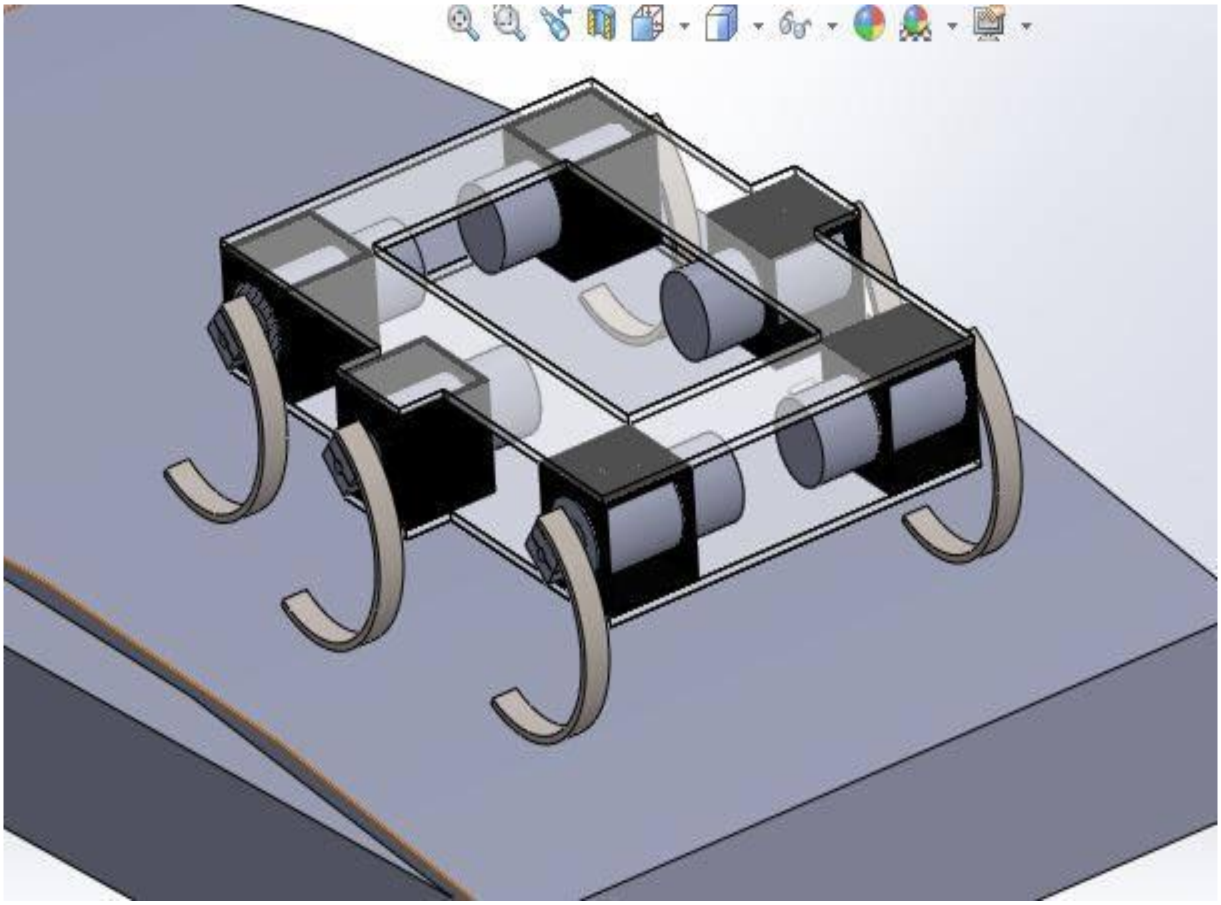

Figure 4.8 fully assembled Pod

4.2 Simulations:

After assembling the full bot we performed simulation to test its design and working.

4.2.1 Obstacle designing:

We designed few obstacles to test the design that whether it traverse the hurdles or not.

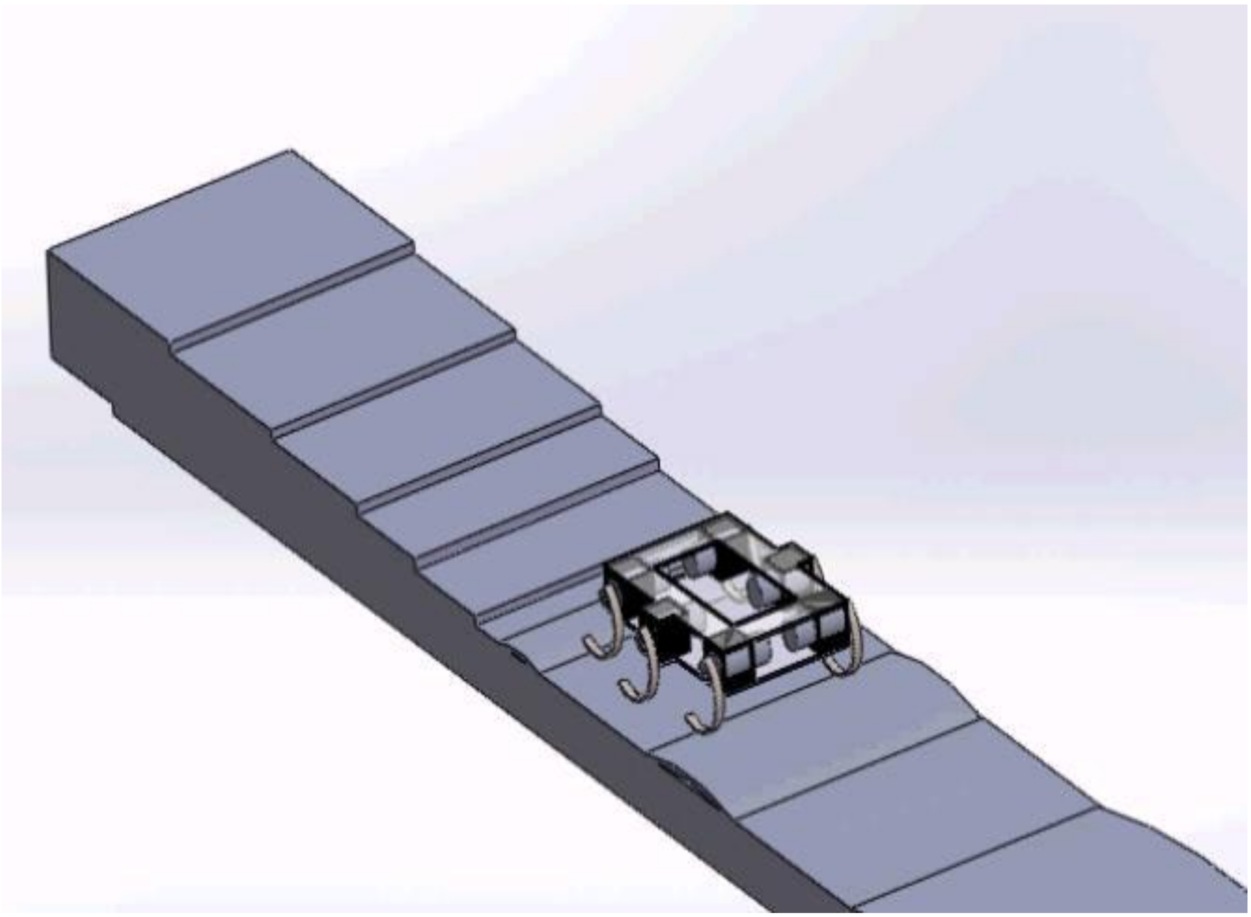

Figure 4.9: Pod traversing the obstacles

4.2.2 Results:

We studied the behavior of the pod and draw conclusions about the torque and speed

4.2.2.1 Torque:

Torque results by simulation shows that our motors should have the torque of 4.5 Nm.

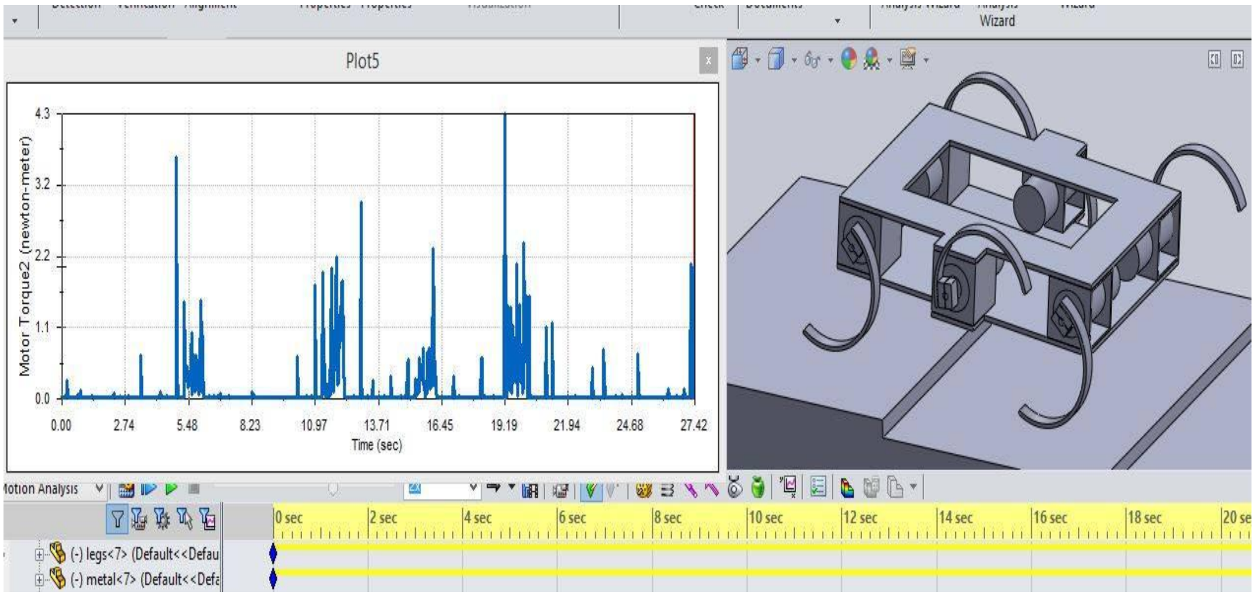

Figure 4.10: Simulation results for Torque

4.2.2.1 Speed:

The figure below shows the results of simulation for the speed of our design.

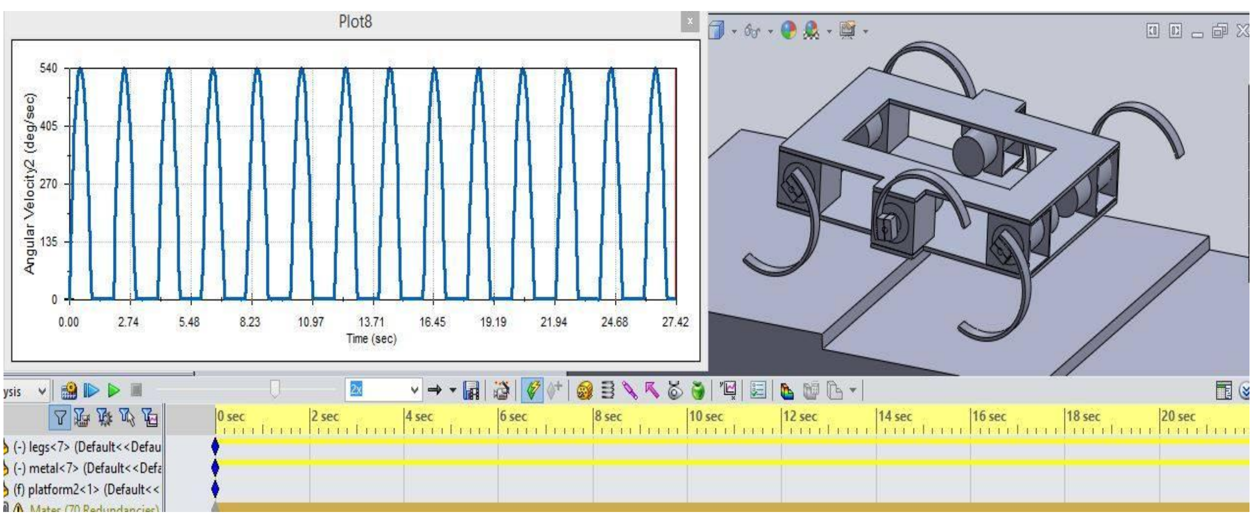

Figure 4.11: Simulation results for speed

4.3 Leg Morphology:

The most recent leg designed for RHex is the Half-Circle leg**.** In addition to the requirements that we set for any RHex leg, two additional requirements helped shape our design of the Half-Circle legs. The first requirement stemmed from our wish to be able to actively control leg length, which means we must add an actuator to each leg. The second requirement we considered was our desire to build legs which could be altered using the leg length changing mechanism, to allow a rolling motion, instead of a walking one. In addition to this half circle legs are less complex as thy have second degree of freedom.

A second degree of freedom will change leg length by moving the center of rotation of the leg from the tip of the Half-Circle to the center of the Half-Circle arc. At the extreme position in the center of the arc, the leg will become a half wheel, with the main drive motor at its center. The second motor will be decoupled from the loads of driving the leg, or the wheel, but should be powerful enough to change the length of the leg quickly.

4.4 Gait study:

The cockroach has proved that it has a very successful locomotion strategy due to its speed and stability over its numerous and varied habitats add concrete performance. Cockroaches do not require high-level neural control to perform well in all types of terrain. Instead of high-level control, Full has found that there is a significant contribution to stability of locomotion from low-level neural reflexes, and from excellent passive leg design, which relies on simple mechanics for passive stability

4.4.1 Forward motion:

Due to these characteristics of cockroach locomotion we have utilized this gait strategy in our pod. In our pod we want to move it forward and also want to prevent it from hitting the ground so in order to do that in our pod only three legs move at a time and other three legs provide support to the pod as center of mass always reaming inside the support triangle so pod remain stable.

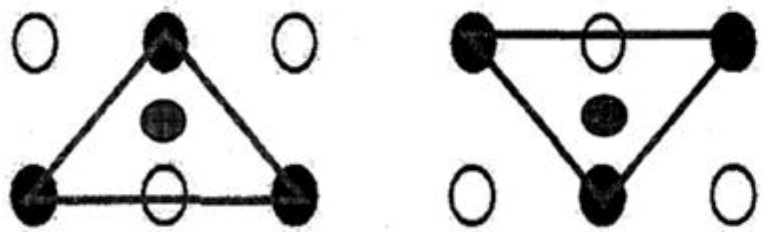

Figure *4.12* **The two phases of the alternating tripod gait. Full circles are legs in stance, open circles are legs in flight. Center of mass, oval dot, must stay inside the *polygon of support* (triangle) formed by stance legs.**

As in the above figure white dots are moving legs and black one are providing support when these moving legs will complete 360 degree rotation then stationary legs will start moving and other three will provide support to the pod. In this way pod will always remain stable.

4.3.2 Turning motion:

So when we want to turn the pod i.e. to the right then the motor on the right side of the pod will move backward and motor on the left will move forward this will create a force toward the right and pod will turn to the right

White circles in the figure shows the motor in motion and the black dots show the legs providing support. Arrow head on the motors shows the direction of rotation of the pod.

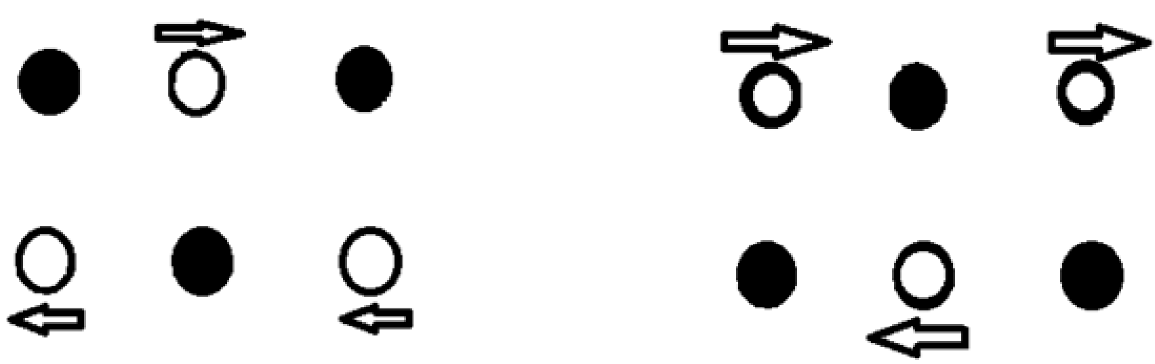

Figure4.13: right turning of the pod

Similarly when we want to turn the pod to the left the motor on the left side of pod will move backwards and motor on the right will move in the forward direction that will create a force to the left side and pod will turn left.

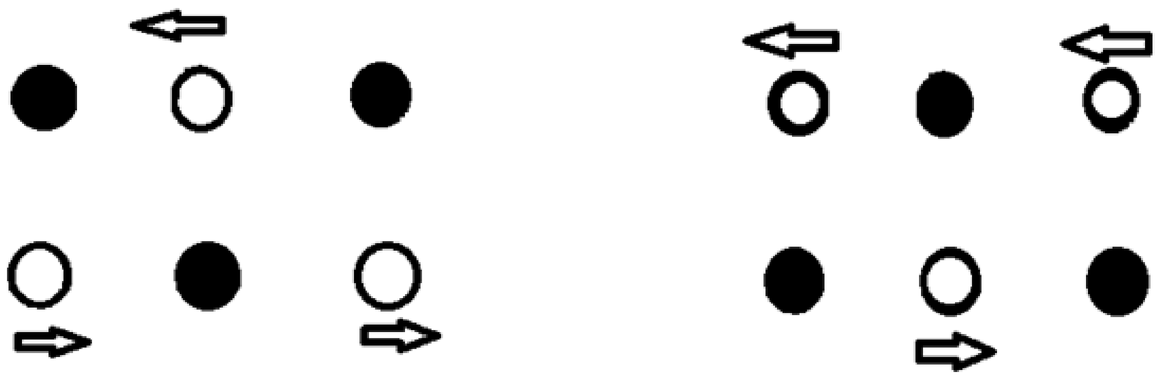

Figure 4.14: left turning of pod

CHAPTER 5

HARDWARE IMPLEMENTATION

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COST ESTIMATION

Chapter 5

5.1 Hardware implementation

The Hardware design encompasses all components required to drive the motors in a pattern that results in a stable Movement. This involves the selection and interface of motors, Arduino, motor drivers, batteries and RC module. The Arduino, motor driver and motor unit form a closed loop link with a time reference trajectory as input and leg position as output. The other components have been selected for high computing power and capability to supply large currents, while keeping weight and dimensions low. Encoder send motor position to the Arduino then controller generate input according to position so that motor track the final position this motor input goes to the motor drivers and motor driver send it to motor. All these components are powered by 24 Volts 6 cell LIPO batteries.

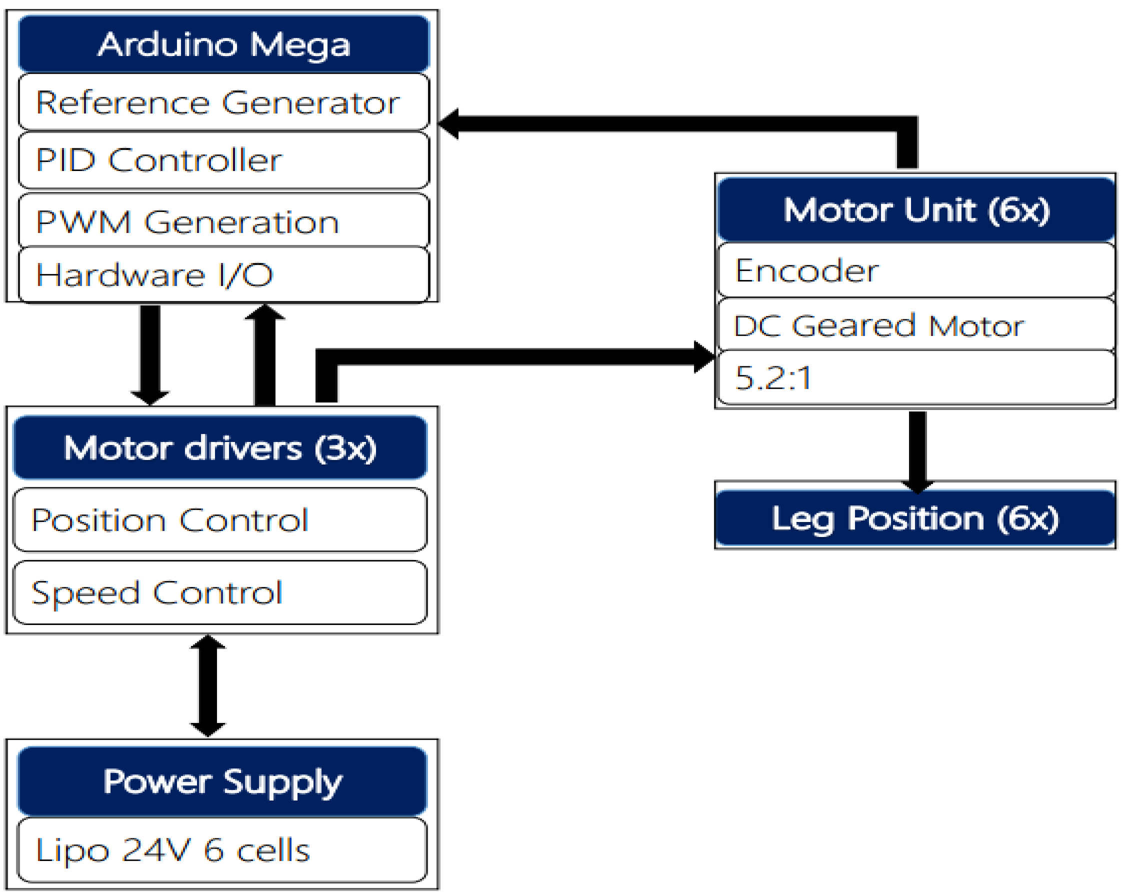


Figure5.1: flow Diagram

5.1.1 Material selection & Fabrication:

5.1.1.1 Body

Body of the hexapoad is made up of Acrylic plastic. Acrylic plastic has following key features:

- Phenomenal optical clarity
- Phenomenal weather ability and imperviousness to daylight
- Inflexible, with great effect quality
- Phenomenal dimensional security and low form shrinkage
- Stretch shaping builds bi-axial durability

5.1.1.2 Legs

Six legs of hexapod are made up stainless steel. Stainless steel does not promptly corrode, rust or stain with water as standard steel does. Notwithstanding, it is not completely recolor verification in low-oxygen, high-saltiness, or poor air-dissemination situations. There are assorted assessments and surface consummations of stainless steel to suit the environment the composite must continue on. Due to these properties it's very suitable for legs.

5.1.1.3 Motor columns

Motor columns are made of stainless steel provide more firm support, lower the noise and enhance the torque.

5.1.2 Fabrication

Machinist fabricated the bot according to our CAD model design with our selected material.

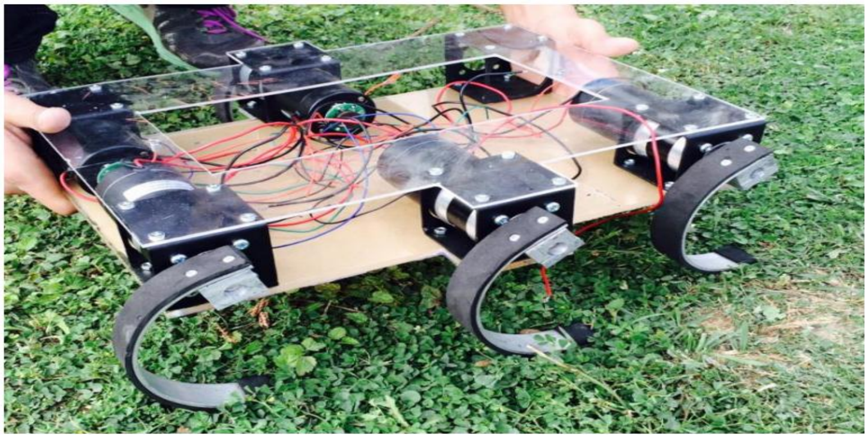


Figure 5.2: prototype

5.1.3 Components selection

Component selection was an important task as we had to minimize the cost without affecting the working of the pod.

5.1.3.1 Motors

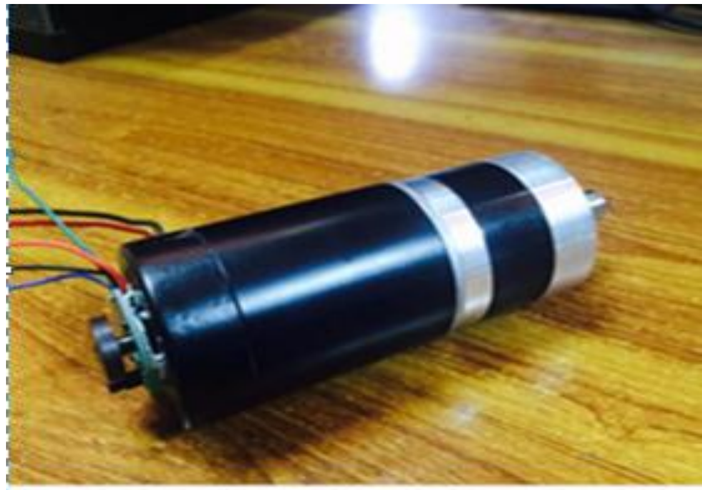
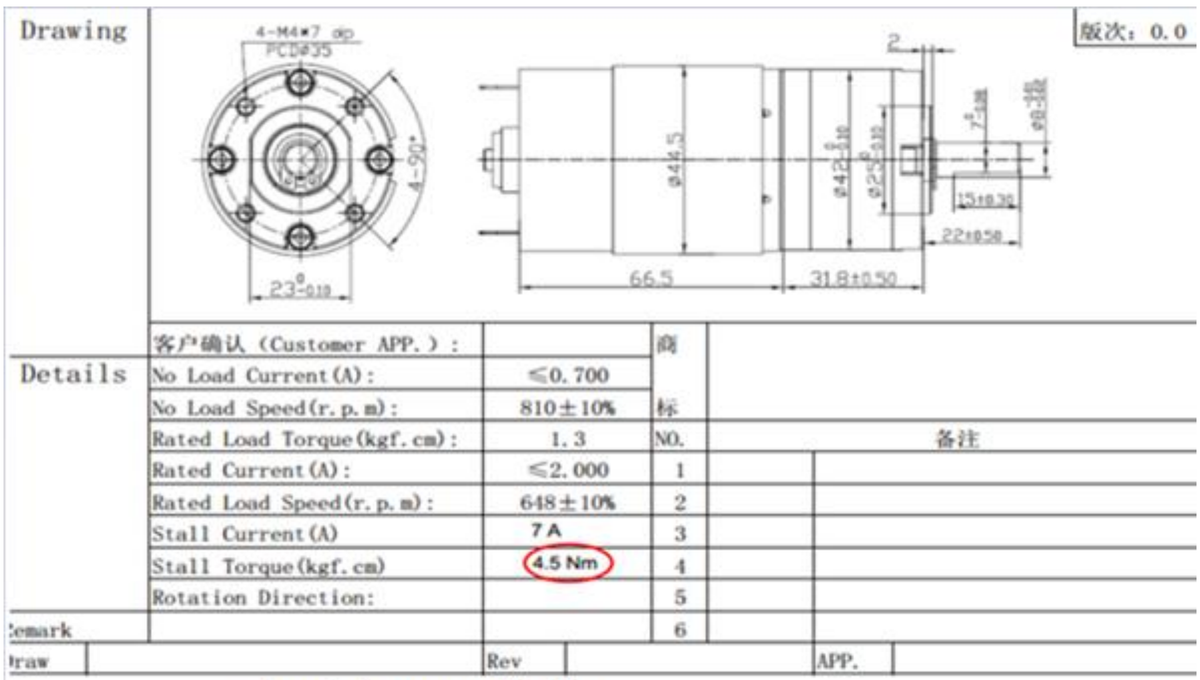


figure 5.3 : DC motor

We have selected DC gear motors with encoder for our pod. DC gear motors have high torque which is suitable for our application of traversing rough terrains. Our selected motor has the torque equal to 4.5 Nm which is according to the required torque we got through our simulation on Solid works. Gear at the end of the motor increase the torque by 5.2 and thus speed is decreased, it a tradeoff in order to get more torque we have compromised motor speed. Encoders of the motor give motor position which we give as a feedback to PID for position tracking. Encoders are most important sensor in this project. Motor specification or are given below in the table below.



	客户确认 (Customer APP.) :		商标	
Details	No Load Current(A):	≤0.700		
	No Load Speed(r.p.m):	810±10%		
	Rated Load Torque(kgf.cm):	1.3	NO.	备注
	Rated Current(A):	≤2.000	1	
	Rated Load Speed(r.p.m):	648±10%	2	
	Stall Current(A)	7 A	3	
	Stall Torque(kgf.cm)	4.5 Nm	4	
	Rotation Direction:		5	
Remark			6	
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figure 5.4 : motor specifications

5.1.3.2 Encoder selection

Figure 5.5: spark optical encoder

Encoders are most important sensor in our project. They give the position of the motor to the controller, so there selection is most important task in the project. We have selected SHARP Optical quadrature encoder.

Incremental encoders provide a specific equally spaced pulse signal per revolution (PPR), ticks are actually those pulses. Optical quadrature is the type of incremental encoder; they are used in the applications where position and direction of motor is required.

Quadrature encoders have two channels usually A and B both are at 90 phase difference with each other. There channels not only give information about the motor position but also provide information about the direction of motor rotation. If channel A is leading channel B then motor is moving in clock wise direction but if B is leading A then it moving in anti-clock wise direction.

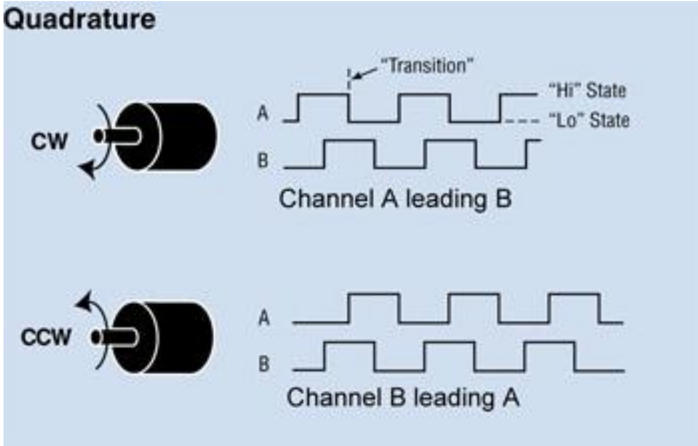


Figure 5.6: Encoder Channels

Our encoder has 25 slits on disk sensor detect the optical changes and produce 25 ticks but as our motor is DC gear motor with 5.2:1 ratio so when encoder completes it one rotation shaft complete 5 rotations so total ticks that we get are 125.

5.1.3.3 Microcontroller selection:

Figure 5.7 : Arduino mega

Microcontroller is considred a self-contained system which can be used as embedded syatem. Almost every machine use micrcontroller to control the system such as digital speedometer , car ignition digital clock, toll plaza system , Led animation , calculator etc. So microcontroller is a building block of each and every modren device or machine. Due to its increased demand and use there are many manufacturers of Microcontroller with different specifications, selection of microcontroller is an important task for an engineer in designing phase by selecting a controller on basis of required features in the completion of task.

For PID controller implementation we decided to move toward arduino because we had already done coding on arduino in our previous courses so, it was easy for us to comprehend, interface and code on arduino.

We have selected Aduino Mega for our project because we need 6 PWM pins for motor and many other pins for interuptes and to interfae with RC module. We searched many Arduino but only Arduino mega was according to our requirments.

Summary

Microcontroller	ATmega1280
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limits)	6-20V
Digital I/O Pins	54 (of which 15 provide PWM output)
Analog Input Pins	16
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	128 KB of which 4 KB used by bootloader
SRAM	8 KB
EEPROM	4 KB
Clock Speed	16 MHz

Figure5.8: Arduino mega specifications

5.1.3.4 Motor drivers

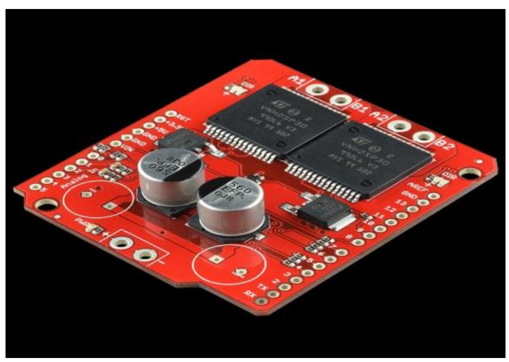


Figure 5.9: Sparkfun monster motor shield

We are using H-Bridge as motor drivers. An H-bridge is an electronic circuit that empowers a voltage to be connected over a load in either heading. These circuits are frequently utilized as a part of mechanical technology and different applications to permit DC engines to run advances and in reverse.

We are using dual H-bridges which has two H-bridge imbedded in one board this on is called “Sparkfun monster motor shield”, this has its unique and rare properties and we are using 3 of them. One to drive 2 motors on the left side front and rare one, second one to drive the 2 motors on right side front and rare and third to drive left and right motor in present the middle, according to the gait of the pod.

5.1.3.5 Batteries

Figure 5.10: 4cell Li-Po battery

We used 4 cell Lipo batteries as power source to provide power to our circuitry each cell is of 3.7 volts so as a collective 4 cell means 14.8 volts, and capacity used was 4400mAh (mAh=milli ampere hour) so, we used 4 cell 4400mAh battery.

Weight (g)	715
capacity (mAh)	4400
max cont discharge rate (C)	65
max burst discharge rate (C)	130
max cont current (Amp)	286
max burst current (Amp)?	572
Series (S)? Parallel (P)	6S1P
Length(mm)	147
width (mm)	50.5
Thickness(mm)	50.5
Wire Gauge	10
balance connector type	JST-XHR
connector type	N/A
Vol. Gap	<0.03V
IR(mohm)	<20mohm
Wire length(C/D)	65mm/120mm

Figure 5.11: Li-Po specifications

5.1.3.6 RC module

Figure5.12: RC module

When we press a button on RC transmitter send radio waves to the receiver, which carry the command, which then drives a motor, causing a specific action to occur. RC toys typically have a small handheld device that includes some type of controls and the radio transmitter. The transmitter uses certain frequency to send radio signals to the receiver. The transmitter has a power source, which provides the power for the generation and transmission of the signal. The basic difference between radio controlled devices and remote controlled devices is that remote controlled objects have a wire connection to the controller and the device, while radio controls are always wireless systems.

Most RC toys operate at either 27 MHz or 49 MHz. These two frequencies are allocated to them such as garage door openers, walkie-talkies and RC toys. Advanced RC models use additional 72-MHz or 75-MHz frequencies.

We have selected a 2 channel RC for our project one channel for forward and backward motion and other for left and right motion. We have selected ZAPTOYS 27 MHz RC which operates by the battery of 6 volts.

5.2 Complete hardware

Completed hardware after fabrication and placing and fixing all components is shown in the figure below:

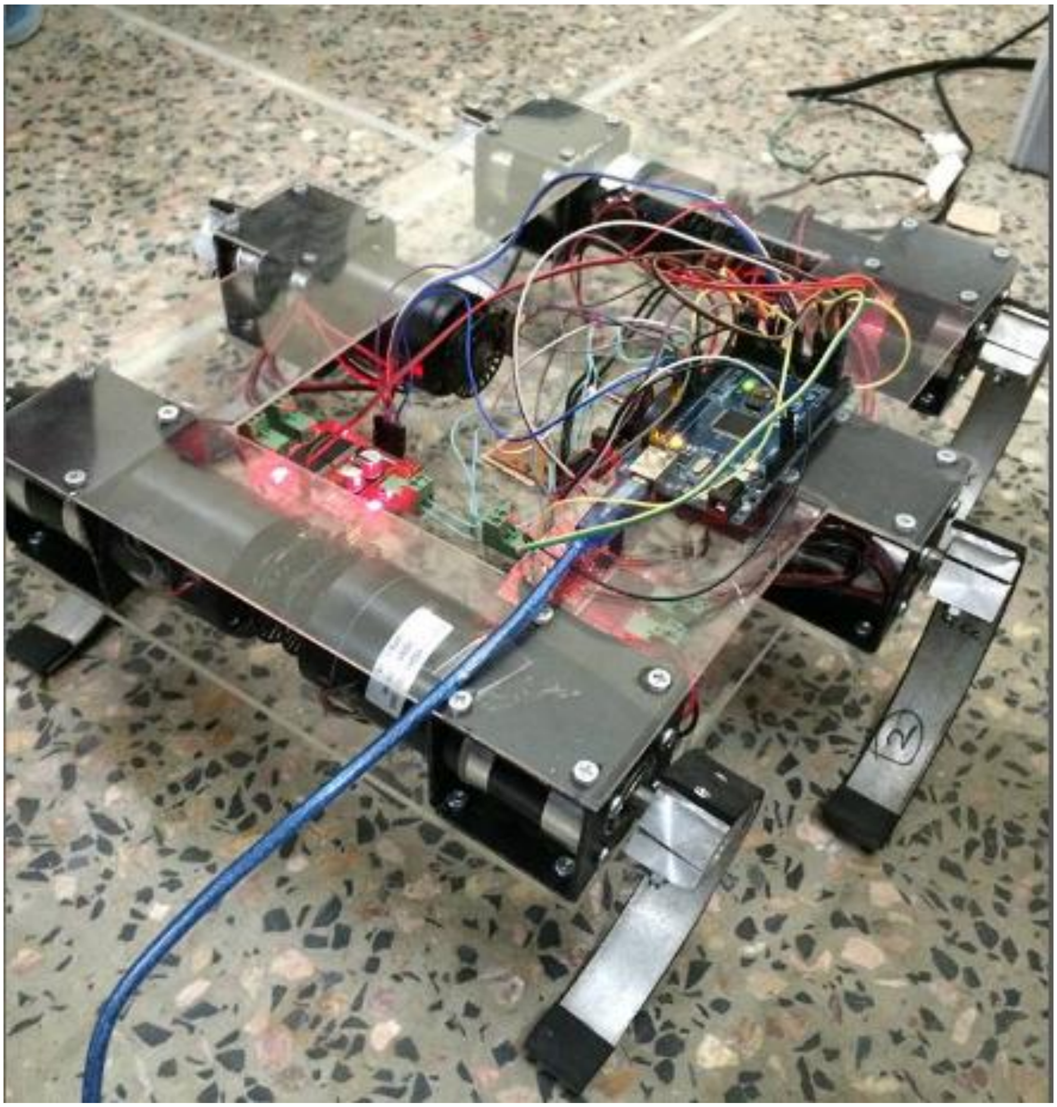


Figure 5.13 fabricated Pod

5.3 Cost estimation

A rough estimation of the total project cost is given below:

Equipments Costs:

Description	No.	Unit cost	Amount (Rs.)	Justification
Major Equipment				
DC Planetary Gear Motor	6	Rs.7,000	Rs.42,000	High torque Precision motor for all terrain movement
Motor Encoder	6	Rs.850	Rs.5,100	To Implement a close loop PID control
Motor Driver	3	Rs.1,700	Rs.5,100	For Bi directional control of motors, Important for PID implementation
Lithium Polymer Battery	1	Rs.9,000	Rs.9,000	For Power Supply
Arduino Controller Mega 2560	1	Rs.2000	Rs.2000	For implementation of PID Algorithm
Radio Control Module	1	Rs.500	Rs.500	For Remotely Controlling the Movement
Sub Total:			**Rs.63,700**	
Fabrication				
Hardware Structure	1	Rs.13,000	Rs.13,000	Platform for the UGV
Sub Total:			**Rs.13,000**	
Other Equipment/Accessories				
Wires	50	Rs.10	Rs.500	For connections between controller and motor drivers and other cercuitry
PCB Board	2	Rs.400	Rs.800	For making circuit boards
Feric Chloride	1	Rs.200	Rs.200	Used in etching of PCB board
Sub Total:			**Rs.1,500**	
Total Equipment Cost:			**Rs.78,200**	

Table 5.1: Equipment cost

Traveling cost:

Mode of Travel	No. of Trips	No. of Persons	Per Trip/Per Person Cost	Total Amount (Rs.)	Itinerary (from-to)	Purpose / Justification
Year 1						
Air Travel						
Foreign	0	0	Rs.0	Rs.0	Isb-NewYork-Isb	Paper presentation
Domestic	0	0	Rs.0	Rs.0		
Sub Total:				*Rs.0*		
Land Travel						
By Road	10	2	Rs.500	Rs.10,000		
By Rail	0	0	Rs.0	Rs.0		
Sub Total:				*Rs.10,000*		
				Rs.10,000		
Total (Traveling):				**Rs.10,000**		

Table 5.2 : Traveling cost

Miscellaneous:

Description	No.	Per unit cost	Amount (Rs.)	Remarks / Justification
Research Materials & Supplies				
Software Tools / License	1	Rs.0	Rs.0	
Others			Rs.0	
Add more entries if required			Rs.0	
Sub Total:			***Rs.0***	
Other Costs				
FYP Poster	1	Rs.1,500	Rs.1,500	
Other 2				
Add more entries if required				
Sub Total:			***Rs.1,500***	
Total (Miscellaneous):			**Rs.1,500**	

Table 5.3: Miscellaneous cost

Proposed Budget

Summary:

Sr.	Description	Amount (Rs)
	Heads of Expenditure	
1		Rs.0
2	Support Staff	Rs.0
3	Equipments	Rs.78,200
4	Traveling	Rs.10,000
5	Boarding & Lodging	Rs.0
7	Miscellaneous	Rs.1,500
	Sub Total:	**Rs.89,700**
8	**Audit Charges**	Rs.0
9	**Contingency**	Rs.0
10	**Institutional/Organizational Overheads**	Rs.0
	Total Budget:	**Rs.89,700**

Table 5.4: Total cost

CHAPTER 6
PID
IMPLEMENTATION

Chapter 6

6.1Controller implementation:

In our project according to the gait of the pod we want to control the position of each six motors. As according to the gate first three motors move and complete there 360 degree rotation when these legs complete their rotation other three legs start their and process continues. So in order to track the position controller was implemented in feedback

The position of each motor is given by the encoder goes in feedback to the controller, controller measures the error and generate input for the motor according to the error this input for motor goes to H-bridges and it generates PWM for motor to track position.

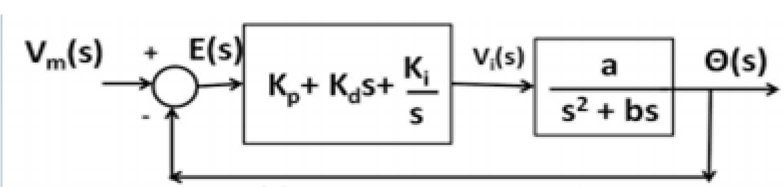
Selection of the controller for tracking the position is very important there are many type of controller present like P, PI, PD and PID. The choice of controller depends on the use.

Proportional controller is a controller in which output of the controller is proportional to the error between reference and feedback it's not good for the tracking purposes.

Proportional-integral controller integral action makes it very useful for tracking. Due to integral it tracks the reference easily and efficiently but it has a large overshoot.

Proportional-Differential controller has less over shoot so it caters the overshoot problem but it's not good for tracking the offset.

Proportional-integral-differential controller has a very good tracking and also has less overshoot because it is the combination of PI and PD, the overshoot problem of PI is eliminated by the use of PD.



$$TF = \frac{\Theta(s)}{V_m(s)} = \frac{aK_p s + K_i}{s^3 + (b + aK_d)s^2 + aK_p s + aK_i}$$

figure 6.1 : PID control of DC motor plant

There are likewise numerous sorts of controllers are being used in industry and technical projects, one such controller is PID controller. PID controller or proportional–integral–Differential controller it feedback loop mechanism is generally utilized as a part of mechanical control frameworks. A PID controller endeavors to eliminate the error between the output and a reference set point by calculating and yielding a restorative activity that can change the output. So by coordinating the PID controller to the DC motor we will be able to track the position.

Due to all these features of PID controller we have implemented it in our project to control the position of DC motor.

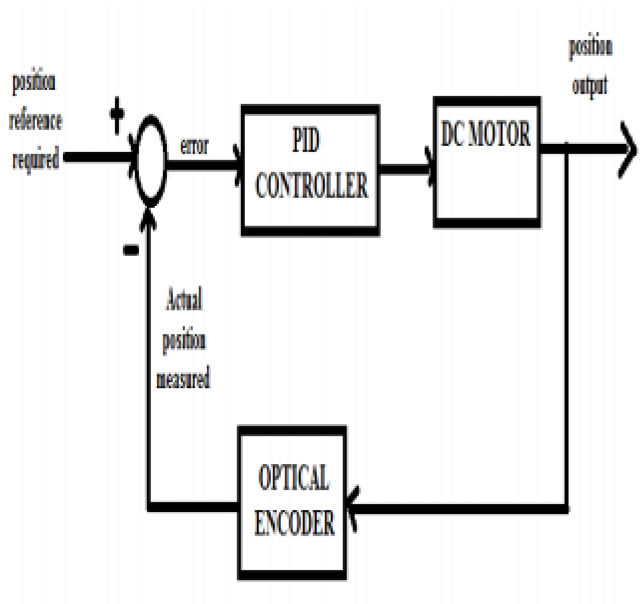


Figure6.2: PID control system

CHAPTER 7
RADIO CONTROL

Chapter 7

7.1 RC working:

When the button on RC is pressed a specific pin get connected to IC circuit and generate sequence of pulses according to the button pressed these pulses contain a sequence of synchronization pulses these pulses signal is modulated with carrier waves and produce modulated wave which are transmitted. Receiver receive these waves synchronization pulses let the receiver know that new signal is coming, receiver decode the pulse signal and provide this signal to Arduino. Then Ardunio generate signal accordingly to perform the certain task.

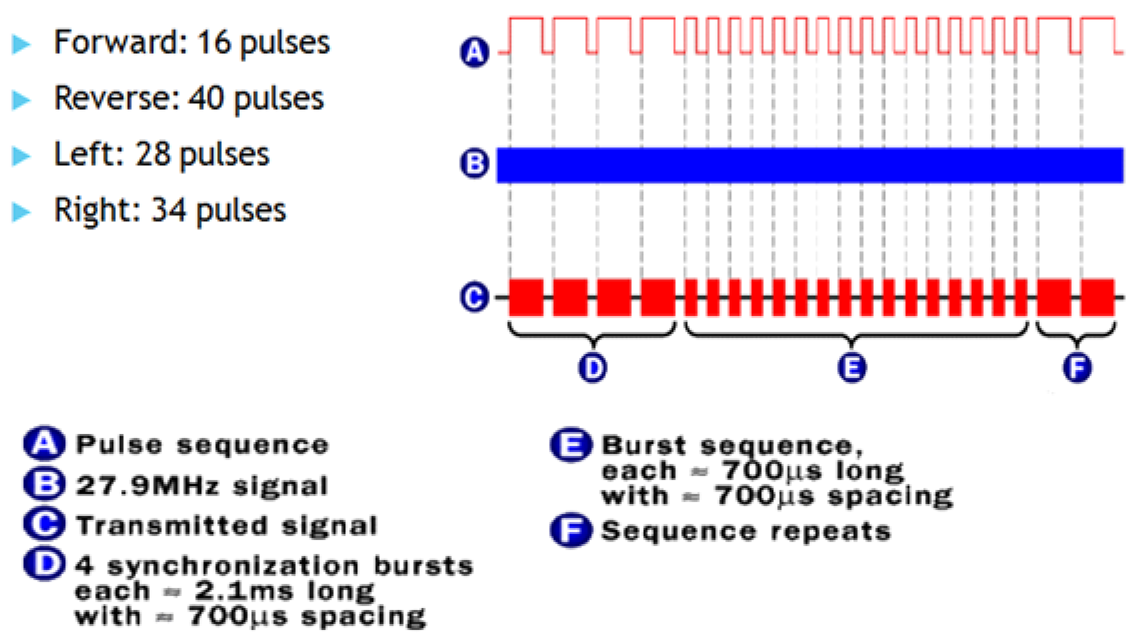


Figure7.1: RC operation

7.2Interface with Arduino:

In order to do the interface between RC and Arduino u must know the number of channels of RC u want to use. Here in this project we are using 2 channels RC. The channel pins of the RC are connected to the digital pins of the Arduino. The 5volts power is provided to the receiver by the ground and 5 volts pins on the Arduino. Arduino read the signal at the digital pins decode the instruction and then act according to the command.

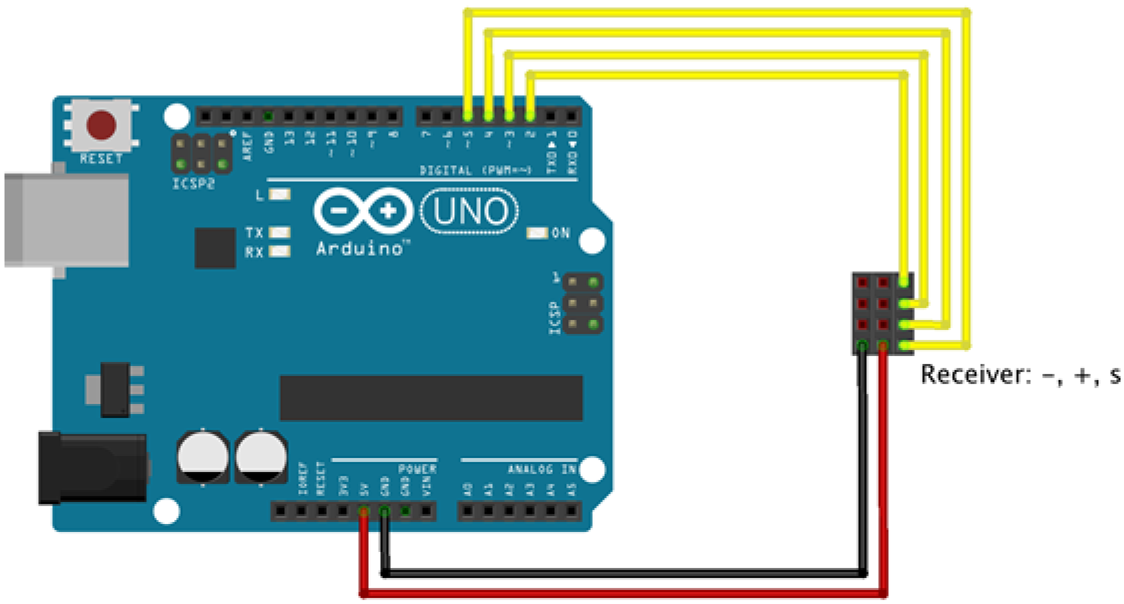


Figure7.2: connections of RC with Arduino

CHAPTER 8

LIMITATIONS

&

FUTURE WORK

Chapter 8

8.1 Conclusion and Results:

We studied the design and related work, we designed the six legged unmanned ground vehicle on the Solid works we performed simulation to test the design, we studied the torque and speed relations, we selected the components according to our requirements we implemented the design on hardware, we implemented PID control on it then interfaced it with RC.

Our Pod is successfully working and traversing rough terrains as according to our goal it has following specifications:

Mass properties of selected components
Coordinate system: -- default --

Mass = 9.08 kilograms

Volume = 0.00 cubic meters

Surface area = 0.66 square meters

Center of mass: (meters)
X = 3.29
Y = -0.51
Z = 0.82

Principal axes of inertia and principal moments of inertia: (kilograms * square meters)
Taken at the center of mass.
Ix = (1.00, -0.06, -0.02) Px = 0.04
Iy = (-0.02, 0.00, -1.00) Py = 0.04
Iz = (0.06, 1.00, 0.00) Pz = 0.07

Moments of inertia: (kilograms * square meters)
Taken at the center of mass and aligned with the output coordinate system.
Lxx = 0.04Lxy = -0.00 Lxz = -0.00
Lyx = -0.00 Lyy = 0.07 Lyz = -0.00
Lzx = -0.00 Lzy = -0.00 Lzz = 0.04

Moments of inertia: (kilograms * square meters)
Taken at the output coordinate system.
Ixx = 8.58 Ixy = -15.24 Ixz = 24.60
Iyx = -15.24 Iyy = 104.29 Iyz = -3.82
Izx = 24.60 Izy = -3.82Izz = 100.45

Figure 8.1: specifications of our project

8.2 Limitations:

While working on our project we faced few limitations.

8.2.1: Encoder limitation:

- Initially we were using magnetic quadrature encoder but the issue that occurred over there was that they were missing pulses. Due to this problem they couldn't be used for tracking. Following diagram shows that lab testing results of encoder pulses.

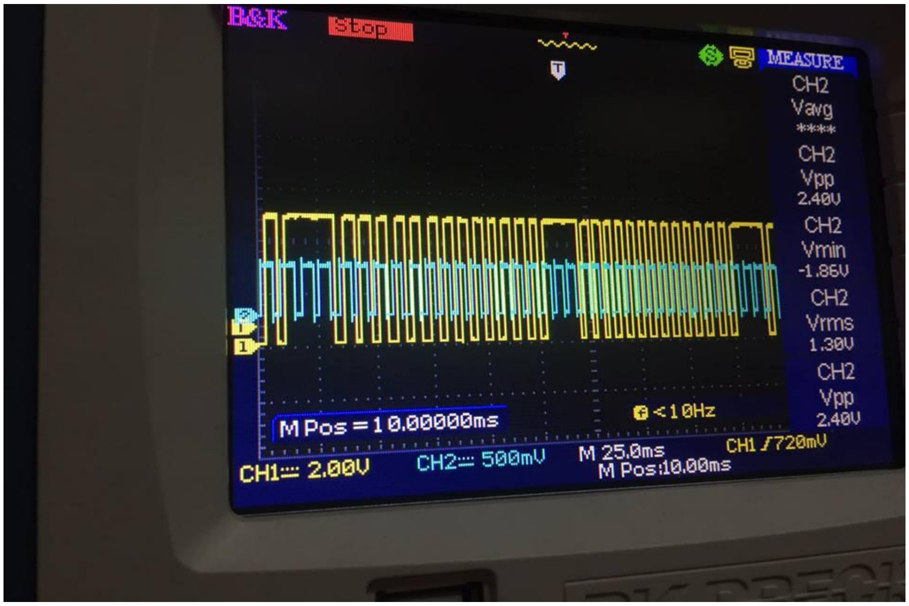


Figure 8.1: Encoder pulses

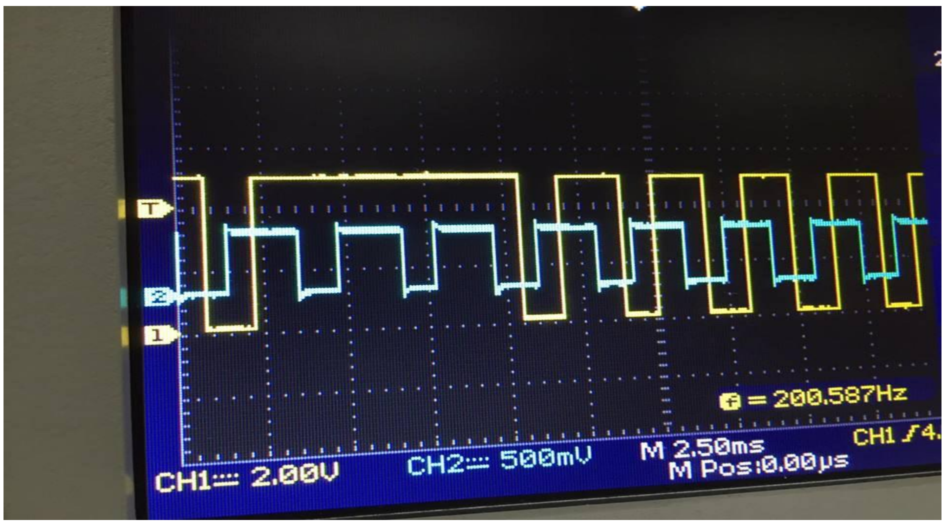


Figure 8.2: Error in encoder pulses

- When we switched to optical encoder the issue that occurred was that the number of pulses generator for CW and CCW rotation was not equal, it varied from encoder to encoder.

  E.g. it was 125 for one CW and 110 for CCW so that control could not be designed with such a large error so finally we switch to more precise SHARP optical encoders to resolve this.

8.2.2RC limitation:

Radio control that we used our project was actually a toy RC which has low range as compared to other RC but we had budget limitation, as we funded the project on our own so we couldn't afford the costly RC module. We had to make compromise on the range with cost.

8.2.3Battery limitation:

As we had budget limitations so we couldn't afford LiPo batteries initially, at start all tests were performed by the power source available in labs.

Motor rated voltage is 24 volts but we are running our system at 16volts because H-bridge turn off above 16volts, so this is affecting our desired results. We are not getting desired output. The torque produced by motor at 16 volts is less as compared to require for perfect moment

8.2.4 External constrains:

- The device need to fulfill external constrains.
- To guarantee the insurance of the client and the maker.
- To honor the demands of nature / environment such as temperature.

8.2.5 Market pressure:

In recent few years unmanned ground vehicles has been concerned to great financial and technological stress. The major priorities are now:

- Less time to market.
- Extend the offer along customization
- Reduced price.

8.3 Future works:

Future work will incorporate a formal examination of its train properties along the configuration focuses we have examined; by investigating the robot's productivity, run-time length, what's more, element capacities, we can gage the viability of our configuration decisions, grouping of tactile payloads to manufacture new sensor-based practices for robots.

APPENDIX A

Coding details

APPENDIX B

Pin diagrams

B.1

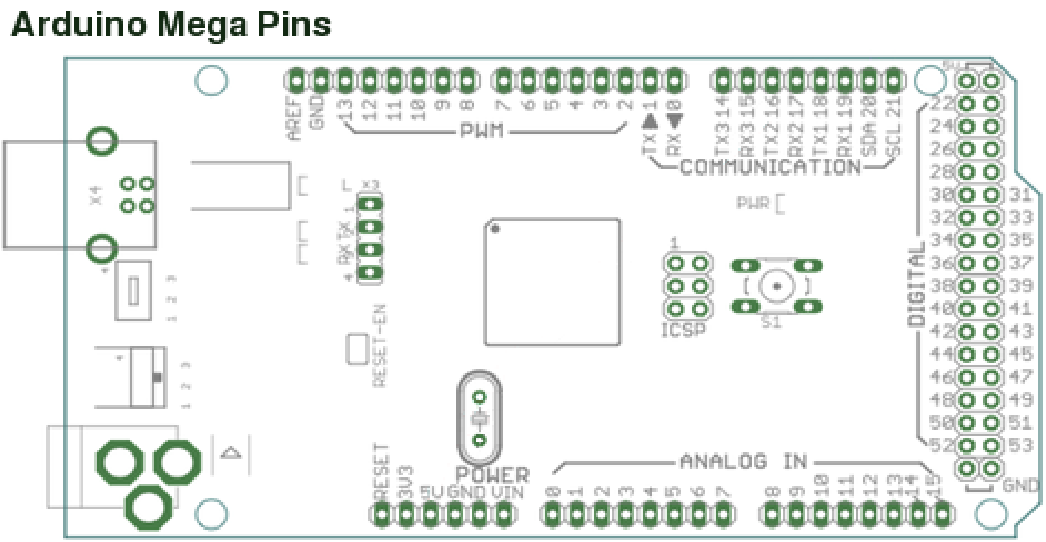
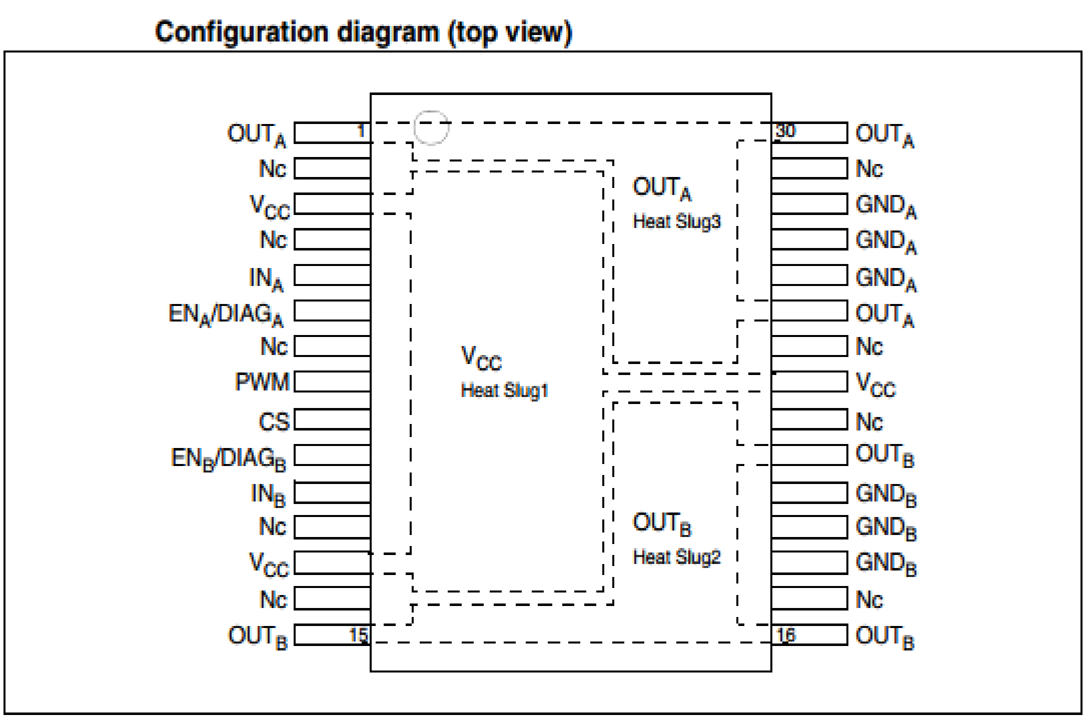


Figure: Arduino mega pin configuration

B.2 Pin configuration of Sparkfun monster motor shield



B.3 pin functions of Sparkfun monster motor shield

Pin definitions and functions

Pin No	Symbol	Function
1, 25, 30	OUT_A, Heat Slug3	Source of high side switch A / Drain of low side switch A
2, 4, 7, 12, 14, 17, 22, 24, 29	NC	Not connected
3, 13, 23	V_{CC}, Heat Slug1	Drain of high side switches and power supply voltage
6	$EN_A/DIAG_A$	Status of high side and low side switches A; open drain output
5	IN_A	Clockwise input
8	PWM	PWM input
9	CS	Output of current sense
11	IN_B	Counter clockwise input
10	$EN_B/DIAG_B$	Status of high side and low side switches B; open drain output
15, 16, 21	OUT_B, Heat Slug2	Source of high side switch B / Drain of low side switch B
26, 27, 28	GND_A	Source of low side switch A[(1)]
18, 19, 20	GND_B	Source of low side switch B[(1)]

1. GND_A and GND_B must be externally connected together.

B.4 Pin function description

Pin functions description

Name	Description
V_{CC}	Battery connection
GND_A, GND_B	Power grounds; must always be externally connected together
OUT_A, OUT_B	Power connections to the motor
IN_A, IN_B	Voltage controlled input pins with hysteresis, CMOS compatible. These two pins control the state of the bridge in normal operation according to the truth table (brake to V_{CC}, brake to GND, clockwise and counterclockwise).
PWM	Voltage controlled input pin with hysteresis, CMOS compatible. Gates of low side FETs are modulated by the PWM signal during their ON phase allowing speed control of the motor.
$EN_A/DIAG_A$, $EN_B/DIAG_B$	Open drain bidirectional logic pins. These pins must be connected to an external pull up resistor. When externally pulled low, they disable half-bridge A or B. In case of fault detection (thermal shutdown of a high side FET or excessive ON state voltage drop across a low side FET), these pins are pulled low by the device (see truth table in fault condition).
CS	Analog current sense output. This output sources a current proportional to the motor current. The information can be read back as an analog voltage across an external resistor.

B.4 DC gear motor specifications:

DC Planetary Gear Motor

力顺电机 LEISON MOTOR

LS-PG45M775

Electrical Specification

Gearbox Data

Number Of Stages	1 stages reduction	2 stages reduction	3 stages reduction	4 stages reduction	5 stages reduction
Reduction Ratio	3.7, 5.2	13.7 19.2, 26.9	50.9, 71.2 99.5, 139	188, 264 369, 516, 721	699, 977, 1367, 1911, 2672, 3736,
Gearbox length "L" mm	33.6	44.9	56.2	67.5	78.8
Max. Running Torque	6.0Kgf · cm	12Kgf · cm	20Kgf · cm	30Kgf · cm	50Kgf · cm
Max. Gear Breaking Torque	18Kgf · cm	36Kgf · cm	60Kgf · cm	90Kgf · cm	150Kgf · cm
Gearing Efficiency	90%	81%	73%	65%	59%

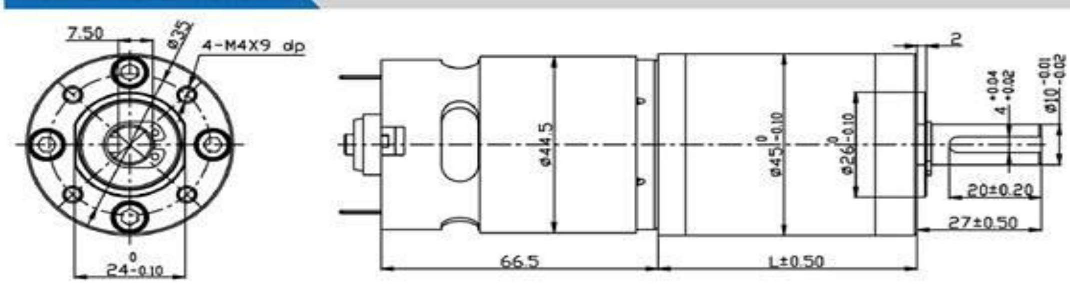
Motor Data

Motor Name	Rated Volt. V	No Load		Load Torque				Stall Torque	
		Current	Speed	Current	Speed	Torque	Output Power	Torque	Current
		mA	r/min	mA	r/min	gf · cm	W	gf · cm	mA
RS-775123000	12	≤220	3000	≤1000	2200	350	7.7	1400	3.5
RS-775124500	12	≤450	4500	≤2000	3300	500	16.5	2000	6.5
RS-775126000	12	≤900	6000	≤4000	4500	750	34	3000	13.0
RS-775243000	24	≤110	3000	≤500	2200	350	7.7	1400	1.8
RS-775244500	24	≤230	4500	≤1000	3300	500	16.5	2000	3.3
RS-775246000	24	≤450	6000	≤2000	4500	750	34	3000	7.0

1. Please refer to motor RS-775 for the motor graph.
2. After connecting motor and gearbox which is named gearmotor the output torque: motor torque X reduction ratio X gearing efficiency; output speed: motor speed /reduction ratio.

* Note: It's only typical technical data,special requirement can be customized.

Mechanical Dimension



Ningbo Leison Motor Co.,Ltd ●Http: //www.leisonmotor.cn ●Tel: 86-574-27950958 ●Add: 1-1001,No.456 Xingning Road jiangdong,Ningbo,China

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