A PROJECT REPORT

ON

"FABRICATION AND CONTROL OF SEMI-AUTONOMOUS AMPHIBIOUS ROVER"

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In partial fulfillment for the award of the Degree

Of

BACHELOR OF ENGINEERING

IN

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UNDER THE GUIDANCE

Of

Prof. RAHUL THAVAI

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CERTIFICATE

This is to certify that the project entitled

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To the Kalsekar Technical Campus, New Panvel is a record of bonafide work carried out by him under our supervision and guidance, for partial fulfillment of the requirements for the award of the Degree of Bachelor of Engineering in Mechanical Engineering as prescribed by **University Of Mumbai**, is approved.

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APPROVAL OF DISSERTATION

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ACKNOWLEDGEMENT

After the completion of this work, we would like to give our sincere thanks to all those who helped us to reach our goal. It's a great pleasure and moment of immense satisfaction for us to express my profound gratitude to our guide **Prof. Rahul Thavai** whose constant encouragement enabled us to work enthusiastically. His perpetual motivation, patience and excellent expertise in discussion during progress of the project work have benefited us to an extent, which is beyond expression.

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Preface

This project aims at the Design of Semi-Autonomous Amphibious Rover.This report contains the basic Introduction & Methodology used for Designing of Amphibious Rover along with the diagrams so that the logic may be apprehended without difficulty. Detail information, calculation with suitable pictures is provided with the report.

Attempt has been made to present the report content in simple, lucid and precise manner. Basic aim of the author has been to clarify the important concepts and to encourage the learners.

Unique features of this report are:

1. Text written in simple and easy to understand.
2. Study is done chapter wise and content are well explained.
3. Calculation shown is easy and simple.

We are grateful to **Prof. Rahul Thavai** who have shown extreme co-operation during the preparation of this report.

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Chapter 1

BASIC INTRODUCTION AND AIM OF THE STUDY

INTRODUCTION

This section is intended for readers who want to gain an understanding of the controlling system, fabrication and basics of amphibious rover and its application in modern field of technology. Amphibious rover is derived from an amphibious cycle is a human-powered vehicle capable of operation on both land and water. The study include fabrication and control system of amphibious rover.Based on the design calculation shown in "Design of Semi-Autonomous Amphibious" aforementioned book, fabrication of important peripherals are done. In further chapters reader can gain knowledge of steps involved in fabrication of different peripherals of rover and control system.

1.1 OBJECTIVE OF THE STUDY

As explained in "Design of Semi-Autonomous Amphibious" aforementioned book about amphibious rover and its various peripherals design. Therefore, this study show you about its fabrication and control system.

The objective is to fabricate all components and peripherals such as chassis, suspension system, jet drive, hull, electromechanical arm etc. The objective is to explain the control system of rover i.e. working of relay circuit, Arduino, motor driver etc. and to expound how it can be controlled semi-autonomously using alternate microcontroller such as ARDUPILOT MEGA.

The Main objective of this study is to show the step involved in fabrication and control system of amphibious rover.

1.3. PROBLEM DEFINITION

Our aim is to fabricate and control a rover which can work on land and as well as sail on water and control it wireless using radio module, and also making it work semi-autonomously.

Chapter 2

REVIEW OF LITERATURE AND STEPS INVOLVED

2.1. LITERATURE REVIEW

In Order to make a project, it is necessary that one should do a literature review and try to grasp the Base Knowledge related to project. Do the market survey to get knowledge about market condition, read various papers related to the project proposal, should do industrial survey and should surf on internet related to the postulate of project.

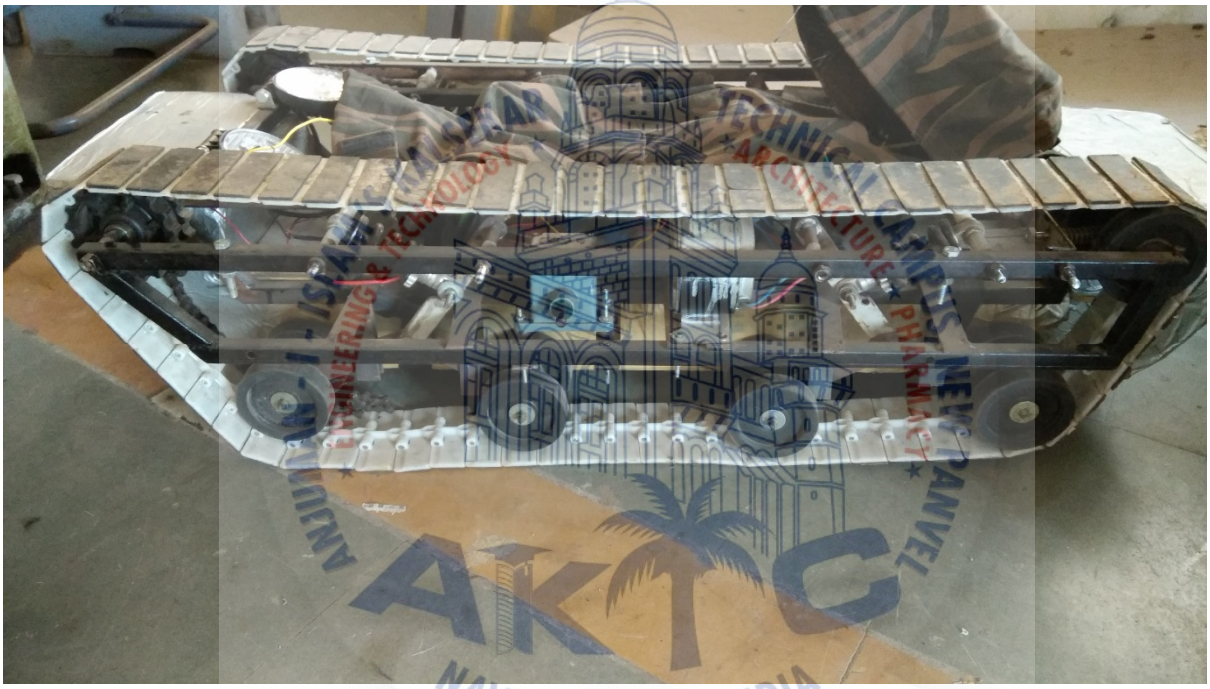
By doing this you will draw your inference regarding the materials, components, resources required in manufacturing, tools etc for the project with respect to market condition. You may get a chance to interact with the expert person for particular idea in your proposal. Expert person may endow you with some good suggestion or opinion regarding to your plan proposal. Sometimes, they can guide better, related to productions of certain assets which form as a unique part of the entire model because this kinds of parts are bit difficult to manufacture as a fresher person with negligible cognition or apprehension.

It is sometimes very necessary to surf on Internet to find your objectives plan so that you can preplan your objectives to fulfill the requirements of your outlook. Therefore, one should read the various papers related to the perception of their ideas and should try to acquire as much knowledge as can relate to that conceptualization. Surfing the internet and various blogs can lead you to build your model effectively and efficiently. It helps a lot when it comes to control part where you can find forums to communicate with people to resolve yours problems and sometimes to learn latest technologies. Some websites offers you step by step information and guide to fulfill the requirements.

Therefore one should do following things to get better proficiency regarding to the abstraction.

- Market survey.
- Industrial survey.
- Expert Advice.
- Internet Survey.

Chapter 3
Fabrication section of terra



3.1. FABRICATION OF MAIN FRAME (CHASSIS).

This chapter comprises of steps involved in fabrication of chassis of semi-autonomous amphibious rover. A chassis is a frame structure on which all the components of rover are being supported. So chassis should be rigid and according to design to provide required support and to resist the external loads

As discussed in earlier book of "Design of Semi-Autonomous Amphibious Rover" about chassis and its terminologies and also about design calculation. Base on that calculation and modeling, fabrication is done.

Steps involved in fabrication of chassis

Step 1:- Selection of material.

Material selection is an important and first step in fabrication part. According to the design material should have properties like high tensile stress, rigid, strong, tough and as well as it should be low in cost. Material should be such that it can be easily cut, grinded and welded. So according to the requirement we selected mild steel square pipes, because it provides good rigidity and it is economic.

Step 2:- Cutting of square pipe.

After selection of material, design calculations are done. Depending upon design parameters and 3D model of hull, accordingly fabrication is done. We cut the MS square pipes according to the planning and design with help of cutter machine.

Step 3:- Welding of different sections.

After cutting of the square pipes according to the dimensions it's time to weld the different sections. Initially four identical right trapezoid shaped frames are made by welding of MS square pipes. After the formation of this identical right trapezoid shaped frames, two pairs are made then. A pair consists of two right trapezoid frames bolted to each other with the help required length strut. After making two pairs like that these pairs are then welded together by the straight square pipes in between which are cut according to the dimensions. This leads to completion of fabrication of main body frame of the rover.

FIG: - MAIN CHASSIS

3.2. ASSEMBLY OF MOTORS AND GEARBOXES ON MAIN FRAME.

As per the design the motor and gearbox has to be mounted on the chassis frame. As it cannot be directly mounted on the chassis frame, few pairs of special mountings are to be made. These mountings are made by MS plate which provides better support and rigidity, and as main body frame is of same material, it is easy to attach these mountings to the chassis frame. The mountings are first attached with the main frame with the help of pairs of nut and bolt then gearboxes and motors are bolted on mounting. This is how assembly of gearboxes and motors are done on the main frame.

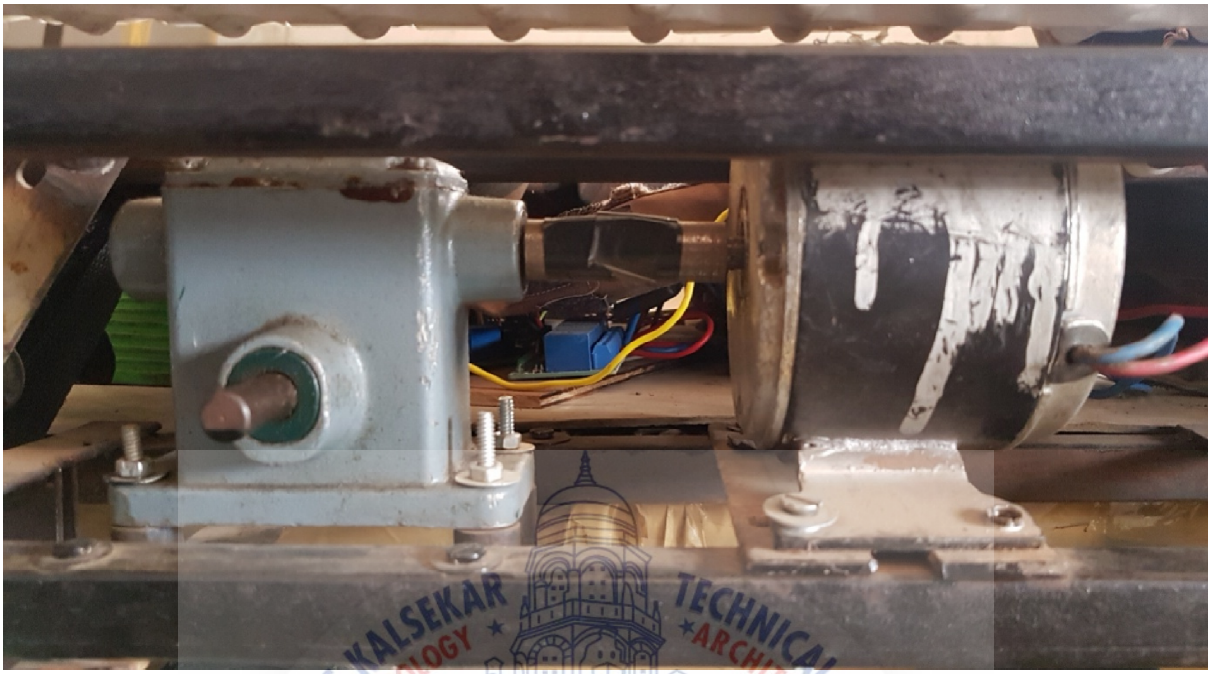


FIG: - ASSEMBLY OF MOTOR AND GEAR BOX

3.3. FABRICATION OF BELL CRANK.

Our rover can work on land and as well as on water, so for riding the rover on land we used the track system which consists of tracks, guiding wheels, suspension system, pulleys. The suspension system used is bell crank type suspension system this bell crank is made of MS plate cut in required size and shape by the cutter. On bell crank two things are mounted i.e. one is shock absorbers and other is guiding wheels. We cut the two plates of required dimensions, one plate is straight and other plate is cut in acute angle. One end of the shock absorber is mounted on the chassis frame and other is mounted on the straight plate. This straight plate is further attached by its one end in tilted condition with the chassis frame and other end with acute angled plate. The acute angled plate consists of two supporting wheels, mounted with the help strut and nuts. A pair of such bell crank system is mounted on the one side of frame and other same pair is mounted on the opposite side of frame. This whole system has following functions

1. Providing support to the track.
2. Providing suspension to the rover.
3. Act as a mounting of guiding wheels.

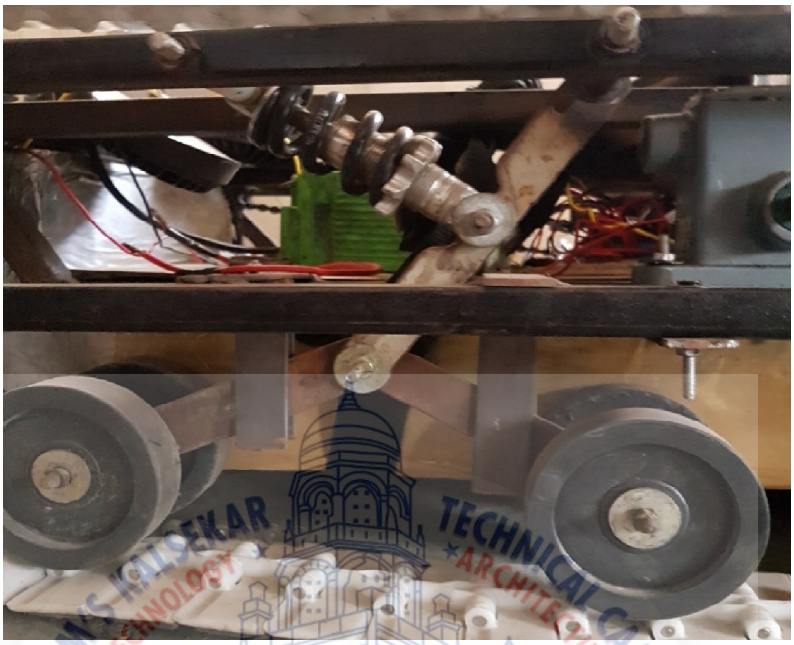


FIG: - SUSPENSION SYSTEM

3.4. ASSEMBLY OF CHAIN DRIVE AND OTHER COMPONENTS.

We are using chain drive to transmit torque from gearbox to pulley. Gearbox is coupled by the motor with help of MS coupling made by us on lathe machine. Pulley and shaft of gearbox consist of sprocket having same number of teethes. On sprocket chain is attached. As the output shat of the gearbox rotates by the motors input torque the chain starts rotating driving the pulley. As the pulley start rotating result in rotation of track. This is how the land part of our amphibious rover works. And this is how the fabrication is completed of Terra.

FIG: - CHAIN DRIVE

Chapter 4
Fabrication Section of Amphibia

This chapter show about steps involved in fabrication of hull and jet drive. In further section of this chapter, fabrication of hull and jet drive is shown.

4.1. FABRICATION OF HULL

As discussed in earlier book of "Design of Semi-Autonomous Amphibious Rover" about hull and hull terminologies and also about design calculation. Base on that calculation and modelling, fabrication is done.

Steps involved in fabrication of hull.

Step 1:- Selection of material

Material selection is important and tricky task. One should select the material on the basis of strength criteria, durability in water, depending upon environmental condition, corrosion resistance etc. By considering above factors we selected thermocol, because in our application we require little strength, thus optimizing the cost of fabrication. To improve the strength of the thermocol further action is been done i.e. making hull as a composite design by laminating it with layer of threaded tape and plywood. Thus, increasing the strength and reducing the cost. But for heavy other materials such as wood, composite material such as fibre glass, mild steel etc. is used for which cost of production is high.

Step 2:- Cutting of hull using hot wire foam cutting machine

After selection of material, design calculation are done. Depending upon design parameters and 3D model of hull, accordingly fabrication is done. We cut the thermocol in required shape using hot wire foam cutting machine as shown in picture below.

Step 3:- Increasing the strength of hull

We need to increase the strength of hull up to certain extent because thermocol has less strength. Therefore, we laminated the hull with layers of threaded tape and plywood (shown in pictures below) which increases its strength and can bear certain amount of impact load which is acceptable for our application.

4.2. FABRICATION OF JET DRIVE

As explained in the earlier book of "Design of Semi-Autonomous Amphibious Rover" about the working of jet drive (inspired by Hamilton jet drive) and its basic construction. Further, reverse engineering is done and calculations are shown in which we find the efficiency of jet drive. Depending upon the known parameters and design calculation we have to fabricate it accordingly. In this section, steps wise procedure is given by virtue of which readers can learn and get knowledge about how to fabricate jet drive.

Here are the steps involved to manufacture jet drive and the steps are as follow:-

Step 1:- Selection of peripherals components of jet drive

Since, we decided to do reverse engineering based on market condition. Motor was selected by having certain constraints parameters such as price and availability of components. We selected high rpm motor compromising with torque for better propulsion. Then we selected PVC pipe of OD 50mm, Nylon rod(used to make bush) of OD 60mm, Motor coupling, Rubber as packing material, the shaft having 6mm diameter and one of the tricky selection was jet drive propeller. We did various market survey, we search for propeller and found the plastic propeller having size of **40x52.** Speb 7 solvent is used as paste.

Step 2:- Mounting coupling on motor shaft

Since, motor shaft having less diameter than coupling ID thus having clearance fit. Therefore, packing material is used to wrap on motor shaft and fitted inside on one side of the coupling as shown in picture below. And after that screw is inserted to hold the motor shaft and coupling.

PICTURE :- COUPLING MOUNTED ON MOTOR SHAFT

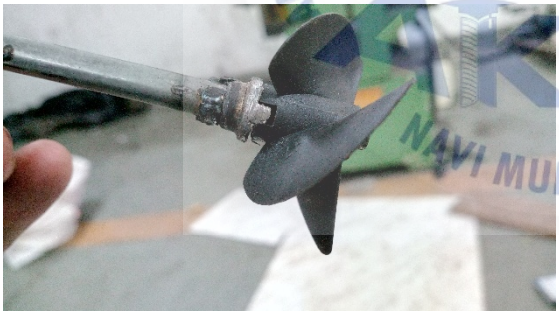
Step 03:- Fabricating propeller key

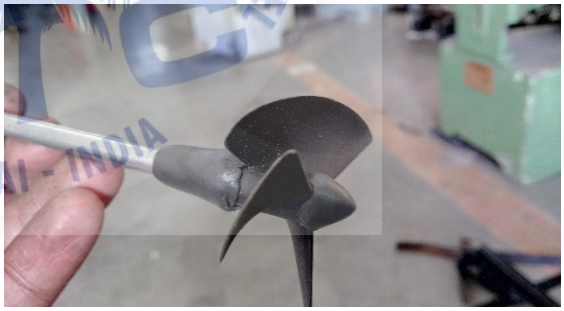
Making of custom propeller key is tricky task. It is available online but it is too costly i.e. around 350rs. Therefore, we decided to make our own thus saving the cost. We selected 8mm nut and grind it one both side, leaving the middle portion which form the key. Afterwards we welded the nut on propeller shaft as shown in picture below.

PICTURE :- KEY AFTER GRINDING ***PICTURE :- KEY AFTER WELDING***

Step 04:- Mounting of propeller on propeller shaft

After welding key, it's time to mount propeller on it. We mounted propeller on the shaft aligning key with propeller and m-seal is used to fix the propeller to the key, so that it cannot come out. It is shown in the picture below.





PICTURE :- ALIGNING PROPLLER AND KEY ***PICTURE :- APLLIED M-SEAL TO FIX PROPELLER***

Step 05:- Fabricating of bush:-

Function: The function is to separate the two compartment i.e. motor compartment and propeller compartment and also it prevent any leakage to motor compartment, thus acting as a sealant. It also act as support to propeller shaft and prevent it from vibration thus allow smooth functioning of jet drive.

We selected a nylon rod of 60mm OD, turning operation is done and reduction of diameter is done to 50mm using lathe machine. A center drill of 6mm is done to allow shaft (diameter 6mm) to pass through it. After that it is cut, 30mm in length

Step 06:- Cutting of PVC pipe

Further we cut the PVC pipe of two lengths i.e. 150mm which form propeller compartment and 200mm which form motor compartment. In propeller compartment an intake port is been cut for suction as shown in picture below.

PICTURE :- CUTTING OF INTAKE PORT

Step 07:- Sticking of bush on one side of propeller compartment

We applied speb 7 solvent on one side surface of bush and inserted up to half length on one side of compartment which is nearer to intake port as shown in picture below.

PICTURE :- APLLYING SOLVENT ON BUSHPICTURE :- BUSH IN PROPELLER COMPARTMENT

Step 08:- Coupling the propeller shaft with motor shaft

We first inserted the propeller shaft from trailing side in propeller compartment and make it pass through the bush and then we match the coupling diameter which was previously fitted to motor compartment as discussed above in step 02. After matching the center lines and hole (as

coupling has hole on it transverse plane and we made same hole on propeller shaft) of both peripherals. Then, both the peripherals were coupled by mean of screw. We wrap a tape on it as shown in picture below, so that to hold the screw in place if something wrong happens such as excessive vibration.

PICTURE :- COUPLING THE PROPELLER AND MOTOR SHAFT

Step 09:- Installation of motor compartment

Apply speb 7 solvent on motor and area of uncovered bush and gently push the motor compartment over the motor and press continuously until the motor compartment touches propeller compartment and rest on bush. Thus, whole assembly of jet drive is done as shown in picture below.

PICTURE:- FINAL ASSEMBLY OF JET DRIVE

Step 10:- Covering the other end of motor compartment

Take out the wires of motor from that side and covered the side properly with multiple layer with cartoon tape so water cannot enter in motor compartment as shown in picture below. Alternated method can be done as this was cheap and fastest method to accomplished.

PICTURE: COVERING END OF MOTOR COMPARTMENT

Chapter 5
Fabrication of Electromechanical Arm

5.1 FABRICATION OF THE ELECTROMECHANICAL ARM

The Electromechanical Arm consist of the major components

1.Frame

2.Linear Actuator

3.Rotary Actuator

4.Worm & Worm wheel Gripper Mechanism

5.1.1. FRAME

FIG: - FRAME

The frame is fabricated by 0.75”x0.75” M.S □ Pipe.

Dimensions

Length 1m x Width 0.25m

The two individual frame is assembled by using threaded steel studs.

5.1.2. LINEAR ACTUATOR

FIG: - LINEAR ACTUATOR

The linear actuator used is an electromechanical linear actuator.

Powered by 24V DC (12x2) Lead Acid Battery.

Capacity of 4000N push force & 3000N Pull force.

The Actuator have 2 Eye ends ie. One fixed and movable end.

The fixed eye end is pivoted to the rover chassis.

5.1.3. ROTARY ACTUATOR

FIG : - ROTARY ACTUATOR

The rotary actuator is a electromechanical rotary actuator.

Powered by 12V DC Lead Acid Battery

It has 270˚DOF in Y-Axis.

5.1.4. WORM AND WORM WHEEL GRIPPER MECHANISM

FIG: - WORM AND WORM WHEEL ARRANGEMENT

The main components of the gripper mechanism are

1. (12V) DC Geared Motor
2. 1 Worm & 2 Worm Wheel
3. Links
4. Gripper
5. Upper & Lower Cover
6. Mounting Studs.

The Gripper Assembly is attached on the End link of the Robotic Arm.

It have the capacity of gripping 10cm width dimension objects.

The overall lifting capacity of the Arm is 10kg.

Chapter 6
CONTROL SYSTEM

6.1 INTRODUCTION

A Control System is a device, or a collection of devices that manage the behavior of other devices. Some devices are not controllable. A control system is an interconnection of components connected or related in such a manner as to command, direct, or regulate itself or another system. Control System is a conceptual framework for designing systems with capabilities of regulation and/or tracking to give a desired performance. For this there must be a set of signals measurable to know the performance, another set of signals measurable to influence the evolution of the system in time and a third set which is not measurable but disturb the evolution.

6.2 DIFFERENT COMPONENTS

There are four main components of our control system:

1. Sabertooth
2. Relay Module
3. Transmitter and Receiver
4. Arduino Uno R3

6.2.1. SABERTOOTH MOTOR DRIVER

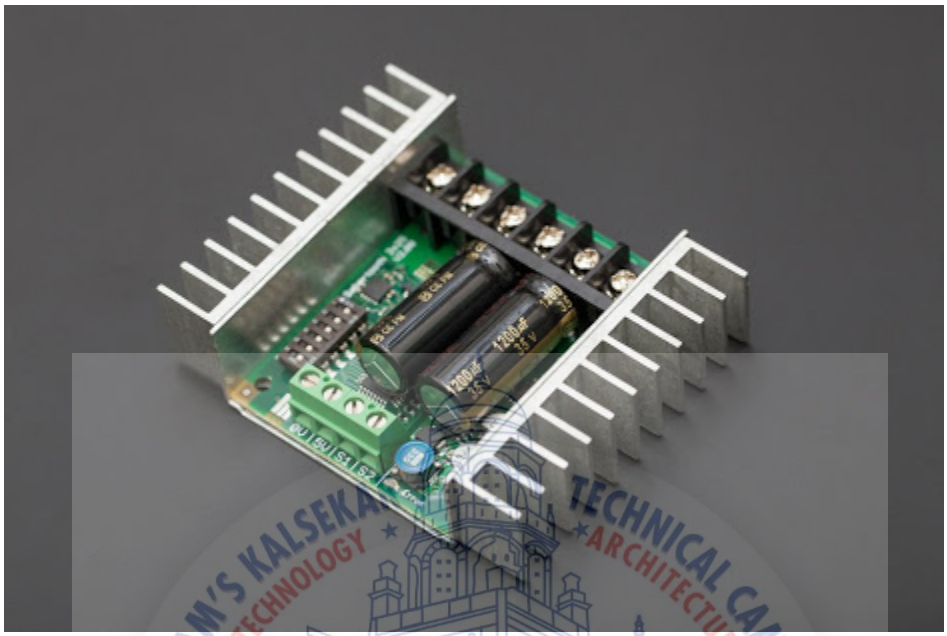


FIG:- SABERTOOTH

The Sabertooth 2X25 is one of the most versatile, efficient and easy to use dual motor drivers on the market. It is suitable for high powered robots - up to 100lbs in combat or 300lbs for general purpose robotics.Out of the box, the Sabertooth can supply two DC brushed motors with up to 25A each. Peak currents of 50A per channel are achievable for a few seconds.Overcurrent and thermal protection means you'll never have to worry about killing the driver with accidental stalls or by hooking up too big a motor.Sabertooth allows you to control two motors with: analog voltage, radio control, serial and packetized serial. You can build many different robots of increasing complexity for years to come with a Sabertooth. Sabertooth has independent and speed+direction operating modes, making it the ideal driver for differential drive (tank style) robots and more.The operating mode is set with the onboard DIP switches so there are no jumpers to lose. Sabertooth features screw terminal connectors - making it possible for you to build a robot without even soldering.Sabertooth is the first synchronous regenerative motor driver in its class. The regenerative topology means that your batteries get recharged whenever you command your robot to slow down or reverse. Sabertooth also allows you to make very fast stops and reverses - giving your robot a quick and nimble edge.

6.2.2RELAY MODULE

FIG:- RELAY BOARD

This relay module allows you to combine the processing power of the Arduino to devices that use higher current and voltage. It does so by providing four relays that are rated for 7A at either 28VDC or 10A at 125VAC.Each relay has a Normally Open (NO) and a Normally Closed (NC) contact.With these relays you can control:Appliance, Motor, Lights, other Relay etc.

The module is supplied with power via the pin labeled VCC and ground via the pin labeled GND.The relays are energized with low inputs to the IN1, IN2, IN3 and IN4 inputs. There are four relays that each provide dry contact outputs. That is to say that each relay provides a common (COM) , normally open (NO) and a normally closed (NC) terminal.

Fundamentally this is four separate circuits on one board. Other than sharing VCC and ground, the channels are isolated from one another.

We are using three 4-channel 24 volt 10 ampere relay boards.

6.2.3TRANSMITTER AND RECEIVER

FIG:- TRANSMITTER

FIG:- RECEIVER

FS-TH9X 2.4GHZ 9CH TRANSMITTER has revolutionized the way people experience RC, and now this radio transmitter can stand up to the top competitions.

FS-TH9X 2.4GHZ 9CH TRANSMITTER'S AFHDS (automatic frequency hopping digital system), is developed by FLYSKY for all the Radio Control model lovers and is patented by FLYSKY at home. The system is specially developed for all the Radio control models, that offers super active and passive anti-jamming capabilities, very low power consumption and high receiver sensitivity. With extreme rigorous testing by engineers and studying the markets for years, FLYSKY AFHDS is now considered to be the one of the best systems available in the market.

2.4GHz is the standard of new generation radio system because it has a lot of advantages. Operating at 2.4 GHz puts the radio control out of the frequency range of any 'noise' generated by the other electronic components on your helicopter – such as the brushless motor, Electronic speed controller, Servos and any metal to metal noise – eliminating interference and glitching that can affect traditional frequency system.

6.2.4 ARDUINO UNO R3

FIG :- ARDUINO UNO R3

The Arduino Uno is a microcontroller board based on the ATmega328 (datasheet). It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started.

The Uno differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega16U2 (Atmega8U2 up to version R2) programmed as a USB-to-serial converter.

Revision 2 of the Uno board has a resistor pulling the 8U2 HWB line to ground, making it easier to put into DFU mode.

Revision 3 of the board has the following new features:

1. 1.0 pinout: added SDA and SCL pins that are near to the AREF pin and two other new pins placed near to the RESET pin, the IOREF that allow the shields to adapt to the voltage provided from the board. In future, shields will be compatible with both the board that uses the AVR, which operates with 5V and with the Arduino Due that operates with 3.3V. The second one is a not connected pin, that is reserved for future purposes.

2. Stronger RESET circuit.
3. Atmega 16U2 replace the 8U2.

6.3 WORKING OF CONTROL SYSTEM

6.3.1 LAYOUT OF ENTIRE CONTROL SYSTEM

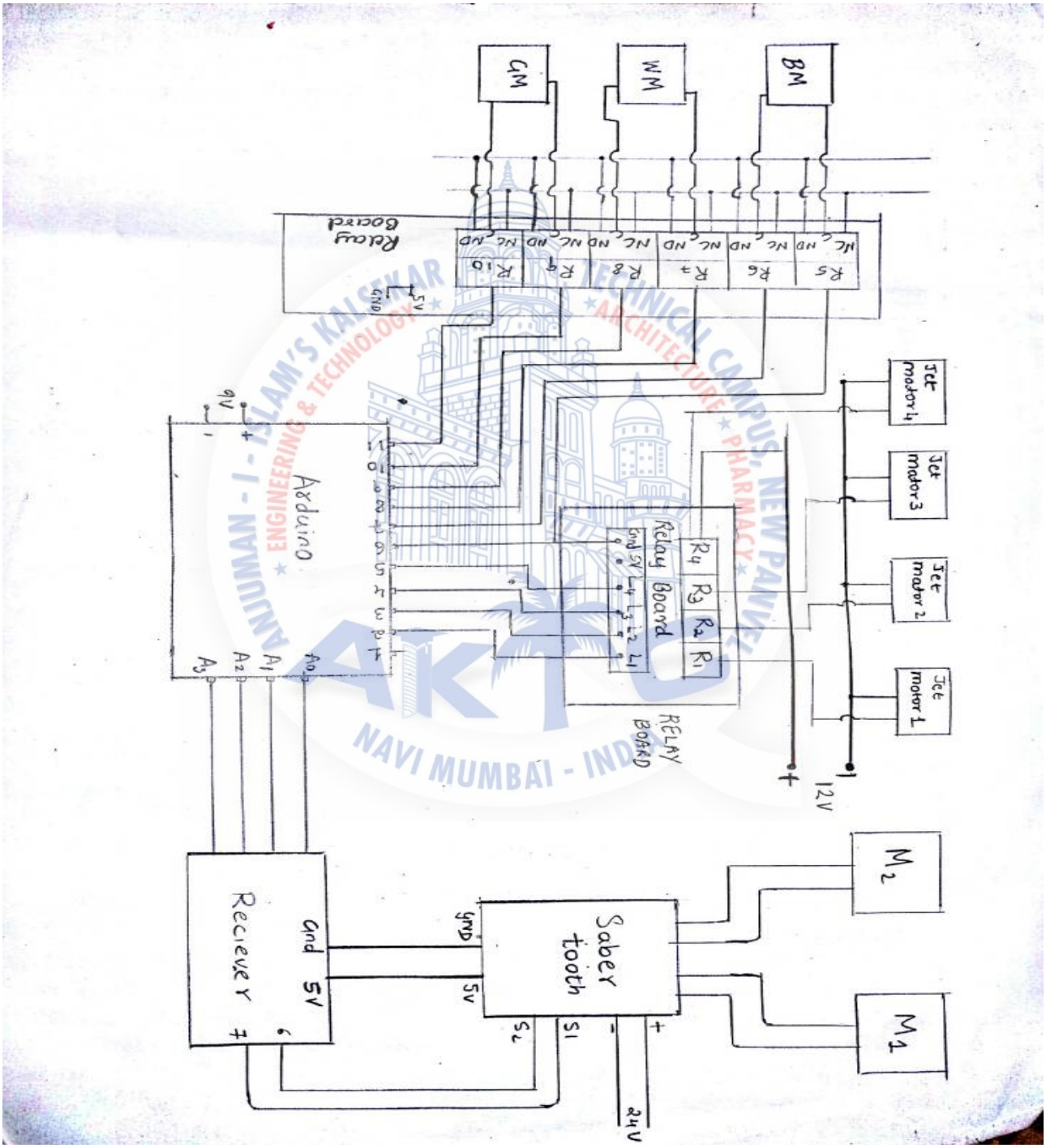


FIG:- LAYOUT OF CONTROL SYSTEM

6.3.2 OPERATION

FIG:- THREE POSITION SWITCH

FIG:- ANALOG STICKS

As our rover is going to work on land and water and also electro-mechanical arm is their so to control all these thing by a single remote we need a three position switch which is there on the remote. We divide the control part into three modes. Three position switch shuffles between these modes as per the requirement of the user.

The signals from the transmitter are fed into the arduino board via receiver. In arduino the signal is processed as per the program that is preloaded in it and accordingly the output is obtained. The output signals from arduino are given to sabertooth or relay boards. From this intermediate circuit the signal is finally given to the respective actuators. Different modes of operations are discussed ahead.

6.3.3 MODES OF OPERATION

MODE 1 [LAND MODE]:-

When the user is using MODE 1 then the output from the receiver is given to the sabertooth. In this case, the arduino board is bypassed. In transmitted the programming is done in such a way that if we are operating on MODE 1 then it will give signal to channel 6 and 7 of the receiver these channels are directly fed into the sabertooth. And from sabertooth the motor is controlled. Our rover is driven by two tracks so for forward motion both motors are run in clockwise direction and vice versa. Similarly for turning both motors are run in opposite direction. We can obtain radial as well as axial turn by using sabertooth.

MODE 2 [WATER MODE]:-

When the user is using MODE 2 then output of the receiver is given to the arduino board and from arduino the output is given to Relay Board1 which is controlling four motor two on the front side of the rover and other two mirrored to the rear side. Each motor terminal is attached to common and normally open pin of a relay. So four relay are required. At a time two relays are actuated simultaneously. In this case the sabertooth signal is cutoff. For forward motion of the rover in water the two rear motor will run and vice versa. Similarly for turning diagonally opposite motors are turned on in this way we obtain radial turning.

MODE 3 [ROBOTIC ARM MODE]:-

When the user is using MODE 3 then output of the receiver is given to the arduino board and from arduino to Relay Board2. Relay Board2 control three motors in both direction so ultimately there are six relay present on this board. Two relay are used to control one motor in both direction. Each analog stick of remote controls one motor so three sticks are required. Connections are shown in the layout.

6.3.4 ARDUINO PROGRAM

```
int rcpin1=A0,rcpin2=A1,rcpin3=A2,rcpin4=A3;
int notpin1=2,notpin2=3,notpin3=4,notpin4=5,notpin5=6,notpin6=7;
  void setup() {
  pinMode(rcpin1,INPUT);
  pinMode(rcpin2,INPUT);
  pinMode(notpin1,OUTPUT);
  pinMode(notpin2,OUTPUT);
  pinMode(notpin3,OUTPUT);
  pinMode(notpin4,OUTPUT);
  pinMode(notpin5,OUTPUT);
  pinMode(notpin6,OUTPUT);
  pinMode(8,OUTPUT);
  pinMode(9,OUTPUT);
  pinMode(10,OUTPUT);
  pinMode(11,OUTPUT);
  Serial.begin(9600);
  // put your setup code here, to run once:

}
```

```
void loop() {
 int dur1,dur2,dur3,three;
 dur1=pulseIn(rcpin1,HIGH);
 dur2=pulseIn(rcpin2,HIGH);
 dur3=pulseIn(rcpin3,HIGH);
 three=pulseIn(rcpin4,HIGH);
  Serial.println(dur1);
  if (three>1900&&three<2000)
  {
              if (dur2>1510)
              {
               digitalWrite(notpin1,HIGH);
               digitalWrite(notpin2,LOW);
               digitalWrite(notpin3,LOW);
               digitalWrite(notpin4,LOW);
               digitalWrite(notpin5,LOW);
               digitalWrite(notpin6,LOW);
               digitalWrite(8,LOW);
              digitalWrite(9,LOW);
              digitalWrite(10,LOW);
              digitalWrite(11,LOW);
               Serial.println("ARM1 up");
               }
              else if(dur2<1400)
              {
               digitalWrite(notpin2,HIGH);
               digitalWrite(notpin1,LOW);
               digitalWrite(notpin3,LOW);
               digitalWrite(notpin4,LOW);
               digitalWrite(notpin5,LOW);
               digitalWrite(notpin6,LOW);
```

```
 digitalWrite(8,LOW);
 digitalWrite(9,LOW);
 digitalWrite(10,LOW);
 digitalWrite(11,LOW);
 Serial.println("ARM1 down");
 }
else if (dur1>1510)
{
 digitalWrite(notpin3,HIGH);
 digitalWrite(notpin1,LOW);
 digitalWrite(notpin2,LOW);
 digitalWrite(notpin4,LOW);
 digitalWrite(notpin5,LOW);
 digitalWrite(notpin6,LOW);
 digitalWrite(8,LOW);
 digitalWrite(9,LOW);
 digitalWrite(10,LOW);
 digitalWrite(11,LOW);
 Serial.println("ARM2 up");
 }
 else if(dur1<1400)
{
 digitalWrite(notpin4,HIGH);
 digitalWrite(notpin1,LOW);
 digitalWrite(notpin2,LOW);
 digitalWrite(notpin3,LOW);
 digitalWrite(notpin5,LOW);
 digitalWrite(notpin6,LOW);
 digitalWrite(8,LOW);
 digitalWrite(9,LOW);
 digitalWrite(10,LOW);
```

```
digitalWrite(11,LOW);
Serial.println("ARM2 down");
}
else if(dur3>1510)
{
 digitalWrite(notpin5,HIGH);
 digitalWrite(notpin1,LOW);
 digitalWrite(notpin2,LOW);
 digitalWrite(notpin3,LOW);
 digitalWrite(notpin4,LOW);
 digitalWrite(notpin6,LOW);
 digitalWrite(8,LOW);
 digitalWrite(9,LOW);
 digitalWrite(10,LOW);
 digitalWrite(11,LOW);
 }

 else if(dur3<1400)
{
 digitalWrite(notpin6,HIGH);
 digitalWrite(notpin1,LOW);
 digitalWrite(notpin2,LOW);
 digitalWrite(notpin3,LOW);
 digitalWrite(notpin4,LOW);
 digitalWrite(notpin5,LOW);
 digitalWrite(8,LOW);
 digitalWrite(9,LOW);
 digitalWrite(10,LOW);
 digitalWrite(11,LOW);
 }
```

```
            else
            {
              digitalWrite(notpin1,LOW);
              digitalWrite(notpin2,LOW);
              digitalWrite(notpin3,LOW);
              digitalWrite(notpin4,LOW);
              digitalWrite(notpin5,LOW);
              digitalWrite(notpin6,LOW);
              digitalWrite(8,LOW);
              digitalWrite(9,LOW);
              digitalWrite(10,LOW);
              digitalWrite(11,LOW);
              Serial.println("OFF");

              }
}
else if(three>1200&&three<1400)
{
 if(dur2>1510)
 {
   digitalWrite(8,HIGH);
   digitalWrite(9,HIGH);
   digitalWrite(10,LOW);
   digitalWrite(11,LOW);
   digitalWrite(notpin1,LOW);
   digitalWrite(notpin2,LOW);
   digitalWrite(notpin3,LOW);
   digitalWrite(notpin4,LOW);
   digitalWrite(notpin5,LOW);
   digitalWrite(notpin6,LOW);
   }
```

```
    else if(dur2<1400)
    {
    digitalWrite(10,HIGH);
    digitalWrite(11,HIGH);
    digitalWrite(8,LOW);
    digitalWrite(9,LOW);
    digitalWrite(notpin1,LOW);
    digitalWrite(notpin2,LOW);
    digitalWrite(notpin3,LOW);
    digitalWrite(notpin4,LOW);
    digitalWrite(notpin5,LOW);
digitalWrite(notpin6,LOW);
     }
     else if(dur1>1510)
     {
      digitalWrite(8,HIGH);
      digitalWrite(11,HIGH);
      digitalWrite(9,LOW);
      digitalWrite(10,LOW);
      digitalWrite(notpin1,LOW);
      digitalWrite(notpin2,LOW);
      digitalWrite(notpin3,LOW);
      digitalWrite(notpin4,LOW);
      digitalWrite(notpin5,LOW);
      digitalWrite(notpin6,LOW);
      }
      else if(dur1<1400)
      {
       digitalWrite(9,HIGH);
      digitalWrite(10,HIGH);
      digitalWrite(8,LOW);
```

```
    digitalWrite(11,LOW);
    digitalWrite(notpin1,LOW);
    digitalWrite(notpin2,LOW);
    digitalWrite(notpin3,LOW);
    digitalWrite(notpin4,LOW);
    digitalWrite(notpin5,LOW);
    digitalWrite(notpin6,LOW);
     }
    else
    {
     digitalWrite(8,LOW);
  digitalWrite(9,LOW);
  digitalWrite(10,LOW);
  digitalWrite(11,LOW);
  digitalWrite(notpin1,LOW);
  digitalWrite(notpin2,LOW);
  digitalWrite(notpin3,LOW);
  digitalWrite(notpin4,LOW);
  digitalWrite(notpin5,LOW);
  digitalWrite(notpin6,LOW);

    }
}
else
{
  digitalWrite(8,LOW);
  digitalWrite(9,LOW);
  digitalWrite(10,LOW);
  digitalWrite(11,LOW);
  digitalWrite(notpin1,LOW);
  digitalWrite(notpin2,LOW);
```

```
    digitalWrite(notpin3,LOW);
    digitalWrite(notpin4,LOW);
    digitalWrite(notpin5,LOW);
    digitalWrite(notpin6,LOW);
    }
  // put your main code here, to run repeatedly:

}
```

CONCLUSION AND FUTURE SCOPE

By thoroughly going through the above chapter one can easily fabricated chassis and different assemblies like suspension assembly, motor and gearbox assembly and chain drive can be made. Electro-mechanical arm can be by referring the chapter no 5. Similarly control system is explained in detail with all the components involved and program is also given so one can easily make his/her own control system as per the requirement. Fabrication of custom jet drive is available referring which one can make it easily without much hesitation.

In future scope, we can increase the add-on like heat sensing camera, thermal sensing camera or some arrangement to clean the beaches and water bodies. Advancement can be done to make the rover fully autonomous. The number of degrees of freedom of electro-mechanical arm can be increase with some more modifications.

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