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# HEXAPOD

Hexapod is an A DRPG project by second year (Y10) UG students which started in summer 2011 as a semester long project, inspired from the arthropoda class of families.

Today robots have been divided under certain classes. One of them is limbed robots under which comes hexapod. It is a six-legged robot used for a variety of purposes, primarily related to research. The design is modelled after six-legged insects categorized by the class *Hexapoda* (Greek). Commonly known members of this class include spiders, cockroaches, crickets and grasshoppers, ants, and beetles. Hexapod robots largely mimic *Hexapoda* locomotion. Some robots are designed with the aim of better understanding how insects in the *Hexapoda* group function from a biological standpoint, while others are created as a means of channelling the efficiency of these creatures' movements into a medium that can be manipulated.

## WHAT BASICALLY HEXAPOD IS???

As per the above description Hexapod is six legged robot. Each leg has three joints so each leg has three degrees of freedom.

Because of having three degrees of freedom the leg can move anywhere in three dimension up to certain extent. Total it has six legs so by summing all the hexapod has eighteen degrees of freedom and that's why we can have various motions in 3D. It can perform various very complex steps like crawling and walking by synchronizing all six legs and eighteen joints. It is more likely a



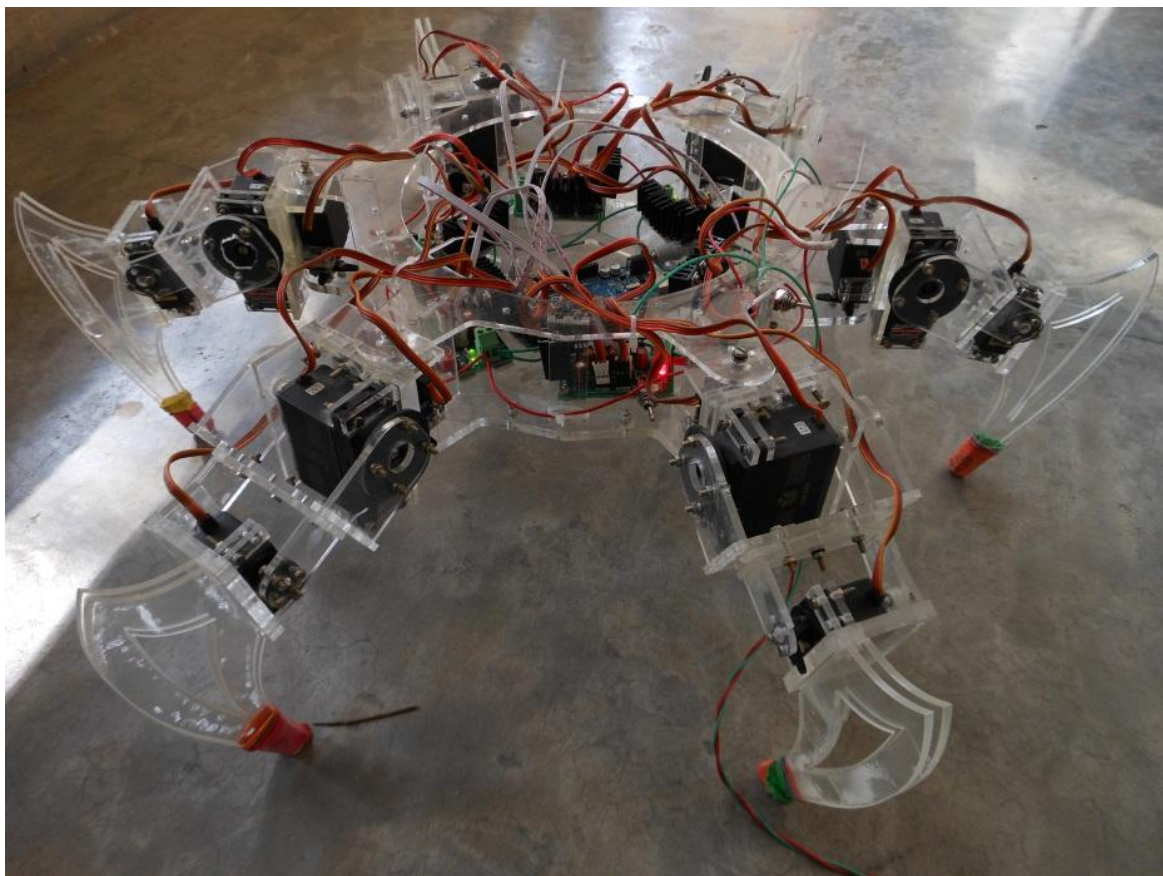
mimic of spider. A spider having six legs!!! Like a spider in the figure we can compare the hexapod in the next figure. The mechanical body frame and locomotion style is totally inspired from the spider. Like spider the hexapod synchronizes the motion of all its servo motors and moves or walk accordingly. The joints of the Hexapod are made of servo motors (servo motors can rotate generally between 0 to 180 degrees as per the requirement with constant rate. No matter how much external torque you apply up to certain limit and the limit is that of the rating of the servo motor) and they control the phi, theta and radius of the particular leg.

There are many terrain where the wheeled robot cannot go further, and cannot overcome the obstacle. However legged structure overcomes that hurdle and get away from it very easily and swiftly. The most efficient use of the Hexapod can be done in the rocky or sandy terrain where the wheels get struck the legged structure can easily be the alternative. And Hexapod is the best choice in legged



**Static Position on 3 legs**

robot because it can easily stabilize the body on three legs. So when there is a time where some legs are not in contact with the ground the other three manage to balance the body.



**Hexapod standing on all of its legs**

## **The walking of hexapod was divided in two methods:**

### **SIMPLE WALKING**

Simple walking mainly consist two major dynamics. One is picking legs and the other is to push the ground backwards to move forward. So in simple walking initially Hexapod is headed towards one of the legs. Then one by one other than the diagonal one all legs are picked and moved forward from the mean by certain angle. After picking the pushing process begins and all other four legs simultaneously push the ground backwards and the hexapod gets the motion in forward direction. And this process continues to make the bot Walk. While pushing the ground the bot moves forward but for the forward displacement and the overall balancing of the hexapod the friction plays the important role and to gain much higher friction rubber pads were used in the Hexapod.

The best thing about the hexapod is its multi directionality. So if its headed toward leg 1 and wants to take a right turn than it will just simply rotate 30 degrees about its central axis and start moving along leg 2. If it wants to move at an angle of 120 degrees will just start move along leg 3 or leg 5.

### **TRIPOD WALKING**

Tripod walking was the revolutionary algorithm of walking. This made the hexapod faster and smart walker. The whole concept of tripod walking was on the basis of balancing on three legs and maintaining equilateral triangle using alternate three legs. In this type of walking the hexapod moved on three legs at a time and at any time of walking the alternate three legs maintained equilateral triangle to avoid a lot amount of unwanted stress.

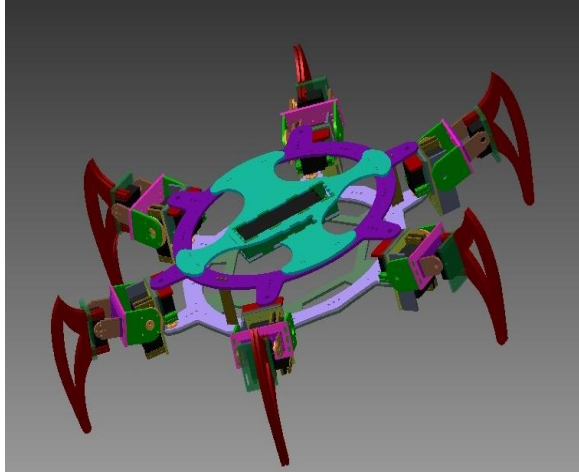
### **OBSTACLE CLEARANCE**

The main motive of making the hexapod was to overcome obstacles comes in the way where the wheeled robots are helpless. Like in rocky surface the wheeled bot cannot pass over a rocks or even small stones and in desert or in sand the wheeled bots get struck and slip. Whereas Hexapod locomotion is based on picking and pushing mechanism and its extensive stability can easily conquer rocky and sandy terrains. Due to this aspect Hexapod can be used in defence and in military applications like mine detection and spying. It can be used in research and exploration in such areas where men cannot reach such as in volcanic research. This concept can also be used for exploration and sample testing in other planets and asteroids.



# MECHANICAL STRUCTURE

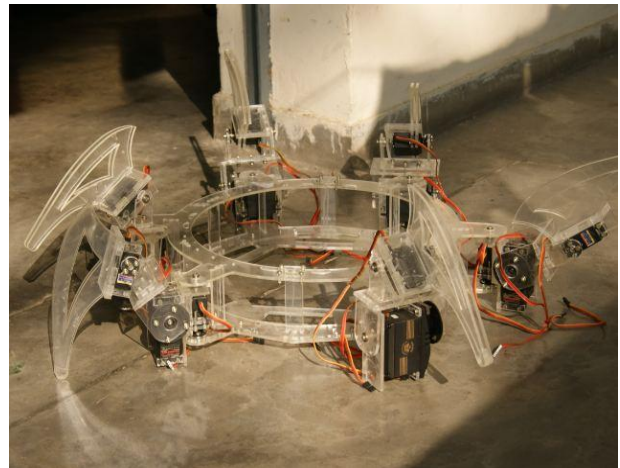
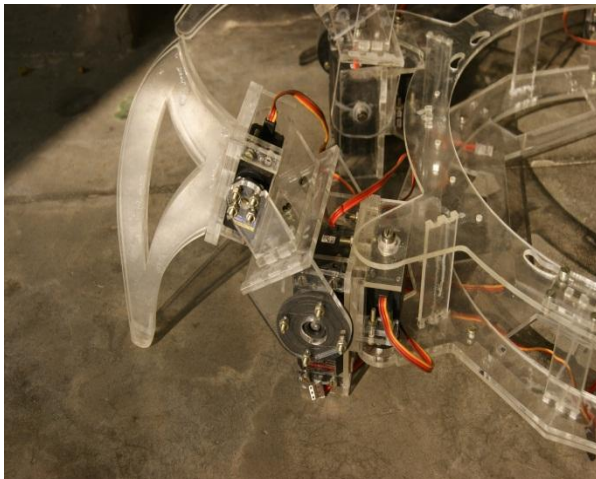
In **MECHANICAL** portion whole mechanical body frame was initially designed in Autodesk inventor professional. The body consists of six limbs and main chassis with battery holder. Each leg is having



three servo motors to have motion in three dimensions. Each and every smallest part was designed according to the precise dimension. For designing the body frame first of all we did some primary stress analysis and found the weak points and designed accordingly. Estimated the approximate moment that would be generated in the joints and then we decided the ratings of servo motors used in particular joints. The joint that is in the middle will be having higher moment compare to

the other ones so we used servos of rating 19.6 kg-cm and rest servos had ratings of 14.9 kg-cm. In the design the main aim was to reduce the weight as much as possible, make it aesthetically cool and strong as well.

To reduce weight we cut out some of the materials from legs and made the chassis totally



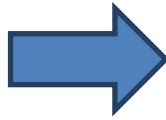
hollow. To distribute load between top and bottom plates of chassis we used twelve beams. To achieve our aim we had to choose a light and strong material and Acrylic was the perfect for us because it was light, easily machineable and could bear high amount of normal stress and easily available in market as well. Each part was manufactured by us according to CAD model on water-jet cutter. To join individual parts we used chloroform because Acrylic is adhesive to chloroform. Another advantage of making the bot of Acrylic is it is very modulus and easy and fast to assemble or disassemble. To add cushioning we put foam at the bottom of the plates and at the tip of the legs and covered the tips with balloons to get higher friction.

## Flow chart: MANUFACTURING

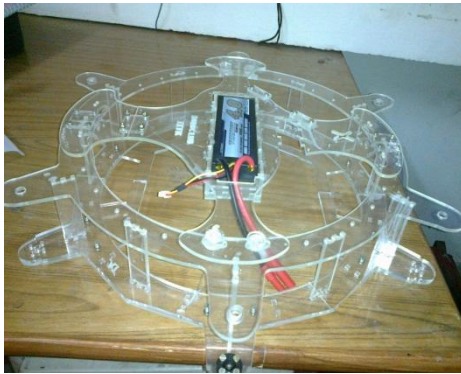
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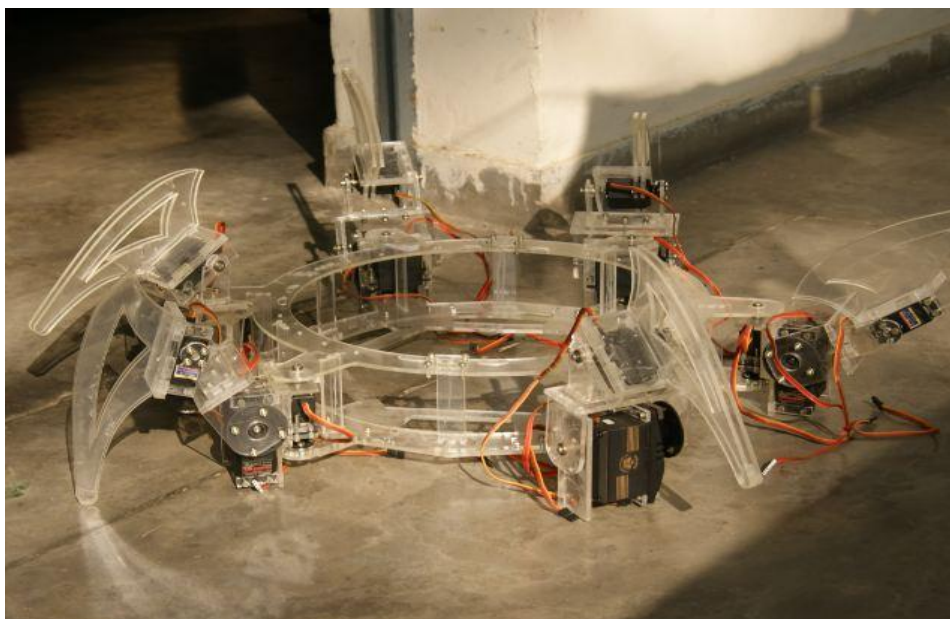
**Step1: Laser Cutting**



**Step2: Joining**



**Step3: Assembly**



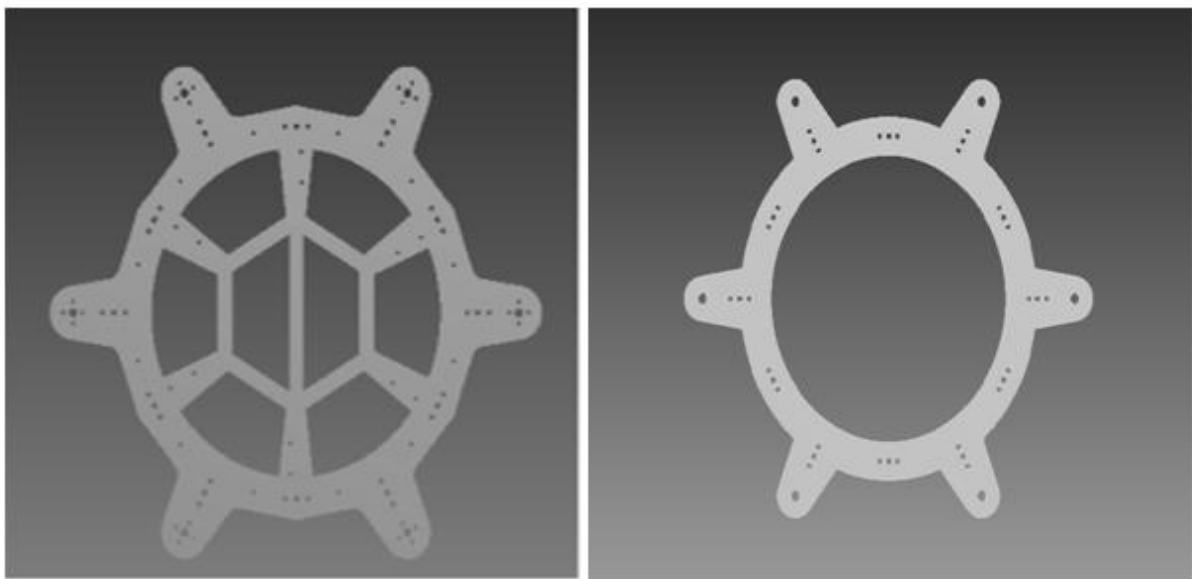
**Step4: Completed chassis**

# Major Parts:

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## 1. CHASSIS

The chassis is the circular part which has 6 protruding parts through which all the limbs are attached. The lid houses the electronic components and batteries. The material used is acrylic because of its light weight and strength. We first created a shape of the chassis on AUTODESK INVENTOR. Then the CAD file was fed into the Laser Cutter machine and we will get the required structure on an acrylic sheet



Chassis upper and lower

The upper and lower part of the chassis were spaced by 12 beams of equal size placed perpendicular to each other. This gave the body strength for all motions. The battery and switches were to be placed on a lid present at the top.



Design of the Limb

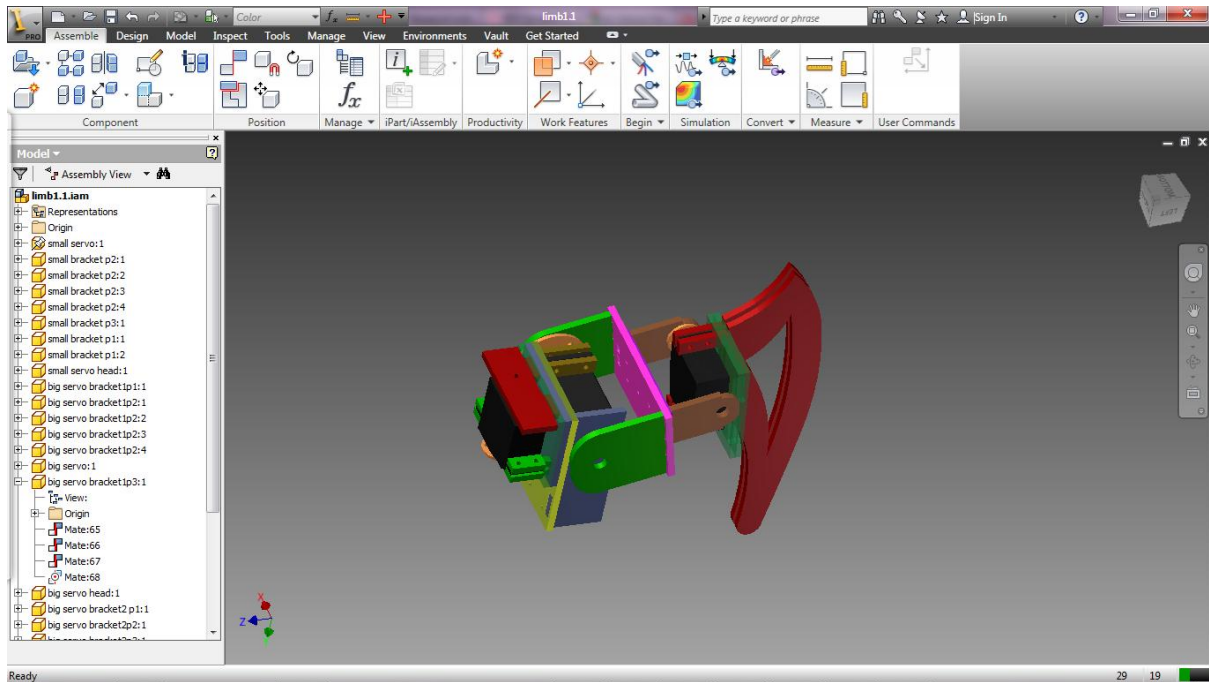


Lid: Battery holder



## 2.LIMB

Each limb of the robot has three servo motors each for providing specific degree of freedom. A servo motor has the special characteristic that it can be moved to a specific angle as per defined by the microcontroller. In this way by setting each servo at a specific configuration we can define a particular orientation for the limb. Limb basically consists of 2 U-shaped brackets, 3 servo mounting brackets and 2 leg pieces.



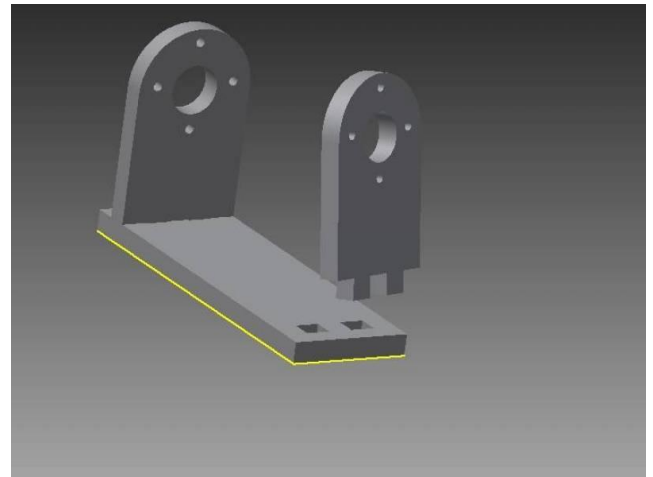
Auto Desk design of limb



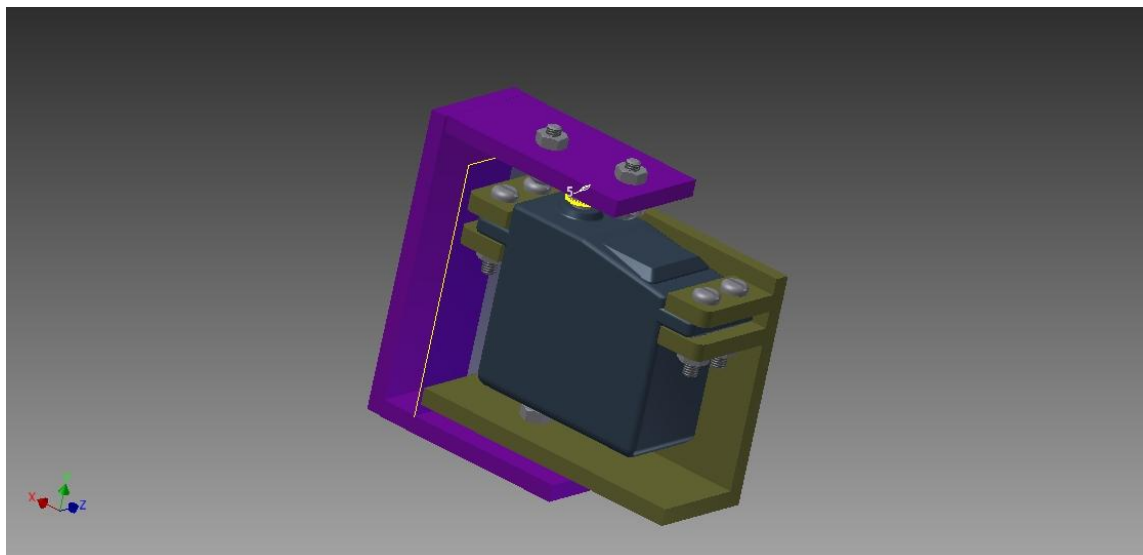
Actual Limb

These U shaped brackets are connected to the servo mounting bracket with the help of bolt fitted with bearing on one side and servo head on another so as to provide the limb joint a friction free motion. Limb has 3 high torque metal geared servos each having torque specific to task. Two servos at the two ends have a torque of 14.9 kg-cm and central servo has a torque of 19.6 kg-cm. This combination of servos provides it a smooth locomotion.

The brown coloured bracket houses the servo. It is made of acrylic sheet 3.5mm thick. The bracket is constructed by first creating 2D objects using the laser cutter at the 4i- lab and then joining them using chloroform. Chloroform acts as a solvent for the acrylate and if it is applied to two surfaces of acrylic they fuse to form one whole surface. The idea of creating the joint is illustrated in the following figure:

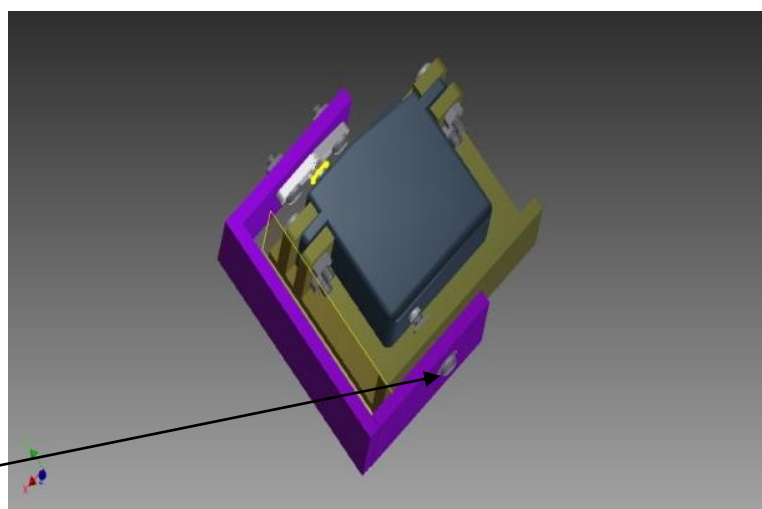


**U-Shaped bracket**



**Servo mounting bracket**

The gear of the servo will be joint with the servo head that comes with the servo. The head will be in turn joined to the bracket 2 with screws. We will also attach a ball bearing joint between the 2 brackets directly opposite the servo shaft so that the servo moves freely.

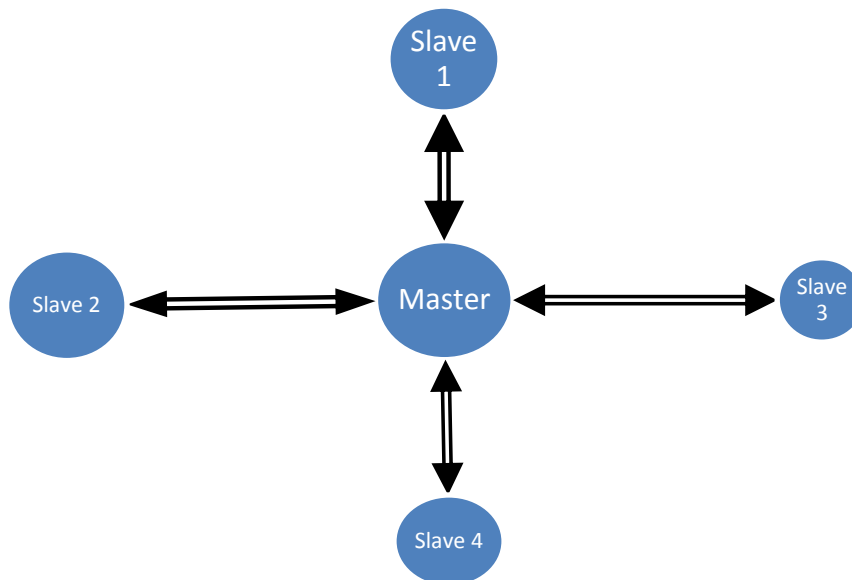


**Ball Bearing 8-3-4**

# Electronics

## Atmega 16 Platform

While designing a circuit, our main purpose was to control 6 different legs synchronously through it. In order to achieve so, we used Serial Peripheral Interface (SPI) mode of communication. In this mode we have a master controller which communicates with its slaves. Data is sent by the master to the slave and slave reflects back a response to the master.

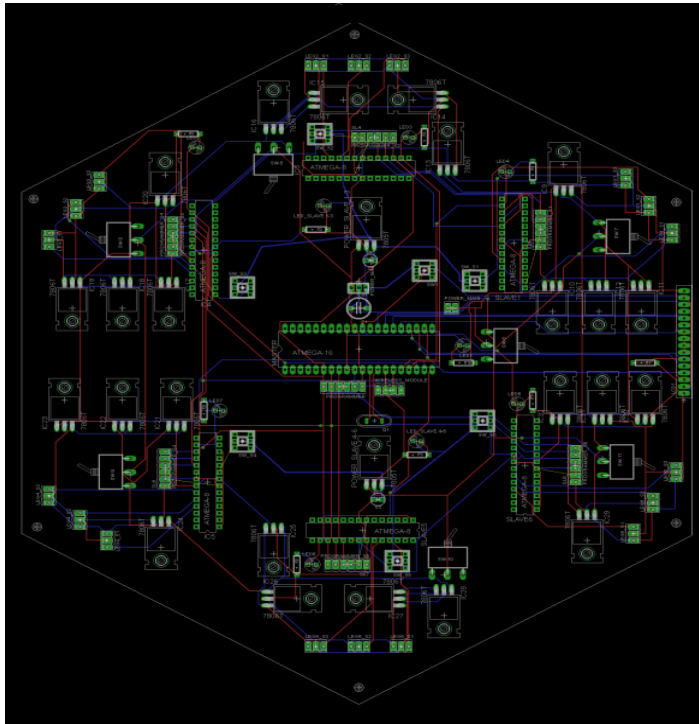


SPI MODE OF COMMUNICATION

SPI requires four lines, and is therefore often termed the “four wire” serial bus. These four lines are described in the table below.

Line	Name	Description
SCLK	Serial Clock	Output from master
MOSI/SIMO	Master Output, Slave Input	Output from master
MISO/SOMI	Master Input, Slave Output	Output from slave
SS	Slave Select	Output from master (active low)

The master, as its name suggests, controls all communication. By controlling the clock, the master decides when data is sent and received. Within each clock cycle a full duplex communication is carried out; each side sends and receives one bit of information. Because there is no standard communication protocol, the master can either send data or both send and receive data, depending on the needs of the application. Likewise, the slave can either receive data or both receive and send data back to the master.



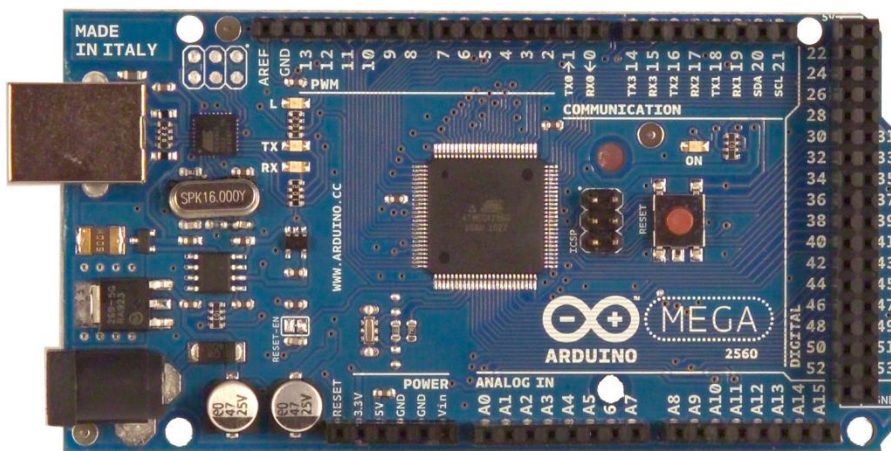
We used an Atmega16 as a master and six Atmega8 microcontrollers as slaves to obtain the desired controlling. One Atmega8 controls a particular leg. The centre IC in the picture is the Atmega 16. We provide signals to the atmega8 uC which are on the six different sides of the hexagon. Each time the master selects some of the slaves and sends a data bit according to which the slave executes a code in it.

Power is delivered to a central junction and then dispatched to different part of the circuit. IC7805 is used to power microcontrollers and IC7806 is used to power the servo motors. IC 7805 is used to get an output voltage of 5 volts and IC7806 is used to

get an output voltage of 6 volts. The microcontrollers work on an input voltage of 5 volts whereas; the servo motors work on a voltage of 6 volts. Since, we have 3 servo motors on each leg we have used four IC7806 to provide the required amount of current for each leg. Each leg segment also contains a switch which monitors the power input for that leg.

The circuit was designed on software named Cadsoft Eagle. First, a schematic of the connections are made which are then converted to a brd file. On the brd file we place the components keeping in mind the best fit and length of the connections.

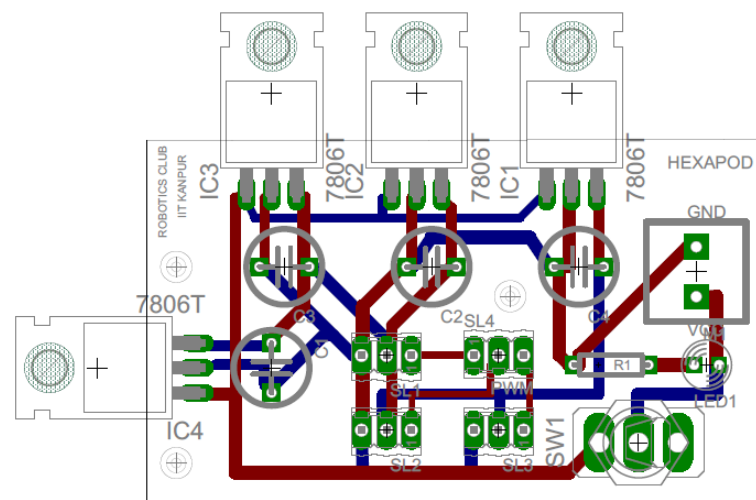
## Arduino Platform





The Arduino Mega 2560 is a microcontroller board based on the ATmega2560. It has 54 digital input/output, 16 analog inputs, 4 UARTs, a 16 MHz crystal oscillator, a USB connection, a power jack and a reset button.

After we switched to the Arduino platform, we decided to make modules to control the legs. The Arduino board helped us in generating 18 different PWM signals. The modules are basically meant for distribution of power and PWM signals. Three PWM signal connections were drawn from the Arduino board for each of the six modules. These 3 signals were divided and given to three connectors along with Vcc and GND pins. The module has four IC 7806 for power and has a switch to turn a leg ON or OFF. Three servo motors are attached to one module.



**Power Module of individual Limb**

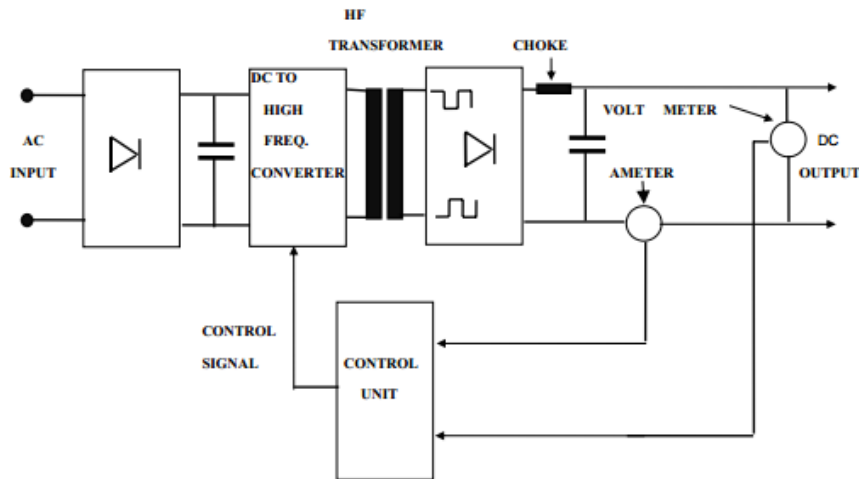
**P.S.** The Schematics of these designs as well as the complete board design files are available in the disc attached to this report.

## Power Supply

### 1]SMPS

One of the most important aspect of running any circuit is power. Required voltage and current to the components should be provided so that proper functioning of them could be achieved. For running 18 servo motors we needed a lot of current. Also, the voltage rating of the supply should also meet the voltage ratings of different components on the circuit. We used SMPS supply for running the electronics. A switched-mode power supply (SMPS) is an electronic power supply that incorporates a switching regulator in order to be highly efficient in the conversion of electrical power. Like other types of power supplies, an SMPS transfers power from a source like the electrical power grid to a load while converting voltage and current characteristics.

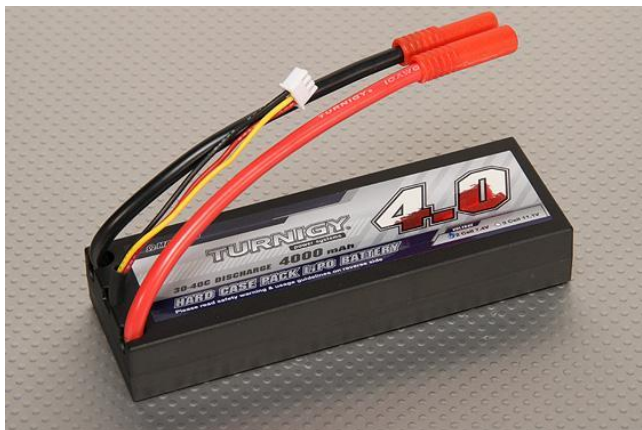
This unit was supplied 220V AC power supply normally present in our distribution supply. The output was a DC voltage supply of 12 V which was connected to the power modules of the limbs and the arduino motherboard.



**BLOCK SCHEMATIC - TWO STAGE CONVERSION SMPS TECHNIQUE**

## 2] LiPo Battery

Another mode of power supply that we used was a 7.4Volt Lithium Polymer (LiPo) Battery. The LiPo battery provides a large amount of current for a long duration of time. It is easily rechargeable. It also does not weigh heavy, so it doesn't add up much to the weight of the robot.



### Specifications of LiPo battery that we used

Capacity: **4000mAh**

Voltage: **2S / 2 Cell / 7.4v**

Discharge: **2C Constant**

Weight: **133g**

## Problem faced with power supply

One Problem that we faced during the last stages of the work was that some legs were behaving in a random manner when the code was being executed. This led to a complete collapse of the functioning of the robot. We tried many ways to cope with the problem. We used different servo motors. We made changes in the circuit. Even the code was sorted out for errors. But, after many failed attempts of debugging we came to know what the real problem was. The length of the wire that we were using was around 5 metres and the resistance was around .12 ohms per metre. So, there was a resistance of .6 ohms in the wire which does sound to be a big resistance value. But, when a current of more than 10 A is flowing through these wires it leads to a potential drop of around 6 Volts. So, because of such a large voltage drop the servo motors were behaving arbitrarily. As a counter for this we used thicker wires of shorter length to power the circuit. Resulting the robot to again came back to its working condition.

# Programming

**PROGRAMMING,** was a tedious and important aspect of the project. There are 18 servos in Hexapod and programming was the responsible for the synchronous motion of 18 servos at a particular time.

The programming was done on two platforms, namely CV AVR platform and the "ARDUINO" platform. Both are based on the language used was "C". In programming "Mean-Delta" method was used. In this method we first took reference of a particular position of leg and calculated servo angles for the position and then we gave command assigning those angles as mean. We followed layered structure in our programming which was the most systematic one.

The most important thing was to make this bot walk rest other were quiet simpler. Walking consists of sliding and picking as well as tripod walking.

The code was built keeping in mind the ease of use , easy to debug and should extract the maximum from the given mechanical structure .

## Algorithm

Limb movement in natural world follows the principle of least action. What that means is to move from point 'A' to 'B' the "action" of the limb is minimised. On the same lines the code calculates the least action and moves all the three joints to give the smoothest possible motion.

Features of the hexapod code library:

- 1) The code is very modular and has a single central function responsible for the whole motion of the hexapod. Doing this the code can be edited very easily for a new change in hardware.
- 2) The code is so flexible that any mechanical system with three servo joints can be controlled with it. This code was once used to run a robotic fish being developed by Bhanu Pratap Solanki under Prof. L Behera.
- 3) As with any good code to control a complex hardware system the code for hexapod has been organised layer wise this allows controlling basic function like moving a servo to controlling the speed and direction of walking.

"The current version is only thousand lines long but can be used to make the hexapod do command it to perform any sequence of steps from dancing to walking."

**P.S.** The code has been thoroughly documented and is available in the disc attached to this report under the section of arduino codes.

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Video: <http://www.youtube.com/watch?v=u5d0L93P0DU>

Related links: <http://students.iitk.ac.in/roboclub/data/projects/summer11/hexapod.pdf>

<http://students.iitk.ac.in/projects/roboticsclub/hexapod>

<http://students.iitk.ac.in/roboclub/>