

e-YSIP 2022

# SELF BALANCING ROBOT DEVELOPMENT



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## Abstract

Spark interest and lessen the burden in learning/Explaining the concepts of Control systems / Robotics / Embedded systems among students, Hobbyist, Kids, Teachers and Professors. and so to develop a Self Balancing robot which can be assembled from a kit and can also act as a toy.

## Completion Status

The work began with conducting market surveys to find similar products online and conducting interviews among various user personas to get their views and so to categorize the needs and wants. After that, CAD designing of the bot was carried out and completed. The necessary parts were procured, laser cut and 3D printed and the bot has been fabricated fully. PCB designing and wiring has also been done and the PID values have been tuned to make the bot balance itself.

## Hardware Parts

Table 1: List of Hardware Components

Sl.No	Component	Qty	Sl.No	Component	Qty
1.	eYFI Board	1	15.	Extension PCB	1
2.	Deadweight	1	16.	Motors	2
3.	85mm Wheels	2	17.	GearBox	2
4.	8-array Line Sensor	1	18.	Battery	1
5.	Large Bearing	2	19.	Small Bearing	8
6.	Hercules Motor Driver	2	20.	Lid for Gearbox	2
7.	Height Adjusting Gears	2	21.	Castor Wheels	2
8.	LeadScrew	1	22.	14.5cm Spacers	4
9.	HC-Sr04 Ultrasonic Sensor	1	23.	OV7670 Camera	1
10.	1.3" OLED	2	24.	GY87 Gyro Sensor	1
11.	Driver Gear	2	25.	Driven Gear	2
12.	IR-Obstacle Sensor	4	26.	1cm Spacers	4
13.	4cm Spacers	4	27.	5cm Spacers	4
14.	Cover-Back	1	28.	Cover-Front	1
15.	Cover-Bottom	1	29.	Acrylic Plates	5

## Details of each Hardware

### 1. eYFI Board

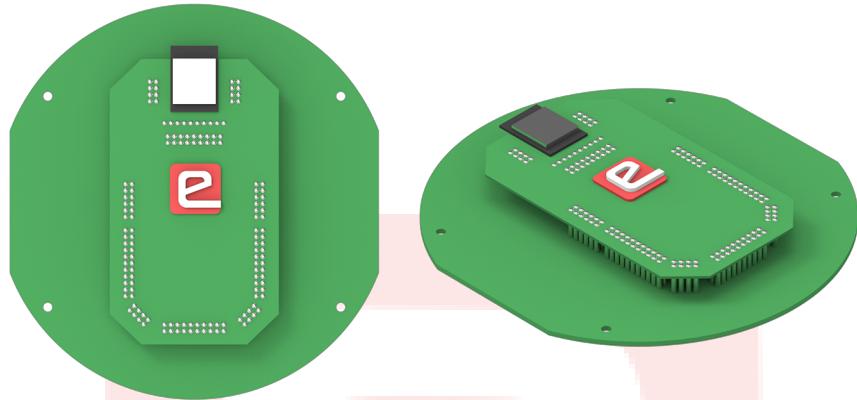


Figure 1: eYFI board with Extension board

Table 2: eYFI board details

<b>eYFI Dimensions(L*W*H)</b>	6.4cm * 1.7cm * 11cm
<b>Extension PCB Dimensions(L*W*H)</b>	14cm * 0.2cm * 15cm
<b>Programming Mode</b>	USB/OTA
<b>Microcontroller</b>	ATmega2560 & ESP32
<b>Operating Voltage(ATmega2560)</b>	5 V
<b>Operating Voltage(ESP32)</b>	3.3 V
<b>INPUT VOLTAGE (RECOMMENDED)</b>	7V - 12V
<b>INPUT VOLTAGE (LIMIT)</b>	6V - 20V

## 2. 85mm Wheel

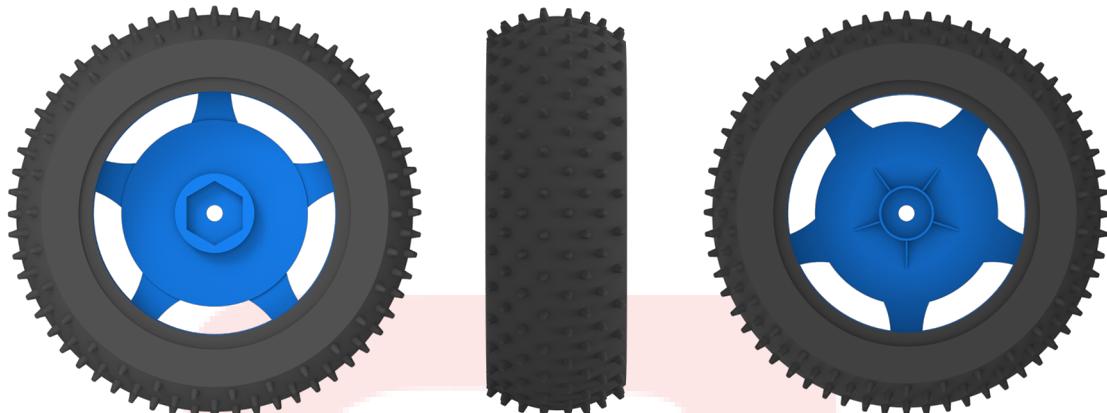


Figure 2: 85mm Wheel

Table 3: 85mm Wheel details

<b>Dimensions(L*W*H)</b>	8.5cm * 3cm * 8.5cm
<b>Material</b>	Rubber & Plastic
<b>Link to Buy</b>	<a href="mailto:85mmWheel@Robu.in">85mmWheel@Robu.in</a>

### 3. GearBox



Figure 3: Gearbox

Table 4: Gear Box Details

<b>Dimensions(L*W*H)</b>	7.5cm * 3.6cm * 6cm
<b>Material</b>	Polylactic acid(PLA) (3D printed)
<b>Small Hole Dia</b>	1.75cm
<b>Large Hole Dia</b>	2.15cm
<b>Screw Hole Dia</b>	0.4cm

#### 4. 8-array Line Sensor

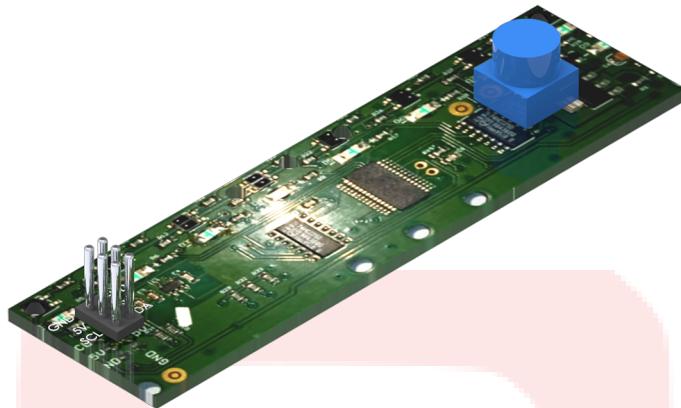


Figure 4: 8-Array Line Sensor

Table 5: Line Sensor Details

<b>Dimensions(L*W*H)</b>	10cm * 2.8cm * 1.3cm
<b>No. of Photodiode</b>	8
<b>Input Voltage</b>	5V
<b>Communication Protocol</b>	I2C
<b>Link to Buy</b>	<a href="#">Products @ eyantra</a>

## 5. Battery

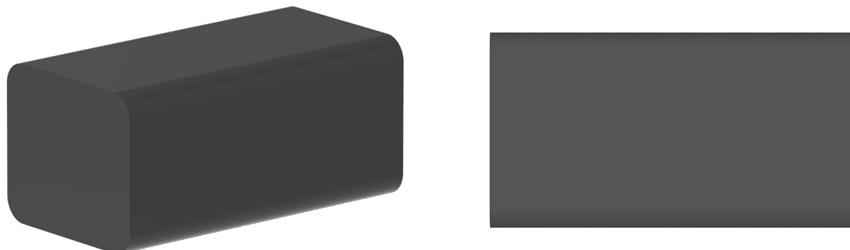


Figure 5: 2200mah battery

Table 6: Battery Details

<b>Dimensions(L*W*H)</b>	6.5cm * 3.5cm * 3cm
<b>Current capacity</b>	1300mah
<b>Voltage capacity</b>	11.1 V
<b>Link to Buy</b>	<a href="#">Robu.in</a>

## 6. Bearing

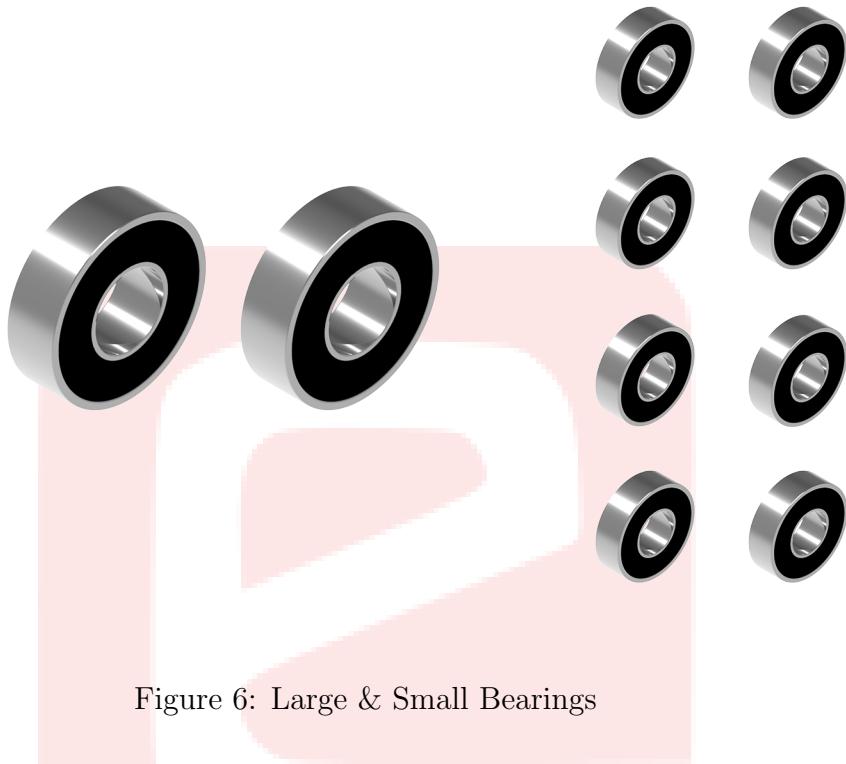


Figure 6: Large & Small Bearings

Table 7: Bearing Details

Large Bearing	
<b>Dimensions(L*W*H)</b>	3.4cm * 1cm * 3.4cm
<b>Inner Dia</b>	1.5cm
Small Bearing	
<b>Dimensions(L*W*H)</b>	1.6cm * 0.5cm * 1.6cm
<b>Inner Dia</b>	0.6cm
<b>Link to Buy</b>	<a href="#">Large Bearing</a>
<b>Link to Buy</b>	<a href="#">SmallBearing @ Robu.in</a>

## 7. Hercules Motor Driver

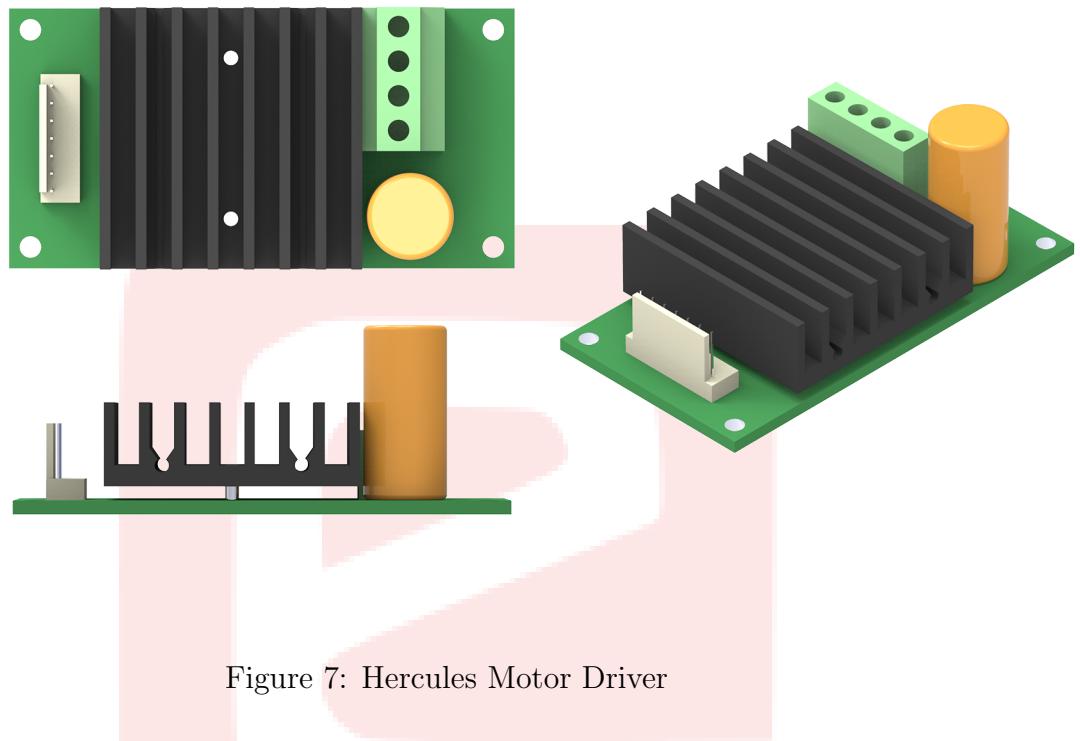


Figure 7: Hercules Motor Driver

Table 8: Motor Driver Details

Dimensions(L*W*H)	7.1cm * 2.5cm * 3.65cm
Logic Input Voltage (Recommended)	5 V
Operating Voltage (Recommended)	12 V
Operating Voltage (Limit)	6 V - 36 V
Link to Buy	<a href="#">@NexRobotics</a>

## 8. Driver and Driven Gears

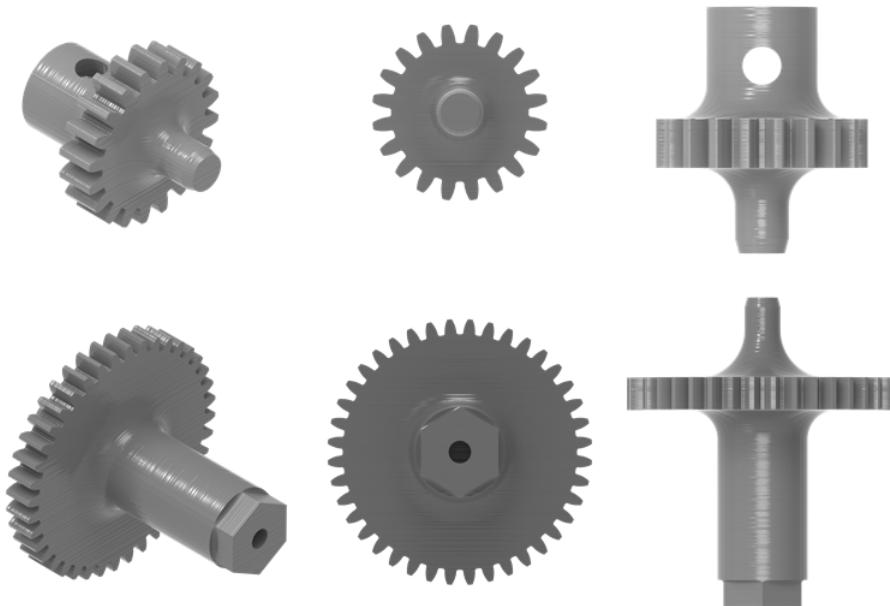


Figure 8: Driver and Driven gears

Table 9: Driver and Driven Gear Details

	Driver gear	Driven gear
<b>Num of Teeth</b>	20	40
<b>Addendum dia</b>	2.2cm	4.2cm
<b>Pitch circle Dia</b>	1.96cm	4cm
<b>Dedendum Dia</b>	1.78cm	3.72cm
<b>Large shaft dia</b>	1.15	1.4cm
<b>small shaft dia</b>	0.56	0.56cm
<b>Module</b>	1mm	
<b>Face width</b>	0.5cm	
<b>Gear Ratio</b>	2:1	

## 9. Height Adjusting Gears

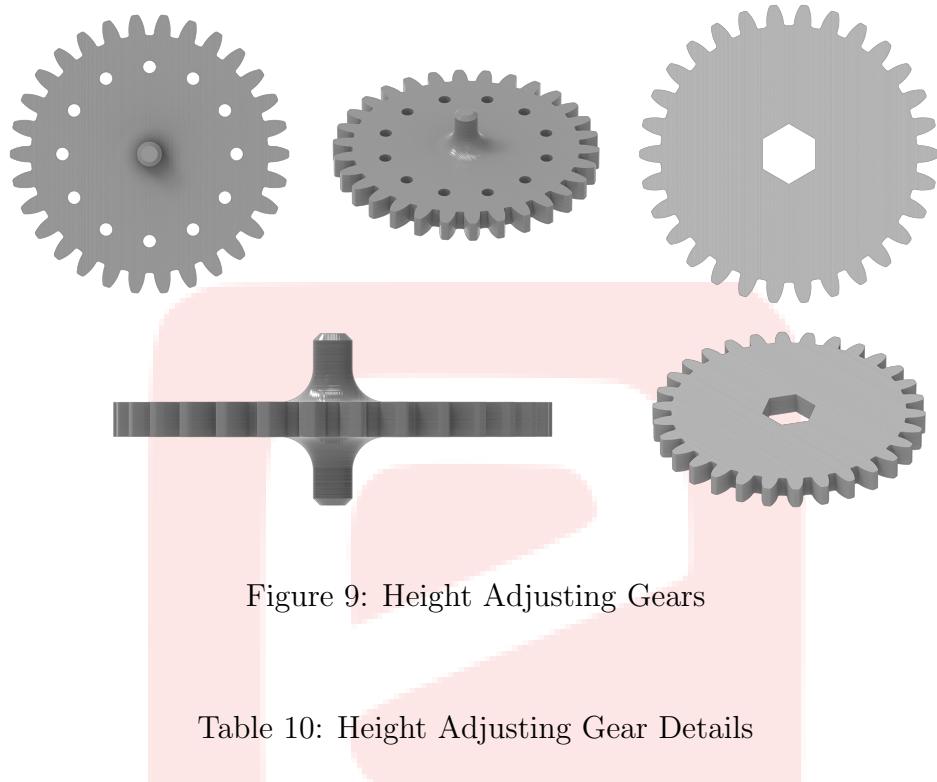


Table 10: Height Adjusting Gear Details

	Main Gear	Side Gear
<b>Num of Teeth</b>	30	30
<b>Addendum Dia</b>	6.4cm	6.4cm
<b>Pitch Circle Dia</b>	5.98cm	5.98cm
<b>Dedendum Dia</b>	5.6cm	5.6cm
<b>Face Width</b>	0.5cm	0.5cm
<b>Shaft Dia</b>	.	0.56cm
<b>Material</b>	Polylactic acid (PLA)	
<b>Module</b>	2mm	
<b>Gear Ratio</b>	2:1	

## 10. Castor Wheels

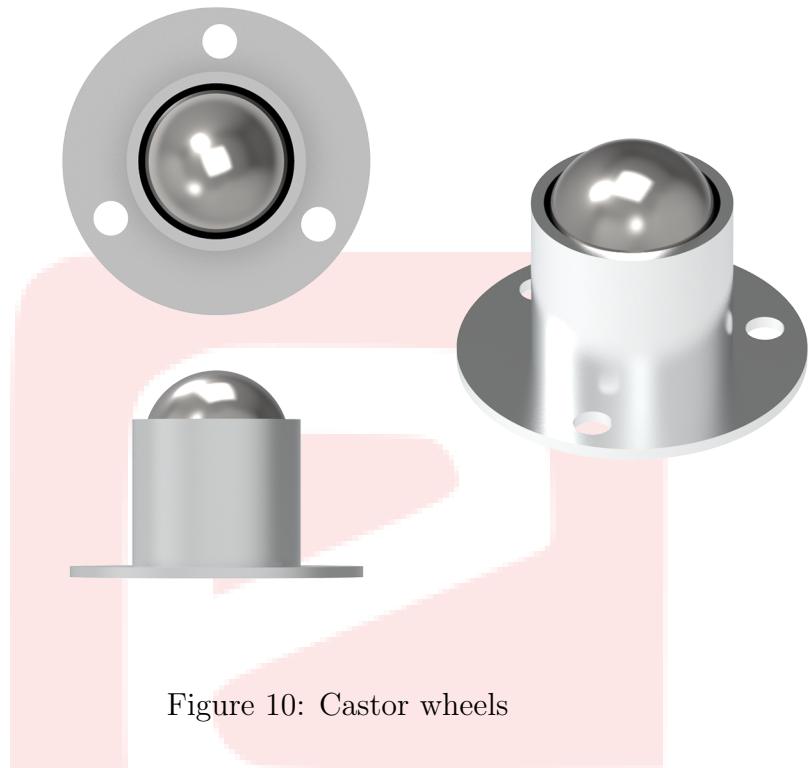


Figure 10: Castor wheels

Table 11: Castor Wheel Details

<b>Base Dia</b>	2.7cm
<b>Screw Hole Dia</b>	0.4cm
<b>Ball Dia</b>	1.36cm
<b>Height</b>	1.9cm
<b>Material</b>	Metal
<b>Link to Buy</b>	<a href="#">@Electron Components</a>

## 11. LeadScrew



Figure 11: LeadScrew for adjusting dead weight

Table 12: LeadScrew Details

<b>Length</b>	15cm
<b>Diameter</b>	0.78cm
<b>Material</b>	Metal

## 12. Spacers

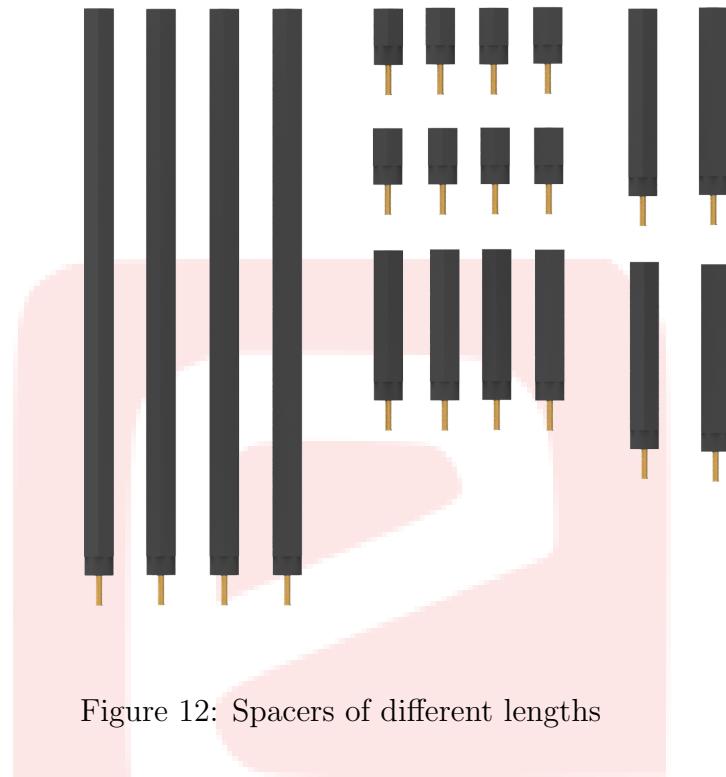


Figure 12: Spacers of different lengths

Table 13: Spacer Details

<b>Lengths of Spacers</b>	1cm Spacer, 4cm Spacer, 5cm Spacer, 14.5cm Spacer
<b>Link to Buy</b>	<a href="#">1cm Spacer</a>
<b>Link to Buy</b>	<a href="#">4cm Spacer</a>
<b>Link to Buy</b>	<a href="#">5cm Spacer</a>
<b>Link to Buy</b>	<a href="#">14.5cm Spacer (???)</a>

### 13. HC-Sr04 Ultrasonic Sensor

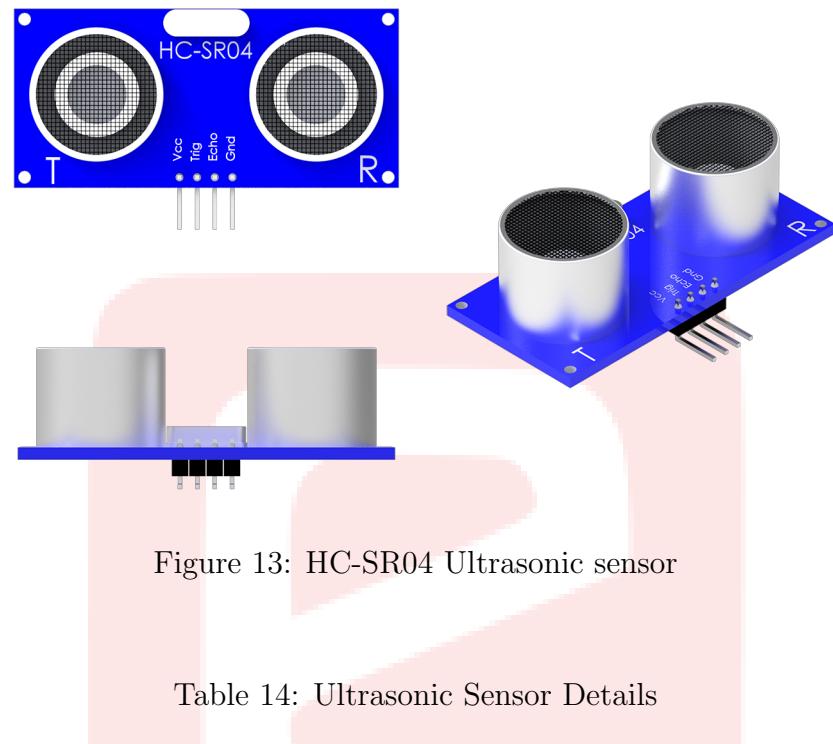


Figure 13: HC-SR04 Ultrasonic sensor

Table 14: Ultrasonic Sensor Details

<b>Dimensions(L*W*H)</b>	4.57cm * 1.7cm * 2.63cm
<b>Pins</b>	4
<b>Input Voltage</b>	5 V
<b>Link to Buy</b>	<a href="https://www.robu.in">@Robu.in</a>

#### 14. OV7670 Camera

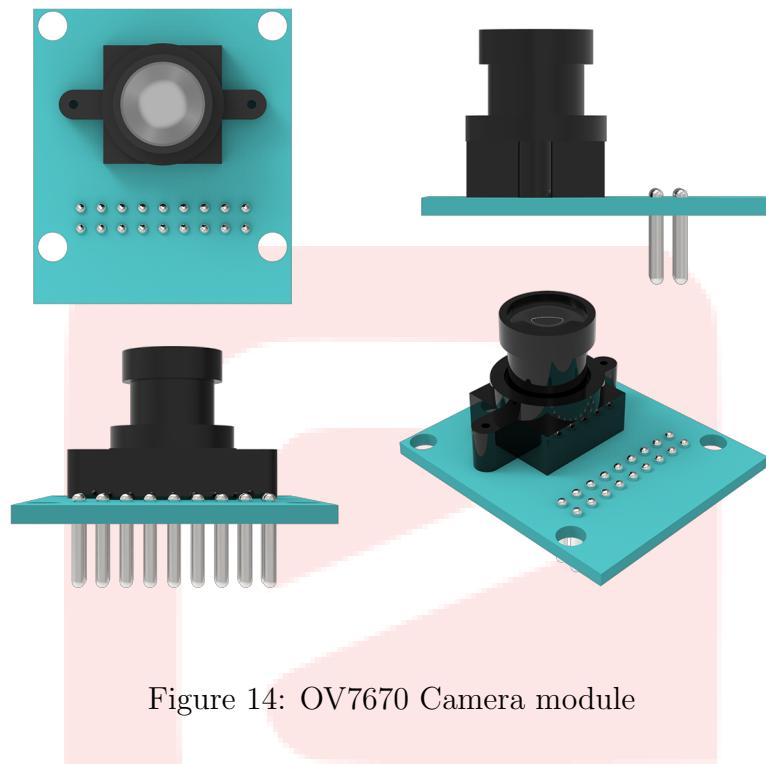


Figure 14: OV7670 Camera module

Table 15: Camera module Details

<b>Dimension(L*W*H)</b>	3.5cm * 3cm * 4cm
<b>Pins</b>	18
<b>Input Voltage</b>	3.3 V
<b>Link to Buy</b>	<a href="http://@Robu.in">@Robu.in</a>

### 15. 1.3" OLED display

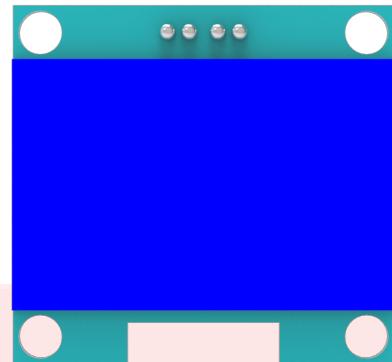


Figure 15: 1.3" OLED Displays

Table 16: OLED Details

<b>Dimensions(L*W*H)</b>	3.5cm * 0.8cm * 3.3cm
<b>Pins</b>	4
<b>Input Voltage</b>	5 V
<b>Link to Buy</b>	<a href="https://www.robu.in">@Robu.in</a>

## 16. GY87 Gyro Sensor

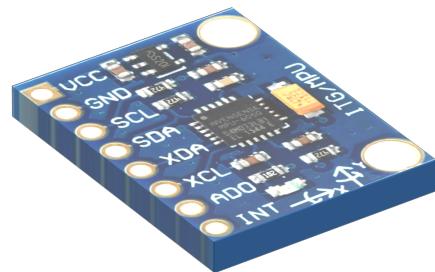


Figure 16: GY87 Gyro Sensor

Table 17: Gyro Sensor Details

<b>Dimensions(L*W*H)</b>	1.5cm * 0.2cm * 2.0cm
<b>Pins</b>	8
<b>Input Voltage</b>	5 V
<b>Communication Protocol</b>	I2C
<b>Link to Buy</b>	<a href="https://www.robu.in">@Robu.in</a>

## 17. IR-Obstacle Sensor

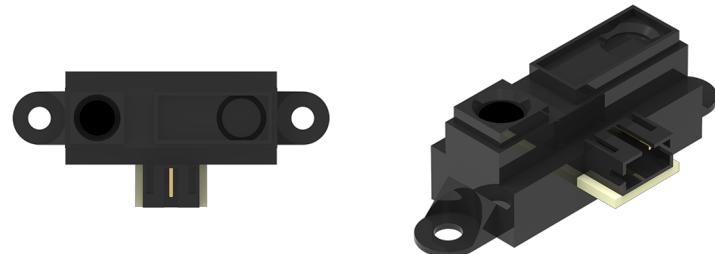


Figure 17: IR-Obstacle sensor

Table 18: IR Sensor Details

Dimensions(L*W*H)	4.45cm * 1.36cm * 1.914cm
Pins	3
Input Voltage	5 V
Link to Buy	<a href="https://www.robu.in">@Robu.in</a>

### 18. Cover

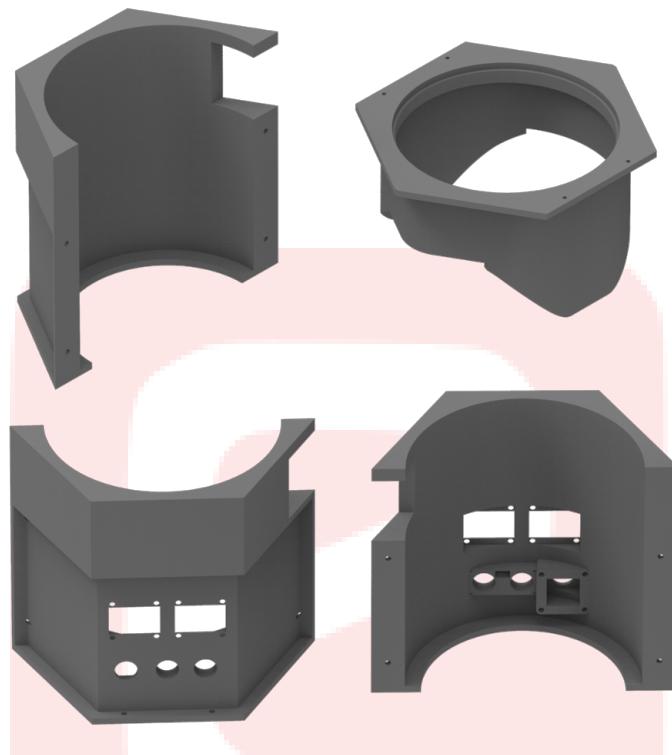


Figure 18: A Three Part cover for easier accessibility

Table 19: Cover Details

<i>Front Cover</i>	
<b>Dimensions(L*W*H)</b>	20.78cm * 9cm * 18.8cm
<i>Back Cover</i>	
<b>Dimensions(L*W*H)</b>	20.78cm * 9cm * 18.8cm
<i>Bottom Cover</i>	
<b>Dimensions(L*W*H)</b>	20.61cm * 18cm * 10.5cm
<b>Material</b>	acid(PLA)

### 19. Acrylic Plates

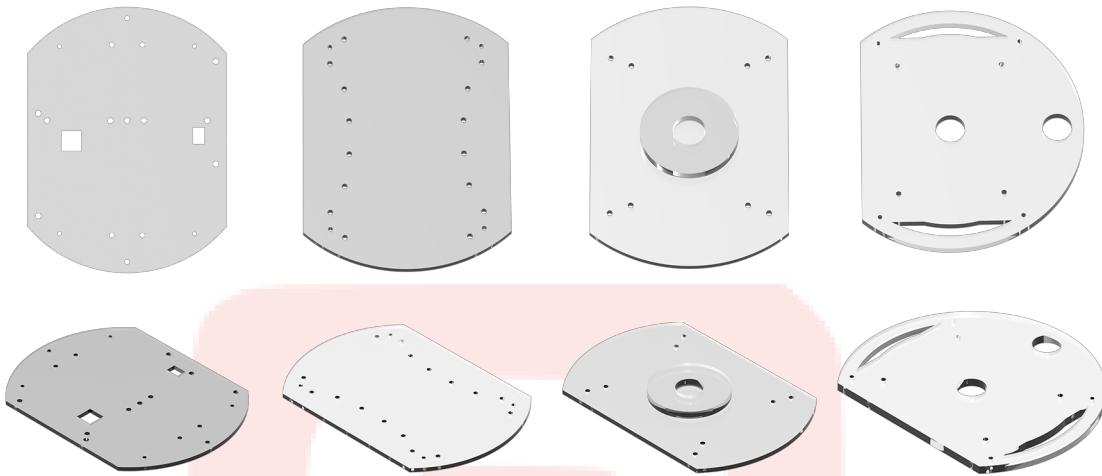
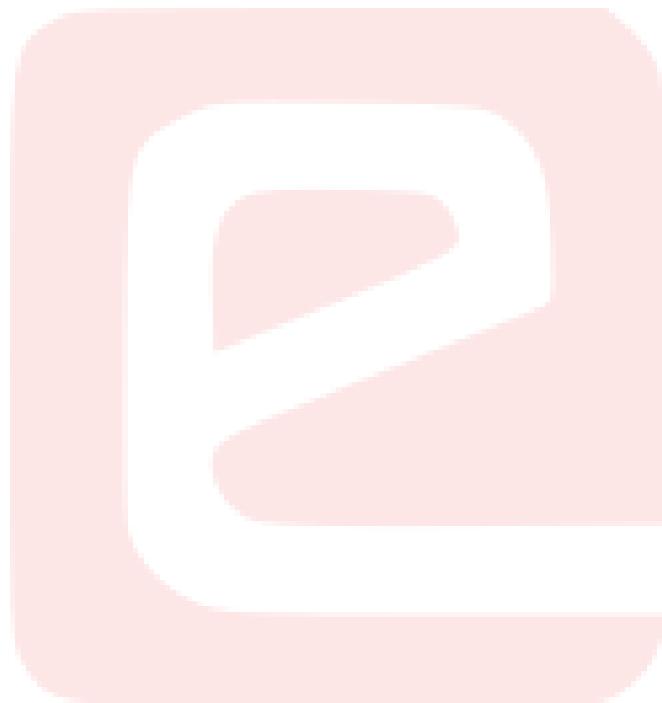


Figure 19: Acrylic Plates

Table 20: Acrylic Plate Details

<b>Material</b>	Acrylic
<b>Thickness</b>	5mm
<b>Quantity</b>	5

Connection Diagram  
*JAYDEV'S WORK*



## Software used

### List of Software used

- Arduino IDE
- Solidworks 2022
- Keyshot 11



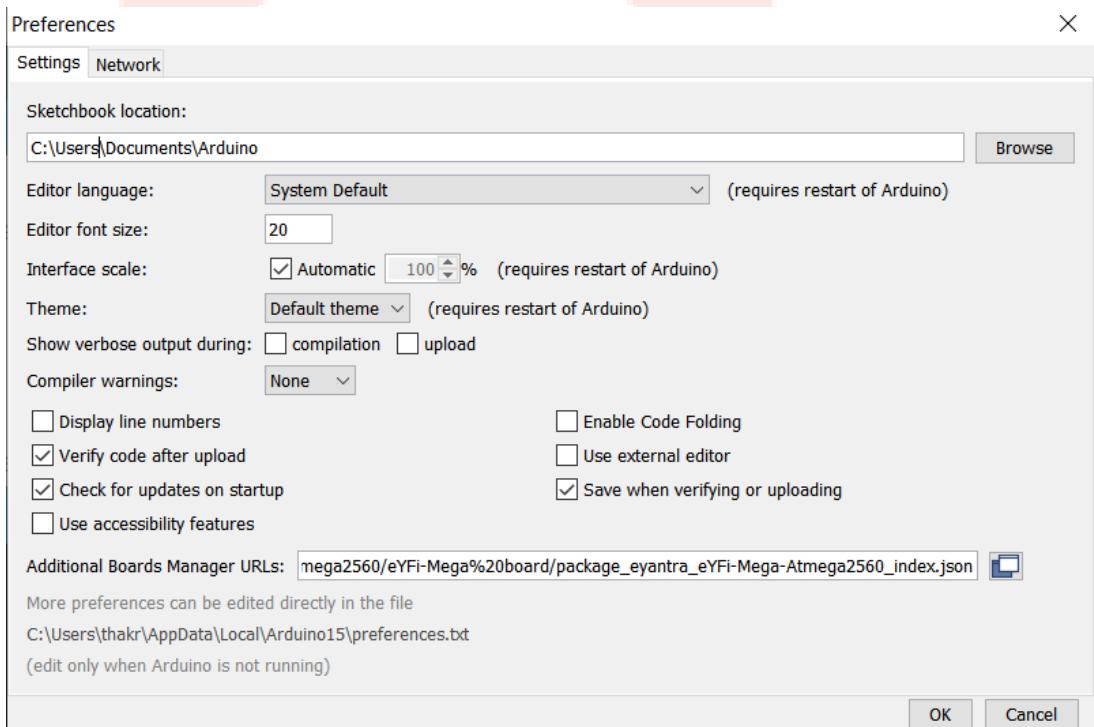
# Environment setup instructions

- Adding eYFi Mega to Arduino IDE

1. Open Preferences

- Files → Preferences

2. Click on the button to the right of the Additional Boards Manager URLs text field.
3. Paste or Remove URLs in the window. There should be one URL for each line.



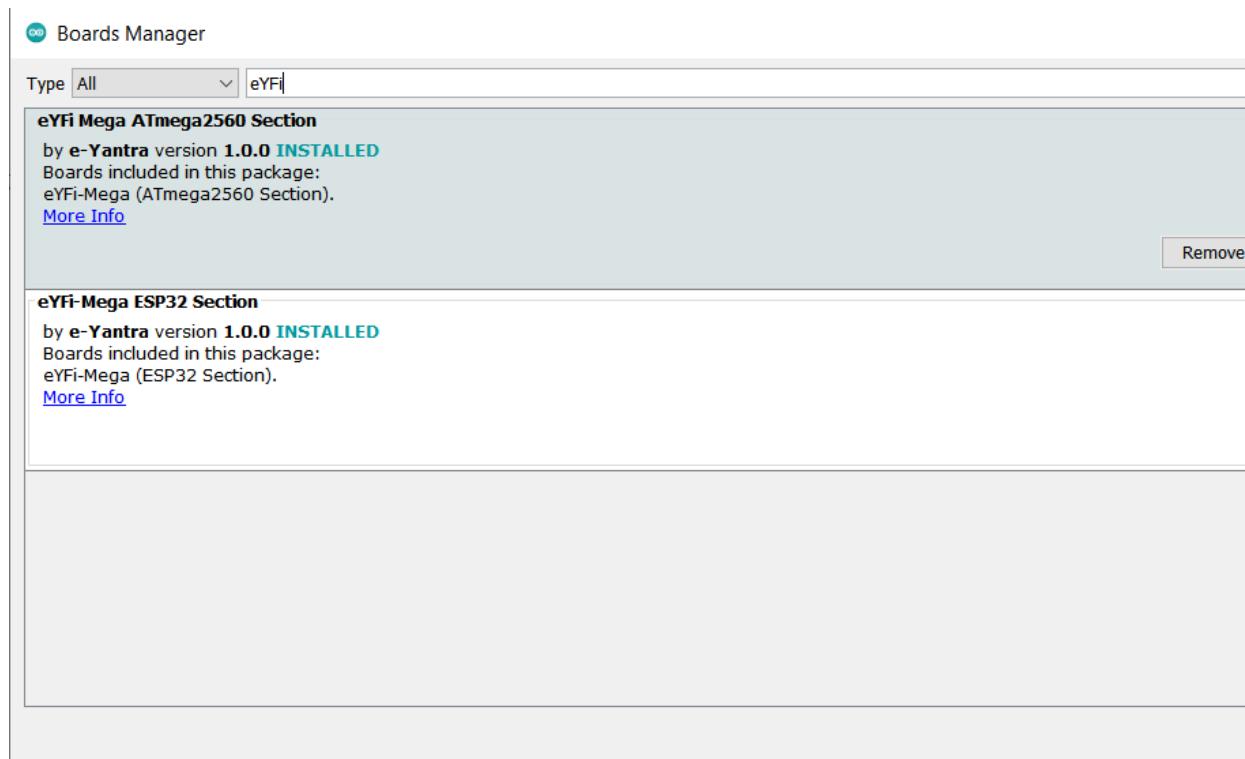
4. Links to be added are given Below :

- [Adding eYFi Mega-ESP32 to Arduino IDE](#)
- [Adding eYFi Mega-Atmega2560 to Arduino IDE](#)

5. Click OK.

6. Click OK in Preferences to save the changes.

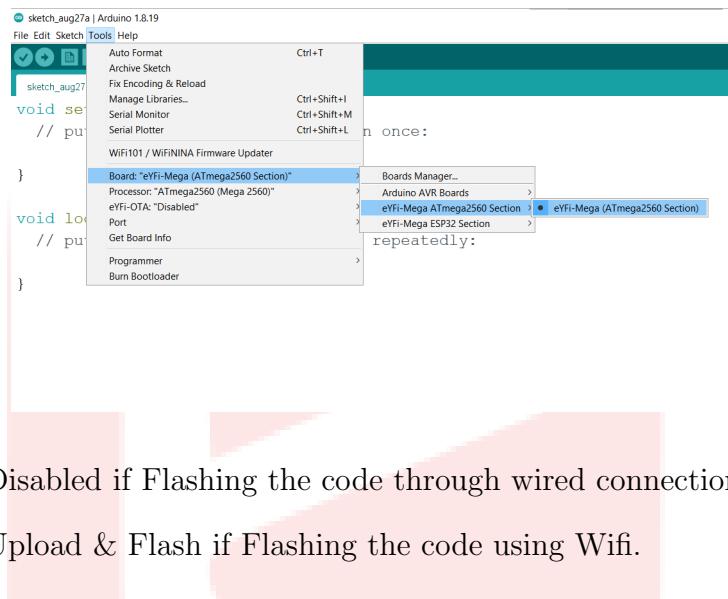
7. Then go to Tools → Board → Boards Manager and search eYFi and install both available options



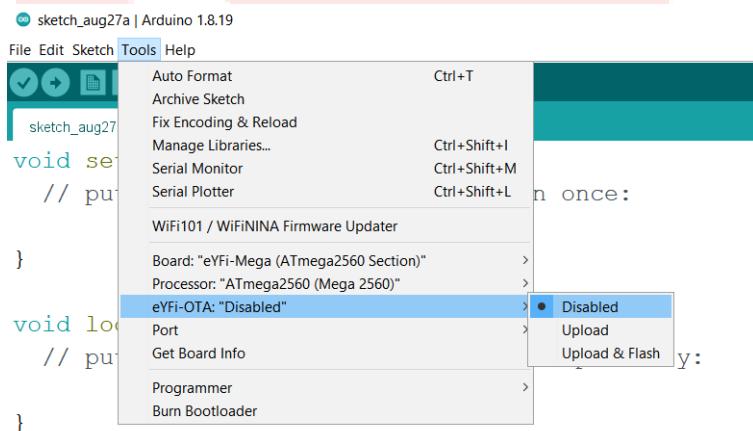
8. Now eYFi Mega Boards are being added to Arduino IDE

# Flashing Code on eYFI Mega

1. Go to Tools then Boards
2. Select eYFi-Mega Atmega2560 Section
3. Select eYFi-Mega(Atmega2560 Section)



4. Select Disabled if Flashing the code through wired connection
5. Select Upload & Flash if Flashing the code using Wifi.



## Assembly of Hardware

### Connections

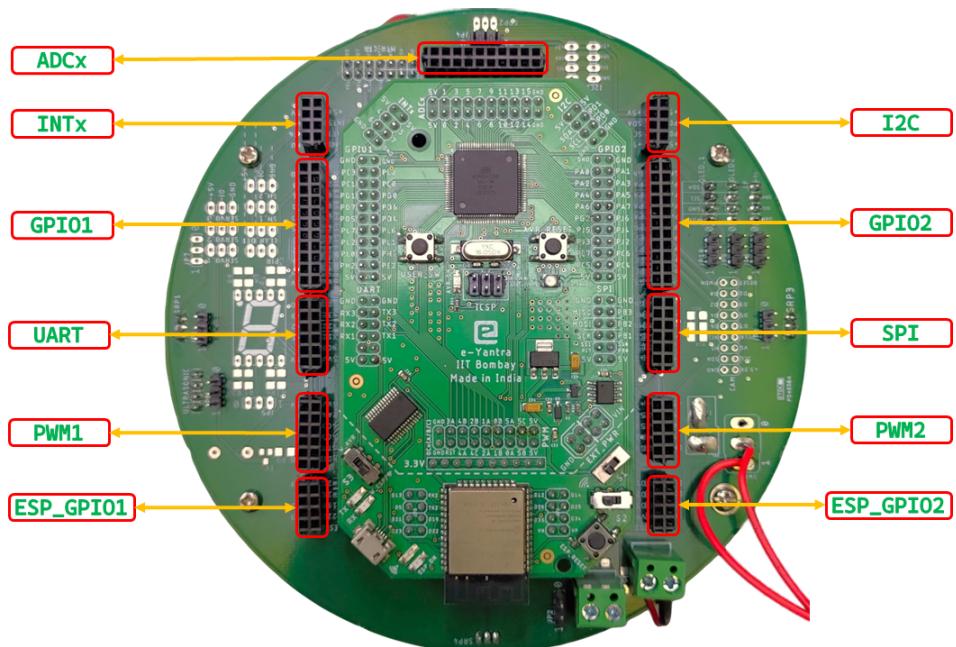


Figure 20: Connectors

- Above Picture is positioning all the different types of peripheral Pins and GPIO of EYFI Mega.

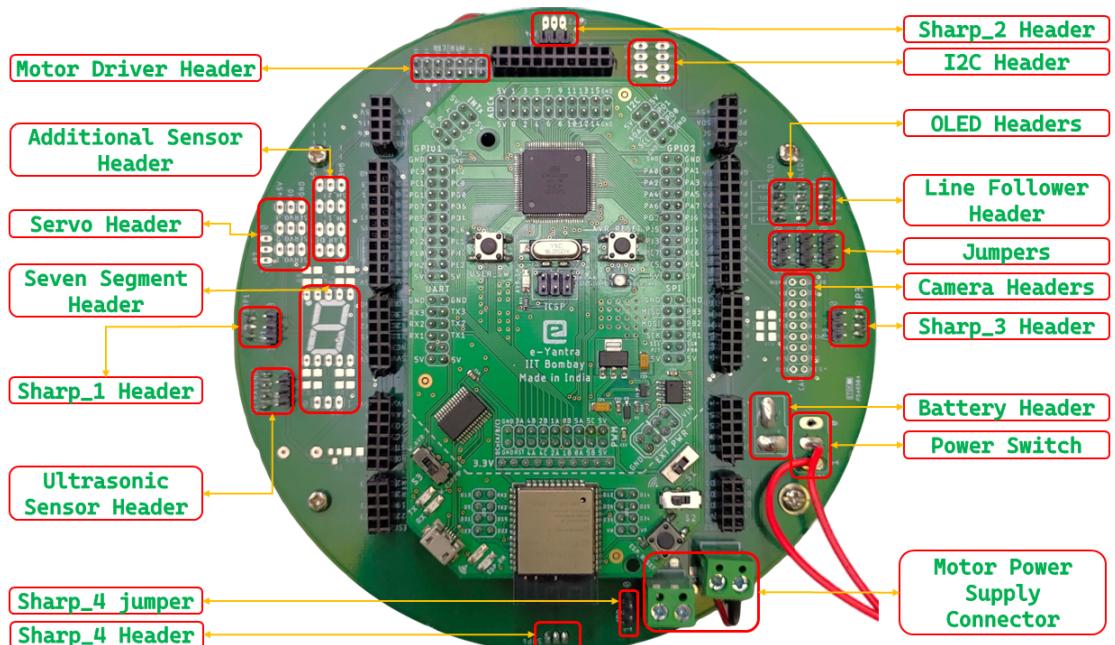


Figure 21: Pinheaders

- Above Picture is positioning headers of different Sensors/Actuators.

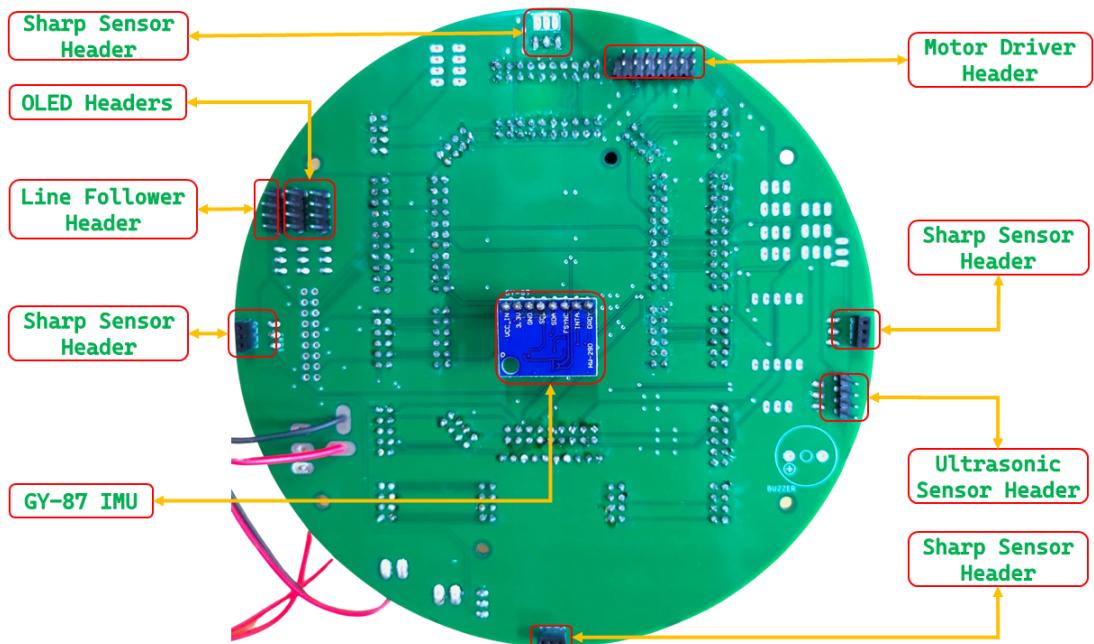


Figure 22: Pinheaders

- Above Picture is positioning headers of different Sensors/Actuators.

## Connection diagrams

### STEP 1

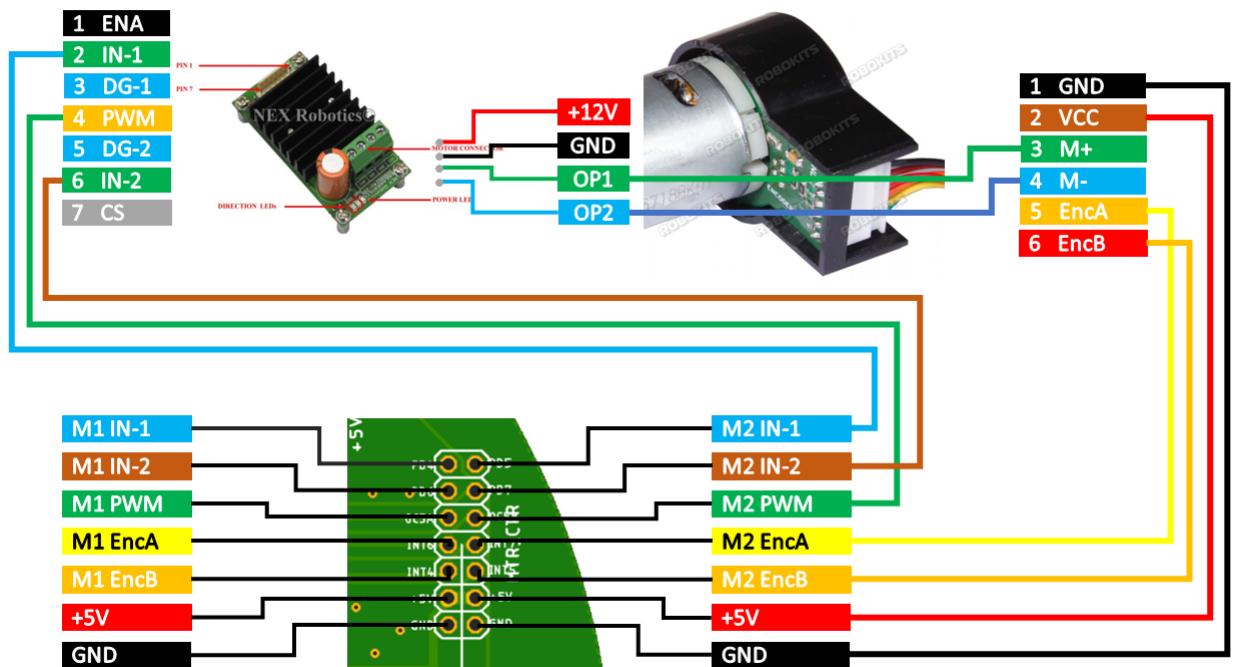


Figure 23: Rhino Motor, Hercules Motor Driver and Board Connection

- To connect motor to Hercules motor driver and Board follow this connection diagram.
- M1 = Motor 1 and M2 = Motor 2

**STEP 2**

Figure 24: Battery and Board Connection

- Follow above connection diagram to connect Battery to board.

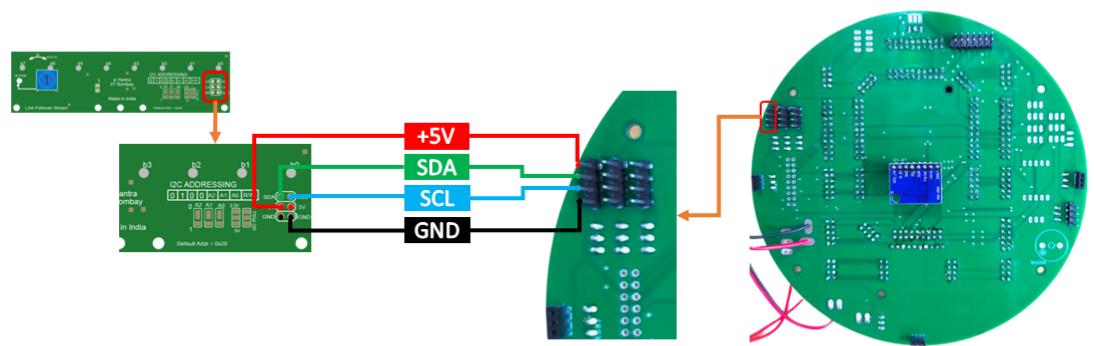
**STEP 3**

Figure 25: Line follower and board connection

- Follow above connection diagram to connect line follower sensor and board.

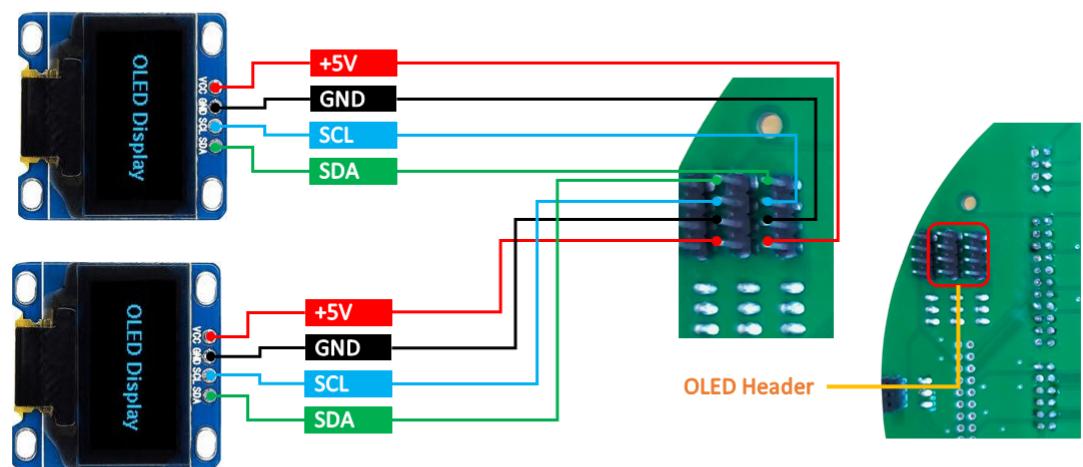
**STEP 4**

Figure 26: OLED display and board connection

- Follow above connection diagram to connect Oled Display and board.

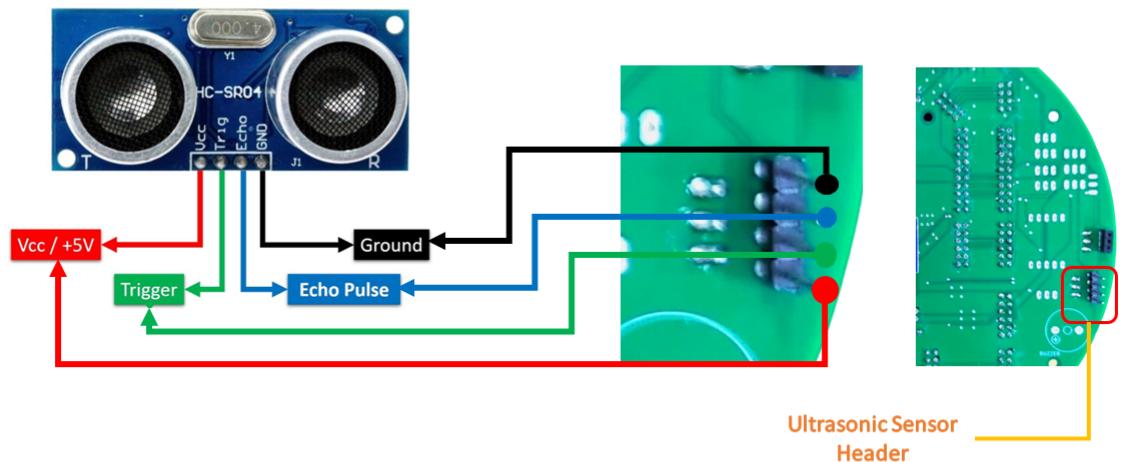
**STEP 5**

Figure 27: Ultrasonic Sensor and board connection

- Follow above connection diagram to connect Ultrasonic Sensor and board.

## STEP 6

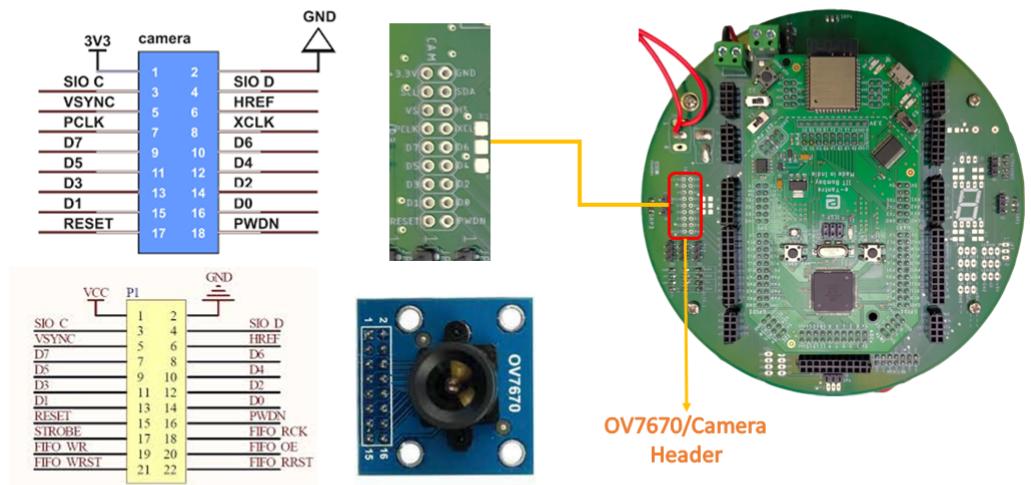


Figure 28: Camera and board connection

- Follow above connection diagram to connect camera and board.

## Assembly Instructions

## STEP 1

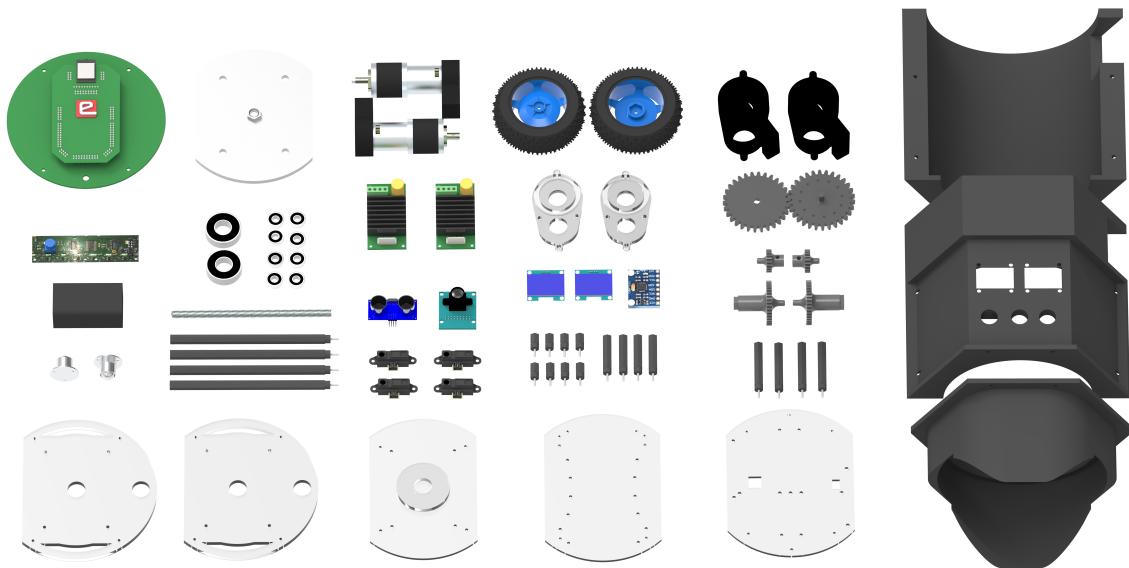


Figure 29: What you get in the box

- Before starting the assembly process, make sure that all the components are present to begin with and arrange them as shown in the Figure for easier identification.

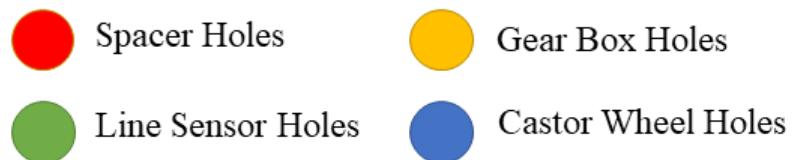
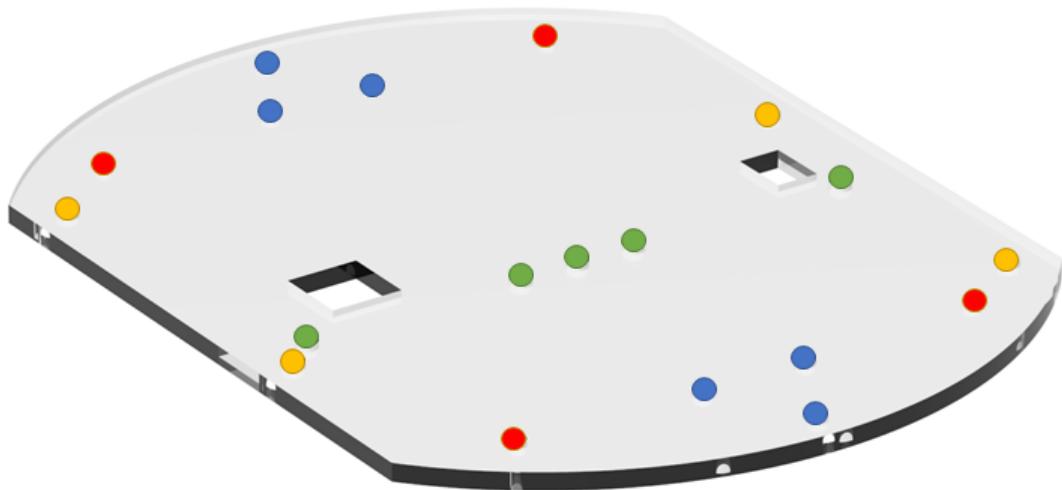
**STEP 2**

Figure 30: Base plate

- First, identify the Base plate among the components. Carefully take note of which hole is to fit what from the illustration shown above in Fig.20

### STEP 3

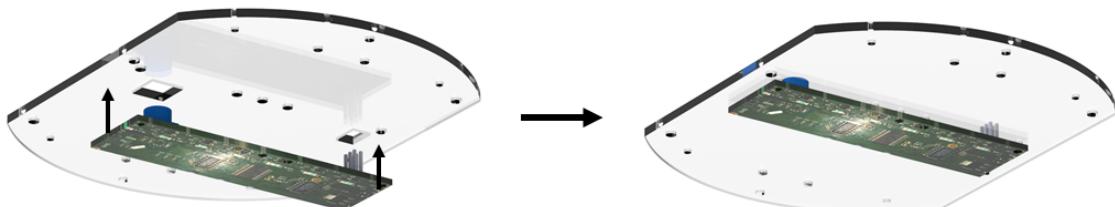


Figure 31: Attaching Line Sensor with Base plate

- Carefully attach the Line sensor to the bottom of the base plate and lock it with M3 nuts and bolts
- Now, the next step is to make the gear box assembly ready before attaching it to the Baseplate

### STEP 4

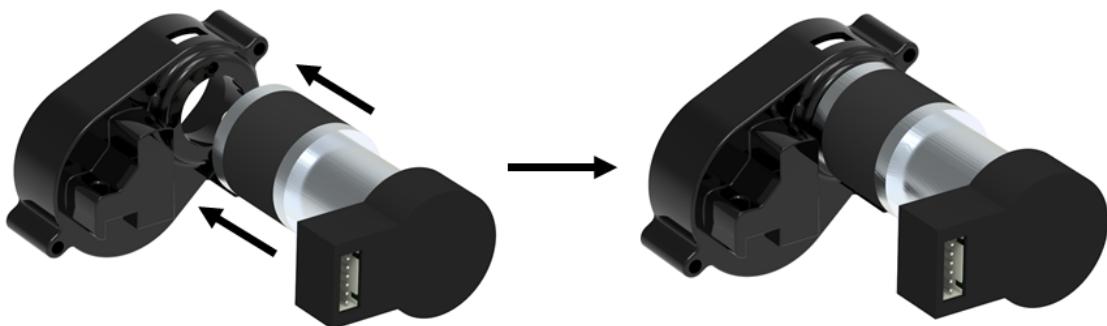


Figure 32: Attaching Motor to Gearbox

- Fix the motor as exactly shown in the **fig.22**, as it is very important. Note that the black color cap in the back of the motor should be facing the direction as shown in **fig.22**
- Now lock it in position with the help of nuts and bolts

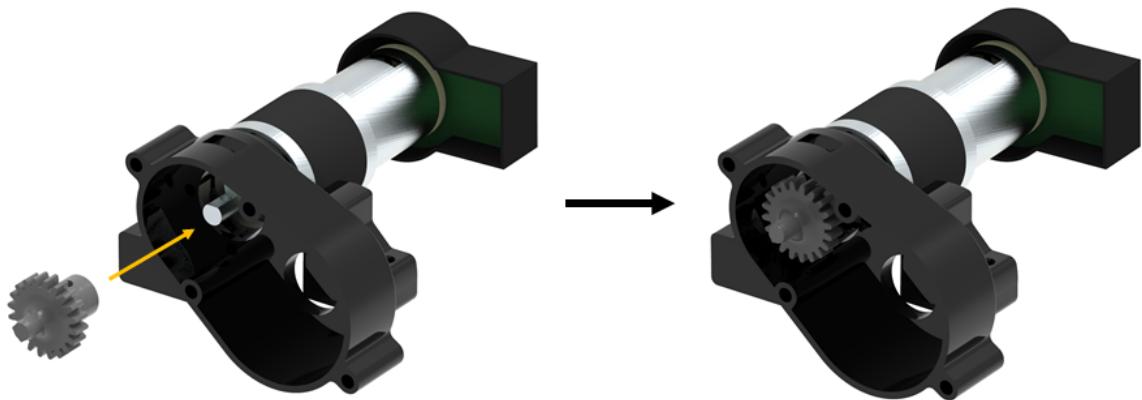
**STEP 5**

Figure 33: Attaching Driver Gear to Motor shaft

- After locking the motor with the Gearbox, take one of the driver gear and attach it to the shaft of the motor.

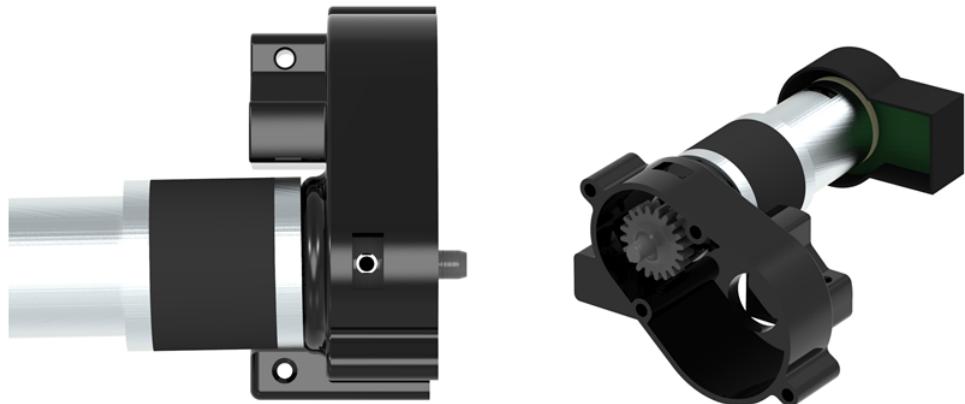
**STEP 6**

Figure 34: Locking the Driver gear with the shaft

- To lock the Driver gear to the motor shaft, the shaft has to be positioned in a manner that its hole is visible from top as it is shown in the **Figure 23**
- Position this by twisting the gear and verify
- After positioning it, lock it with M3 nut and bolt

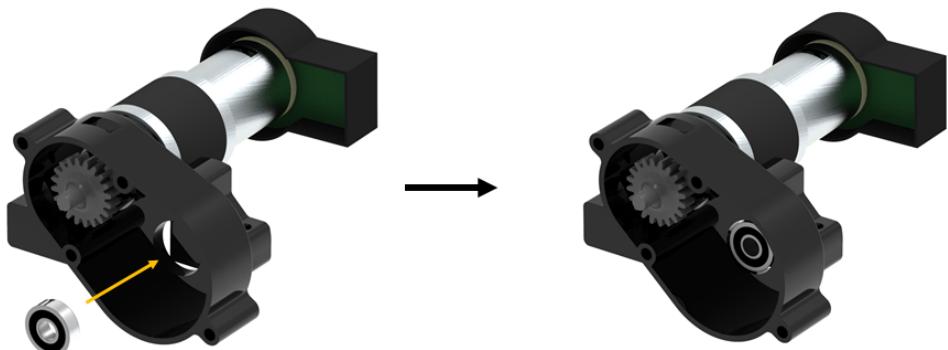
**STEP 7**

Figure 35: Attaching small bearing to gearbox

- Now, as the next step, take one small bearing and attach it to the gearbox as shown in the **figure 24**

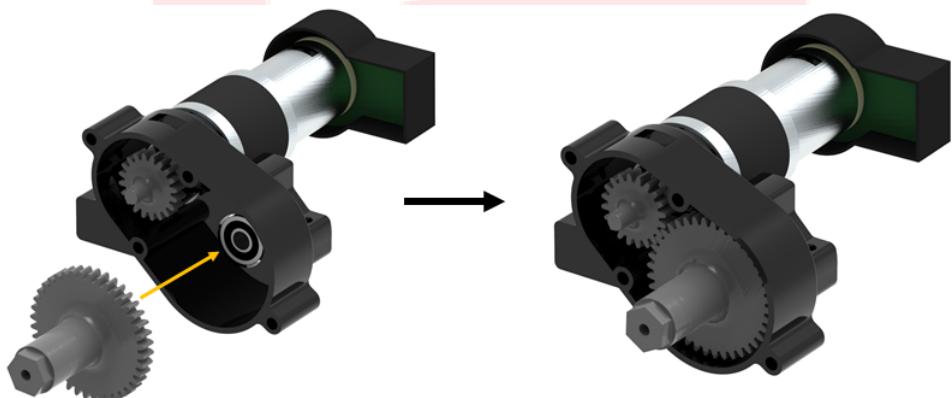
**STEP 8**

Figure 36: Attaching Driven gear to gearbox

- After fixing the small bearing, take one of the driven gears and attach it to the gearbox by fixing the lean shaft of the driven gear go inside the bearing that was fixed before.
- Make sure that the gears have properly meshed such that their motion will be smooth

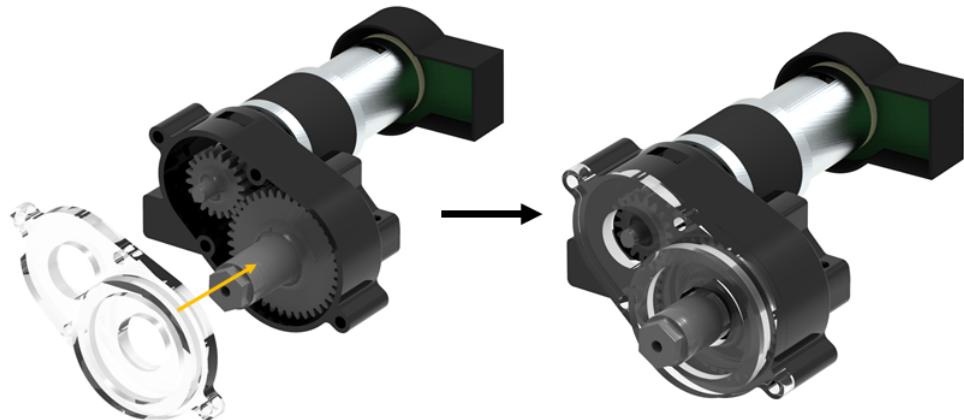
**STEP 9**

Figure 37: Attaching the Acrylic lid to gearbox

- Now take one of the acrylic lid and fix it to the gearbox as shown in the **figure 25**. Lock it using nuts and bolts of proper dimension. longer bolts will be needed.

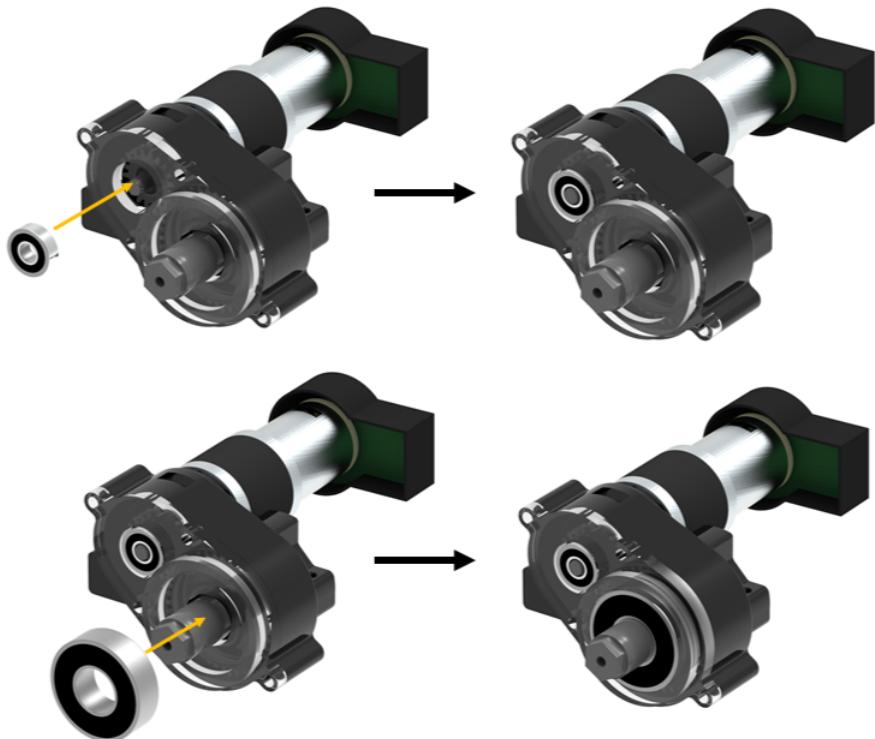
**STEP 10**

Figure 38: Attaching bearing to the Acrylic lid

- After locking the lid to the gearbox, take one small and one large bearing and attach it to the lid such that the front shafts of both the gears fit through the bearing.

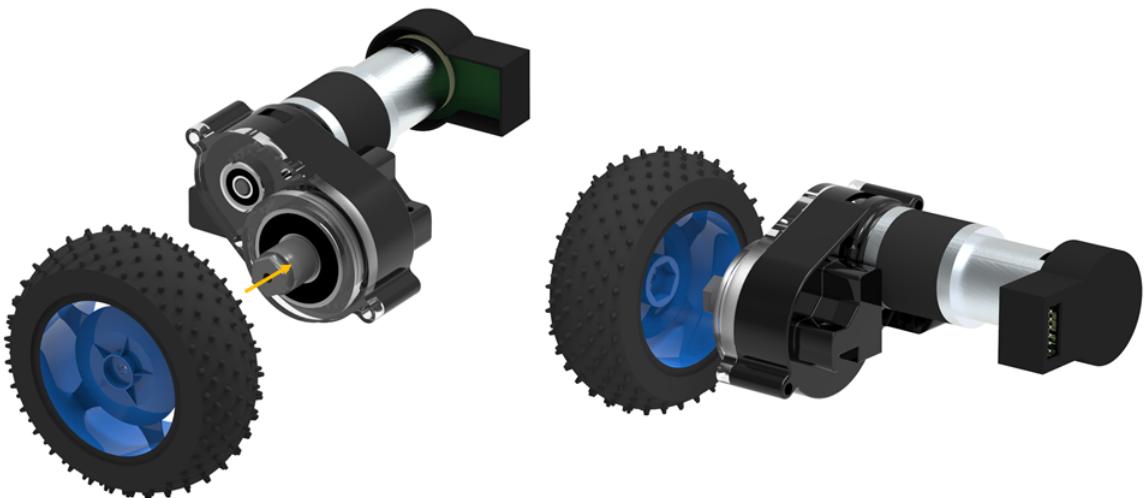
**STEP 11**

Figure 39: Attaching Wheel

- Now, take one of the 85mm wheels and fix it to the large gear's shaft that's protruding out
- Align the hexagons of the wheel and the gear and lock it in place with a M3 screw

**STEP 12**

Figure 40: Completed Gearbox assembly

- If everything is attached accordingly, the gear box assembly will look like the **Figure 30**. Check and verify before proceeding further

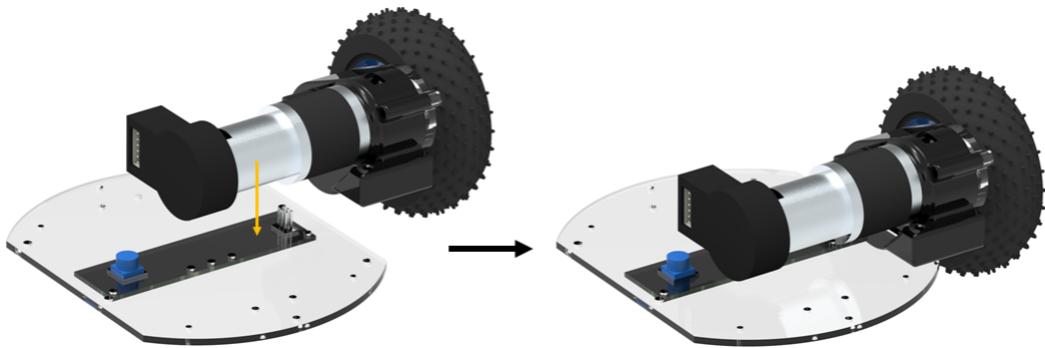
**STEP 13**

Figure 41: Attaching Gearbox assembly to Baseplate

- Now, attach the Gearbox assembly with the Baseplate.
- Lock it properly in correct holes using nuts and bolts. For hole reference, check the **Figure 20**

**STEP 14**

Figure 42: Gearbox and Baseplate assembly

- For the next part, repeat the steps from 4 to 11 for the other side and attach that gearbox assembly to the base plate as well

- If everything was done properly, the assembly will look like the one in the **figure 32**
- Note that the back covers of motors should face each other
- Kindly verify before proceeding further

### STEP 15

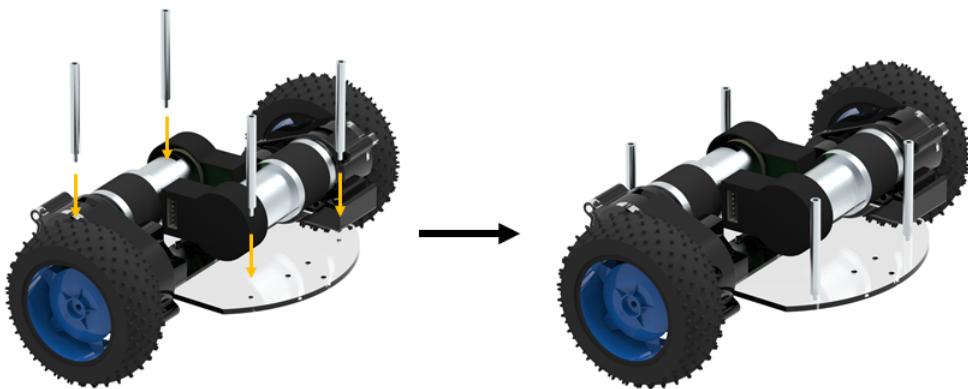


Figure 43: Attaching 5cm Spacers

- After verification of the base, if you are good to go, then find 4 of the 5cm spacers and attach them to the Base plate as shown in the **figure 33**
- lock the spacers in right holes using nuts at the bottom of the Base plate. Again, verify if you are locking it in the right hole by referring to the **figure 20**

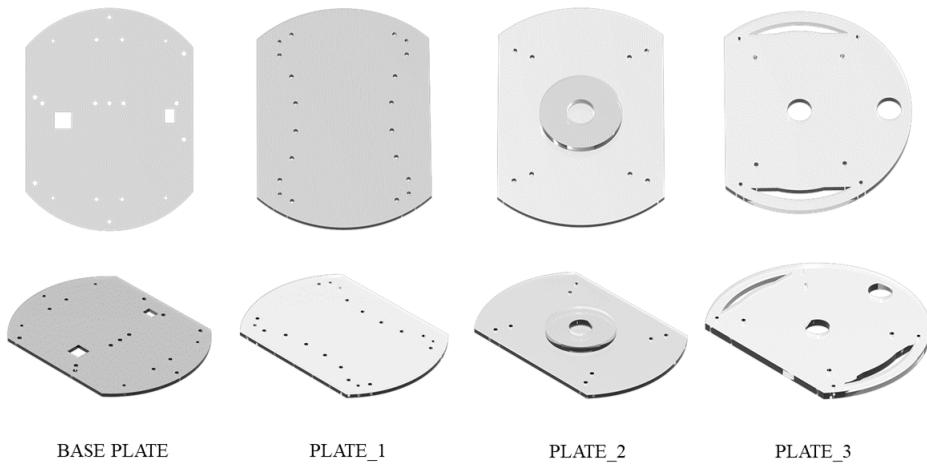
**STEP 16**

Figure 44: Acrylic Plates

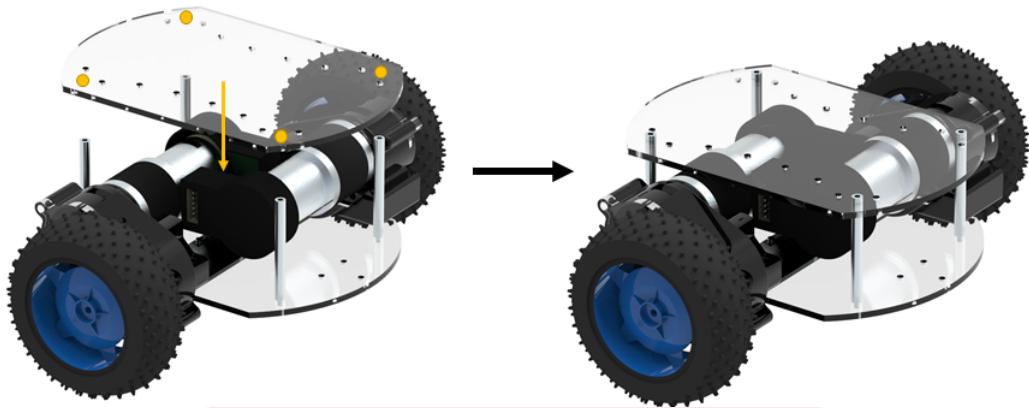


Figure 45: Attaching first level plate

- For the next step, identify Plate\_1 using the reference **figure 34**
- Attach it to the assembly by locking it using M3 bolts in the 5cm spacer's top part(female)

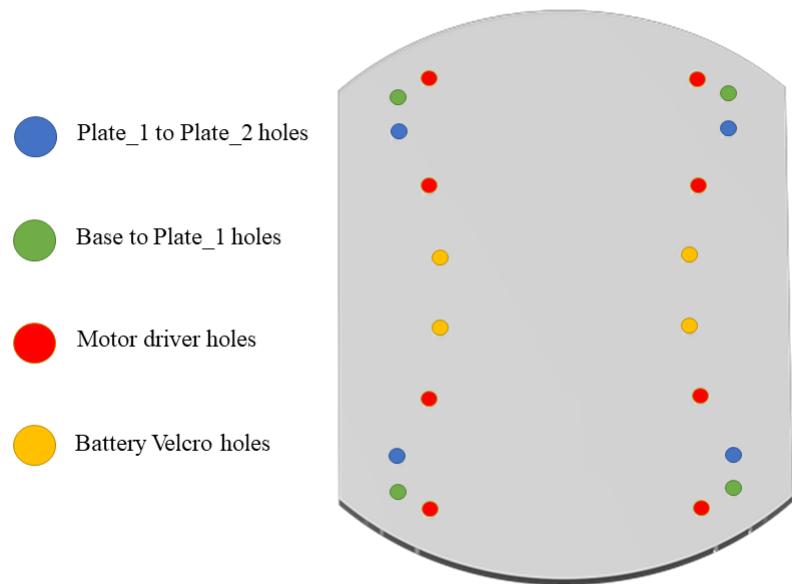
**STEP 17**

Figure 46: Plate\_1 Hole reference

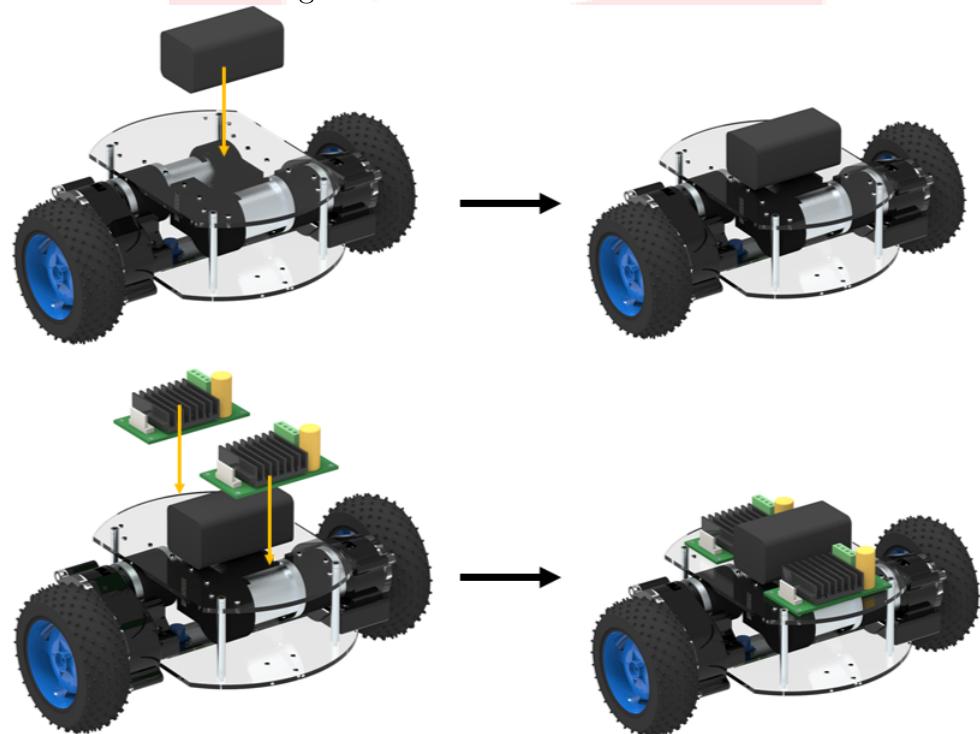


Figure 47: Attaching Battery and Motor Driver

- Now, Attach the battery to the center of the Plate\_1 and lock it using velcro.
- Then, take the two motor drivers and lock it using nuts and bolts in the correct holes. For reference, check **Figure 36**

### STEP 18

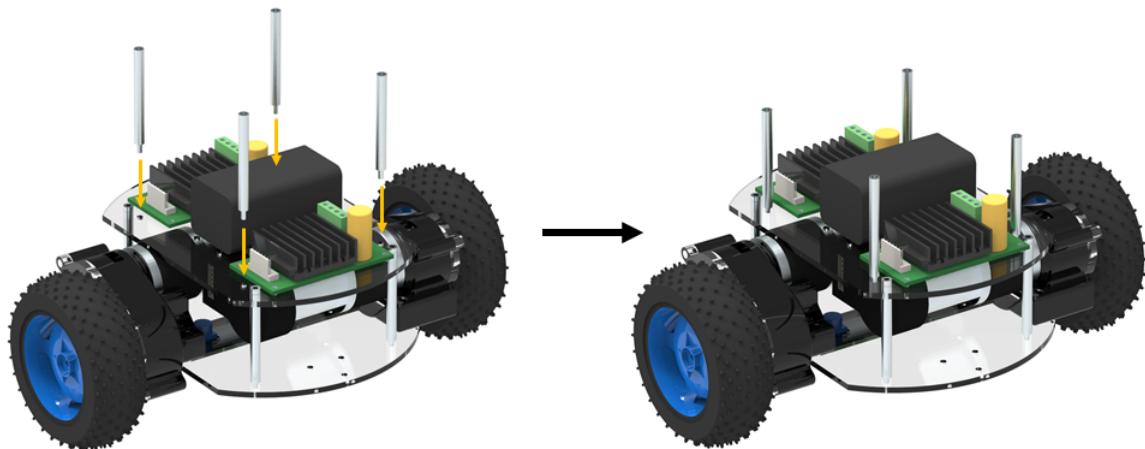


Figure 48: Attaching 4cm Spacers to Plate\_1

- Now, take 4 of the 4cm Spacers and attach them to the Plate\_1 and lock them at the bottom using M3 nuts

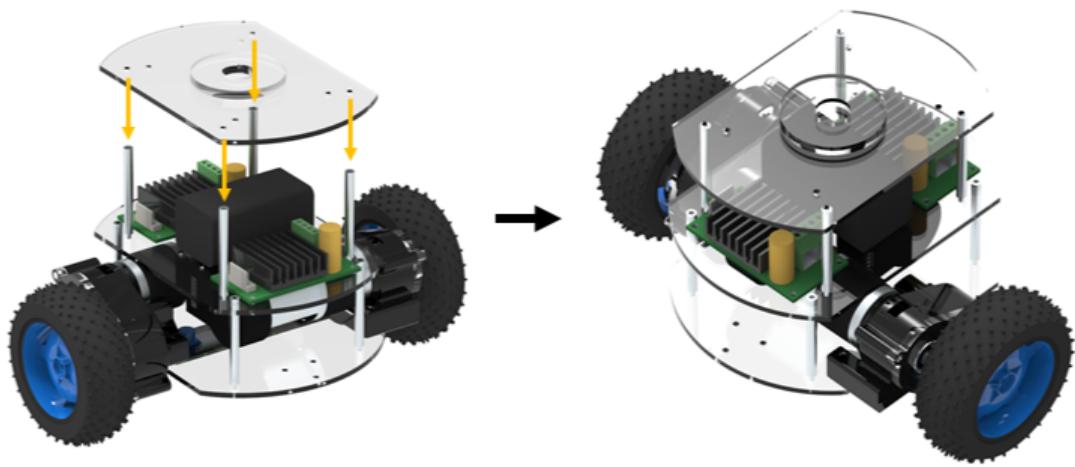
**STEP 19**

Figure 49: Attaching Plate\_2 to the assembly

- Next, identify Plate\_2. Use **figure 34** for reference
- Lock it to the assembly using M3 bolts.

**STEP 20**

Figure 50: Attaching 14.5cm spacers and Lead screw

- For the next part, find 4 of the 14.5cm spacers and attach them to the Plate\_2 and lock them at the bottom using M3 nuts
- Then, find the lead screw and hold it at the center of the Plate\_2

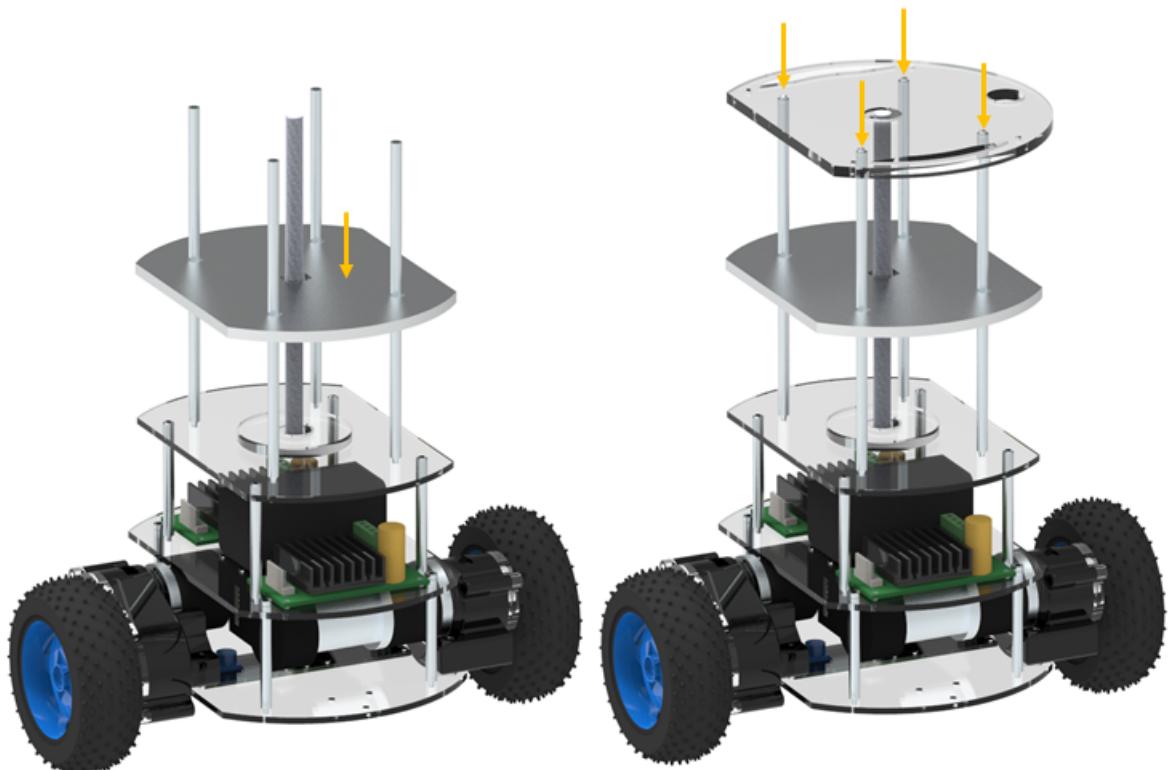
**STEP 21**

Figure 51: Attaching Deadweight and Plate\_3

- Now, take the Dead weight and insert it along the lead screw
- Then, identify the Plate\_3 using the reference **figure 34**

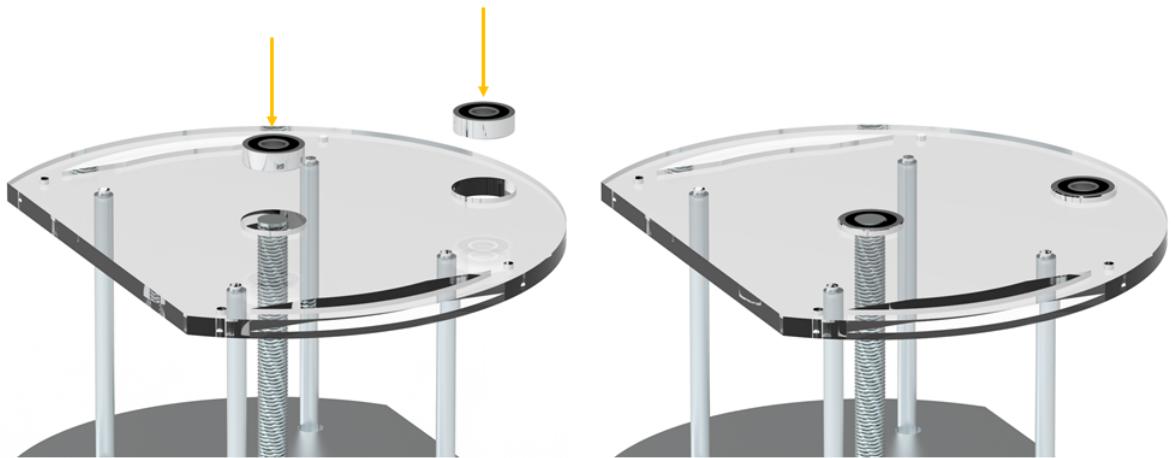
**STEP 22**

Figure 52: Attaching bearing to Plate\_3

- Find two of small bearings and attach it to the Plate\_3 as shown in the **figure 42**

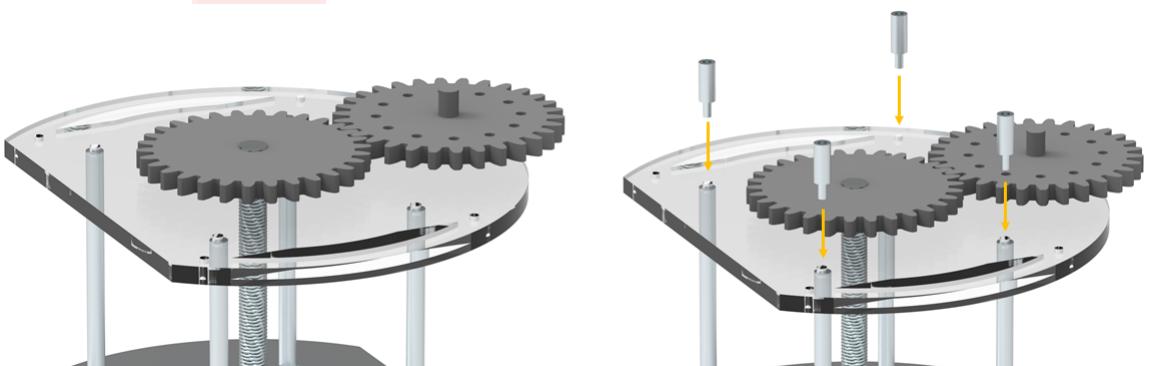
**STEP 23**

Figure 53: Attaching Height adjusting gears and 1cm spacers

- Find two of the Height adjusting gears and attach it to the assembly as shown in the **figure 43**

- Next, take 4 of the 1cm spacers and lock the Plate\_3 in its position by inserting them in the right holes.

#### STEP 24



Figure 54: Attaching Top Plate\_3 and Top bearings

- Find the other Plate\_3 and alight it parallel to the already placed Plate\_3.
- Now, find two of the small bearings and attach similarly to what was done in step 22.
- lock the Top Plate\_3 using M3 bolts on the right holes.

#### STEP 25

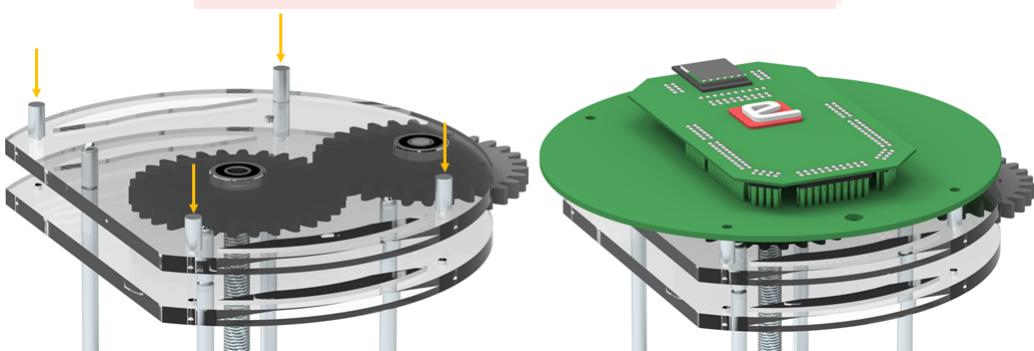


Figure 55: Attaching 1cm spacers and eYFI board

- Then, take 4 of the 1cm of spacers and attach them to the Top Plate\_3.

- After tightening them, find the eYFI board (attached with the extension PCB) and attach it to the top of assembly as shown in the **Figure 45**

#### STEP 26



Figure 56: Strucutral assembly

- If everything was followed exactly as per the instructions so far, then the structural assembly will look like **figure 46**
- Verify before proceeding any further

**STEP 27**

- At this point, it is recommended to connect the battery and motor driver to the eYFI board using wires before proceeding to the next part

**STEP 28**

Figure 57: Attaching the bottom and back part of cover

- Find and attach the bottom and the back part of cover as shown in the **Figure 47**
- The cover is made as 3 individual parts for easier accessibility and replaceability

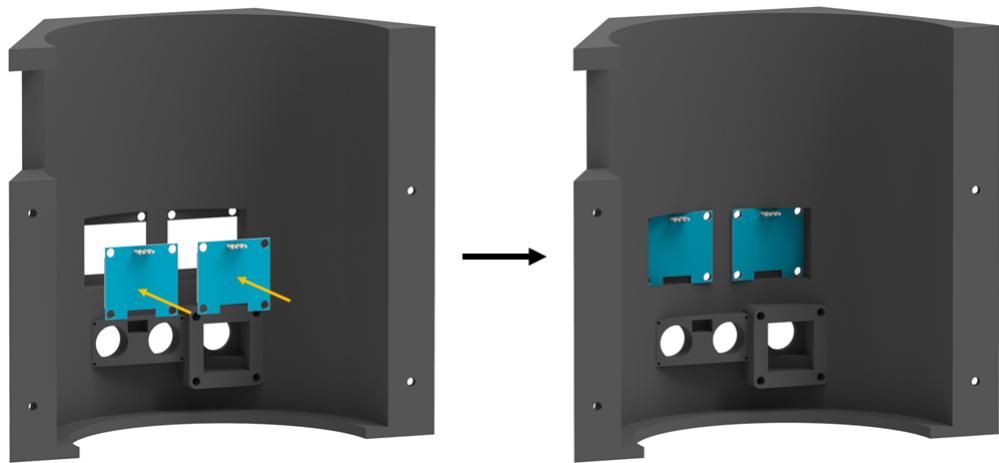
**STEP 29**

Figure 58: Attaching OLEDs to the Front part of cover

- Now, let's make the front cover assembly
- For that, first take two of the OLEDs and attach it to the front cover as shown in the **figure 48**
- Lock them using the M3 nuts and bolts
- Make sure that the heads of the M3 bolts are on the front side of the cover as the other way would look awkward

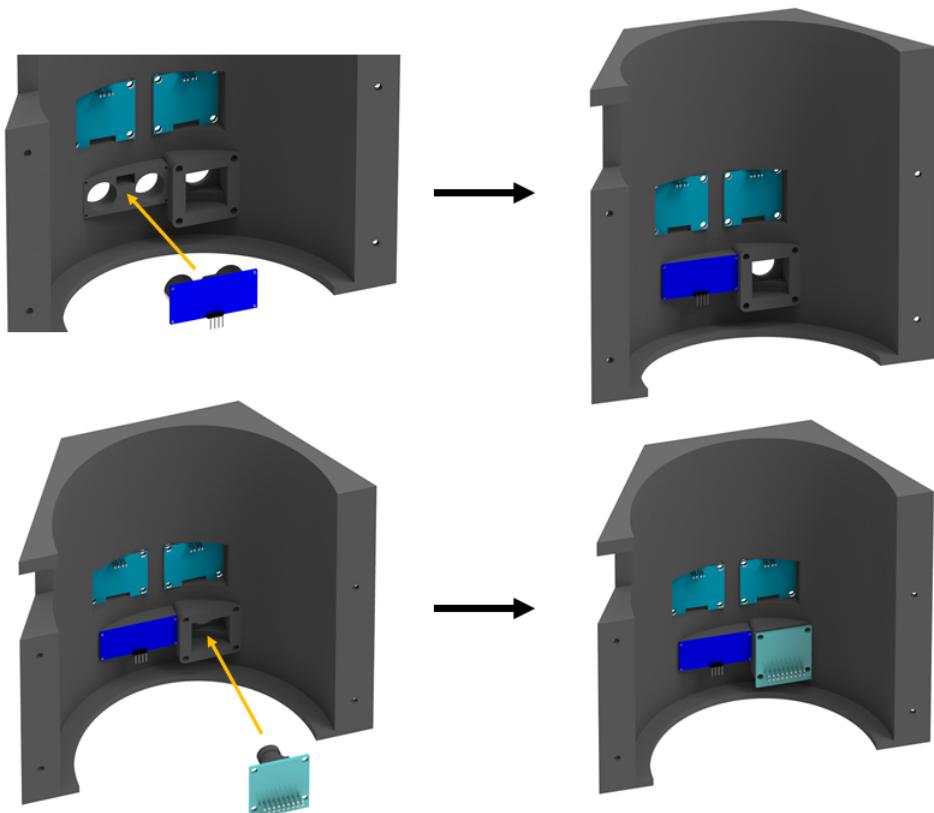
**STEP 30**

Figure 59: Attaching Ultrasonic sensor and OV7670 camera

- Next, attach the HC-Sr04 Ultrasonic sensor and OV7670 camera module to the front cover and lock them using M3 bolts

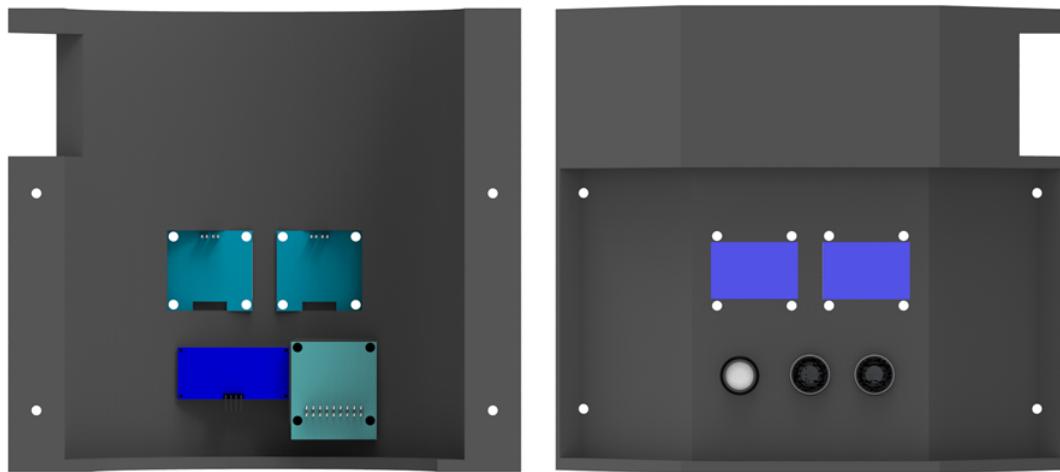
**STEP 31**

Figure 60: Complete Front cover assembly

- After attaching the OLEDs, Ultrasonic and Camera, the front cover should look like the one in the **Figure 50**
- Verify before proceeding

**STEP 32**

- Before attaching the front part of the cover to the assembly, don't forget to connect the OLEDs, ultrasonic sensor and camera to the eYFI board using wires.

## STEP 33



Figure 61: Complete Assembly

- Now attach the front cover to the assembly
- Congratulations. You have successfully assembled a Self-Balancing robot
- Checkout to the next section to learn on how to program the bot

# Software and Code

- We will be using Arduino IDE To flash the code on our eYFi Mega Board,
- Let's make our Bot Self Balance using the [Self balancing code.ino](#) file.

```

Self_balancing_code | Arduino 1.8.19
File Edit Sketch Tools Help
Self_balancing_code
#define F_CPU 16000000UL // Define Crystal Frequency of eYFi-Mega Board
#include <avr/io.h> // Standard AVR IO Library
#include <util/delay.h> // Standard AVR Delay Library

#include <stdio.h>
#include <math.h>

#include <Wire.h>
#include <MPU6050_light.h>
|
#include "motor_driver.h"

#define LED_RED 6
#define LED_BLUE 7
#define LED_GREEN 8

#define LED_RED_ON digitalWrite(LED_RED, LOW)
#define LED_RED_OFF digitalWrite(LED_RED, HIGH)

#define T_E_D_BLUE_ON digitalWrite(T_E_D_BLUE, LOW)
<

```

Done Saving.

10 eYFi-Mega (ATmega2560 Section), Disabled, ATmega2560 (Mega 2560) on COM13

## Use and Demo

- SBR can be used a Toy, Educational Product and Development Kit
- Demo Video [Self Balancing Robot](#).

## Future Work

Accessibility to implement other sensors like LIDAR or HQ cameras will open up opportunities in areas of Auto-navigation and Image processing / AI / ML. Also, provision to fixing a manipulator on top of the bot will make the possibility of using the bot in pick and place operations.

## Bug report and Challenges

- Motor Used for current SBR development does not provide much inertia to balance robustly.
- More Maintained CG will give better results.
- PID requires Tuning after any change in physical Parameters.