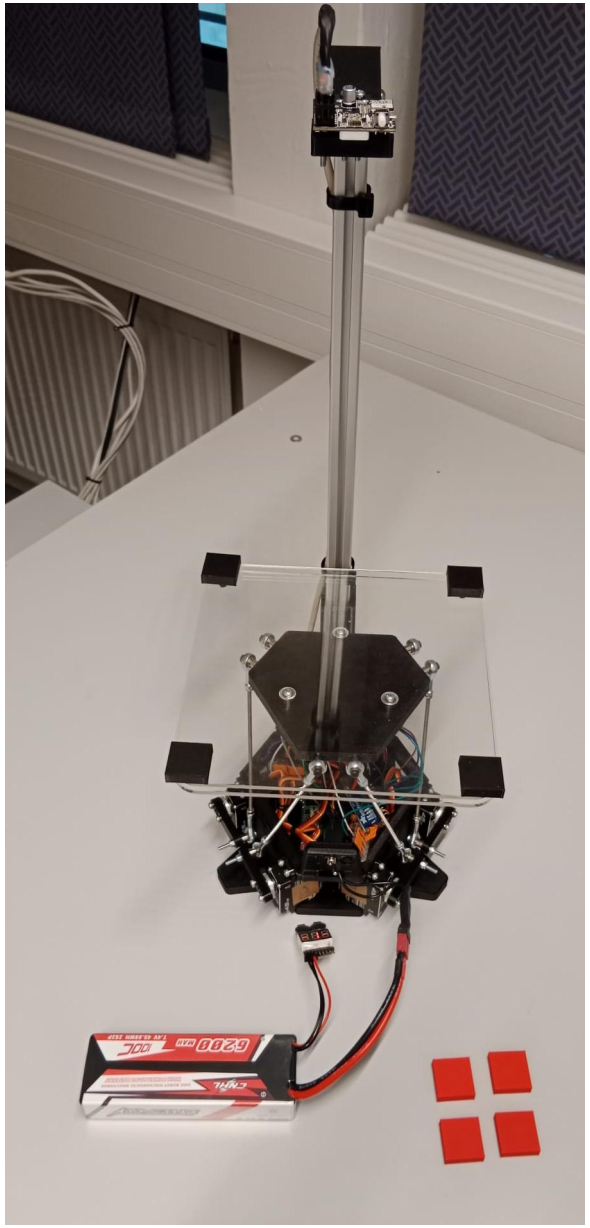


6-Degree-of-Freedom Ball Balancing Robot

Step by step guide

Steps for building the robot

1. Check components.
2. Install Software.
3. 3D print + Lasercut.
4. Electronics.
5. Assemble camera and base.
6. Assemble platform.
7. Camera calibration.

Step 1. Check Components

- Check components from the "**List of Materials.xlsx**".
- Make sure you have all the components.

Electronics	Units
Servo Motor 20Kg 7.4V	6
Teensy 4.1	1
Micro Maestro 6-channel USB Servo Controlle	1
Pixy 2 Camera	1
3.3V to 5V LLC	1
Custom PCB	1
Male Pins 1 Row for PCB	84
Female Pins 1 Row for PCB	80
Male-female/male-male wire	6
2-Contact Screw Termination	1
USB cable	2
3x2 Male Pins	1
3x2 Female Pins	2
Toggle Switch	1
18 AWG Wire	40cm
Amass T-Plug2 [deans] - 1x Male	1
LiPo Battery 7.4V 6200mAh	1
Cable x5 cores	80cm
Cable Nylon Cover	5cm
LiPo Alarm	1
Voltage Regulator 5V	1

Materials	Units
3D printer filament	-
Acrylic 3mm thickness	-
Aluminium Servo Disc	6
M3 Stainless Steel Threaded Rod 1m	1
M3 x 6mm Inserts	48
M3 x 5mm Standoff	22
M3 Locknuts	24
M3 x 5mm Screws	24
M3 x 14mm Screws	30
M3 x 20mm Button Head Screw	3
M3 x 25mm Screw	9
20 x 20mm Alum Profile 5mm Groove 2m	1.2
M5 T-Slot Nut Groove Size 5mm	8
M5 x 12mm Screw	8
Silicon Glue Tube	1

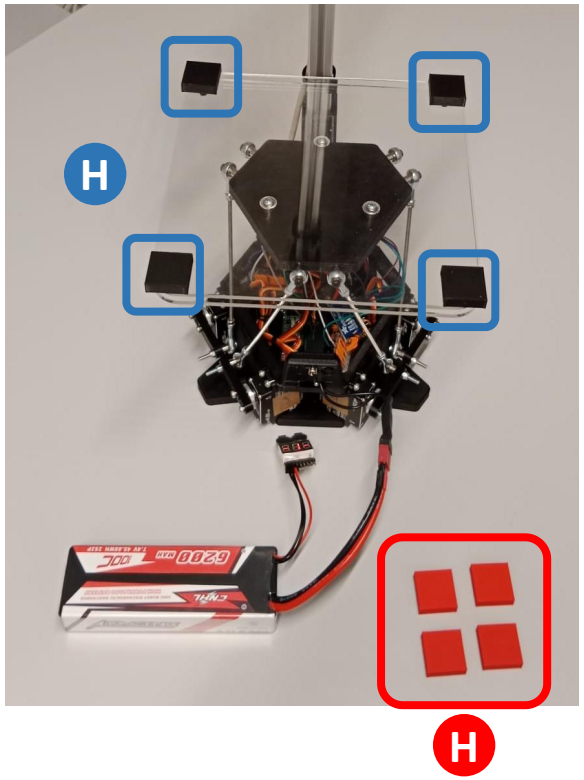
Step 2. 3D print + Lasercut

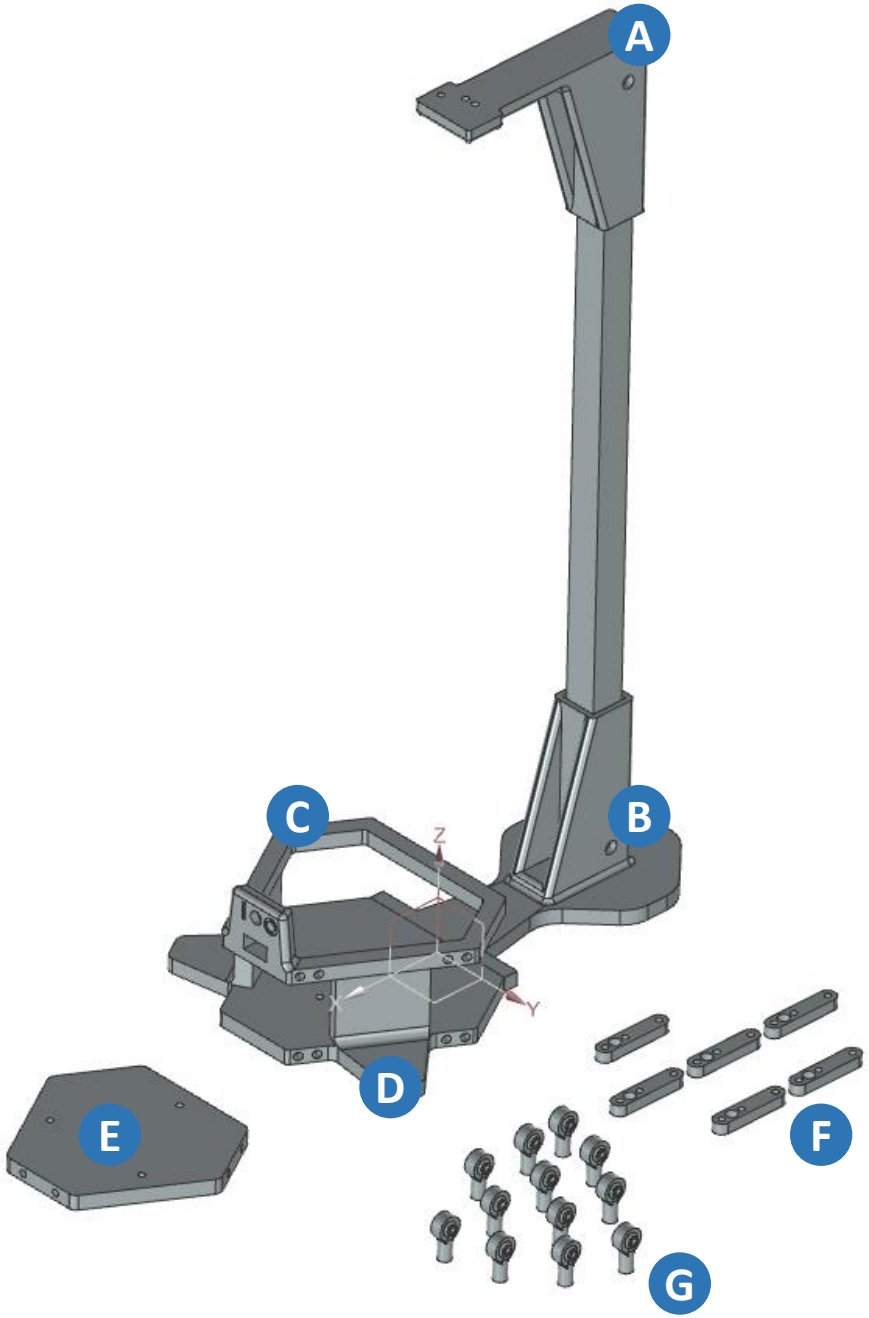
- 3D Print using color **different than red**:

A • x1 Camera Top
B • x1 Camera Bottom
C • x1 Base Top
D • x1 Base Bottom
E • x1 Platform Bottom
F • x6 Motor Arm
G • x12 Rod End
H • x4 Marker

- 3D Print using **red** color:

H • x4 Marker



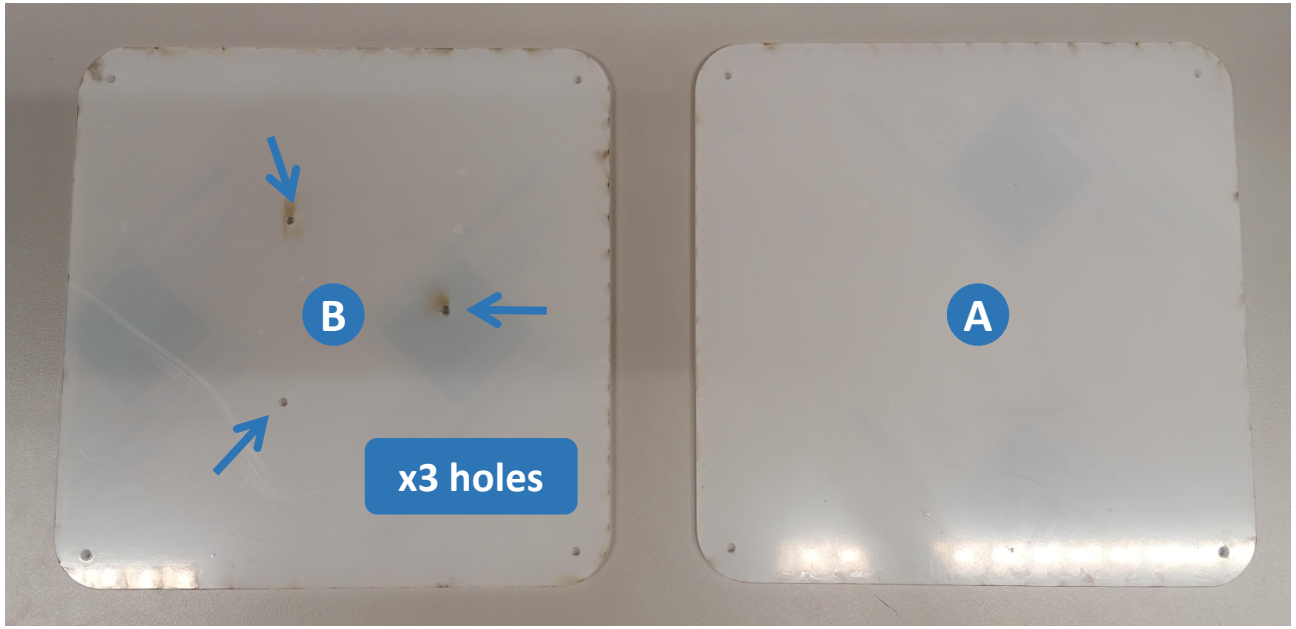


Step 2. 3D print + Lasercut

- Lasercut in Acrylic:

A • x1 Plarform Top (given)

B • x1 Platform Bottom (given)

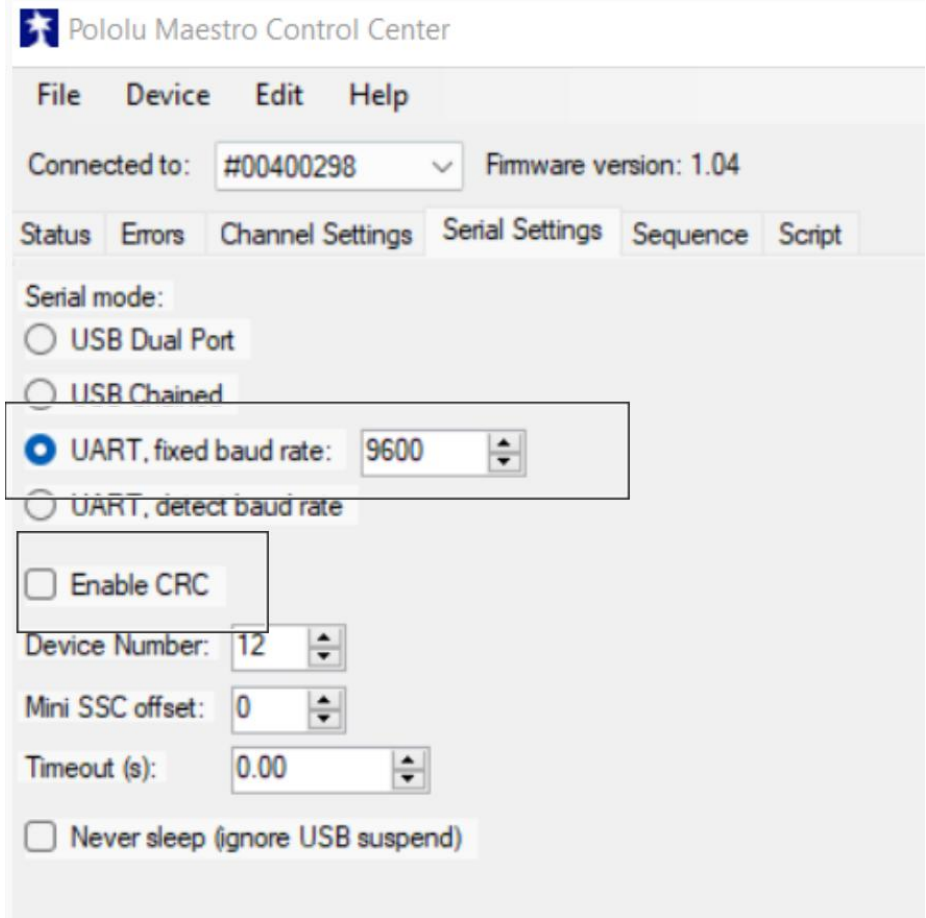


Step 3. Install Software

- Install Arduino IDE
- Install libraries (how to install libraries):
  - Pixy2 (.zip)
  - maestro-arduino-master (.zip)
  - Teensy
- Connect and check that theTeensy is detected.

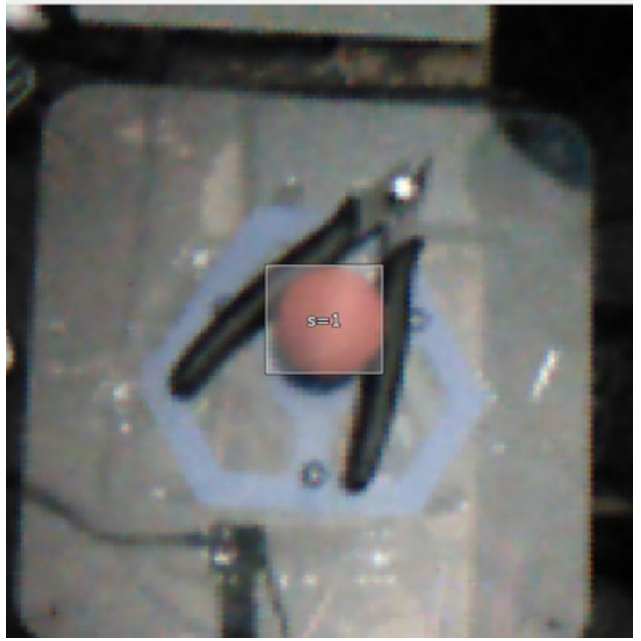
Step 3. Install Software

- Install Maestro Control Center
- Connect to Maestro, open the installed program, go to **Serial Settings** and apply these settings:
  - Serial mode: UART, fixed baud rate
  - Baud rate: 9600
  - CRC disabled
- Connect Motors to the Maestro and check if you can move them from the software.



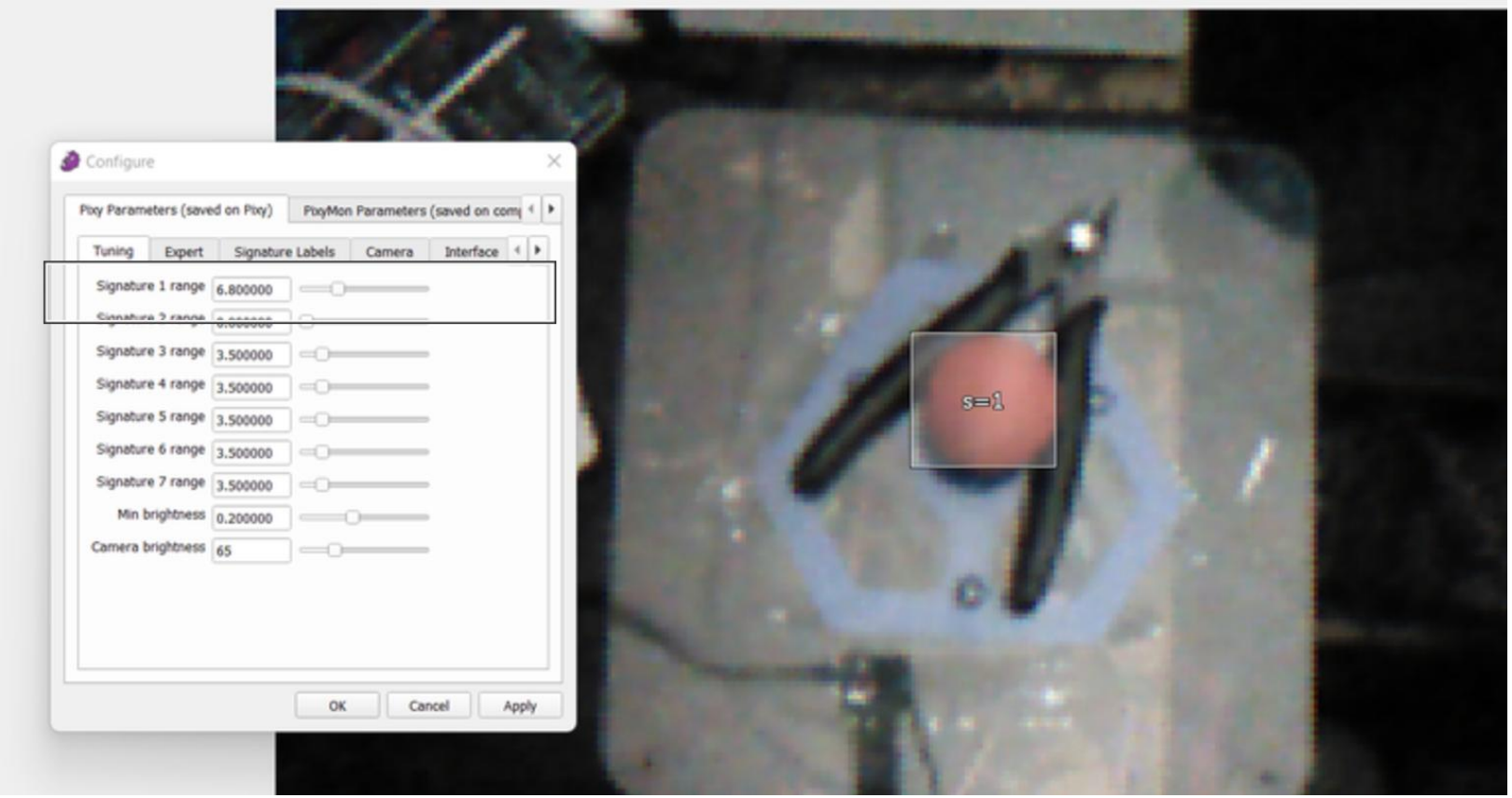
Step 3. Install Software

- Install PixiMon v2
- Connect to Pixy2 and check if it works.
- Teach to detect red objects:
  - Pixy2 Camera - Image Recognition for Arduino & Raspberry Pi
  - Tips on Improving Detection Accuracy

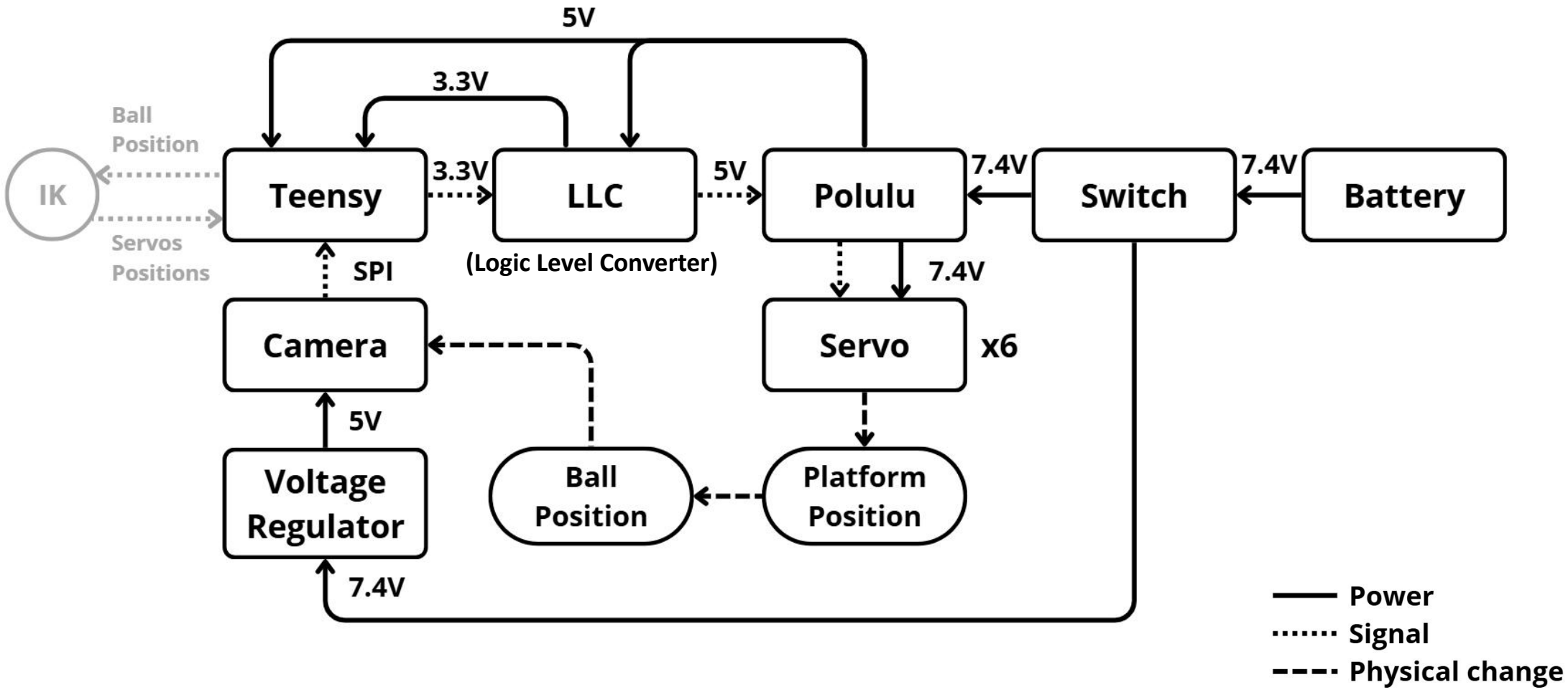


Step 3. Install Software

- Set signature 1 range to 6.8 / rest as in the image below:

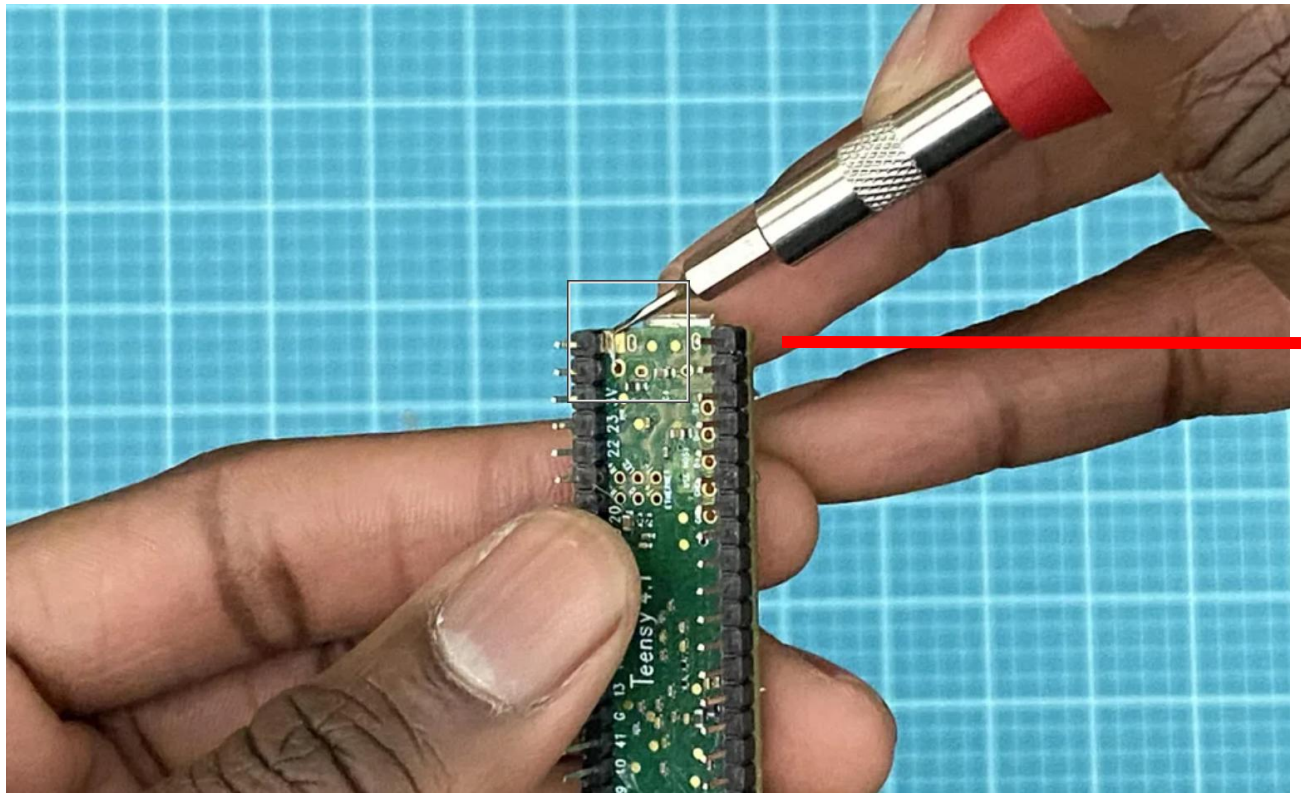


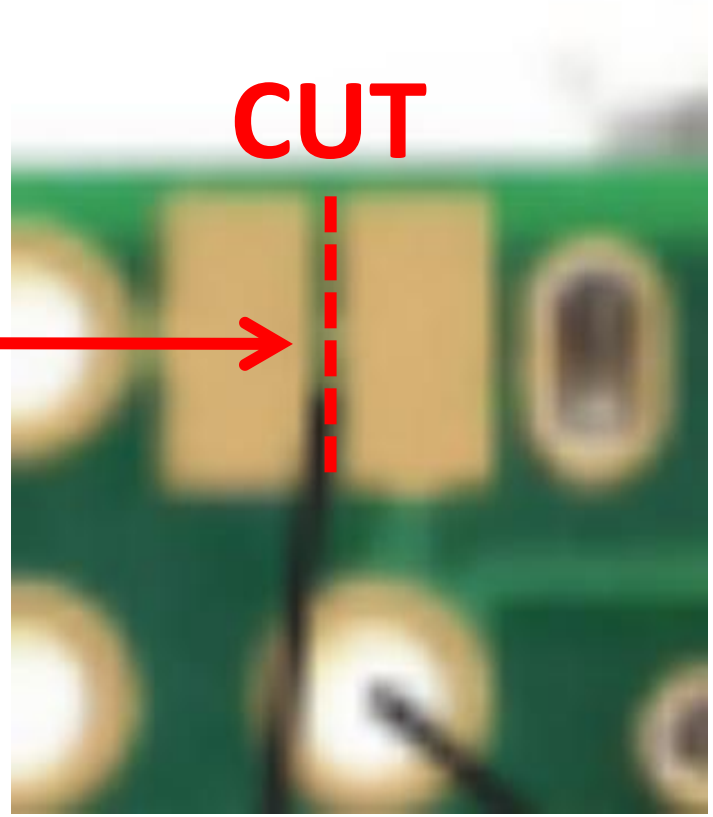
Step 4. Electronics (overview)



Step 4. Electronics

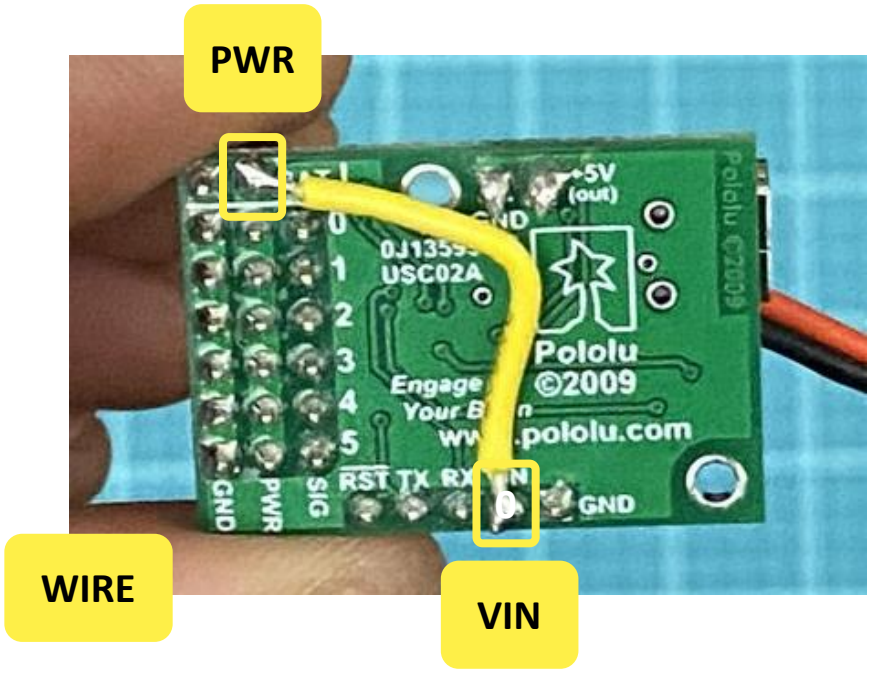
- Cut Vin to USB trace on the back of the Teensy

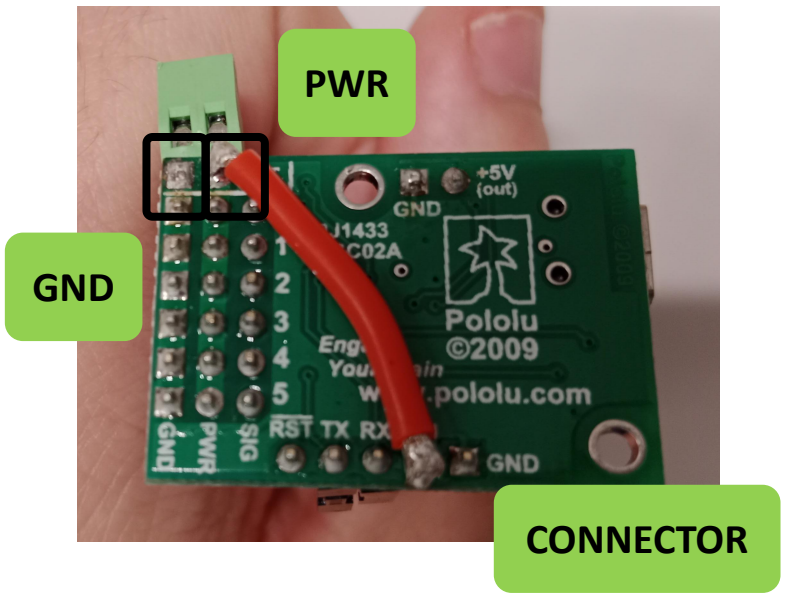


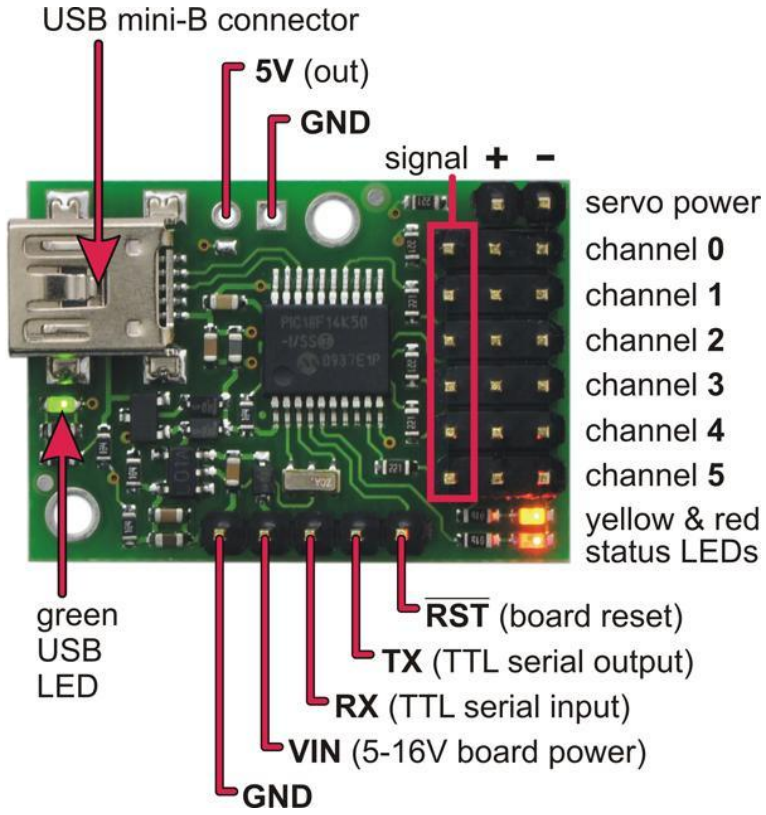


Step 4. Electronics

- Modify polulu. Solder:
  - **Wire** from **Vin** to **PWR**
  - **Connector** to **Vin** and **GND**







Step 4. Electronics

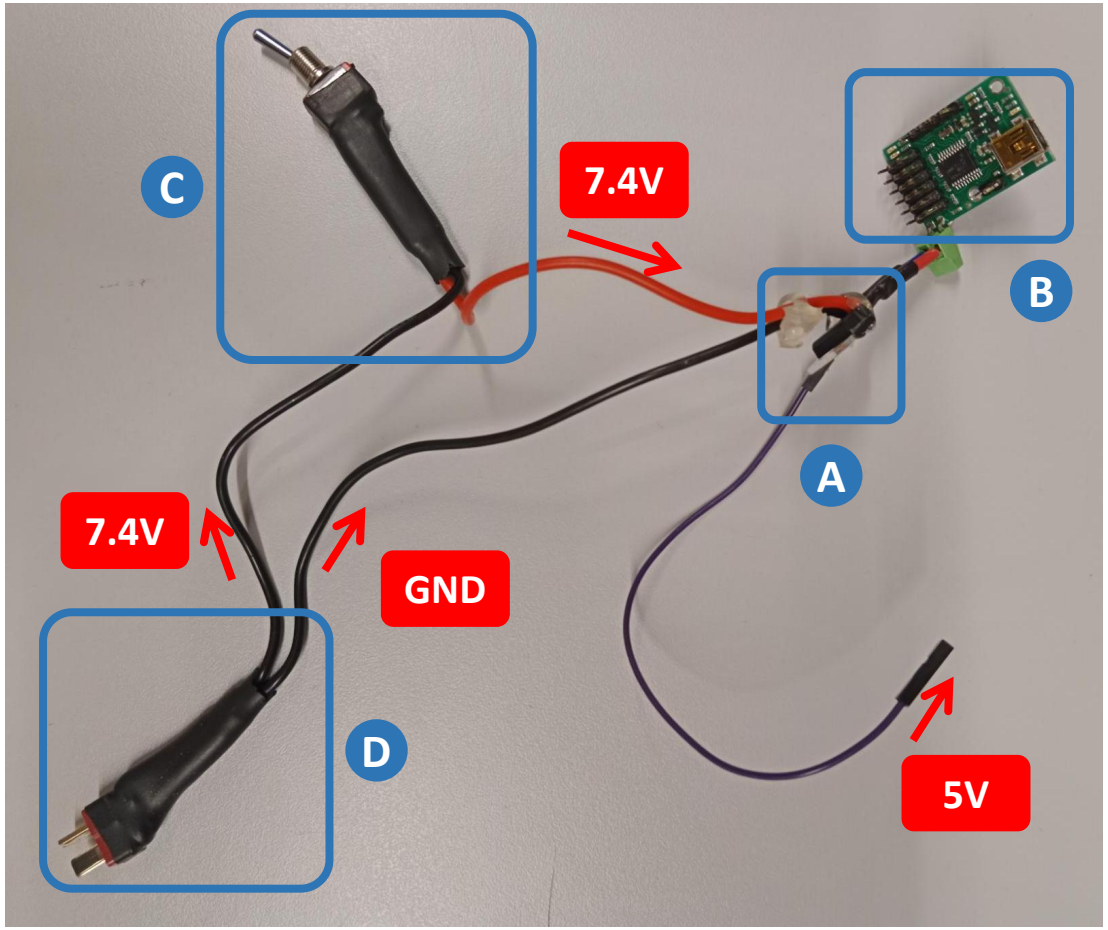
- Solder and make connections:

A
- 5V Voltage Regulator:
  - Inputs: 7.4V and GND from battery.
  - Output: 5V for Pixy2.

B
- Polulu to 7.4V and GND from battery.

C
- Switch in 7.4V from battery.

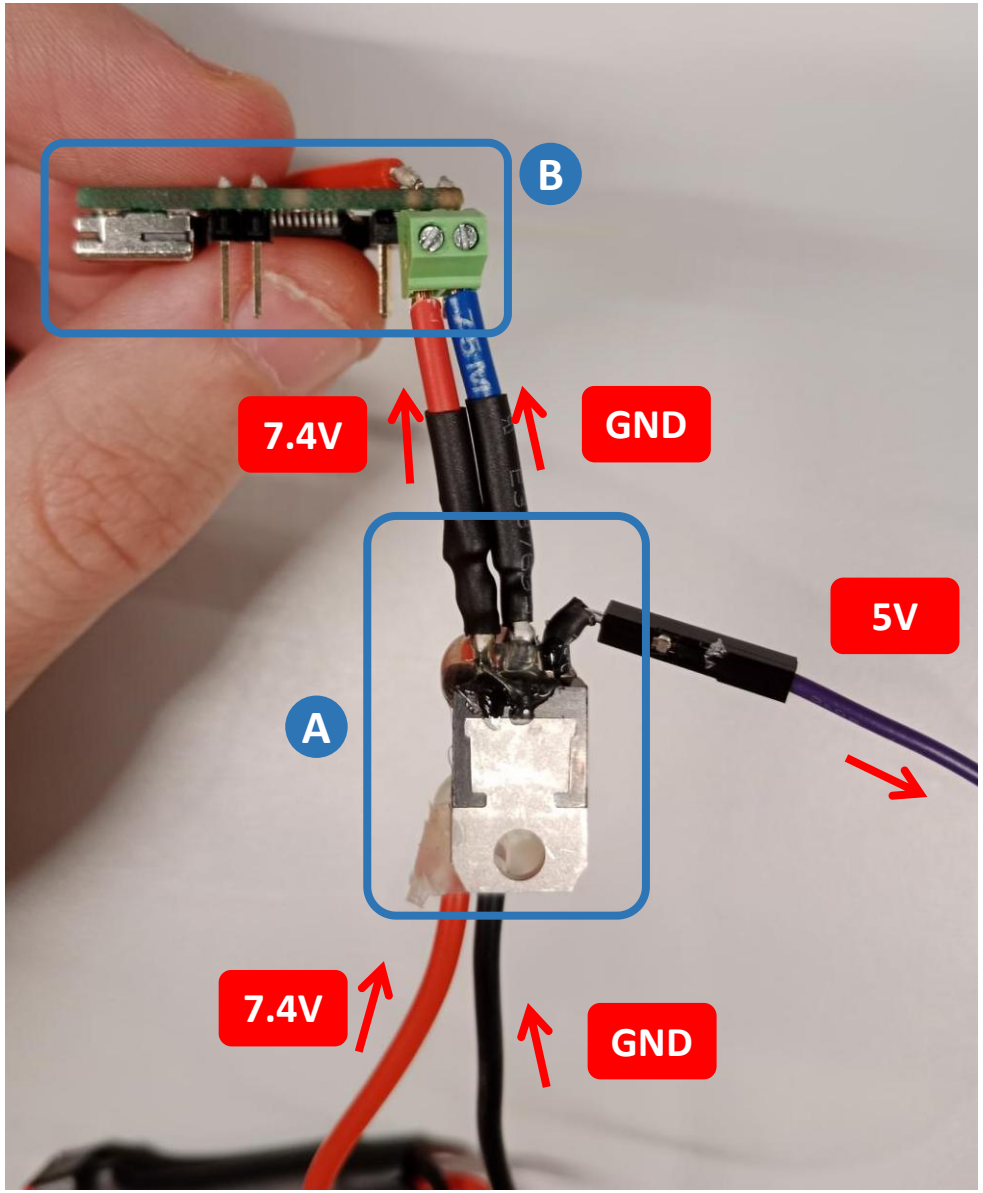
D
- Battery T-Plug (male).



Step 4. Electronics

- A • 5V Voltage Regulator:
  - Inputs: 7.4V and GND from battery.
  - Output: 5V for Pixy2.
- B • Polulu to 7.4V and GND from battery.

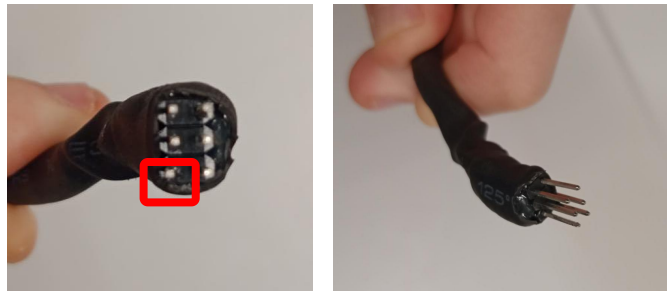
***Important!** Make sure 7.4V and GND do not touch each other, to avoid fireworks

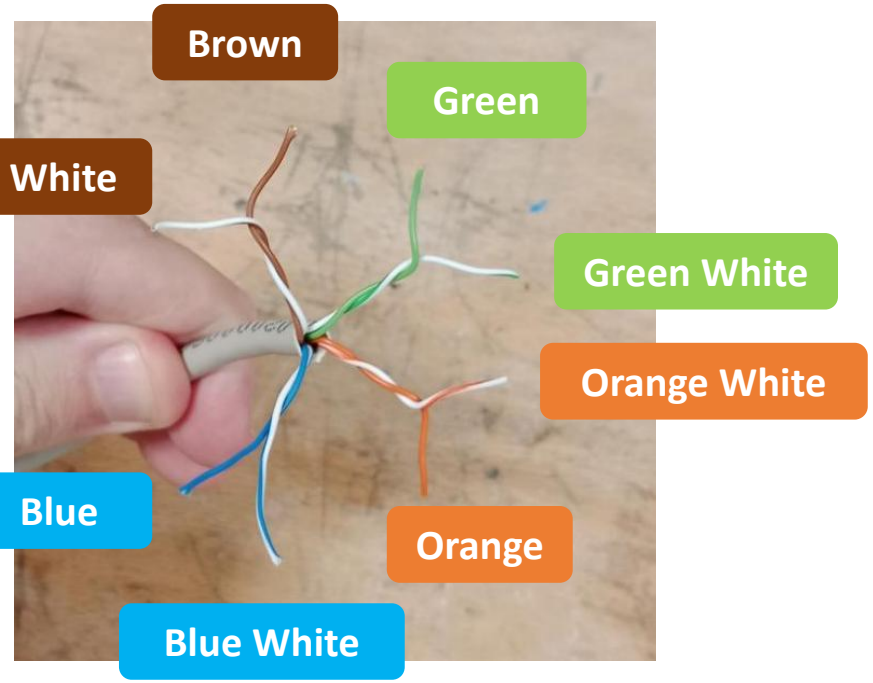


Step 4. Electronics

- Cable for camera

Mark (6) GND as Reference!





A

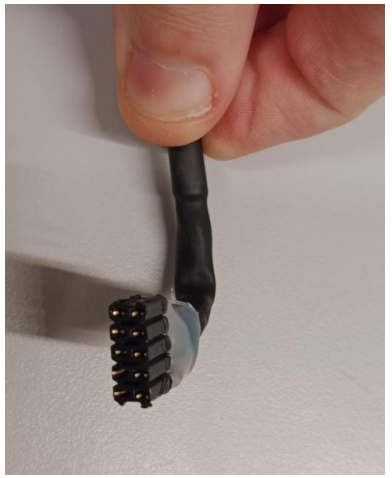
Cable to PCB (Male pins)

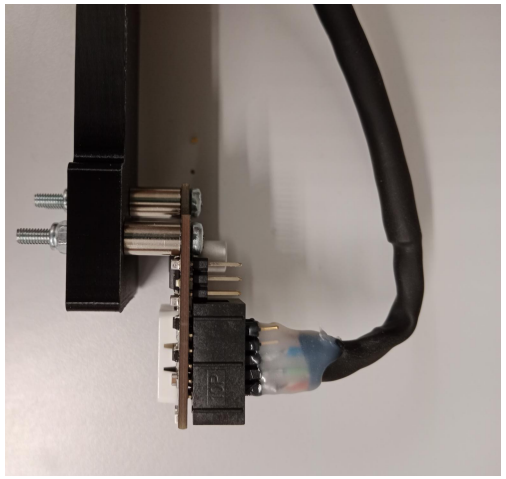
Green White	(1) (2)	Orange Both
Brown White	(3) (4)	Green
Brown	(5) (6)	Blue Both

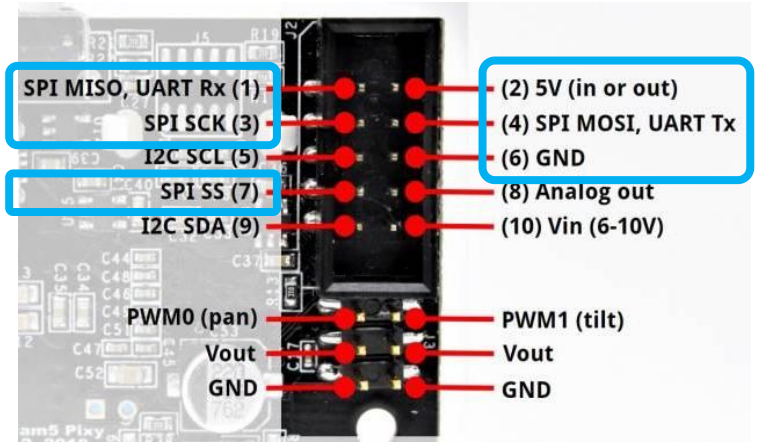
B

Cable to Pixy2 (Female pins)

Green White	(1) (2)	Orange Both
Brown White	(3) (4)	Green
	(5) (6)	Blue Both
Brown	(7) (8)	
	(9) (10)	

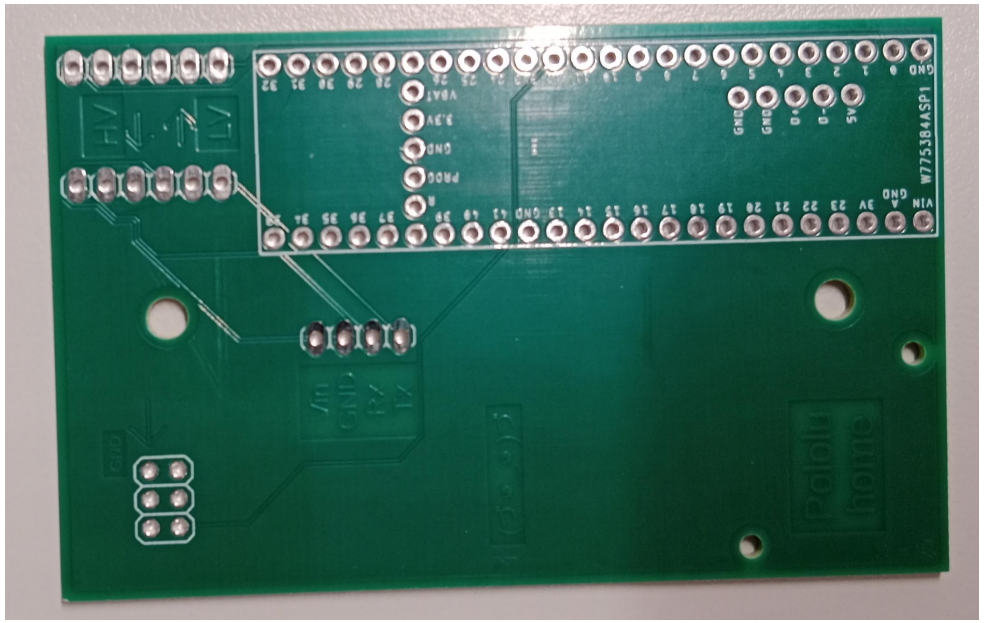


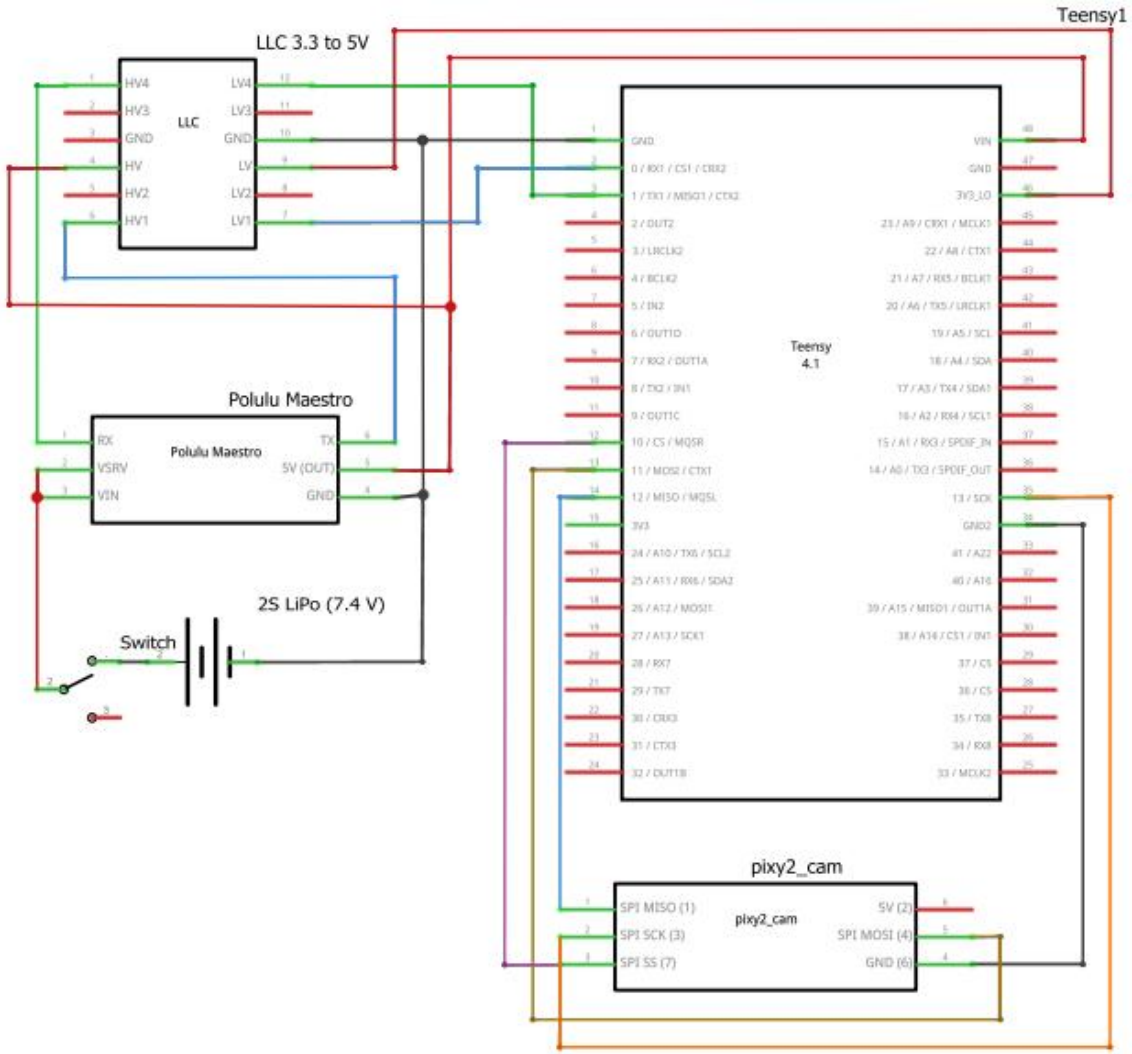




Step 4. Electronics

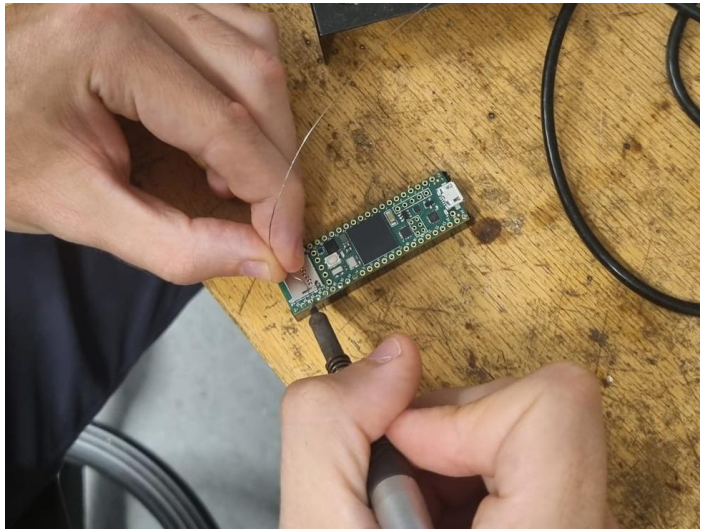
- Printed Circuit Board (PCB)

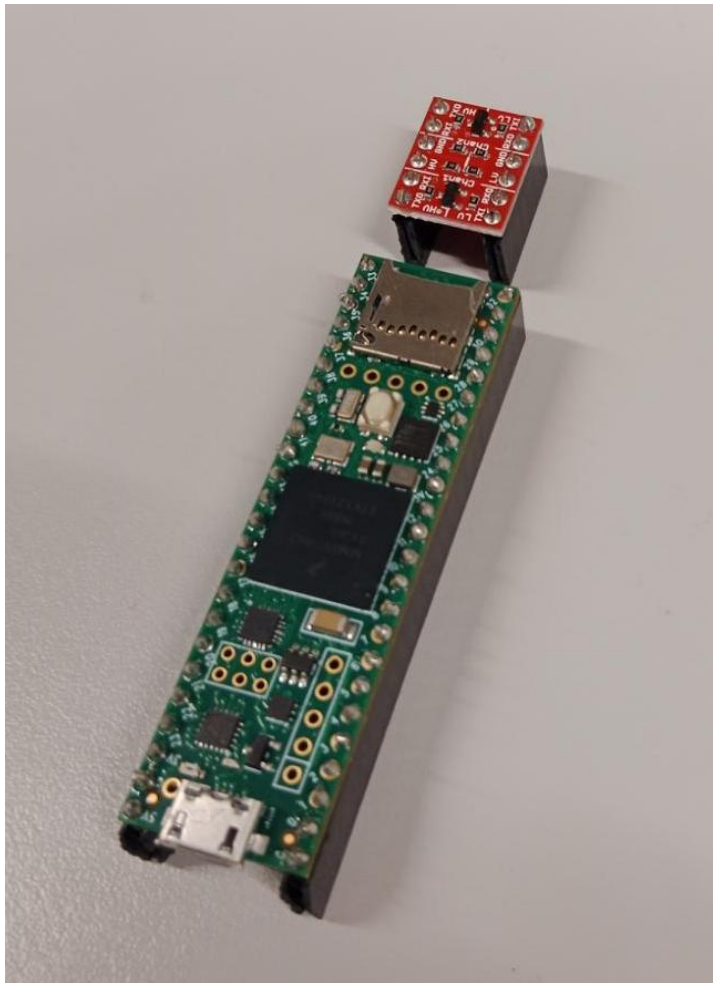


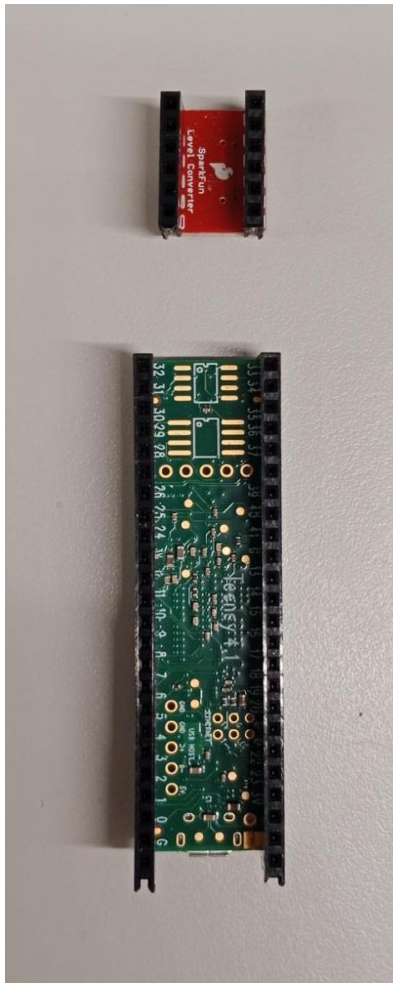


Step 4. Electronics

- Solder:
  - Female Pins to Teensy
  - Female Pins to LLC







Step 4. Electronics

- Solder to PCB:
  - A • Male pins for Teensy
  - B • Male pins for LLC
  - C • Female pins for Camera Cable
  - D • Female Pins for Polulu
  - E • Cable for camera 5V

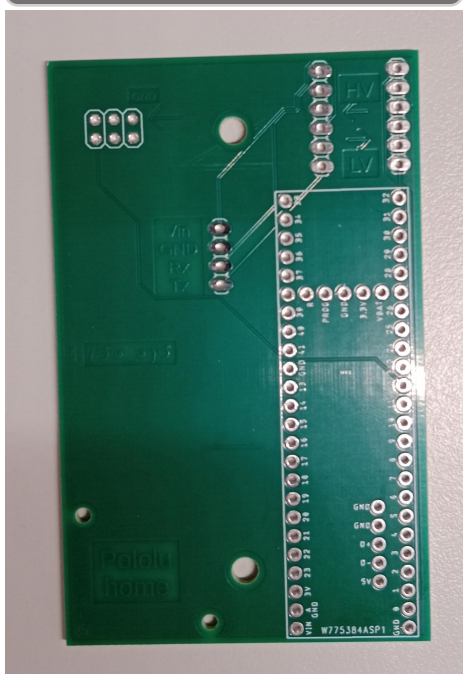
***Remember from camera connection:**

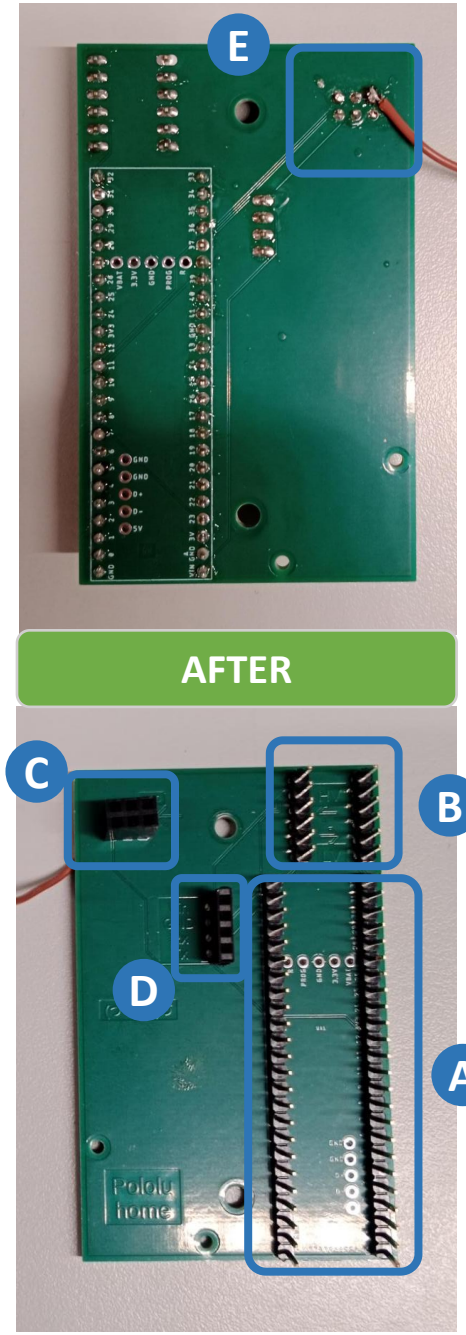
Cable to PCB (Male pins)

Green	White	(1) (2)	Orange	Both
Brown	White	(3) (4)	Green	
	Brown	(5) (6)	Blue	Both

(2) 5V (in or out)

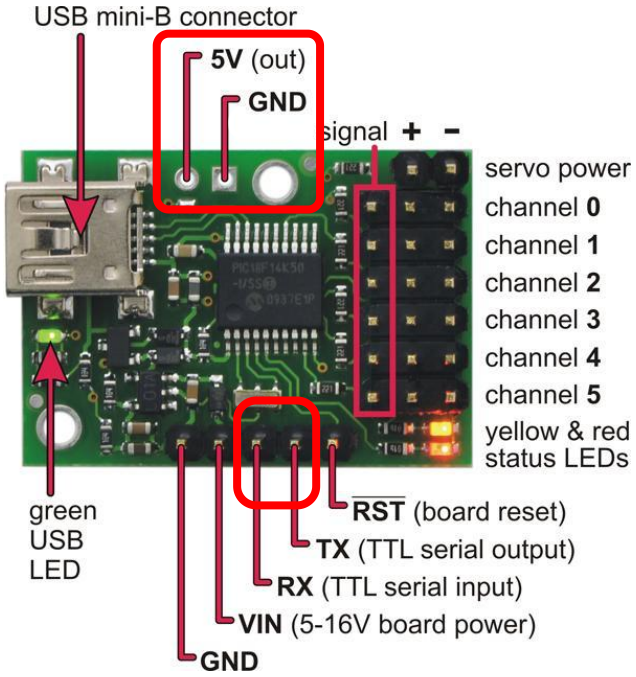
BEFORE

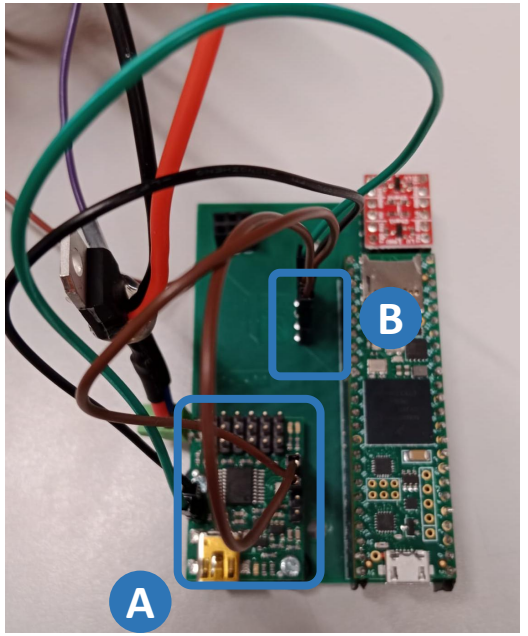




Step 4. Electronics

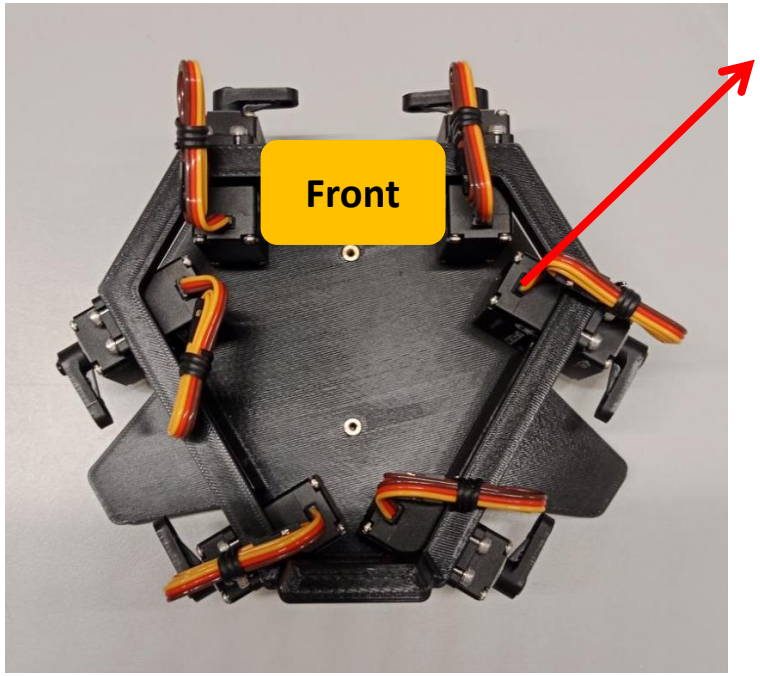
- PCB assembly:
  - A • Screw Polulu to PCB.
  - B • Plug Polulu connections to PCB (marked in PCB): RX, TX, Vin, GND.
  - C • Connect 5V wire from camera: from PCB to Voltage Regulator.





Step 5. Assemble Camera and Base

- Assemble: Base Top and Bottom + Motors + Motor Arms



x6 Motors

x4 Screws

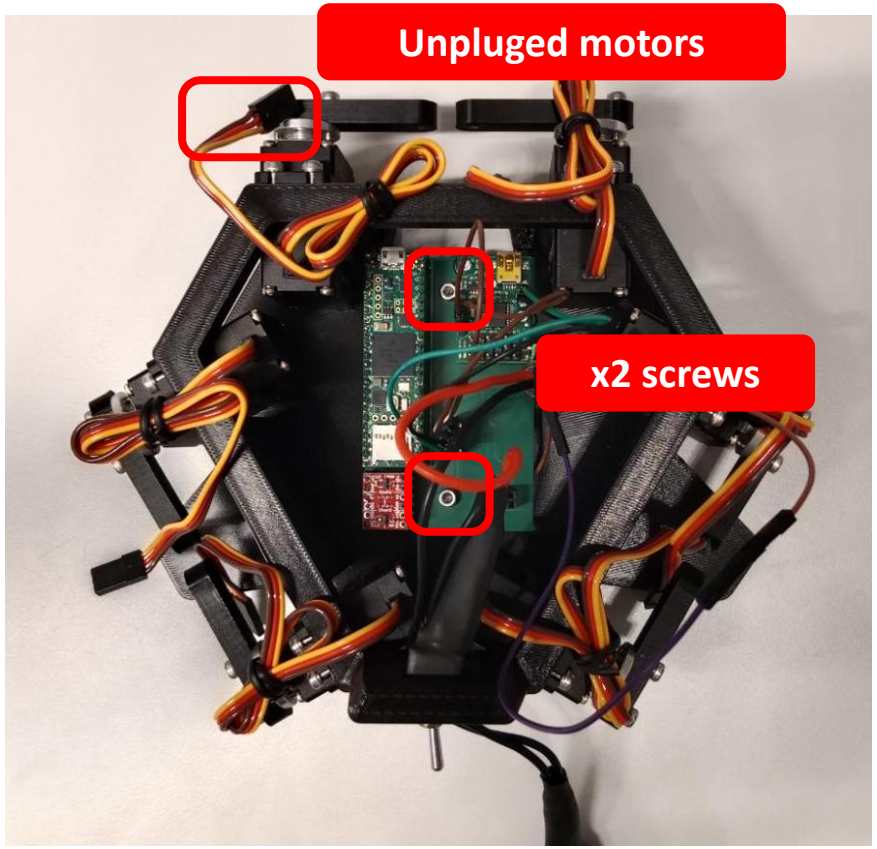
*Use heat from solderer for fixing inserts

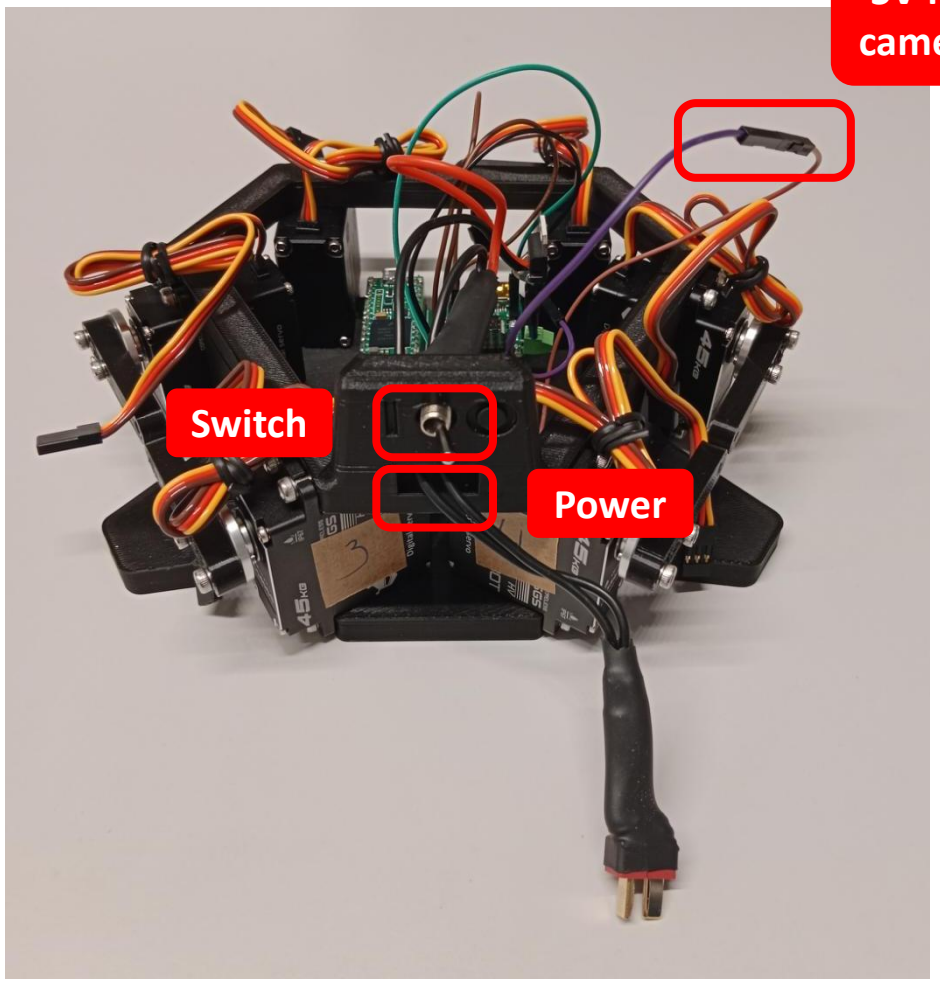
Aluminium servo disk + motor screw

x2 M3x5mm screws + 3D printed motor arms

Step 5. Assemble Camera and Base

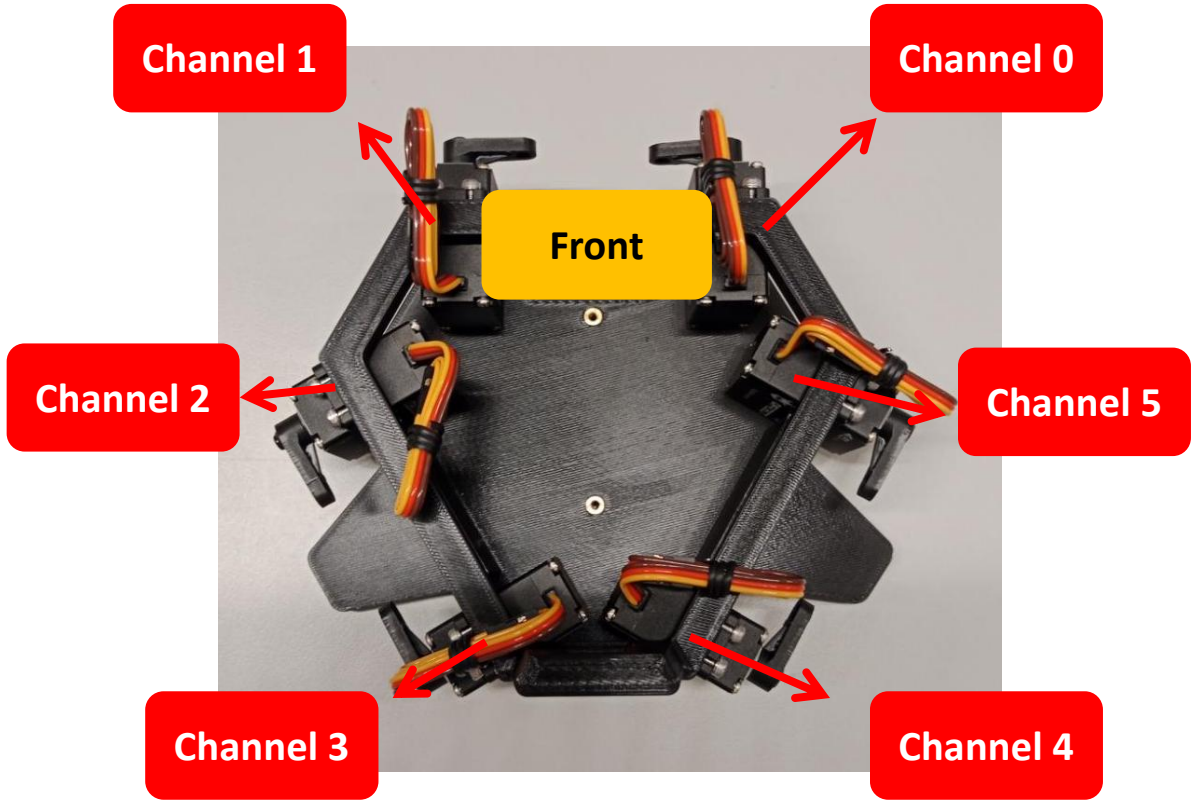
- Assemble PCB to base

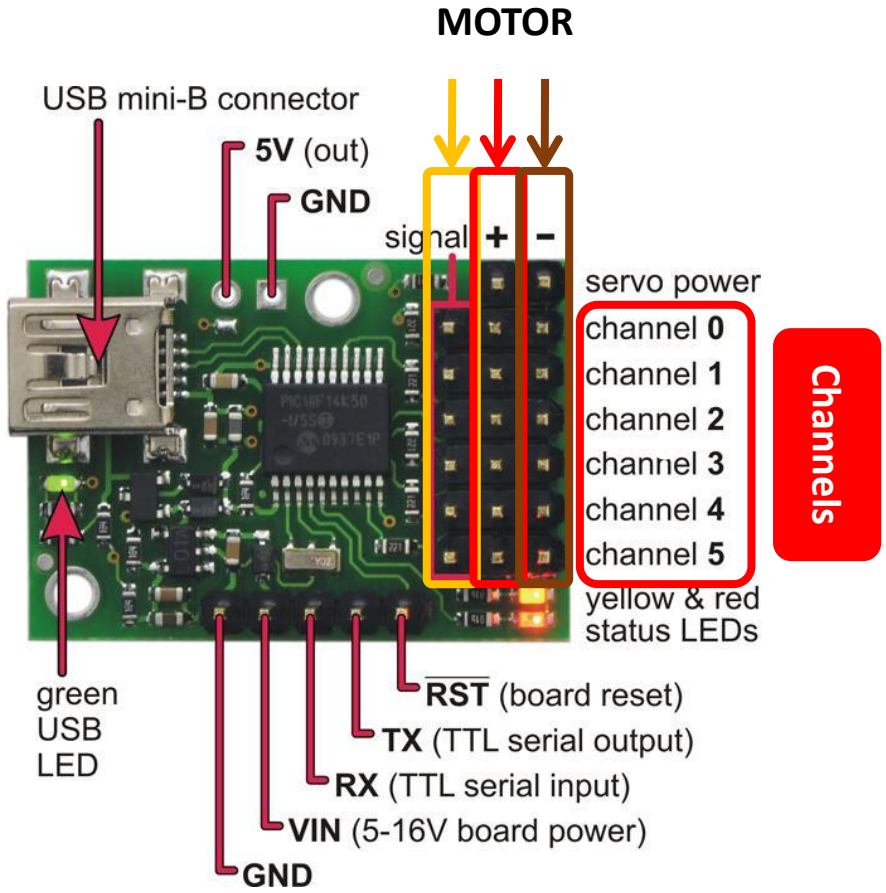




Step 5. Assemble Camera and Base

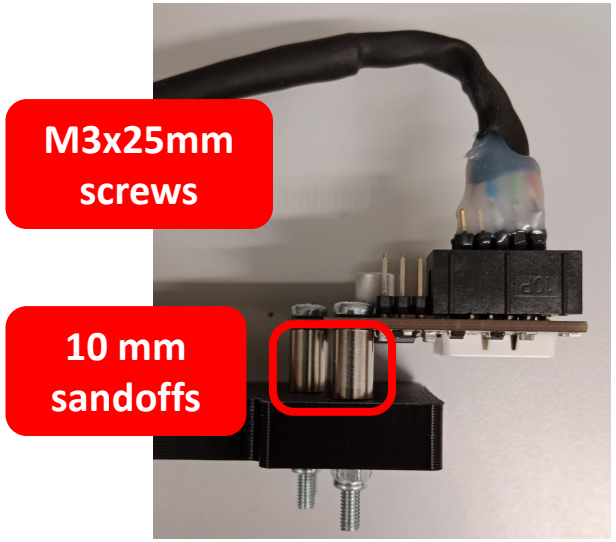
- Connect motors to Polulu: **Order is important!**

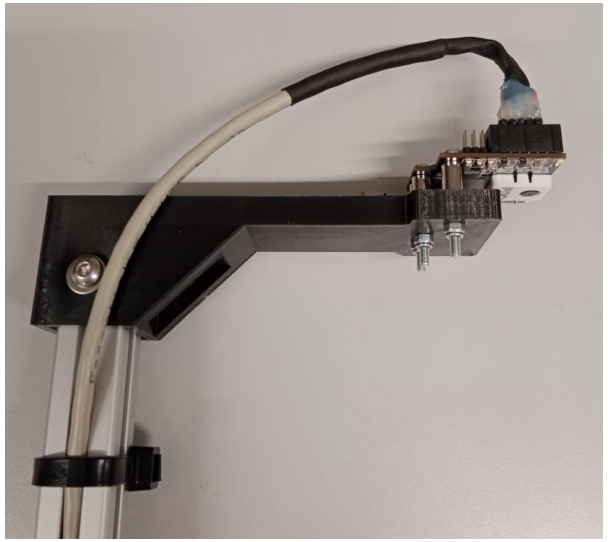


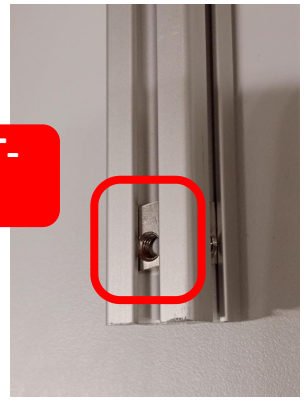


Step 5. Assemble Camera and Base

- Assemble: Pixy2 + Camera Top and Bottom + Aluminium Profile + Cable

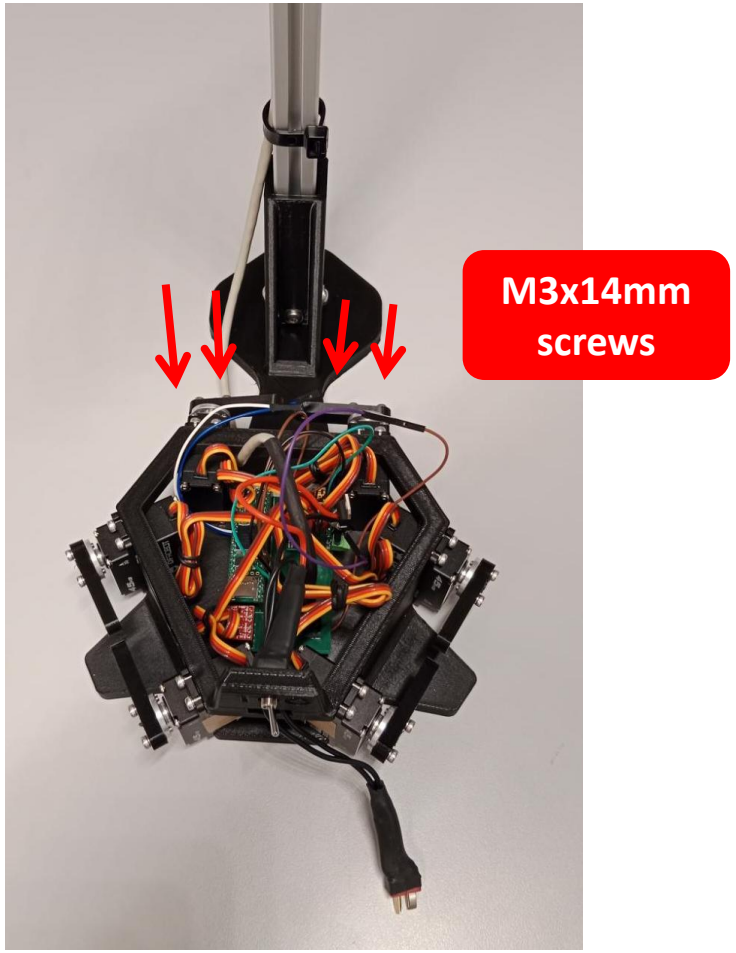






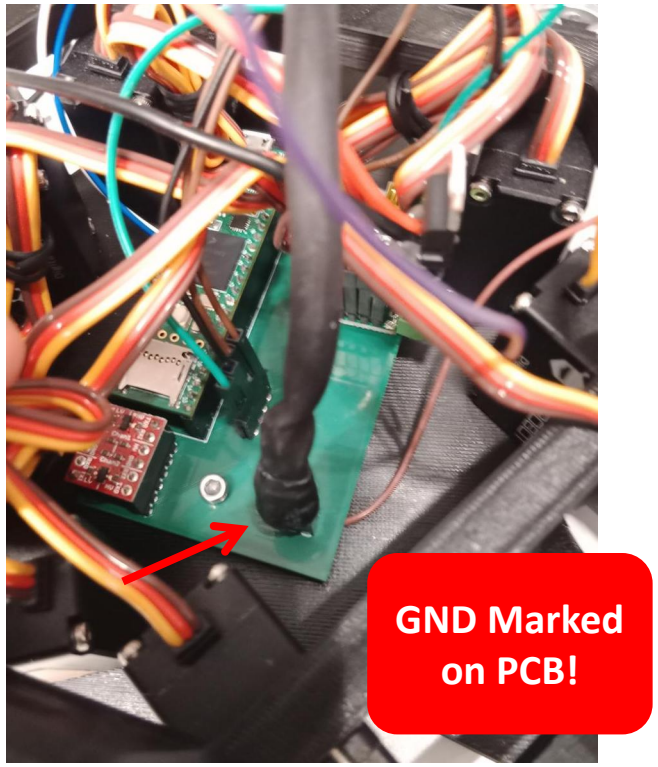
Step 5. Assemble Camera and Base

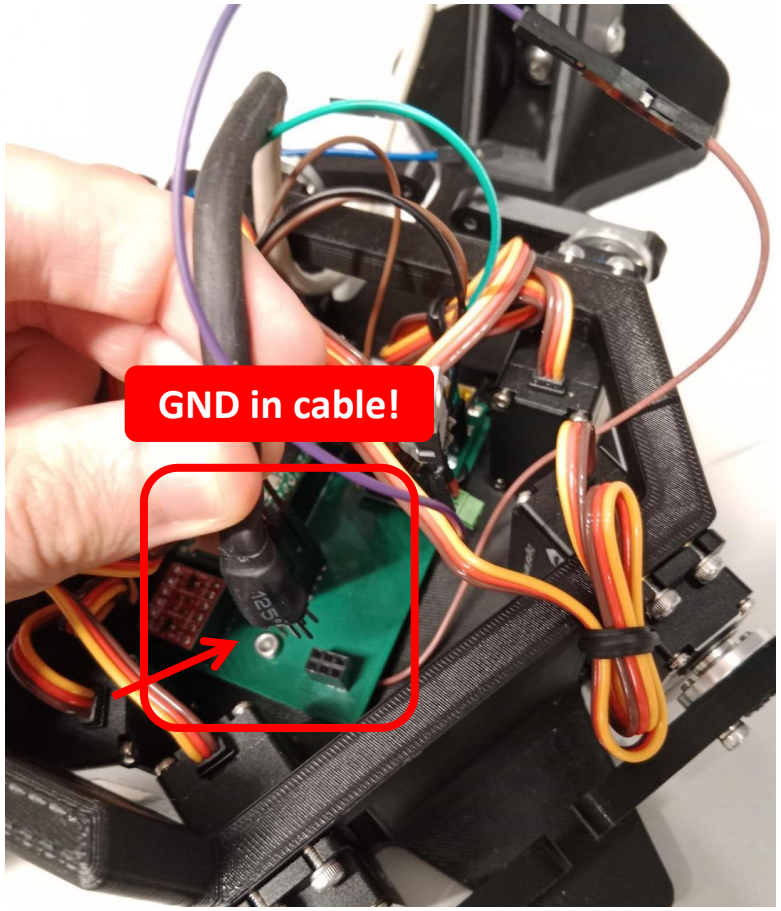
- Assemble together camera stick and base



Step 5. Assemble Camera and Base

- Connect camera to PCB





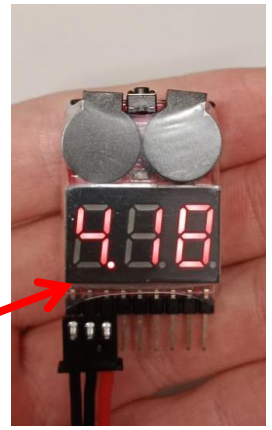
Step 5. Assemble Camera and Base

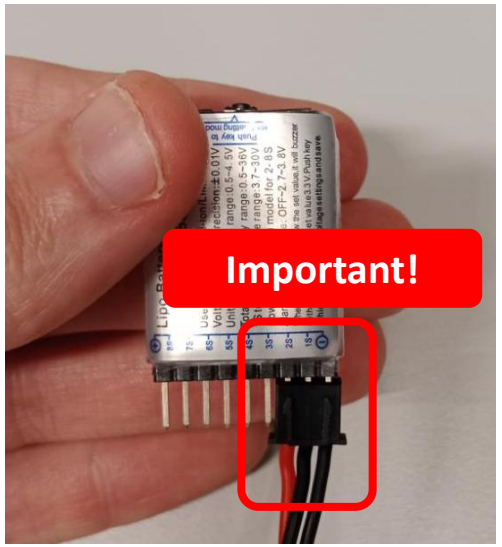
- Connect battery and battery tester

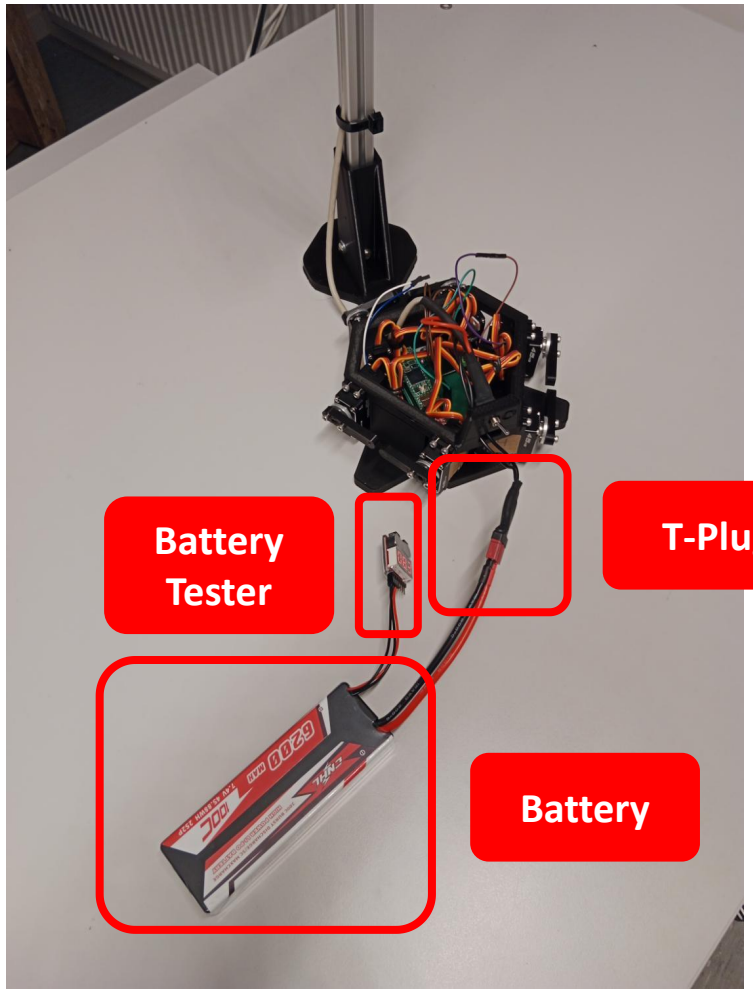
The battery tester will beep when the battery voltage is low. This prevents the battery from going too low voltage, which would destroy the battery

The battery has 2 cells. Their nominal voltage is 3.7V each (3.7V x 2 = 7.4V)

The battery tester needs to be programmed to start beeping at a cell voltage of 3.6V







Red (2S) - Black (1S) - Black (-)

Step 5. Assemble Camera and Base

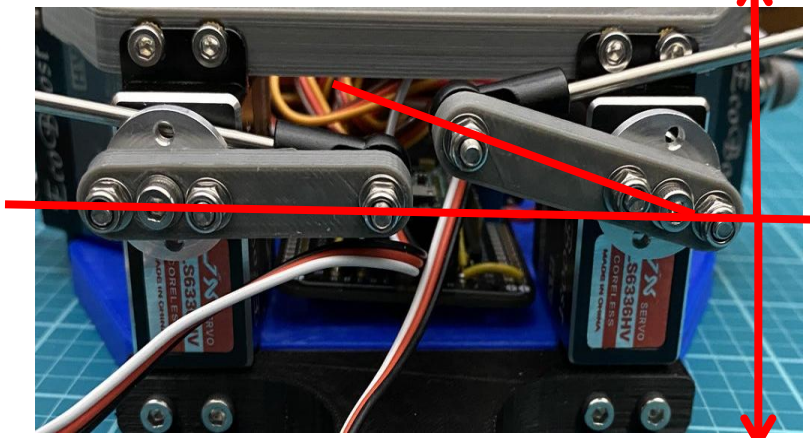
- Run “Home_Servos.ino” in the Teensy
- Fine tune motor angles to be horizontal

```
float offset[6] = { 0.0, 0.0,    // channel #0 and channel #1
                    0.0, 0.0,    // channel #2 and channel #3
                    0.0, 0.0 };  // channel #4 and channel #5
```

***Save the obtained values!**

Negative offset values (up)

Horizontal



Positive offset values (down)

Step 6. Assemble Platform

- Cut M3 rod -> x6 120mm long rods
- Put inserts in tie rods (x12)

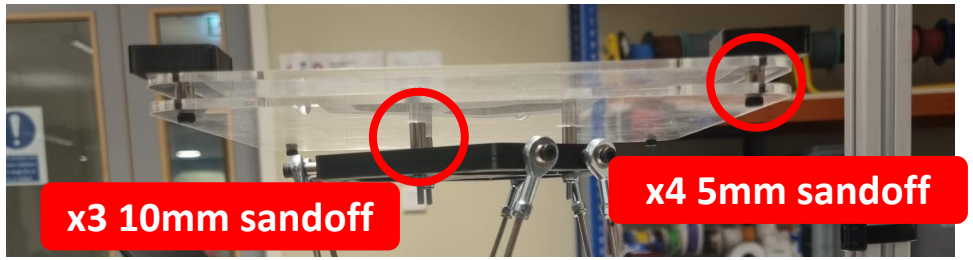
Cut

Grind

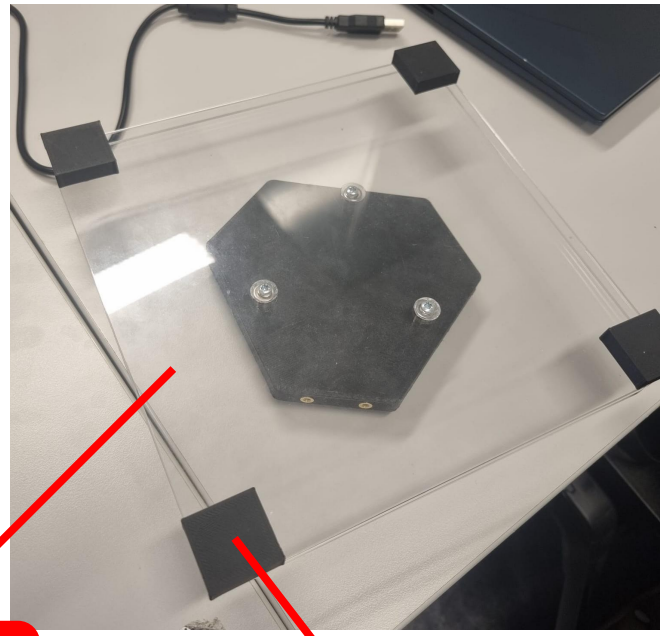
Tie rod

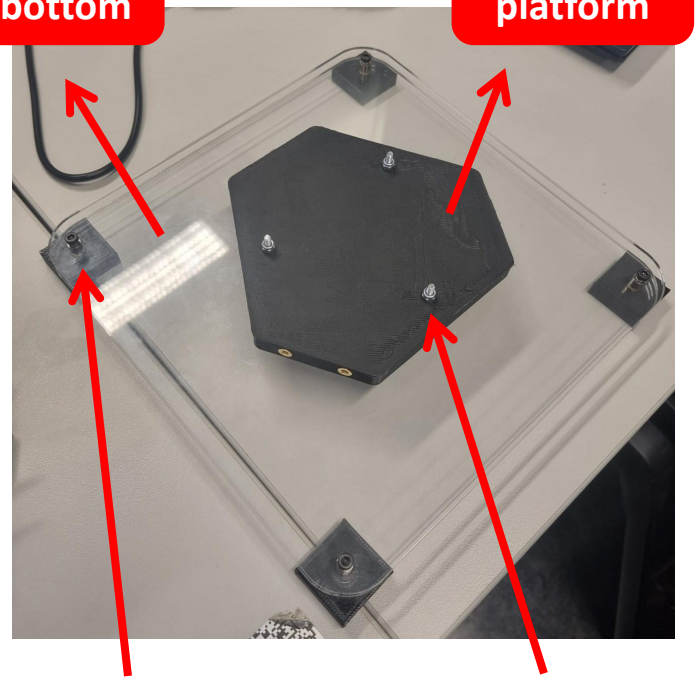
Insert

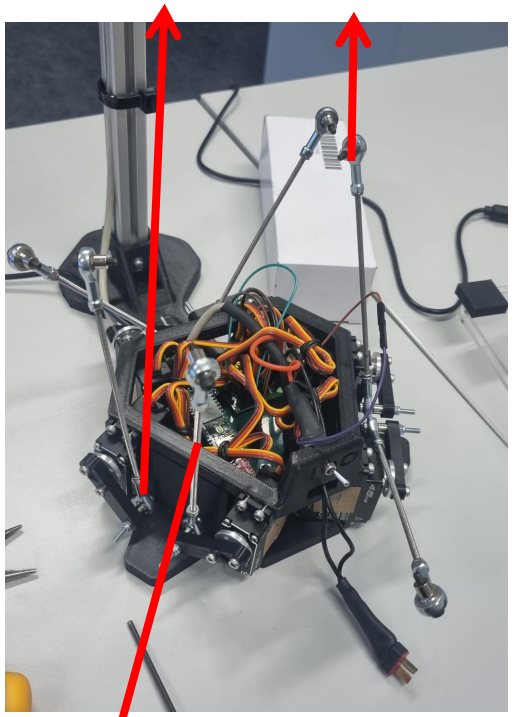
Step 6. Assemble Platform



- Assemble platform

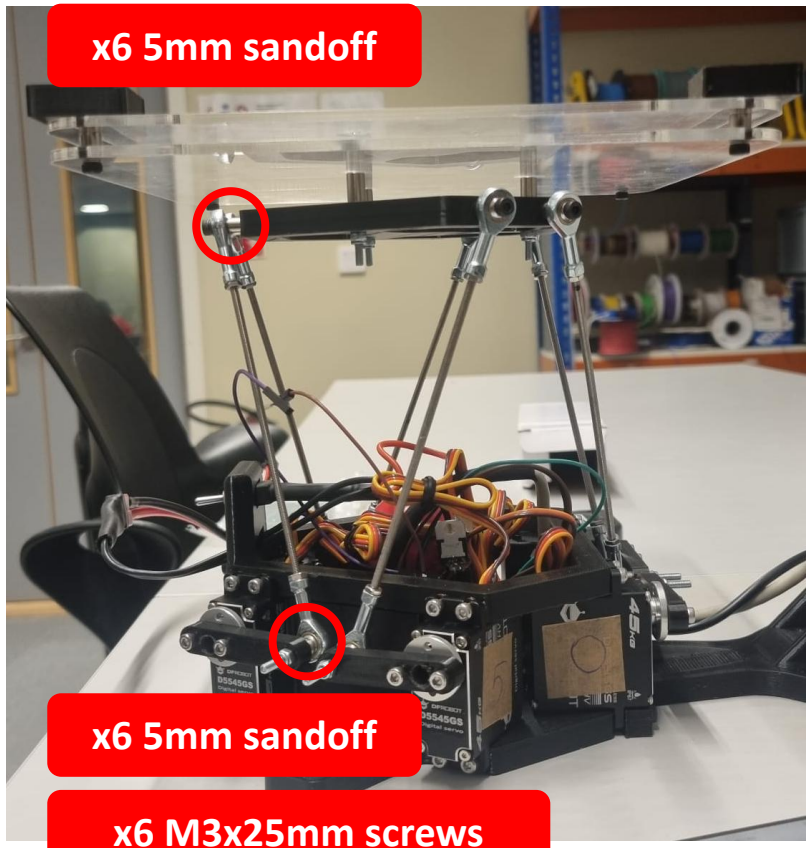


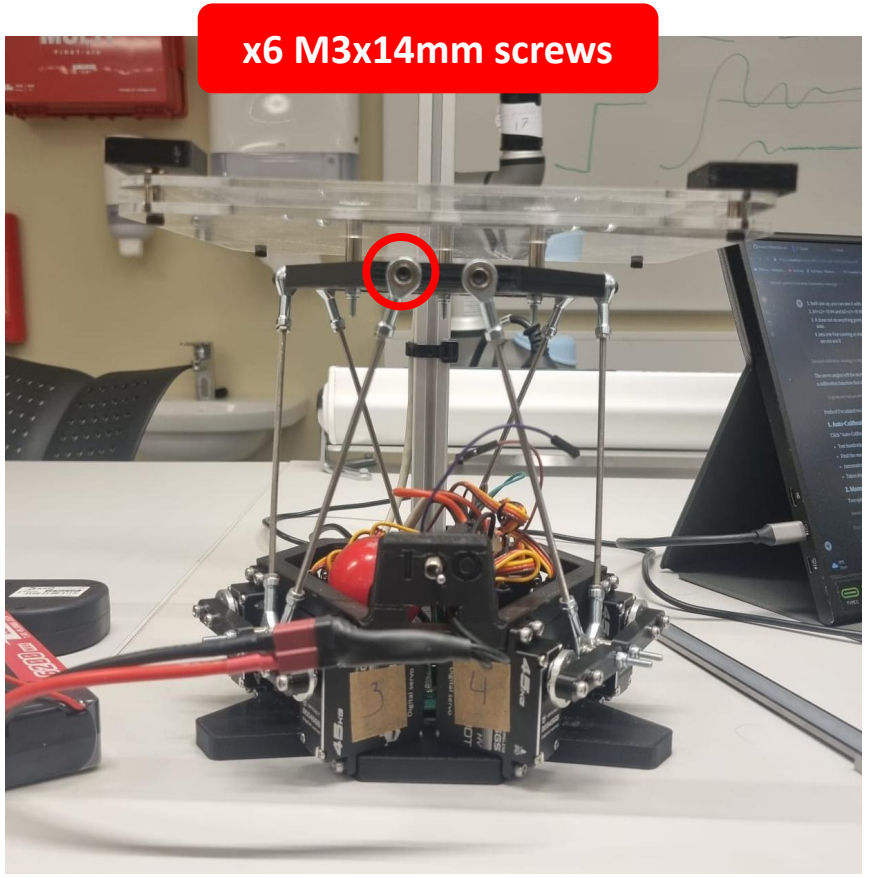




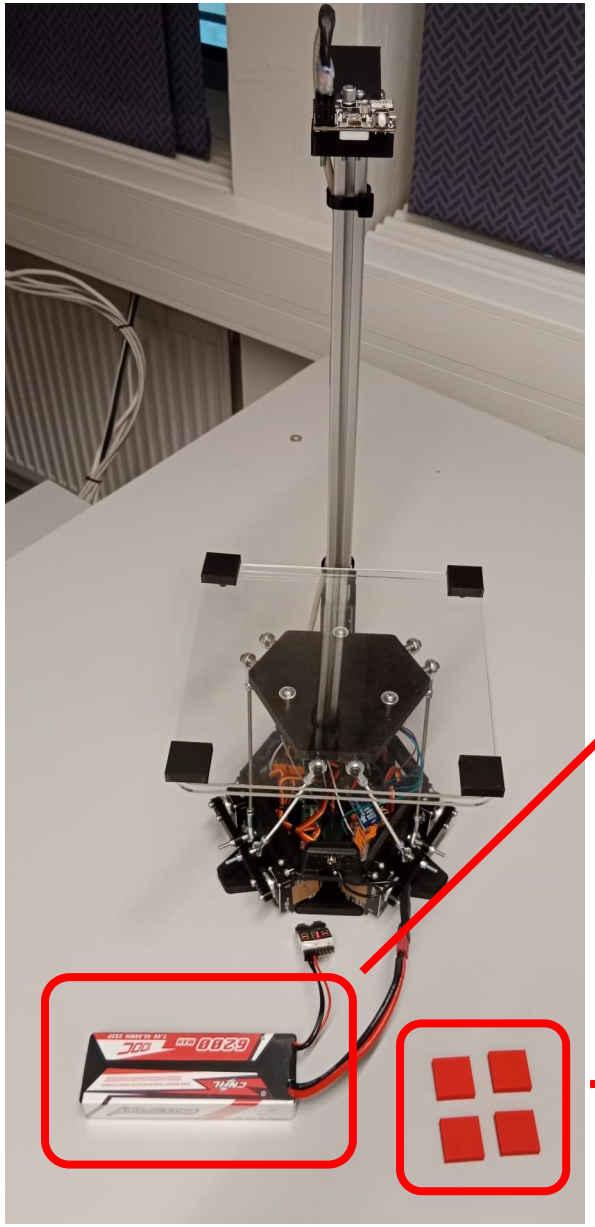
Step 6. Assemble Platform

- Connect platform to base



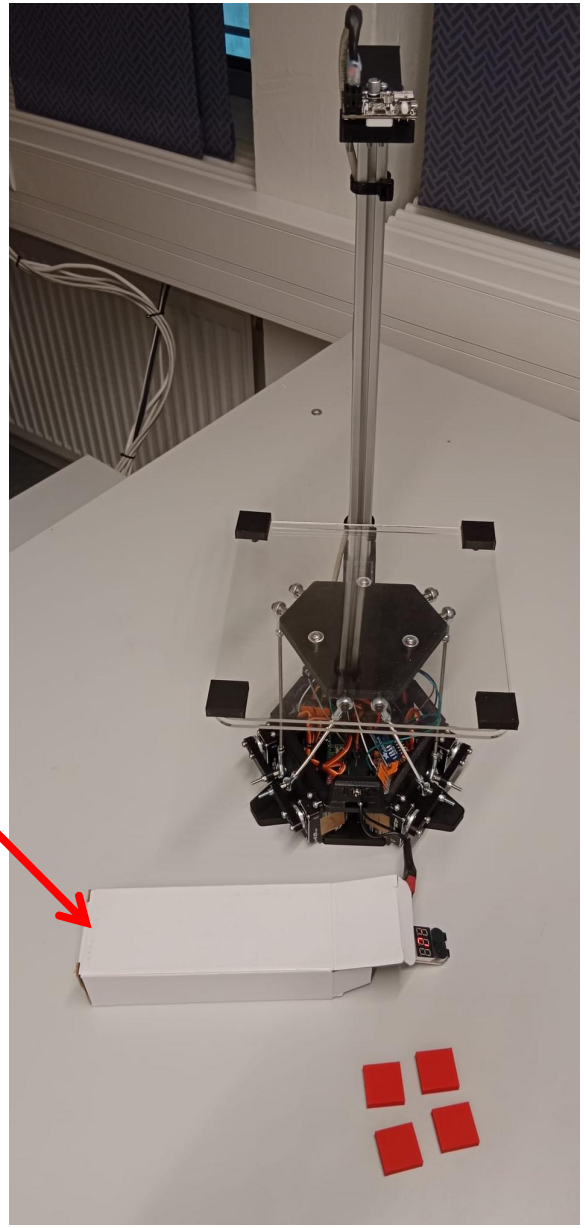


Assemble finished!



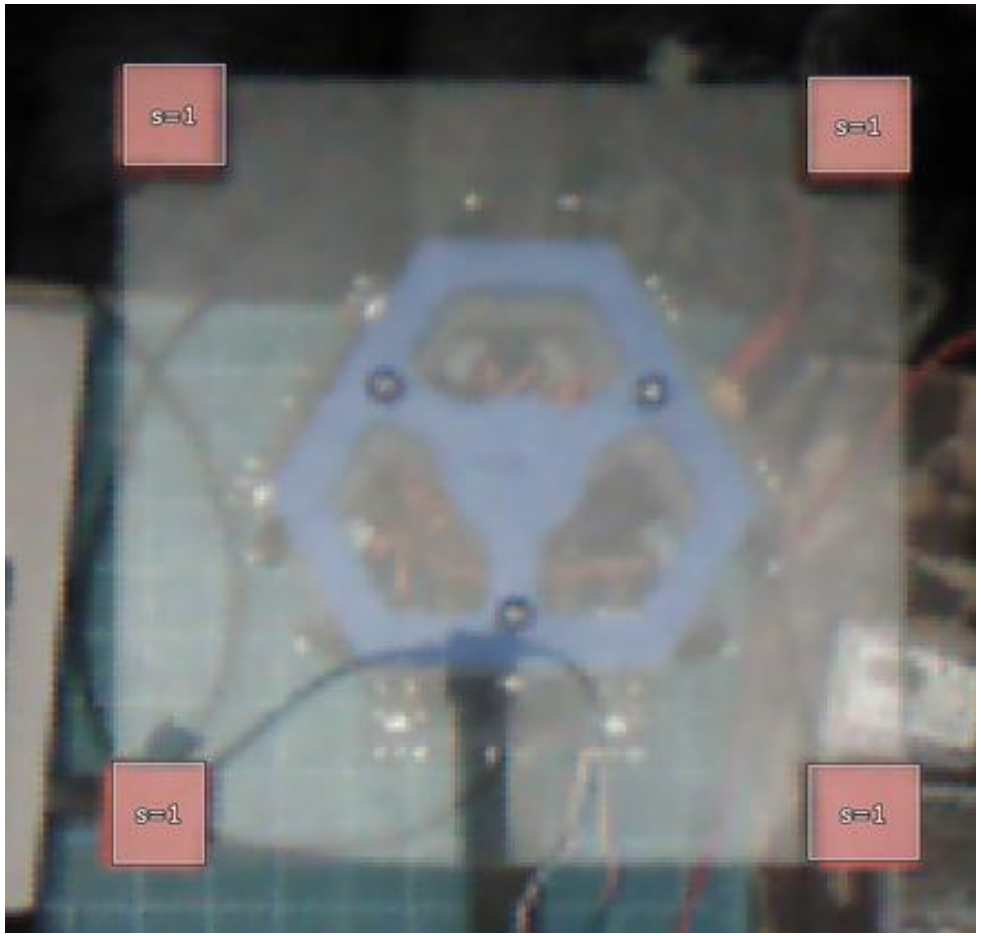
Hide battery in white box to avoid false detections from camera, as camera detects red color

Save x4 red corners for camera calibration



Step 7. Camera Calibration

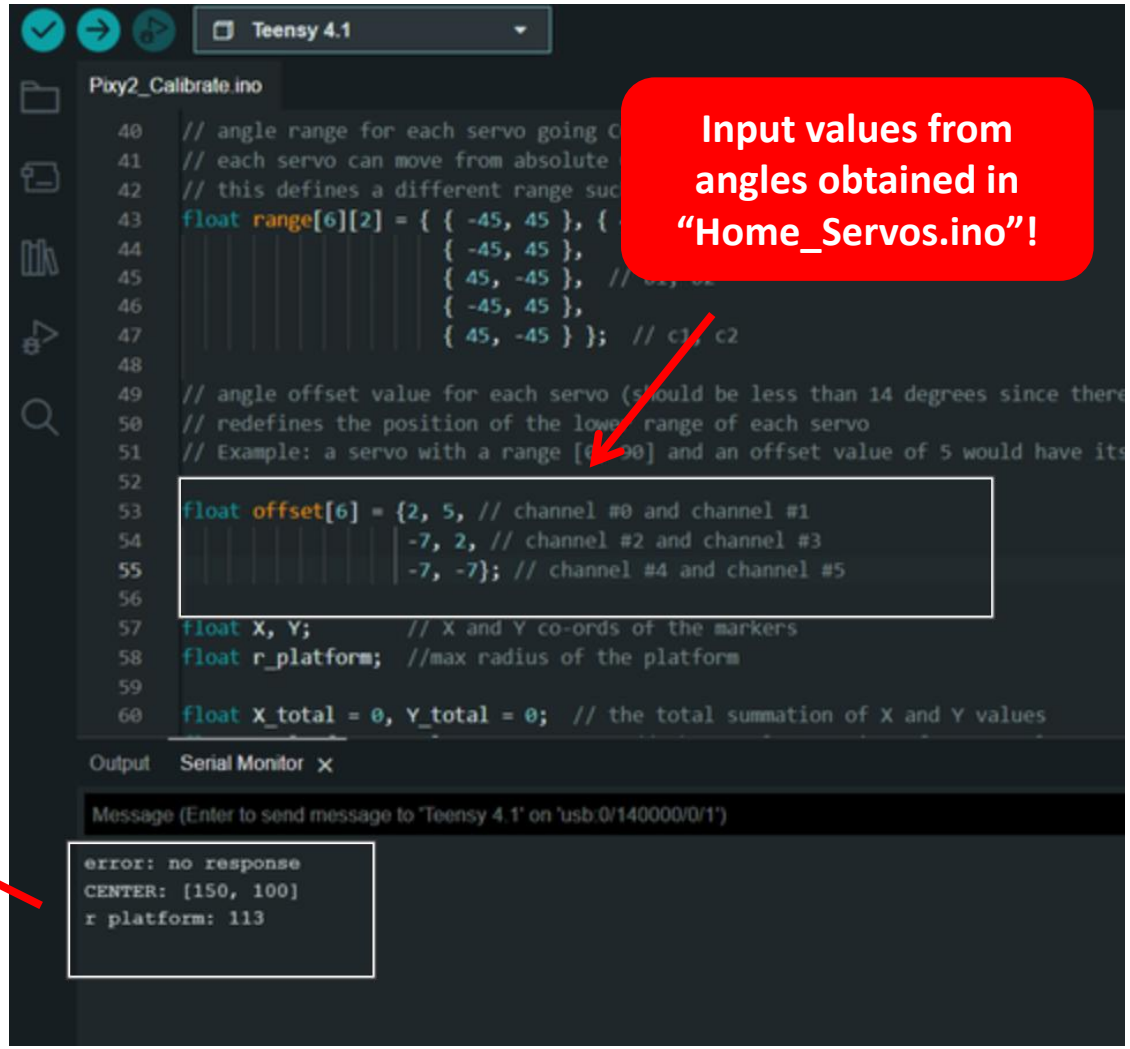
- Assemble the **red** markers into the platform and make sure they are detected



Step 7. Camera Calibration

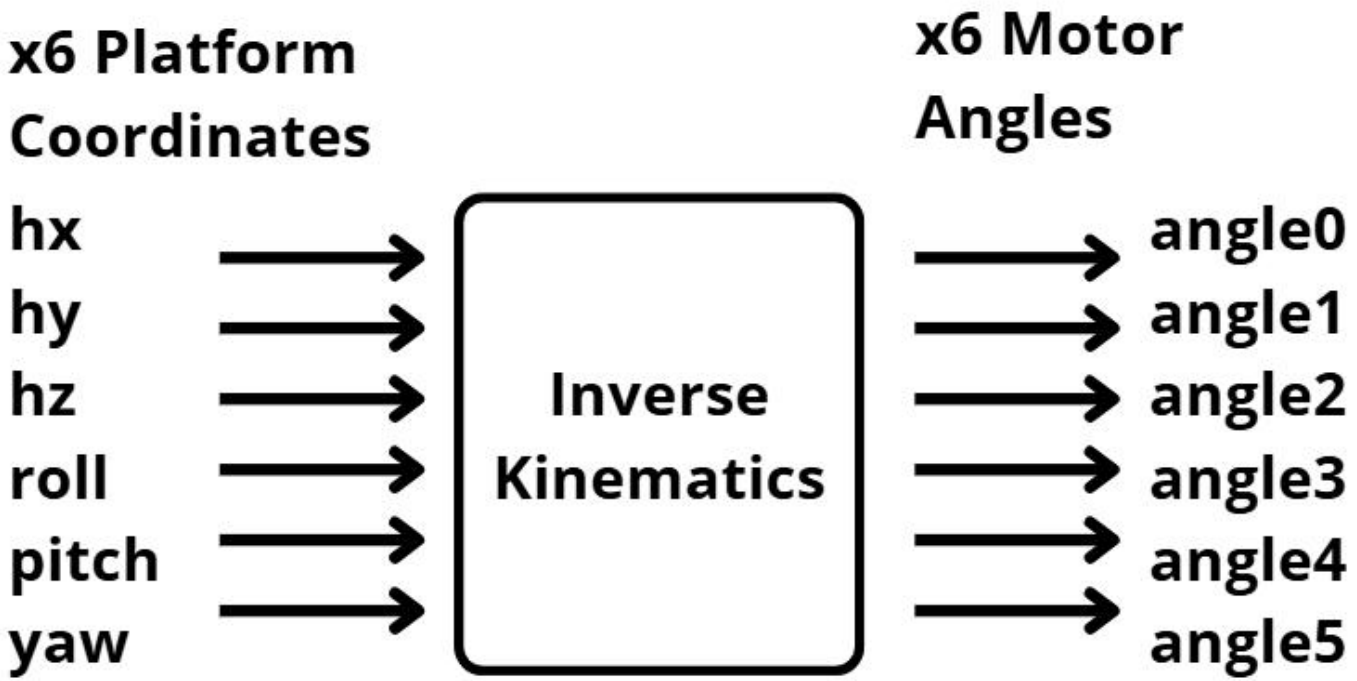
- Run “**Pixy2_Calibrate.ino**” in the Teensy
  - Get (x, y) of the center of the platform
  - Get radius of platform

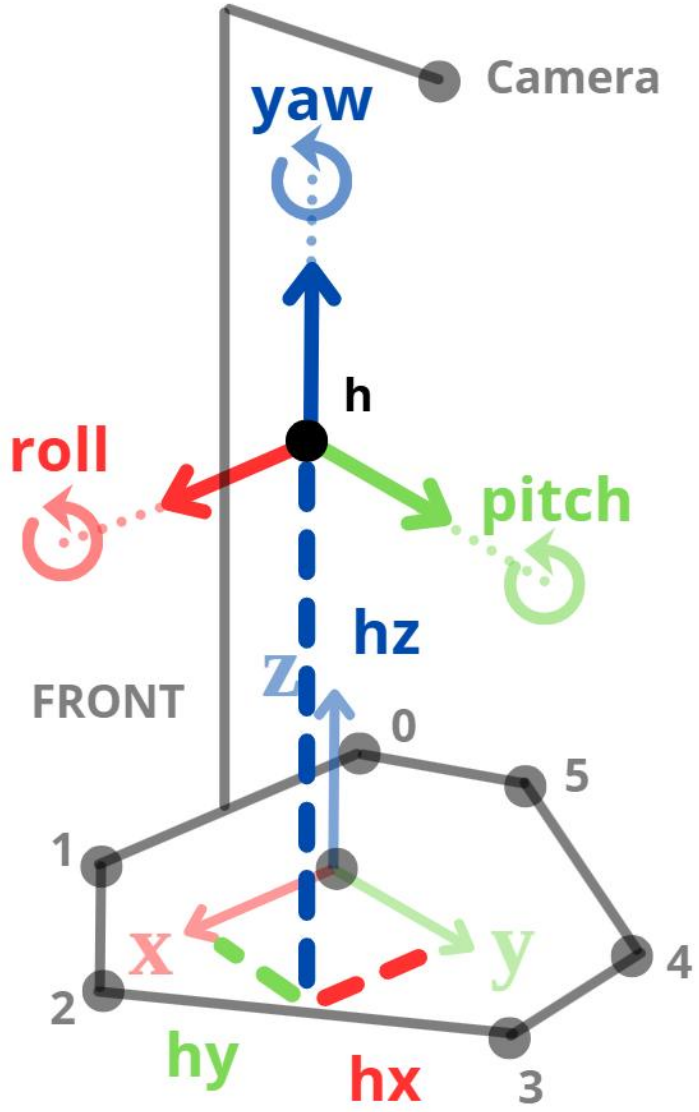
***Save these values!**



Exercise 1. Inverse Kinematics

Formulate IK and check with “**Demo.ino**”





Exercise 2. PID

Implement PID control in
“**Ball_Balance_PID.ino**”