Hexabot Handbook

User Manual for Constructing Hexabot

HEXABOT

https://github.com/Mystery2913/Hexabot

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Table of Content

1 Introduction

Thank you for taking the time to look at this project and consider building it. I have worked many hours to refine this design so that it is easy to assemble by 3D printer, and that it builds skills of 3D printing, electronics, and software development. This manual will instruct you how to build your own Hexabot, and how to troubleshoot any problems that present themselves along the way.

1.1 Safety Disclaimer

The building of this robot will require the use of techniques and tools which when used incorrectly could result in physical harm. When using these tools, please take the time to follow the safety instructions listed with each tool and technique. Overall personal protection equipment (PPE) should be used when using most tools.

1.2 Symbols

This part of the text contains important information, either about safety or about the construction of Hexabot

This part of the text contains helpful tips and information about the construction of Hexabot

2 Overview

Hexabot is hexapedal 3D printed robot that is designed to walk around in developed areas to gather data and to scout the area. At the current time, the data collection feature is still being developed, and will be implemented in the future. The rigid design allows the robot to be sturdy, and also to be able to carry heavy loads on its back. Each of the 6 legs has 3 servo motors: two for the X and Y axis, and one for Z axis. Each leg's motors are connected to a breakout board that connects each motor to power and signal. The signal wires of the motors are connected to 2 Adafruit 16-Channel I2C Servo Driver called the PCA9685. This board controls the PWM signal for the motors and allows the motors to be controlled by the brains of the robot: a Raspberry Pi 4. The robot is powered by a 7500mAh LiPo battery that is connected by a slot-in battery design that allows for easy connection of the battery. The link to repository to make Hexabot is here: https://github.com/Mystery2913/Hexabot

3 Components and Tools List

This robot requires multiple tools and components to fully construct it. Most of the components for the body are 3D printed, a lot of the functional components that drives Hexabot are not.

3.1 Components

This list contains all the components and their quantities required to build Hexabot. The links provided are where I purchased the supplies, however the same or similar products from different supplies are also satisfactory. Just make sure that their dimensions are the same, as they may not be compatible with the 3D prints.

3.1.1 Threaded inserts

Purchase link: https://nz.rs-online.com/web/p/threaded-inserts/2040616/

Quantity: 800

Notes: 800 is enough to assemble Hexabot, however if any mistakes are made and some parts are needed to be remade, more will be required.

3.1.2 Screws

Purchase link: https://nz.rs-online.com/web/p/socket-screws/0281192/

Quantity: 800

3.1.3 Servos

Purchase link: https://nz.banggood.com/URUAV-URS001-180-20KG-Digital-Metal-Gear-Servo-Waterproof-CNC-For-RC-Car-Models-or-Quadcopter-or-Helicopter-or-Robot-or-Intelligent-Robot-Arm-p-1691893.html

Quantity: 18

3.1.4 Servo Drivers

Purchase link: https://learningdevelopments.co.nz/products/adafruit-16-channel-12-bit-pwm-servo-driver-i2c-interface

Quantity: 2

3.1.5 Raspberry Pi 4 and SD card

Purchase link: https://www.pbtech.co.nz/product/SEVRBP0206/Raspberry-Pi-4-Model-B-4GB-LPDDR4-FIRST-28nm-Based

Quantity: 1

Notes: The purchase link has a 4GB model attached to it, but a 2GB or 8GB model will also be sufficient.

Purchase link: h https://www.pbtech.co.nz/product/MEMKIC11132/Kingston-High-Endurance-32GB-microSDHC-CL10-UHS-I

Quantity: 1

3.1.6 Power switch

Purchase link: https://www.jaycar.co.nz/spst-mini-rocker-switch/p/SK0984

Quantity: 1

3.1.7 Wires

Purchase link: https://www.jaycar.co.nz/8-gauge-figure-8-power-cable-sold-per-metre/p/WH3063

Quantity: 1m

Purchase link: https://www.jaycar.co.nz/25a-2-core-tinned-dc-power-cable-sold-per-metre/p/WH3087

Quantity: 2m

Purchase link: https://www.jaycar.co.nz/150mm-socket-to-socket-jumper-leads-40-piece/p/WC6026

Quantity: 1 pack of 40

3.1.8 Wire crimps large/small

Purchase link: https://www.jaycar.co.nz/red-black-gold-crimp-cable-small-eye-terminals-pk-2/p/PT4560

Quantity: 2 sets of 2

Purchase link: https://www.jaycar.co.nz/eye-terminal-red-pk-100/p/PT4515

Quantity: 100

Notes: 100 will not be needed, but it is good to have so spare.

3.1.9 Power screws and bolts

Purchase link: https://www.mitre10.co.nz/shop/hillman-machine-screws-m5-x-40mm-pack-of-6-zinc-plated/p/325944

Quantity: 1 pack of 6

Purchase link: https://www.mitre10.co.nz/shop/hillman-machine-screws-m5-x-10mm-zinc-plated/p/325938

Quantity: 2 pack of 8

Purchase link: https://www.mitre10.co.nz/shop/bremick-hex-nuts-m5/p/349125

Quantity: 20

3.1.10 PCB and header pins

Purchase link: https://jlcpcb.com/

Quantity: 10

Notes: I used JLCPCB for my PCBs, however other companies are also good. To order them, upload the PCB .gerber file found in GitHub repo to the website and order 10 PCBs with default settings **but** with **an outer copper weight of 2 oz**.

Purchase link: https://www.jaycar.co.nz/40-pin-header-terminal-strip/p/HM3212

Quantity: 2 sets of 40

Notes: These are used for the wire connection to the PCBs, and the spares pins are used for the power indicator circuit.

3.1.11 Battery

Purchase link: https://hobbystation.co.nz/giant-power-graphene-2s-7-4v-7500mah-100c-hardcase-li-po-w-bullet-to-t-plug/

Quantity: 1

3.1.12 Metal plates

Purchase link: https://www.jaycar.co.nz/rare-earth-magnet-small-pk-4/p/LM1622

Quantity: 1

Notes: I used the piece of metal that these magnets came with since it was the right dimensions and material for the battery plates. However other nickel-plated steel will work with the right dimensions.

3.1.13 Spring

Purchase link: https://nz.rs-online.com/web/p/compression-springs/0821245/

Quantity: 1

3.1.14 JST-XH connector

Purchase link: https://www.jaycar.co.nz/connectors-kit-with-popular-jst-xhp-and-ph2-headers/p/PT4457

Quantity: 1

Notes: This kit has the connectors and headers to wire up the charging port.

3.1.15 Heat shrink tubing

Purchase link: https://www.mitre10.co.nz/shop/swordfish-heat-shrink-assortment-127-piece/p/228818

Quantity: 1

Notes: This kit has heat shrink tubing for all posable wire in this project. A heat source is also needed for them, e.g., lighter, matches.

3.1.16 Power indicator circuit

The power indictor circuit is made on a perfboard using hand soldering and THT (through hole technology) components.

3.1.16.1 Perfboard

Purchase link: https://www.jaycar.co.nz/connectors-kit-with-popular-jst-xhp-and-ph2-headers/p/PT4457

Quantity: 1

Notes: This kit has the connectors and headers to wire up the charging port.

3.1.16.2 Resistors

Purchase link: https://www.jaycar.co.nz/680-ohm-1-watt-carbon-film-resistors-pack-of-2/p/RR2770

Quantity: 1 set of 2

Purchase link: https://www.jaycar.co.nz/330-ohm-1-watt-carbon-film-resistors-pack-of-2/p/RR2762

Quantity: 1 set of 2

3.1.16.3 Transistors

Purchase link: https://www.jaycar.co.nz/2n2222a-npn-transistor/p/ZT2298

Quantity: 2

3.1.16.4 RGB LED

Purchase link: https://www.jaycar.co.nz/tricolour-rgb-5mm-led-600-1000mcd-round-diffused/p/ZD0270

Quantity: 1

3.1.17 Battery Spring Contacts

Purchase link: https://nz.rs-online.com/web/p/battery-contacts/1094719/

Quantity: 1 bag of 10

3.1.17 Raspberry pi battery pack and cable

Purchase link: https://www.jaycar.co.nz/power-pack-for-raspberry-pi-with-li-ion-battery/p/XC9060

Quantity: 1

Purchase link: https://www.jaycar.co.nz/usb-type-c-to-usb-3-0-a-male-cable/p/WC7758

Quantity: 1

3.2 Tools

3.2.1 Soldering iron, soldering tip, and solder

Purchase link: https://www.jaycar.co.nz/duratech-48w-temperature-controlled-soldering-station/p/TS1620

Quantity: 1

Purchase link: https://www.jaycar.co.nz/conical-0-5mm-soldering-iron-tip/p/TS1622

Quantity: 1

Purchase link: https://www.jaycar.co.nz/0-71mm-duratech-solder-200gm/p/NS3005

Quantity: 1

Note: This solder is lead-based and therefore is not RoHS (Restriction of Hazardous Substances) compliant. Lead free solder will work the same for this application so it is based on personal preference.

3.2.2 Screw drivers set

Purchase link: https://www.mitre10.co.nz/shop/number-8-precision-bits-set-23-pieces-black-and-orange/p/343370

Quantity: 1

3.2.3 Electric screwdriver

Purchase link: https://www.banggood.com/Wowstick-1F+-64-In-1-Cordless-Electric-Screwdriver-Lithium-ion-Charge-LED-Power-Screwdriver-p-1294707.html

Quantity: 1

Notes: This electric screwdriver has a good balance between price and quality and has worked well for its purpose during my time of using it. However, did have an issue with the charging port stopping charging. To Banggood's credit, they did send me a replacement. Purchase at own discretion.

3.2.4 Scraper

Purchase link: https://www.mitre10.co.nz/shop/number-8-paint-scraper-38mm/p/286933

Quantity: 1

Notes: Most 3D printers come with a scraper for removing prints from the heated bed, which can be used instead.

3.2.5 Wire crimper/stripper

Purchase link: https://www.jaycar.co.nz/heavy-duty-wire-stripper-cutter-crimper-with-wire-guide/p/TH1827

Quantity: 1

3.2.6 Tweezers

Purchase link: https://www.jaycar.co.nz/anti-magnetic-precision-tweezers/p/TH1754

Quantity: 1

3.2.7 Needle nose pliers

Purchase link: https://www.jaycar.co.nz/precision-6-long-nose-pliers/p/TH1887

Quantity: 1

3.2.8 Helping hand

Purchase link: https://www.jaycar.co.nz/third-hand-pcb-holder-tool-with-2-clips-and-heavy-base/p/TH1982

Quantity: 1

3.2.9 File set

Purchase link: https://www.mitre10.co.nz/shop/jobmate-file-set-10-piece-black/orange/p/367947

Quantity: 1

3.2.10 Clippers

Purchase link: https://www.jaycar.co.nz/precision-127mm-angled-side-cutters/p/TH1897

Quantity: 1

3.2.11 Battery charger

Purchase link: https://hobbystation.co.nz/gt-power-battery-charger-b3-lipo-1amp-2-3cell-240v/

Quantity: 1

3.2.12 Glue gun and glue

Purchase link: https://www.jaycar.co.nz/mini-glue-gun/p/TH1997

Quantity: 1

Purchase link: https://www.jaycar.co.nz/7mm-glue-sticks-for-mini-gun-pack-of-6/p/TH1991

Quantity: 1 pack of 6

3.2.13 Drill and bits

Purchase link: https://www.mitre10.co.nz/shop/black-decker-drill-driver-kit-18-volt/p/348328

Quantity: 1

Purchase link: https://www.mitre10.co.nz/shop/number-8-drill-bit-set-19-piece/p/277294

Quantity: 1

Purchase link: https://www.mitre10.co.nz/shop/bosch-metal-drill-bit-5-5mm-silver/p/278417

Quantity: 1

3.2.14 8mm spanner

Purchase link: https://www.mitre10.co.nz/shop/fuller-pro-spanner-ring-and-open-end-8mm/p/254065

Quantity: 1

3.3 Safety instructions

The tools and instruments used in the assembly of this robot are hazardous and have safety risks involved in their use. Foremostly, many of them have hot temperature areas that can cause serious damage to your person. As well as the risk to personal health, there is the risk of leaving a tool on and causing a house fire. When finishing with a tool, make sure it is turned off and in a safe place.

4 3D Printing

The most important tool in the making of Hexabot is a 3D printer. The main body and walking mechanism of Hexabot is 3D printed, the quality of the parts is paramount to the quality of the final result.

4.1 3D Printer

The 3D printer I used is Creality's Ender 5 Pro. I purchased mine from Kiwi3D, and I have only got amazing service from them, I can highly recommend. It is priced at around $650 NZD and is more of an intermediate level printer. However, all the parts are printable on an entry level 3D printer as long as it has a minimum print volume of 140x140x130mm which is pretty standard. If the printer volume is less than this, adjustments can be made so that it all works out. For the prints, I highly recommended upgrading the default nozzle of 0.4mm to a 0.6mm nozzle. This will half the print times and the lost resolution will not affect the printed parts. This 0.6mm stainless steel nozzle from Kiwi3D has worked well for me. The only other modification that I can recommend is the use of octoprint. Octoprint is a printer management software that is installed on a raspberry pi and is connected to the printer. It allows full control of the printer from anywhere on the local network and has a thriving community of developers making amazing extension for the software. For more information on how to do that, visit All3DP.

4.2 3D Filament

For the making of Hexabot, a lot of high-quality plastics is needed. PLA is a great polymer that is cost effective, easy to 3D print, and is in ready supply. I get all my filament form Kiwi3D, as they have good prices, a wide range, and most importantly they are based in New Zealand. In my version, I use black and green as my main 2 colours, however any colour can be used. The only important characteristics to look for when buying other filaments is the 1.75mm diameter and print temperature in the range of 190-220°C.

Black PLA

Purchase link: https://kiwi3d.co.nz/product/kiwi3d-black-pla-3kg/

Quantity: 2 spools of 3kg

Notes: Black is used for the main prints of Hexabot. If the colour of the part is not specified, then use black PLA.

Green PLA

Purchase link: https://kiwi3d.co.nz/product/kiwi3d-green-pla/

Quantity: 1 spool of 1kg

Notes: Green is used for the highlights of Hexabot. When green is required, it will be specified in the assembly requirements.

4.3 Printer settings

The settings that a printer uses are very important for obtaining high quality prints and ensuring the effectiveness of the device. This process of finding the best settings for a printer is a tedious one, however it is vital for making good prints. I have exported my specific settings that I used to print the parts in the GitHub repository. These settings will not work for all printers, however their key principles will. Here are the most important settings for printing these parts with a 0.6mm nozzle:

Layer height: 0.4mm

Line width: 0.6mm

Wall thickness: 1.2mm

Wall count: 2

Top/Bottom thickness: 1.6mm

Top/Bottom layer count: 3

Infill density: 20%

> *Note: This value may change depending on the print, which will be noted in its required section.*

Infill pattern: Grid

> *Note: This setting is personal preference, and because it runs nicely on my printer. Other patterns will be suitable.*

Printing Temperature: 230°C

> *Note: This temperature is required because of the larger nozzle. If the filament is too 'runny' lower the print temperature incrementally until the issue goes away.*

Build Plate Temperature: 60°C

Print Speed: 50mm/s

> Note: This value is dependent on the stability of the printer and the power of the hotend. This value should be as high as possible while keep good print quality.

5 Part preparation instructions

During assembly, many parts will require preparation before they are able to be installed. These range from when they are of the print bed, to just before they are in their final place.

5.1 3D parts naming scheme

Because of the large number of parts, and therefore files that are needed to construct Hexabot, there is a naming scheme such that all the files are organised. There are 5 main groups where there installs will be at the start of the file name. These 5 groups are: **battery housing**, **body frame**, **detachable plates**, **motion system**, and **robot main**. All of the STL files will be sorted into folders in these 5 groups, as well as other distinctions made below:

RM = Robot Main	BF = Body Frame	EP = External Plates	IF = Internal Frame
BF = Bottom Frame	TF = Top Frame	S = Strut	B = Bracket
DP = Detachable Plates	TP = Top Plates	BP = Bottom Plates	OP = Outer Plates
BC = Battery Clasp	BH = Battery Housing	MS = Motion System	LC = Leg Connector
L = Leg	LP = Logo Plates	EM= Electronics mount	

These file codes will be used to refer to parts during the assembly process. For example the first part in the top frame of body frame has the code BF-IF-TF-S-1. This is for body frame, internal frame, top frame, strut.

5.2 Preparing off the print bed

After a print has finished, there a few things that need to be prepared before threaded inserts can be installed. Firstly, some prints need supports to be printed and then subsequently removed. To do this pulling them off by hand will mostly do, however in some cases, using the scraper can speed the task up. Secondly, after the print has finished, there can be some minor errors on print that need to be removed (e.g. stringing). To remove these, use a file and grind off these imperfections.

5.3 Drilling holes and inserting brass threads

After the printed parts have been initially prepared, the holes in the parts need to be drilled because of the expansion that print causes. Before doing this, check using one of the screws if it can fit through directly off the print. If it can, the drilling step is not necessary. Use a 3.5mm drill bit and widen the holes in the prints. This step for all prints is only an issue if the printer over extrudes on wall layers. When drilling out the holes, make sure that the holes go all the way through the parts, since otherwise it could be meant for a hole with brass thread. After drilling is finished, the brass threaded inserts need to be installed. The brass threads are inserted into the small holes about 4mm wide and 7mm deep (see **Figure 1**). To do this follow the steps below:

1. Turn on soldering iron to highest temperature setting.
2. Prepare 3D part by having it with the holes facing upwards and having the brass thread and a pair of tweezers nearby.
3. Once the soldering iron has headed up, use the tweezers to place bottom (smaller diameter section) of the threaded insert into the hole. Then place the tip of the soldering iron into the opening of the threaded insert and start to apply downward pressure (see **Figure 1**).
4. Just before the threaded insert is flush with the part, use the tweezers to stop pushing in the part and return the soldering iron to its holder (see **Figure 2**).
5. Take the scraper and use to make sure the threaded insert is flush with the part by pushing the threaded insert down the rest of the way (see **Figure 3**).

Figure 1

How to start inserting the brass thread.

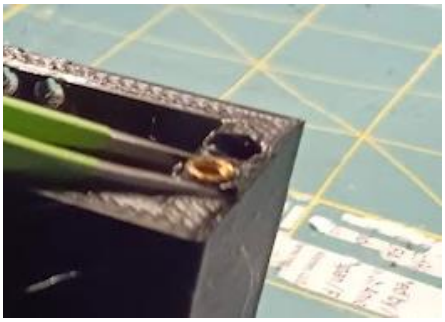

Figure 2

Stopping the threaded insert from being completely flush.

Figure 3

Making the threaded insert flush with the scraper.

6 Top frame assembly

6.1 Required parts and tools

3D parts:	Tools:
- BF-IF-TF-S-1 through BF-IF-TF-S-16 - BF-IF-B x 24 (print with 100% infill) Components: - 116 threaded inserts - 72 screws	- Soldering iron - Tweezers - Scraper - Drill - Star-head electric screwdriver - Screwdriver set

6.2 Preparing parts

Prepare parts as instructed in section 5.2 and 5.3. In this part there are some threaded inserts that will not be used immediately, as they will be used at a later date. The only ones that will be needed are ones used in the assembly diagram.

6.3 Assembly

Layout frame as seen in diagram below (**Figure 4**). Use screws in conjunction with the angled brackets (BF-IF-B) to connect all the frame together. The brackets at ends of the frames will only be partially attached.

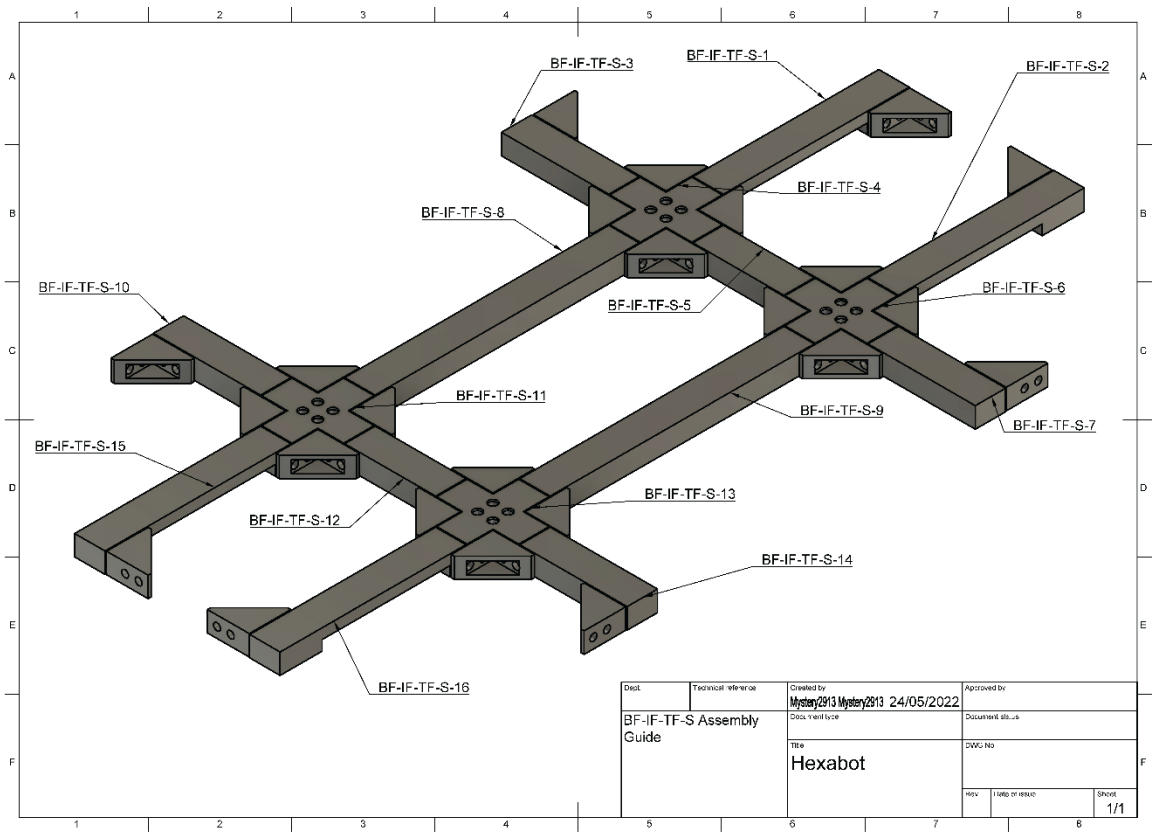

Figure 4 - 6 Top frame assembly

7 Bottom Frame Assembly

7.1 Required parts and tools

3D parts:	Tools:
- BF-IF-BF-S-1 through BF-IF-BF-S-16 - BF-IF-B x 24 (print with 100% infill) - BF-IF-BF-EM-1 Components: - 132 threaded inserts - 72 screws - 2 40mm power screws - 2 power bolts	- Soldering iron - Tweezers - Scraper - Drill - Star-head electric screwdriver - Screwdriver set - 8mm spanner

7.2 Preparing parts

Prepare parts as instructed in section 5.2 and 5.3. In this part there are some threaded inserts that will not be used immediately, as they will be used at a later date.

7.3 Assembly

Layout frame as seen in diagram below (**Figure 5**). Use screws in conjunction with the angled brackets (BF-IF-B) to connect all the frame together. The brackets at ends of the frames will only be partially attached. To install power screws, slot the screws into the 5mm holes in parts BF-IF-BF-S-8 and BF-IF-BF-S-9. Then use the power bolt to attach them to the parts using the 8mm spanner.

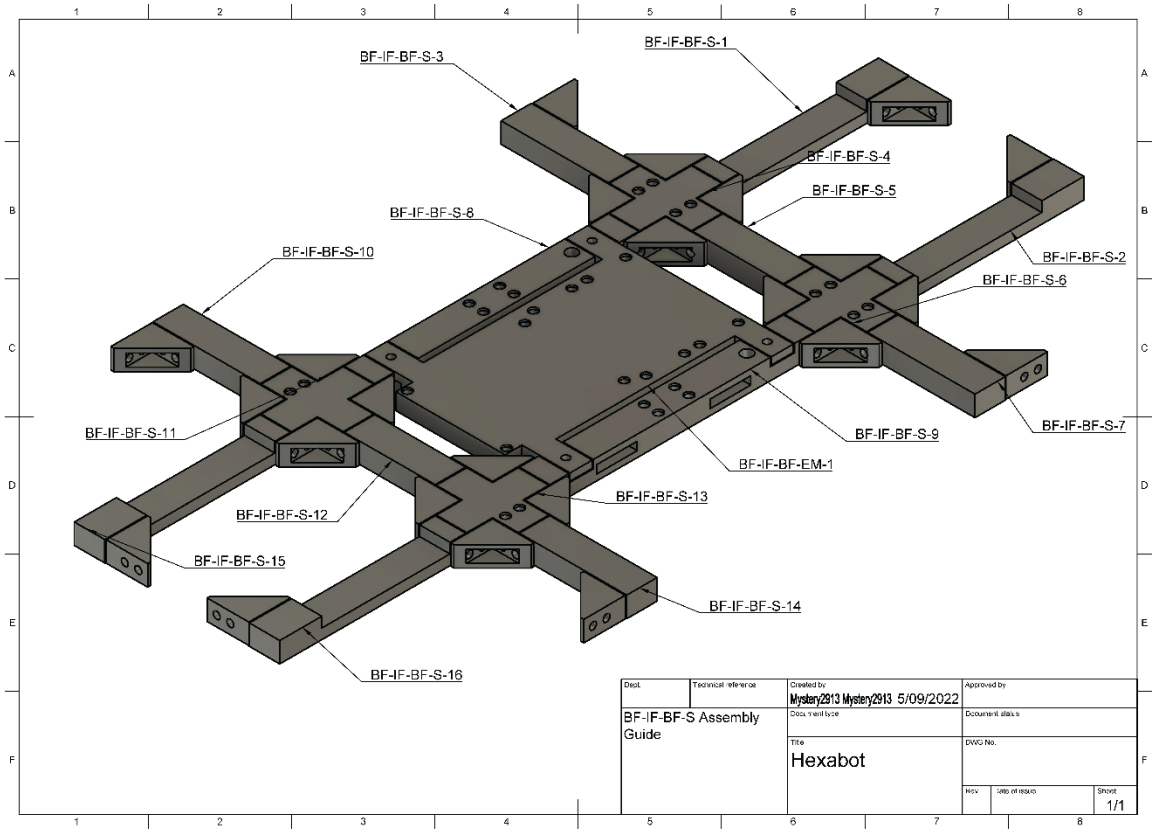

Figure 5 – 7 Bottom frame assembly

8 External Frame Assembly

8.1 Required parts and tools

3D parts:	Tools:
- BF-EP-1 through BF-EP-16 Components: - 160 threaded inserts - 32 screws	- Soldering iron - Tweezers - Scraper - Drill - Star-head electric screwdriver - Screwdriver set

8.2 Preparing parts

Prepare parts as instructed in section 5.2 and 5.3. In these parts there are screw holes that have openings for the heads to be 'submerged' in the plastic. Because of this there are some holes that may need to be widened with a larger drill bit. When doing this, use a 6mm drill bit.

8.3 Assembly

To assemble, insert the screws in the two holes in the side of each piece. Do this around the whole part so that it connects together in an enclosed loop and is held strong.

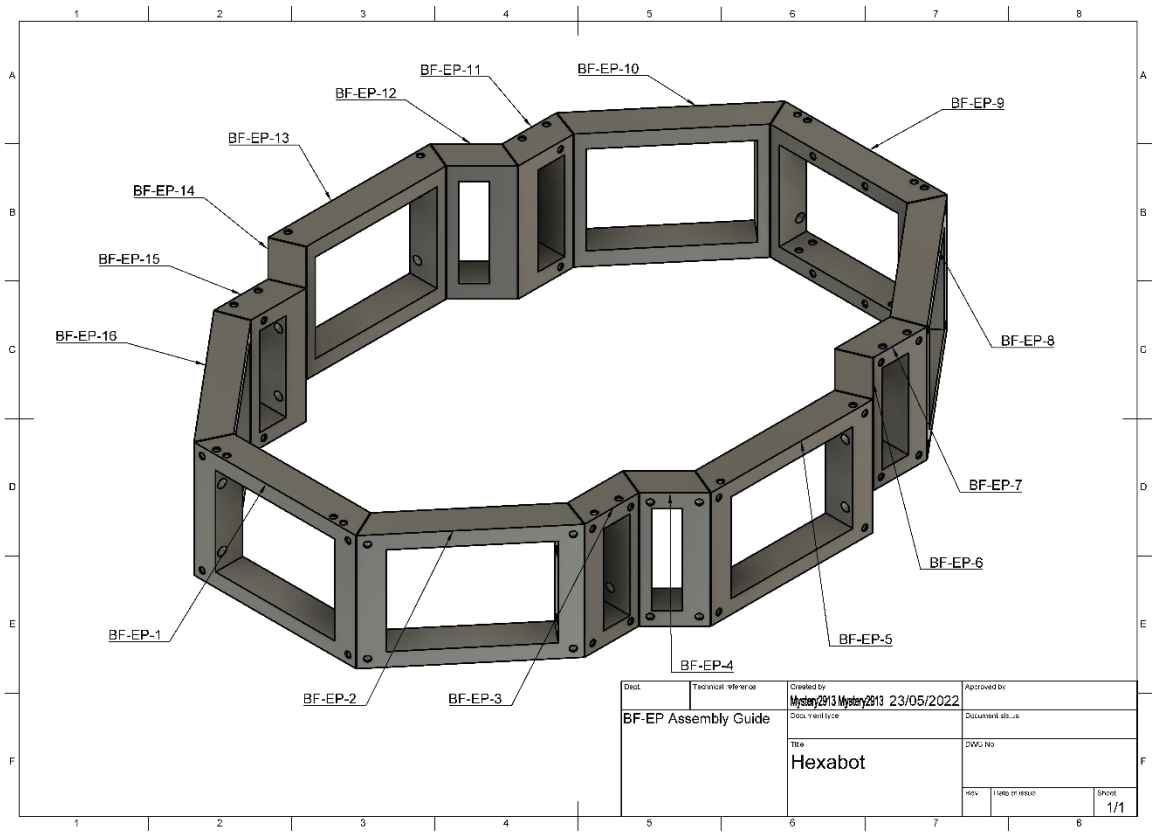

Figure 6 – 8 External frame assembly

9 Body Frame Assembly

9.1 Required parts and tools

3D parts:	Tools:
- Top frame assembly - Bottom frame assembly - External frame assembly Components: - 16 screws	- Star-head electric screwdriver - Screwdriver set

9.2 Assembly

To connect these 3 sections together, use screws in the angled brackets at the ends of the top and bottom frame assembly and connect them to the external frame.

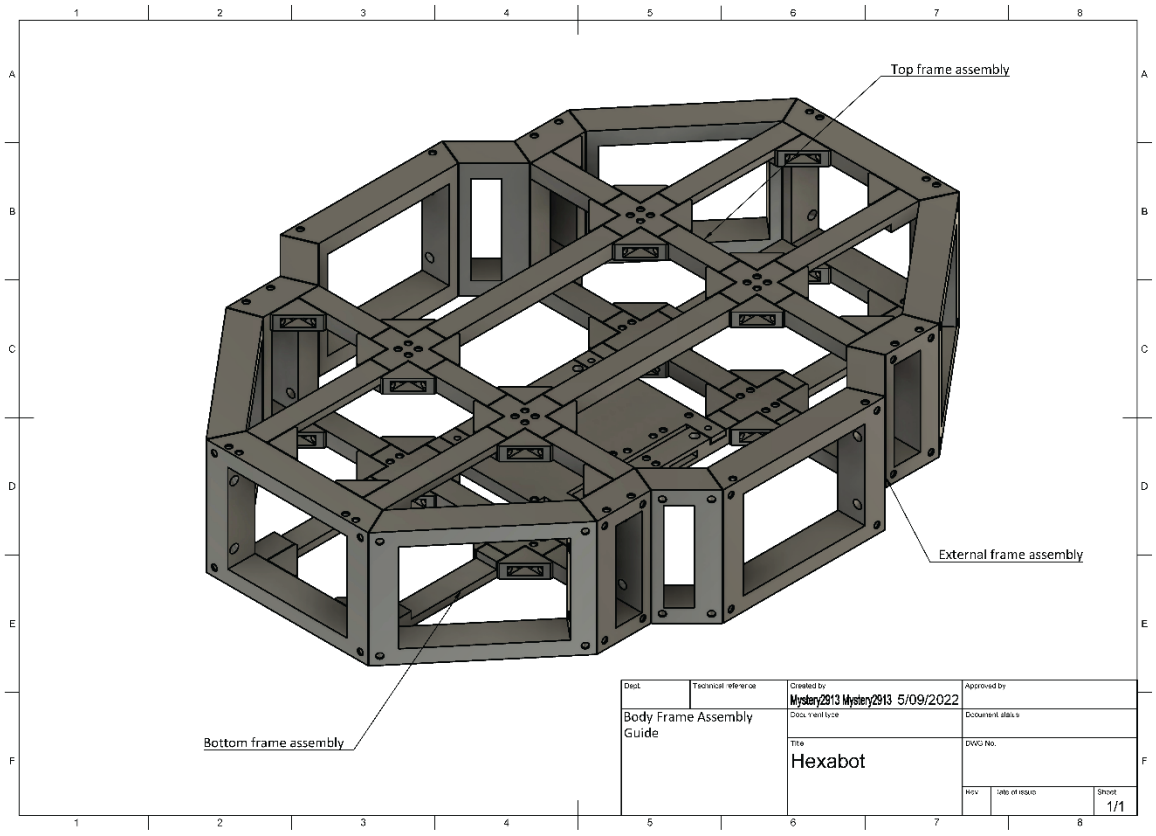

Figure 7 – 9 Body Frame Assembly

10 Leg Assembly

10.1 Required parts and tools

3D parts:	Tools:
- (MS-L-1 through MS-L-16) x 6 - (MS-LC-1 through MS-LC-5) x 2 - (MS-LC-3) x 4 - (MS-LC-4) x 6 - RM-MS-1 through RM-MS-8 Components: - 378 threaded inserts - 390 screws - 18 servos - 6 PCBs - 72 header pins	- Soldering iron - Tweezers - Scraper - Drill - Star-head electric screwdriver - Screwdriver set

10.2 Preparing parts

The parts MS-L-3, MS-L-8, MS-L-12, MS-L-14 should be printed in green or the chosen highlight colour. Some of these parts need supports to be printed. These should only be used on the prints that absolutely need them. After they have finished printing, the supports can be removed using a scraper. Prepare the rest of the parts as instructed in section 5.2 and 5.3.

10.3 Assembly

Follow the steps as instructed below, as well as referring to **Figure 8** and **Figure 9**.

1. Start by taking MS-L-12 and placing a servo motor inside it so that the wire comes out the open side.
2. Screw in the motor at the rear of MS-L-12.
3. Use screws to attach MS-L-13 to MS-L-12 also well as attaching MS-L-13 to the servo motor.
4. Connect MS-L-10, MS-L-11, and MS-L-14 to MS-L-12 using screws.
5. Slot MS-L-6 into the rotational slot in MS-L-10.
6. Refer to section 16 to setup and use the calibration jig.
7. After calibration is complete, take the servo arm and place it onto the motor axle. This is done by placing the assembled leg so far on to **Figure 9** and aligning the motor arm so that it is parallel to the next section of the arm. Use a screw to attach the motor arm to the next section of the leg.

8. Slot MS-L-7 into the rotational slot in MS-L-11.
9. Repeat step 1 and 2 but using MS-L-8 instead.
10. Use screws to attach MS-L-9 to MS-L-8 as well as attaching MS-L-9 to the servo motor.
11. Connect MS-L-6 and MS-L-7 to MS-L-8 using screws.
12. Slot MS-L-4 into the rotational slot in MS-L-6.
13. Refer to section 16 to use and setup calibration jig.
14. Repeat step 7 using current servo motor.
15. Slot MS-L-5 into the rotational slot in MS-L-7.
16. Connect MS-L-1, MS-L-2, and MS-L-3 to MS-L-4 and MS-L-5 using screws. Keep the screws that attach to MS-L-2 loose so there is play in that part.
17. Repeat step 1 and 2 but using MC-LC-2 (or its equivalent using the robot main parts) instead.
18. Use screws to attach MC-LC-3 to MS-LC-2 also well as attaching MS-LC-3 to the servo motor.
19. Connect MC-LC-1 to MC-LC-2 using MC-LC-4 and MC-LC-5.
20. Slot MS-L-1 into the rotational slot in MS-LC-1.
21. Refer to section 16 to use and setup calibration jig.
22. Repeat step 7 using current servo motor.

After the leg has been assembled, the PCBs need to be attached to the back of the leg:

1. To prepare the PCB, solder the header pins into each of the 4 pin attachment points on the PCBs. The header pins will need to be split into 3 pin sections.
2. Using screws and the screws holes at the bottom of the PCBs, attach the PCB to the back of the third servo motors housing.

Repeat these processes 6 times so that 6 legs are assembled with PCBs attached. The section with the 3rd servo motor attached will use parts from robot main for 4 out of 6 of the legs.

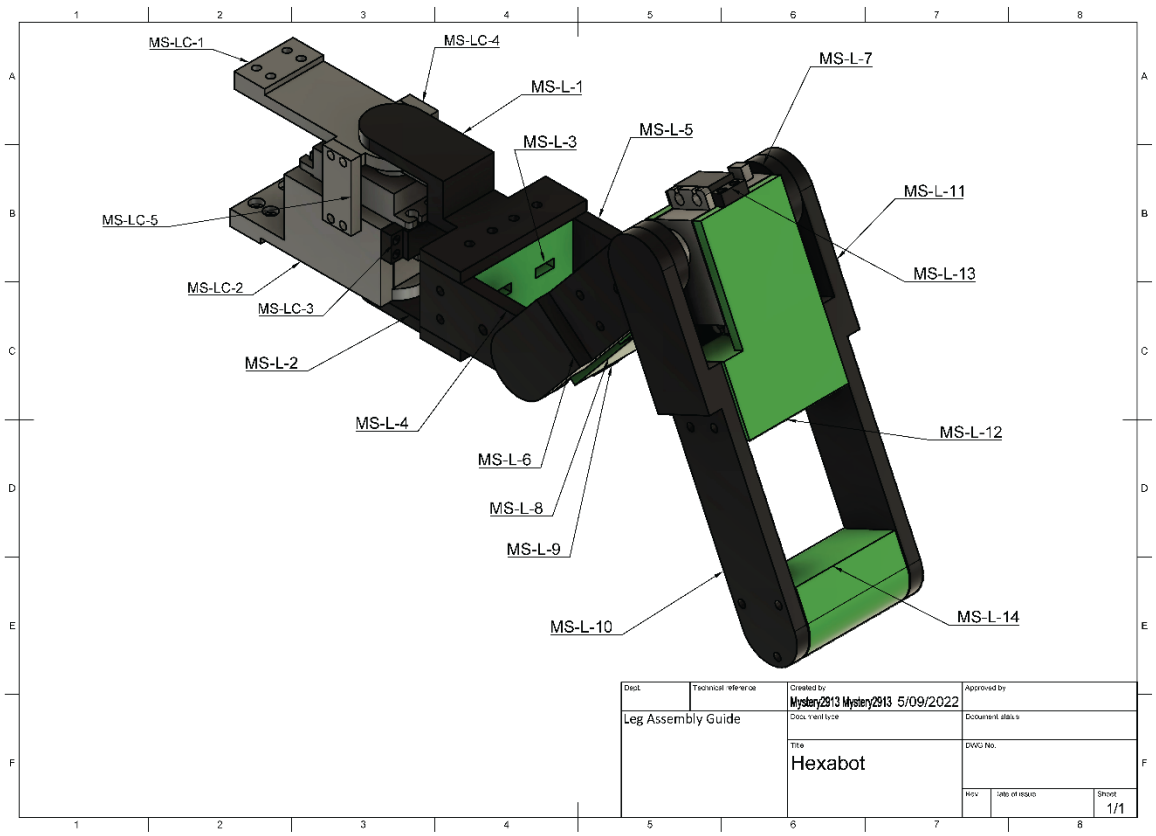

Figure 8 – 10 Leg Assembly

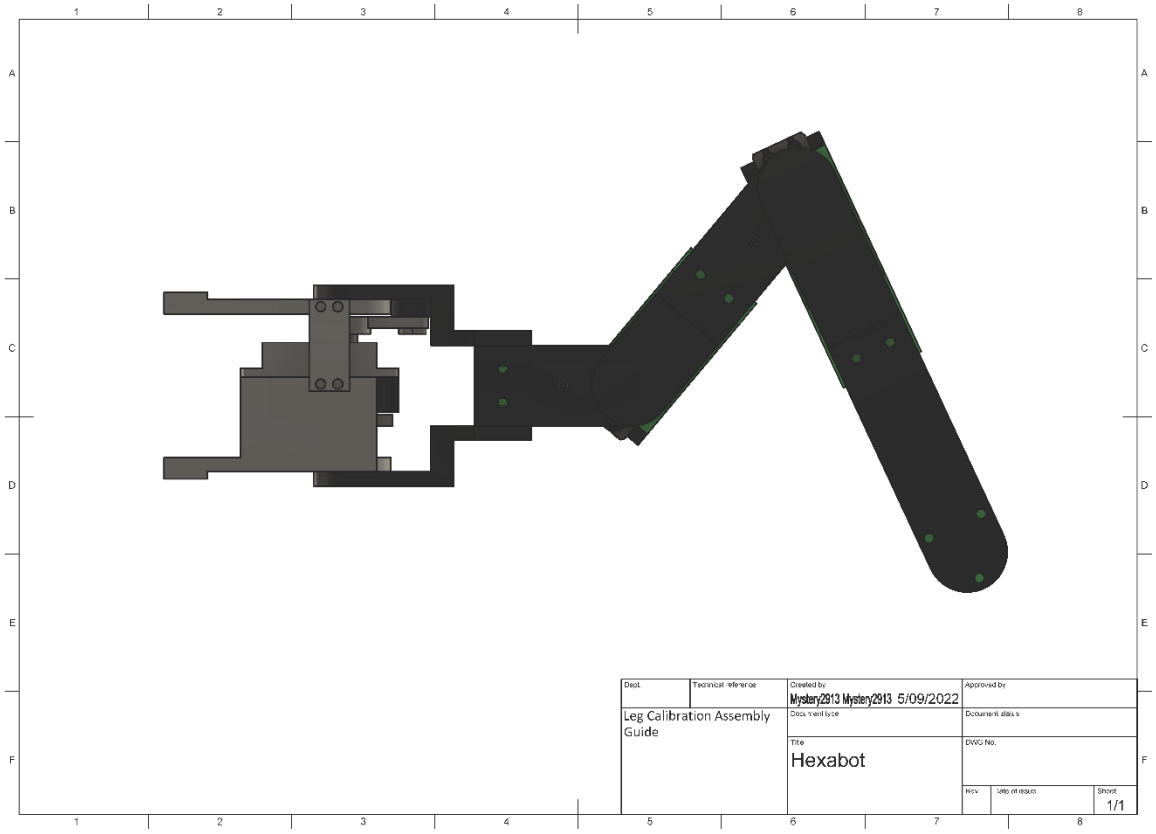

Figure 9 – 10 Leg calibration Assembly

11 Battery Frame Assembly

11.1 Required parts and tools

3D parts:	Tools:
- RM-BH-1 and RM-BH-2 Components: - 2 threaded inserts - 13 screws - 2 battery spring contacts - 1m 8-gauge wire - 1 Spring	- Soldering iron - Solder - Helping hand - Wire strippers - Tweezers - Scraper - Drill - Star-head electric screwdriver - Screwdriver set

11.2 Preparing parts

Prepare parts as instructed in section 5.2 and 5.3. In RM-BH-2, there are screw holes that have openings for the heads to be 'submerged' in the plastic. Because of this there are some holes that may need to be widened with a larger drill bit. When doing this, use a 6mm drill bit. RM-BH-1 will need supports while printing. Orienting RM-BH-1 so that the two t-shaped terminals are facing up will give the best result.

11.3 Assembly

Before these parts can be attached to the rest of the frame there are some other electronics aspects that need to be completed first.

1. Take the 8-gauge wire and cut 200mm of the red wire off and 100mm of the black wire off.
2. Strip one end of each wire using the wire stripper and tin (put solder on the end) the wires.
3. Solder a wire each to the battery spring contacts on the side where the very small, looped bit of metal is. Use the helping hand to assist.
4. After the battery spring contacts have cooled down, slide the clips on the T-shaped terminals on RM-BH-1 so that that the ends of the spring part of the contacts point towards the front of Hexabot (see **Figure 11**). Based on **Figure 10**, the battery spring contact with the red wire should go on the left terminal and the battery spring contact with the black wire should go on the right terminal.

After the battery spring contacts have been prepared, RM-BH-2 needs to have its sprint attached. This can be done by placing the spring in the circular cut in the part in the centre. Then spring can be attached by using the soldering iron to melt the plastic around the base of the spring, stopping it from being unseated (see **Figure 11**).

Now RM-BH-1 can be attached to the frame as seen in **Figure 10**. Note that the bottom, front, right brackets has a cut-out for an LED to be placed where one of the screws would sit. Do not put a screw here. After this, RM-BH-2 can be connected to RM-BH-1 with screws.

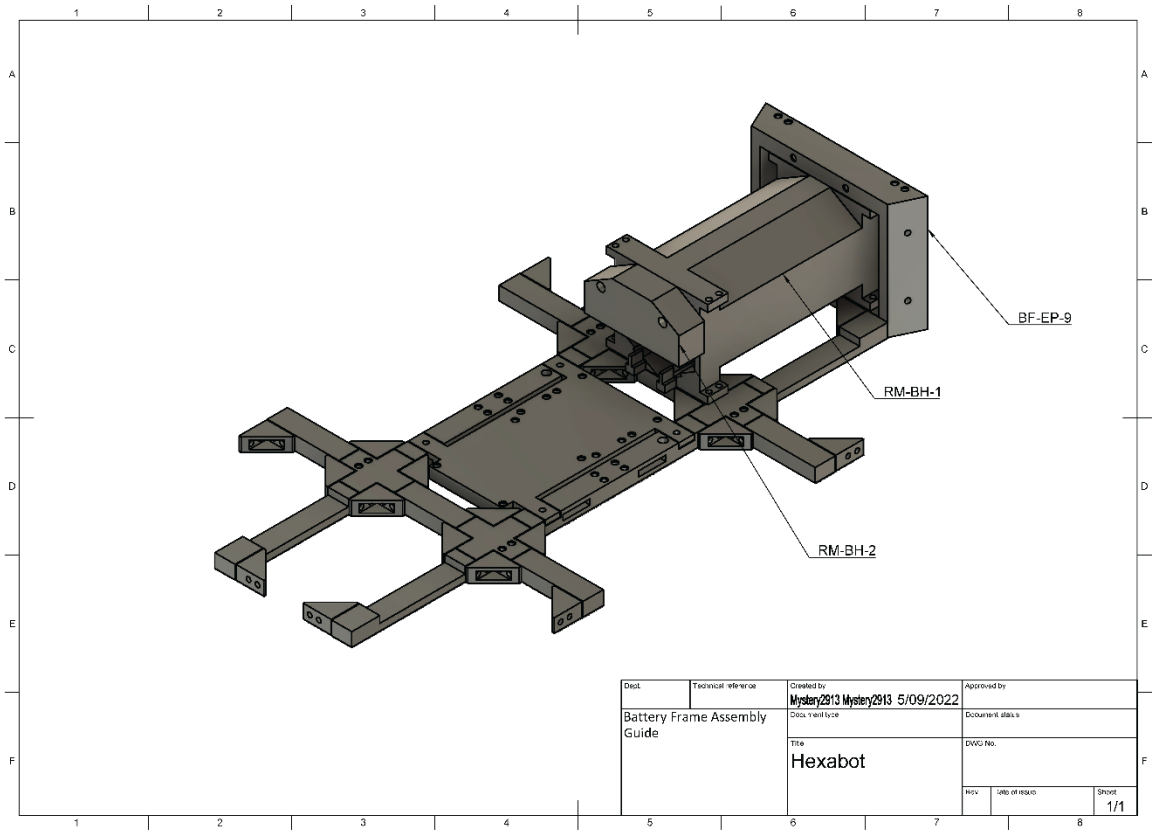

Figure 10 – 11 Battery Frame Assembly. (Note that the top frame has been removed from this diagram for ease of use, however the RM-BH-1 should be attached to the top frame.)

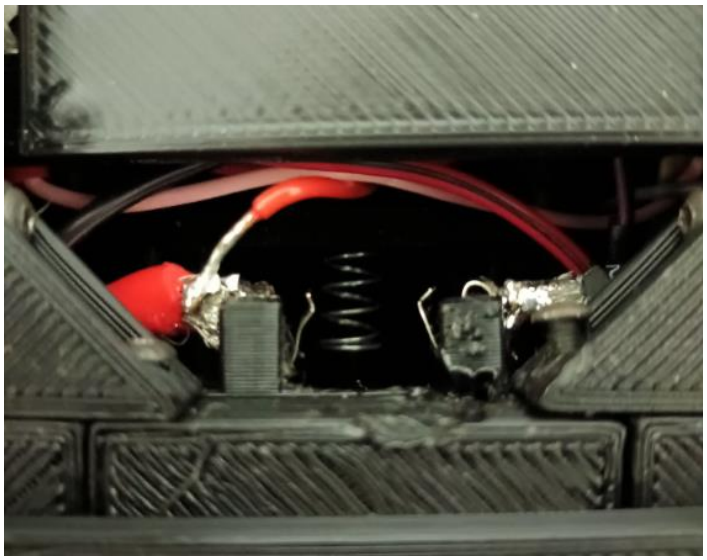

Figure 11

This picture is taken from underneath Hexabot, the bottom of the image is towards the back of Hexabot. The spring and its orientation can be seen in the middle of the image.

12 Battery Housing Assembly

12.1 Required parts and tools

3D parts:	Tools:
- BH-1 through BH-4 - BH-5 is optional but is highly recommended as safety precaution Components: - 8 threaded inserts - 8 screws - 1 Battery - 1 JST-XH connector - 2 large wire crimps - Heat shrink tubing - 2 M5 10mm screws - 2 M5 nuts	- Soldering iron - Solder - Helping hand - Wire strippers - Tweezers - Scraper - Drill - Metal drill bit - Star-head electric screwdriver - Screwdriver set - Glue gun

12.2 Preparing parts

Prepare parts as instructed in section 5.2 and 5.3. BH-1 and BH-2 will require supports. This is best done this the point of the part facing up. To prepare the metal plates, use a hacksaw to cut 2 metal plates with the following dimensions: 24mm by 10mm. Then using a metal-rated 5.5mm drill bit, drill a hole 8mm down from the top (along the long edge) on each plate.

12.3 Battery safety instructions

During this assembly process, there will be work done around a battery that is charged. Since the use of metal tools is required, be very careful using them around the terminals of the battery because of the risk of a short circuit.

12.4 Assembly

First connect BH-1, BH-2, and BH-3 using screws. Once this is done, the insertion of the electronics can start. Refer to **Figure 13** during this process.

1. Slide the battery into the housing with the wires at the top.
2. Cross the power wires over and pull them down so they are positioned near the slots for the metal plates. It is useful to place the plates temporarily in their positions so that they can guide where the wire will go.
3. Mark the length that power wires need to be to reach that point and cut them there.
4. Take the large wire crimps temporarily on the ends of the power wires so that you can see at what angle they will need to be positioned at so you can solder them there later.
5. Pull the battery out and take off the power wires.
6. Strip the ends of the power wires and tin them.
7. Slide heat shrink tubing over each wire away from the solder joint.
8. Solder the large wire crimps onto the power wires, matching the colours of the wires and crimps and matching the angle that was found in **step 4**.
9. Use the ambient heat from the soldering iron or a lighter to shrink the tubing over the exposed solder joint.
10. Replace the wires onto the battery and the battery into the housing.
11. Re-cross the wires and position them, next to the metal plates.
12. Take the power screws and bolts and place slot them through the wire crimps and plates and bolt them tight.
13. Making sure that they are not touching, position the plates as shown in **Figure 12** and **Figure 13**. Use hot glue to lock them in place.

Now that the power from the battery is attached, the balance charging port needs to be transferred.

1. Place a male JST-XH connector and place it into the hole in BH-4. Place it so that the open slots are orientated upwards, and that the exposed pines go into the housing.

2. Cut the existing JST-XH connector from the battery. **WARNING. Cut each wire individually, since if multiple wires are cut at once, a short circuit will occur.**
3. Strip each wire and tin the end. This process will be slightly difficult since the wires will be connected to the battery.
4. Slide heat shrink tubing over each wire away from the solder joint.
5. Solder the wires to the JST-XH connector's pins and make sure to keep the wire in the correct order with respect to the original configuration.
6. Use the ambient heat from the solder iron or a lighter to shrink the tubing over the exposed solder joint.
7. Connect BH-4 to the rest of the housing and squish down the wires to that BH-4 fits overtop.
8. Using the glue gun, put a spot of glue between the metal plates on the outside of the housing to add more support to them.

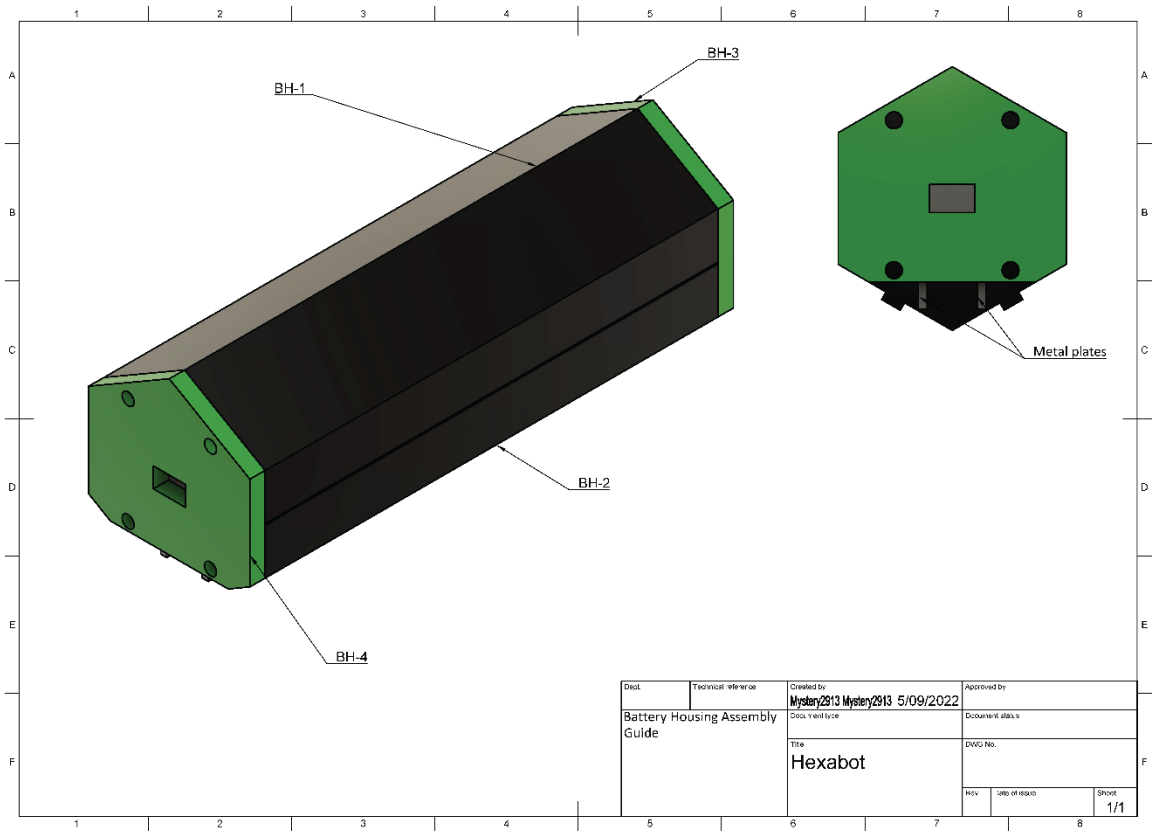

Figure 12 – 12 Battery Housing Assembly

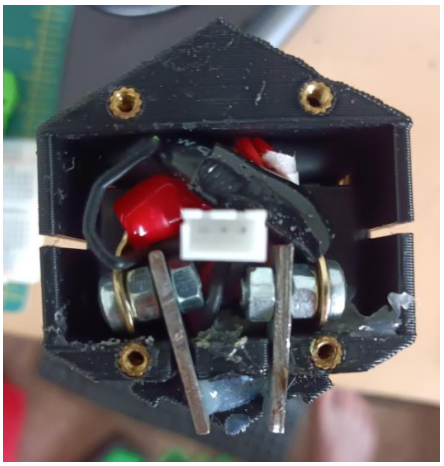

Figure 13

12 Battery Housing Assembly, internal battery wiring.

13 Leg Connection Assembly

13.1 Required parts and tools

3D parts:	Tools:
- 6 legs Components: - 32 screws	- Star-head electric screwdriver - Screwdriver set

13.2 Preparing parts

Place each leg in its corresponding place. Depending on which parts the 3rd section of leg was made of, either robot main or leg connector.

13.3 Assembly

To connect the legs to the body frame, some of the legs may need to be partly dismantled to get them in the right positions. It is also recommended to remove the top frame while trying to get the legs in place, as it will make it easier to install them. The top frame can them be reinstalled later while attaching the screws to it. When installing the rear to legs, one of the connecting bars between

RM-MS-1 and RM-MS-2 as well as RM-MS-3 and RM-MS-4 will not fit because of the battery frame. Because of this remove the connecting bar that is getting in the way.

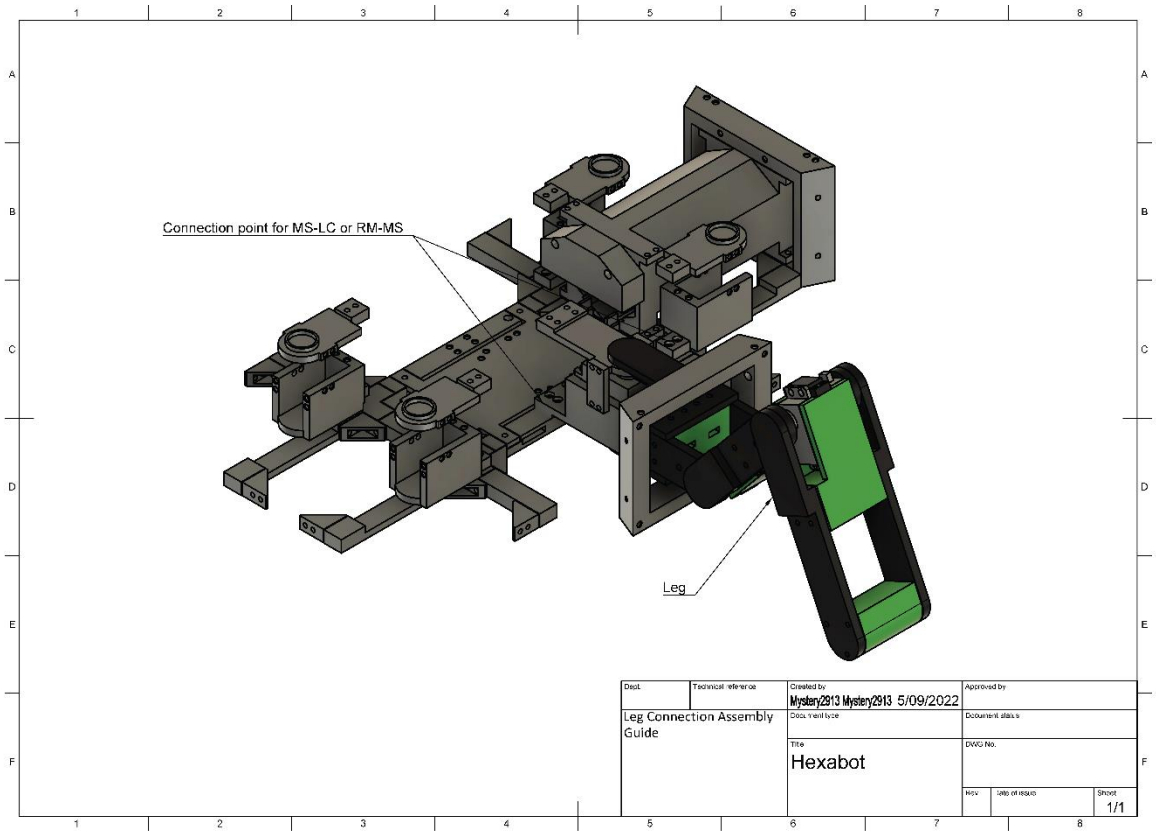

Figure 14 – 13 Leg Connection Assembly. For the sake of simplicity, there is only one leg, however each leg is used and positioned based on whether it use MS-LC or MS-RM.

14 Electronics Assembly

14.1 Required parts and tools

3D parts:	Tools:
- DP-EP-OP-9 Components: - 1 raspberry pi - 2 servo driver - 16 screws - 1 power switch - 2m 25A wire - 1m 8-gauge wire - 40 jumper wires - Heat shrink tubing - 2 large wire crimps - 30 red wire crimps - 12 10mm power screws - 14 power bolts	- Soldering iron - Solder - Helping hand - Wire strippers - Tweezers - Scraper - Drill - Star-head electric screwdriver - Screwdriver set - Glue gun -

14.2 Preparing parts

To prepare the servo motor drivers, solder the header pins that are supplied onto the boards.

14.3 Assembly

The first step is to attach the switch to the back panel.

1. Screw DP-EP-OP-9 to the back of the frame where the battery housing is.
2. Place the power switch in the slot such that the dot on the switch is oriented towards the battery slot.
3. Put a heat shrink tube over red wire that is already attached to the battery frame terminal.
4. Solder the red wire to one of the switch terminals and use heat to shrink the tubing over the solder joint.
5. Get a new section of red 8-gauge wire that is the length of the power screw terminal closest to the switch, to the switch.
6. Strip the wire on both ends.
7. Crimp a large red wire crimp to it and place a heat shrink tube on the wire.
8. Solder the other end of the wire to the switch and shrink the tube over the solder joint.
9. Put the wire crimp onto the power screw.

10. Take the black wire that is already soldered onto the battery frame terminal and crimp a large black wire crimp to it.
11. Place it on the closest power screw.

Next is to assemble and install the power indicator circuit.

1. Using all components specified in the parts list for the power indicator circuit, assemble the circuit by following the power indicator wiring diagram (see **Figure 16**). To do this, follow this tutorial on how to solder circuits on perfboard: https://www.instructables.com/Using-Perfboard/. The breakout wires VCC, and GND should have wire crimps on them. The V+ wire should be soldered directly to the positive battery frame terminal wire as seen in **Figure 11**. VCC should be attached to the positive power screw and GND should be attached to the negative power screw.
2. Take the RGB LED and trim their leads and solder wires to them. The blue lead can be completely removed as it is not used. Use heat shrink tubing on each lead to isolate them from each other.
3. Place the RGB LED through the slot for it in the rear of Hexabot. This is positioned on the bracket of the battery frame. Use the glue gun to secure it in place.
4. The other ends of the wires can be attached to their respective header pins on the indicator circuit.

The next step is to attach the motors to the PCBs.

1. Each servo motor needs to connect to the PCBs. The yellow wire is PWM, the red wire is V+, and the brown wire is GND.
2. Servo motor 1 (the first motor that is attached in 10 Leg Assembly) is connected to SRV1.
3. Servo motor 2 (second motor in 10 Leg Assembly) is connected to SRV2.
4. Servo motor 3 (third motor in 10 Leg Assembly) is connected to SRV3.
5. Repeat this for all legs.

Next the boards need to be attached to the electronics plate.

1. Screw the raspberry pi and the servo drivers onto BF-IF-BF-EM-1
2. Using the jumper wires, connect the signal connections (PWM1, PWM2, and PWM3 on the PCBs) to the motor driver board by following **Figure 15**.

Next is connecting the PCBs power to the power screws.

1. On each PCB, place 2 10mm power screws onto the V+ and GND connections.
2. By measuring out the length of the wires, use the 25A red and black wires to connect the PCBs to the power screws based on the wiring diagram shown on **Figure 15**. Red wire crimps should be used to connect the wires together.
3. Tighten the crimps to the PCB by using the power nuts.

Now the servo driver board and the raspberry pi needs to be connected.

1. Using jumper wires, connect the servo driver boards together with the raspberry pi as show in **Figure 15.**
2. Alter a jumper wire by cutting 1 off one of the plastic connectors, striping the wire, and crimping a red wire crimp to the end.
3. Attach this between the raspberry pi and the negative power screw as shown in **Figure 15**.
4. Use 2 power bolts to bolt all the crimps on the power screws down.

The last step is to attach the raspberry pi battery pack to the raspberry pi using the corresponding cable. Then place the battery back in the front of Hexabot.

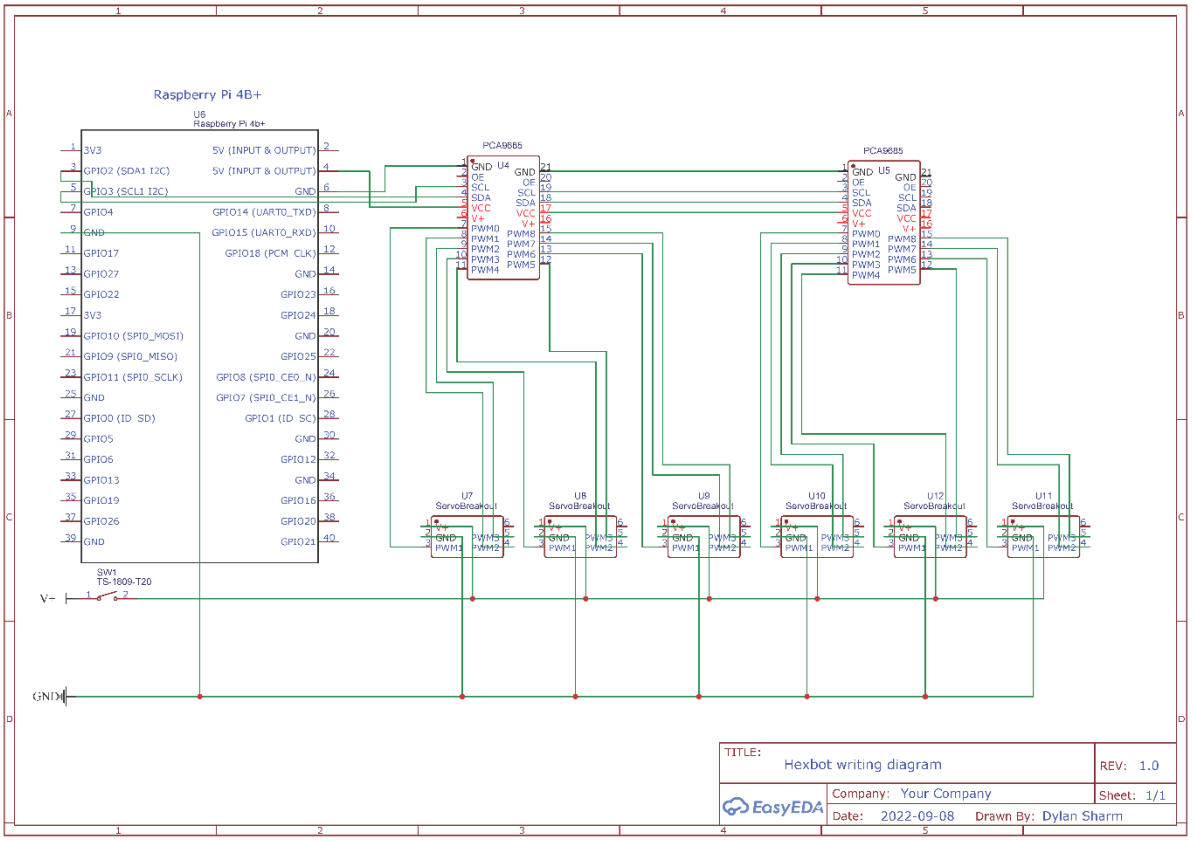

Figure 15 – 14 Electronics Assembly, Electronics Wiring Diagram

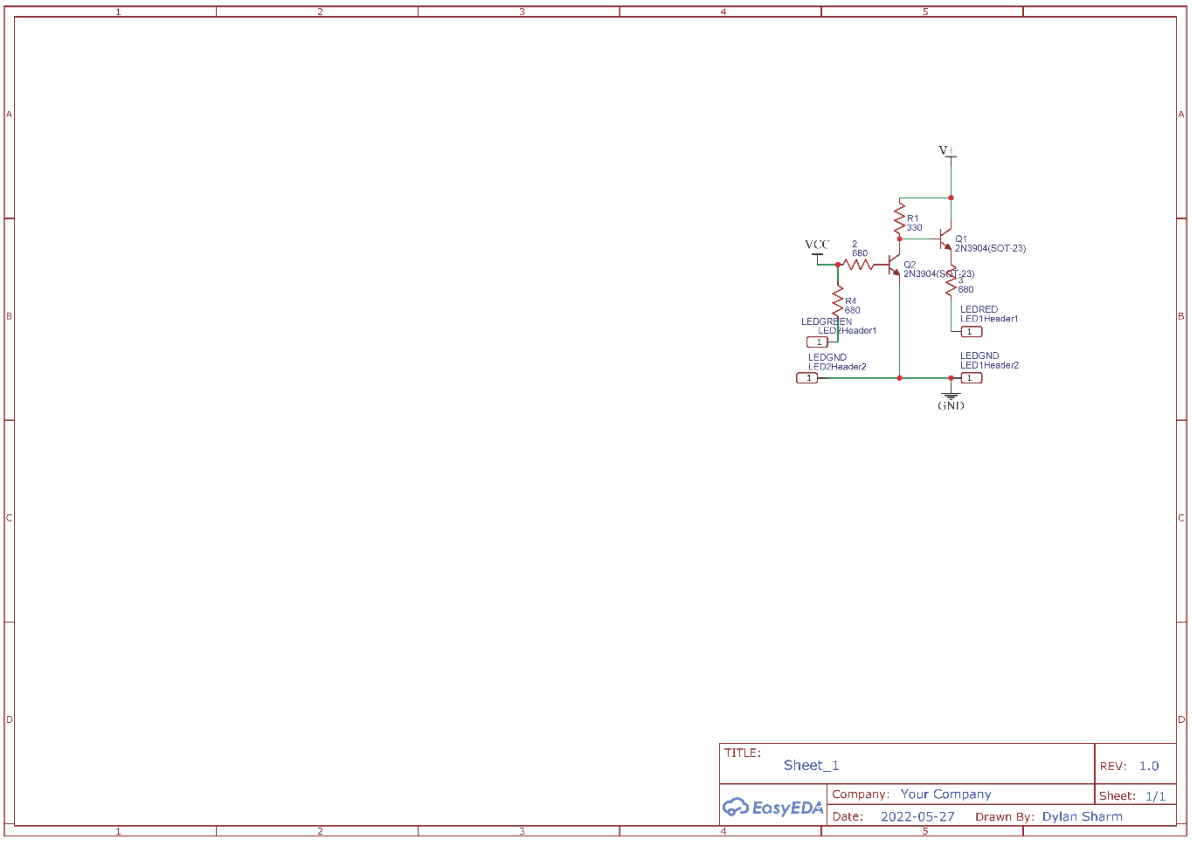

Figure 16 – 14 Electronics Assembly, Power Indicator Wiring Diagram

15 Detachable Plates Assembly

15.1 Required parts and tools

3D parts:	Tools:
- DP-EP-BP-1 through DP-EP-BP-9 - DP-EP-TP-1 through DP-EP-TP-9 - DP-EP-OP-1 through DP-EP-OP-16 (minus DP-EP-OP-9) - DP-EP-LP-1 through DP-EP-LP-10 - DP-BC Components: - 1 threaded inserts - 132 screws	- Tweezers - Scraper - Drill - Star-head electric screwdriver - Screwdriver set

15.2 Preparing parts

Prepare parts as instructed in section 5.2 and 5.3. All of DP-EP-LP should be printed green or the chosen highlight colour.

15.3 Assembly

To assemble, attach all plates to the body frame as shown in **Figure 17**. DP-BC can be attached onto the threaded insert in DP-EP-OP-9.

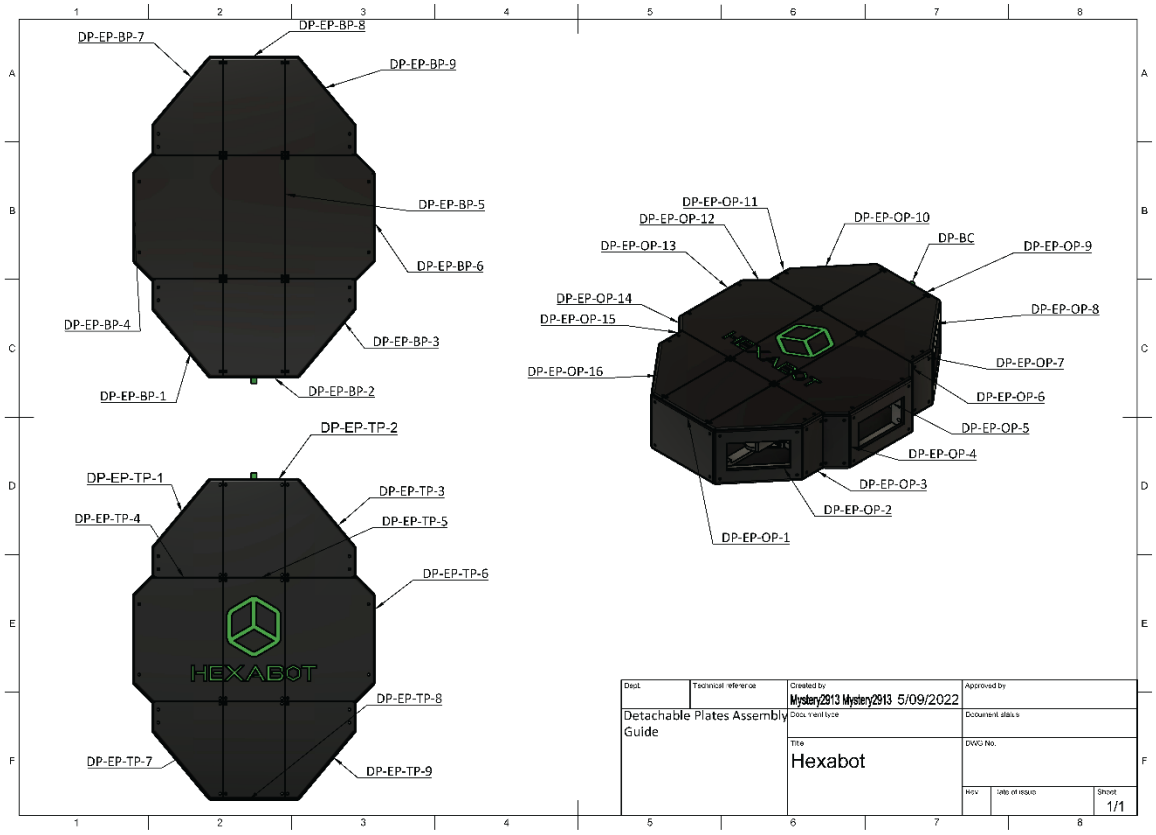

Figure 17 – 15 Detachable Plates Assembly

16 Software setup

16.1 Install raspberry pi OS and booting

To install raspberry pi OS follow this guide by Tom's Hardware:
https://www.tomshardware.com/reviews/raspberry-pi-headless-setup-how-to,6028.html

Next turn on raspberry pi by plugging it in to power. After about 30s for it to boot, open a command prompt or terminal on **your computer** and type:

- ssh pi@raspberrypi

When prompted, type in the password that you set as the user password when you installed the OS. If successful, you should be greeted with a terminal from the raspberry pi.

16.2 Setup raspberry pi

There are multiple other settings that need to be enabled on the raspberry pi. If these steps are being done for the calibration of the legs, stop at step 7 and proceed to section 16.3:

1. Enable I2C by typing:
   - sudo raspi-config

   Use arrow keys and the enter button to navigate to and enable > Interface Options > I2C
2. Install git onto system:
   - sudo apt update
   - sudo apt install git
3. Verify the installation. Should return lasted version (2.32.0):
   - git –version
4. Then after installation and configuration, navigate to Projects in users:
   - cd Projects
5. Clone repository:
   - git clone https://github.com/Mystery2913/Hexabot.git
6. Navigate into repo:
   - cd Hexabot
7. Install dependencies:
   - pip install -r requirements.txt
8. Start-up Control site:
   - flask run --no-debugger --host=0.0.0.0
9. Use addresses printed in console to connect to website and add /joy to address to access control panel. E.g. *192.168.20.115:5000/joy*

16.3 Leg calibration

Connect the motor, servo driver, and raspberry pi together by following the wire diagram **Figure 18**. The flags **V+** and **GND** are the connections to the battery, they can be connected to the rest of the electronics with alligator clips. Depending on which motor you are calibrating, connect the motor to the corresponding PWM slot. First servo motor goes to motor channel 0, seconds servo motor goes to motor channel 1, and third servo motor goes to motor channel 2. Once this is done return to the SSH terminal and type:

- python calibrate.py

Then continue on with steps from section 10.

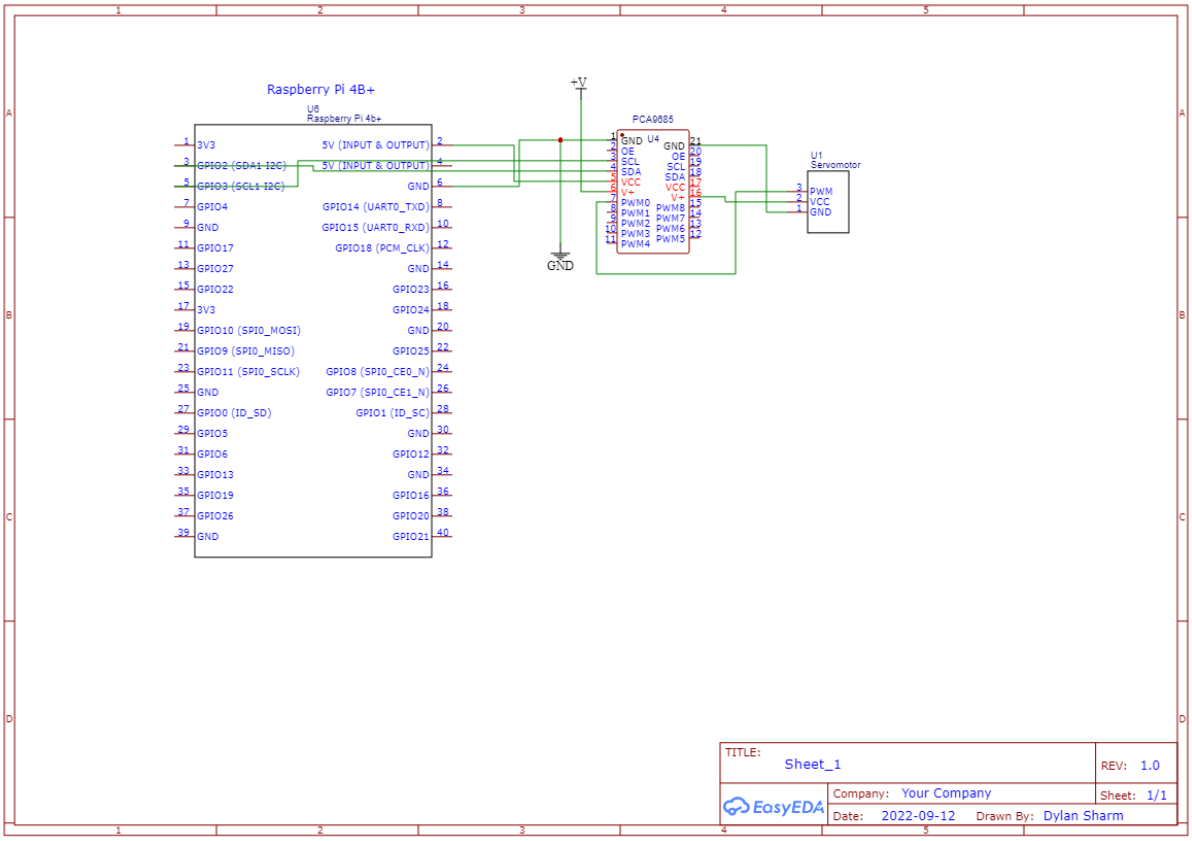

Figure 18 – 16 Leg calibration wiring diagram

17 Acknowledgments

17.1 Thank you

Thank you for downloading this user manual in the hope of making Hexabot. I have put a lot of time into this creation, and I am extremely proud of what I have made.

17.2 Front cover background

Credit to the maker of the background of the front cover: Алексей Безродний. Thank you for the free license of this image.