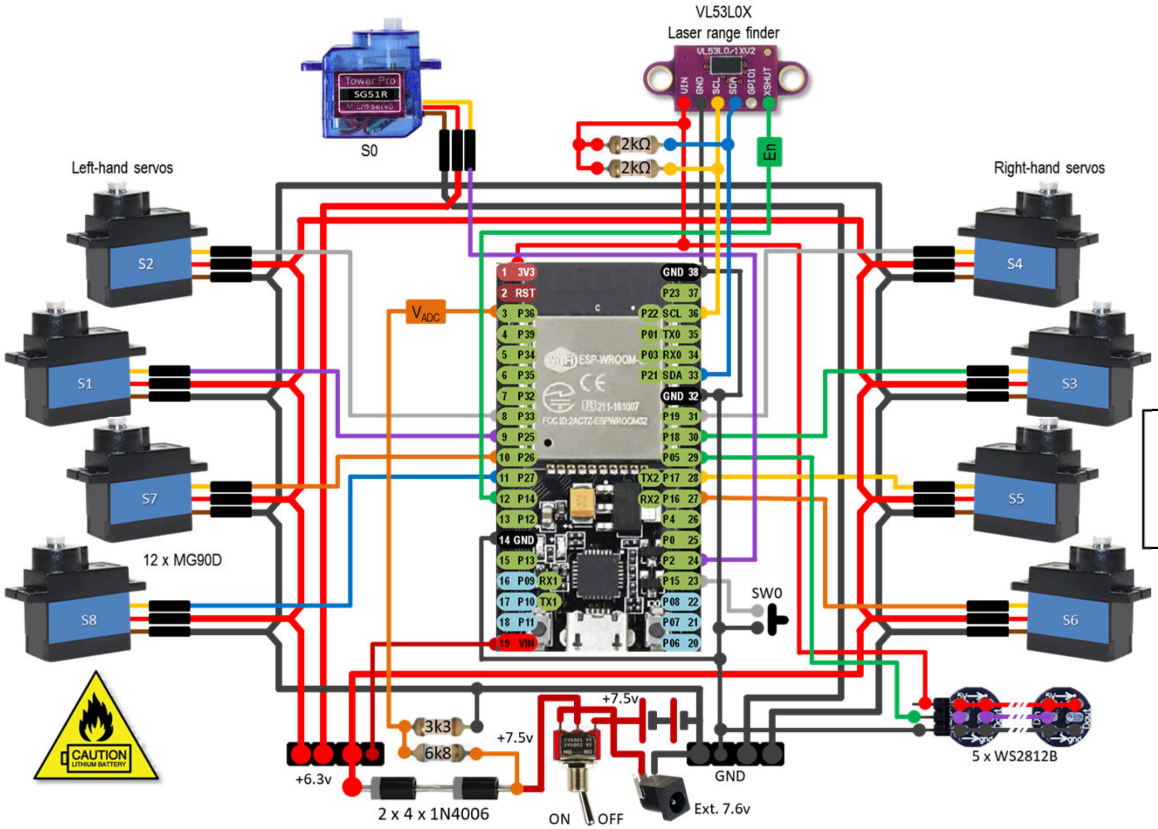
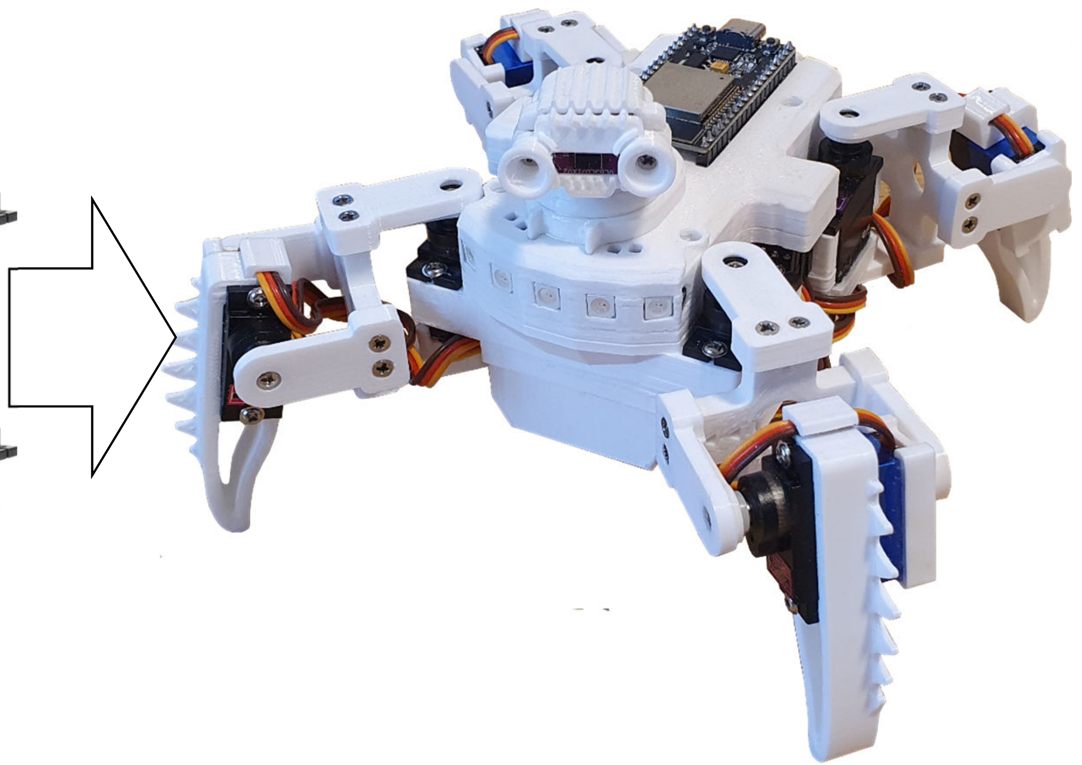
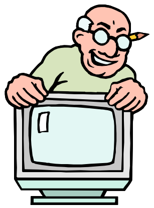
QuadAuto MKII (ESP32)

Circuits & Wiring







Good advice: read through the whole of this document before attempting this project.

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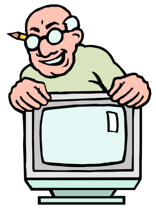
CAUTION



Lithium batteries can be extremely dangerous, if not handled and cared for properly. This design does not include any form of current limiting circuit, like a fuse. So, care must be taken to ensure that the wiring guidelines are followed accurately, that checks are made for short-circuits, and that battery polarities are marked, and they are inserted the correct way round. Failure to do so, could result in an explosive fire.

Charging Practices: Always remove batteries from your project to charge them. Use a charger, designed for the battery used, and from a trusted supplier. Choose a flat, non-flammable surface to charge on, away from flammable materials. Never leave unattended when charging. Don't charge overnight. Monitor charging to ensure charge characteristics are as expected. Only pair batteries with similar characteristics. Do not overcharge, or leave charging for prolonged periods. This increases the risk of damage and fire.

Battery care & maintenance: Stop using a battery if it is swollen, damaged, dented or leaking. Never charge a damaged battery. Never allow a Lithium battery to discharge below 3.2 volts, as cell damage will occur. Avoid extreme temperatures. Do not charge or store batteries in very hot or cold environments. Don't cover batteries whilst charging, as this can trap heat, causing overheating.

In case of fire: Get out and stay out. If a fire starts, leave immediately, and call the fire brigade. For low voltage Lithium batteries, water is a safe extinguisher.

Built-in Monitoring: Most of my project designs include code, and circuitry, to monitor battery voltage, whilst in use. This code then seeks to alert the operator, when the battery has reached a critical low voltage, before shutting down power consuming circuitry; including the micro. Time should therefore be spent on calibrating this feature, as a precaution, for good battery management and maintenance.

Carefully dispose of batteries that damaged, or discharged below their critical voltage.

Hand Tools:

Recommended:
- Fine Nosed Pliers
- Side Cutters
- 1.5 mm Drill
- 2.0 mm Drill
- 4.0 mm Drill
- Needle Files
- Screwdrivers
- Craft Knife

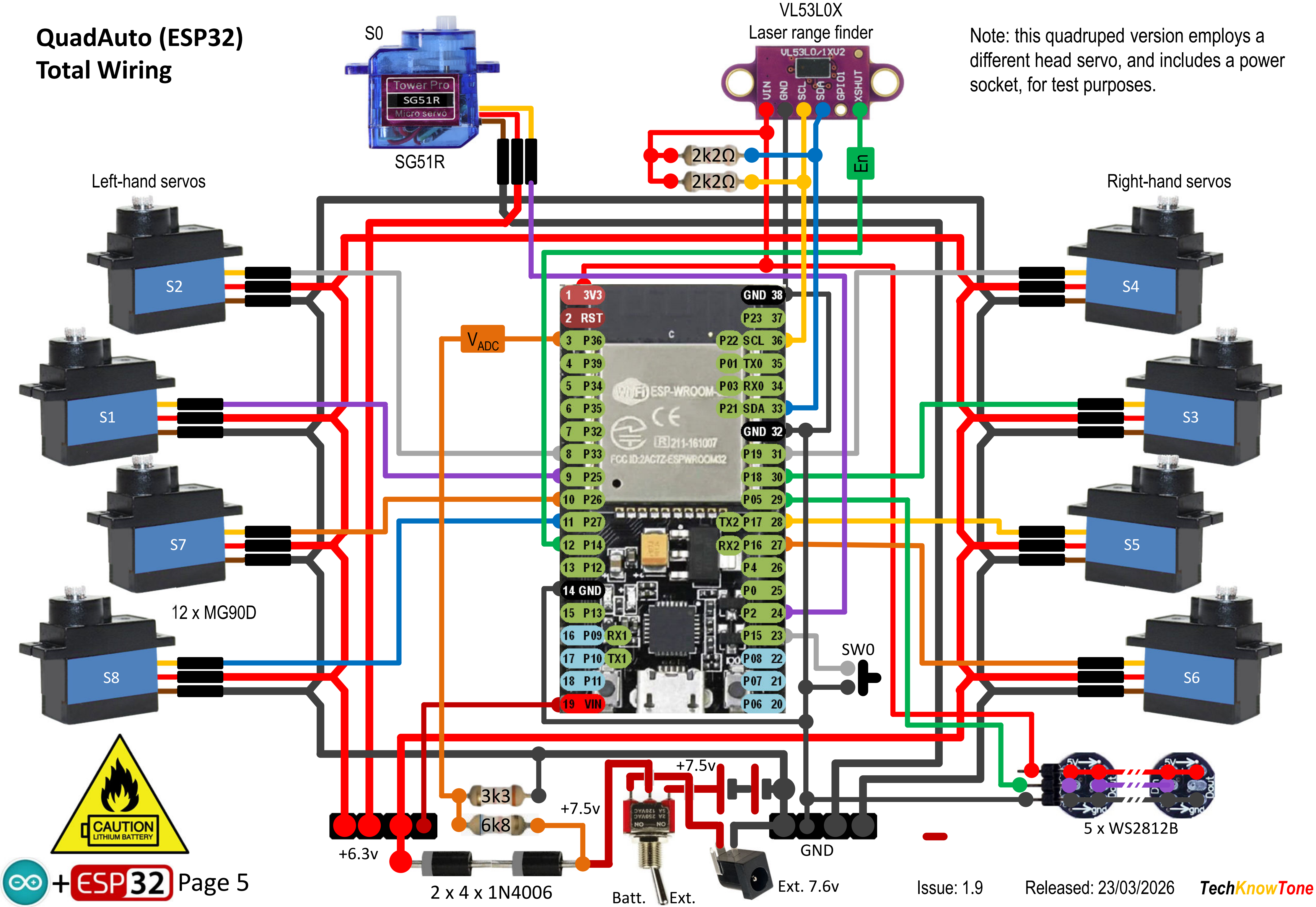
Note: Not all items are shown here.

Tools & Materials:

Temperature controlled iron
Solder flux
Resin cored solder
Hot melt glue gun {optional)
2-part epoxy resin glue
Screw drivers
Tweezers
Wire wrapping tool
Wire wrapping wire 30 AWG
24 AWG stranded wire (red, black & yellow)
Multimeter


QuadAuto (ESP32) Total Wiring

Note: this quadruped version employs a different head servo, and includes a power socket, for test purposes.



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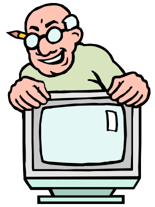
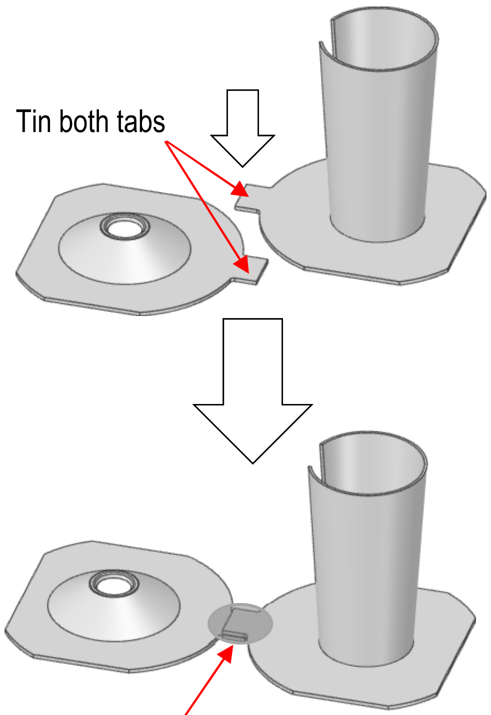
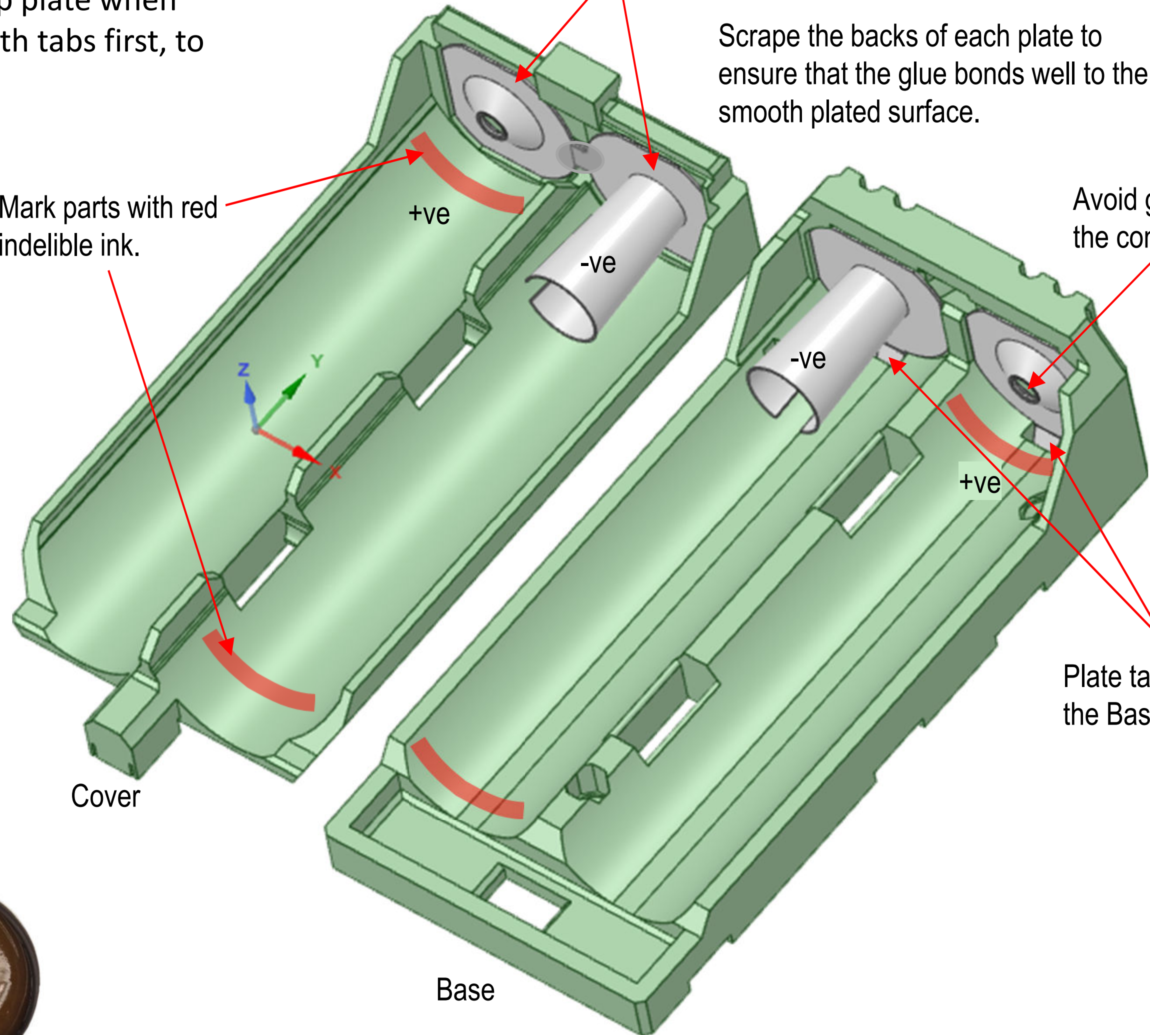
Battery Box Wiring

The Battery Box is made from two parts, the base (which screws onto the robot) and the cover. As the ends of 18650 batteries are easily damaged, this design makes it easy to insert and remove the batteries, whilst supported in the cover.



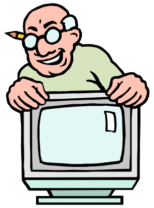
The covers metal spring and cap plates are cropped, and soldered together as shown, before gluing them into the cover. Note that the spring plates cropped tab, is positioned above the cap plate when soldered. Brush on a small amount of flux, and tin both tabs first, to aid the soldering process.

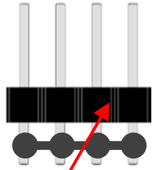




Base Plate Wiring

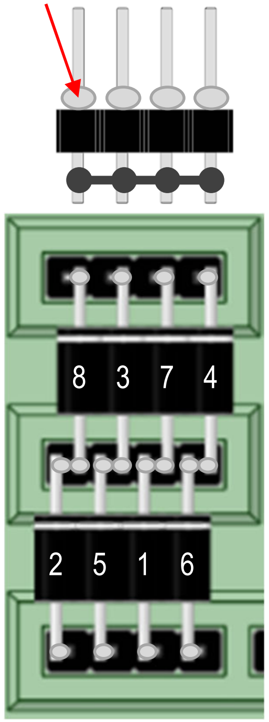
The Base plate connects to the battery case, and distributes power connections to both the Middle and Upper plates. The Power switch selects either batteries or an external source. Therefore, acting as a battery ON/OFF normally.

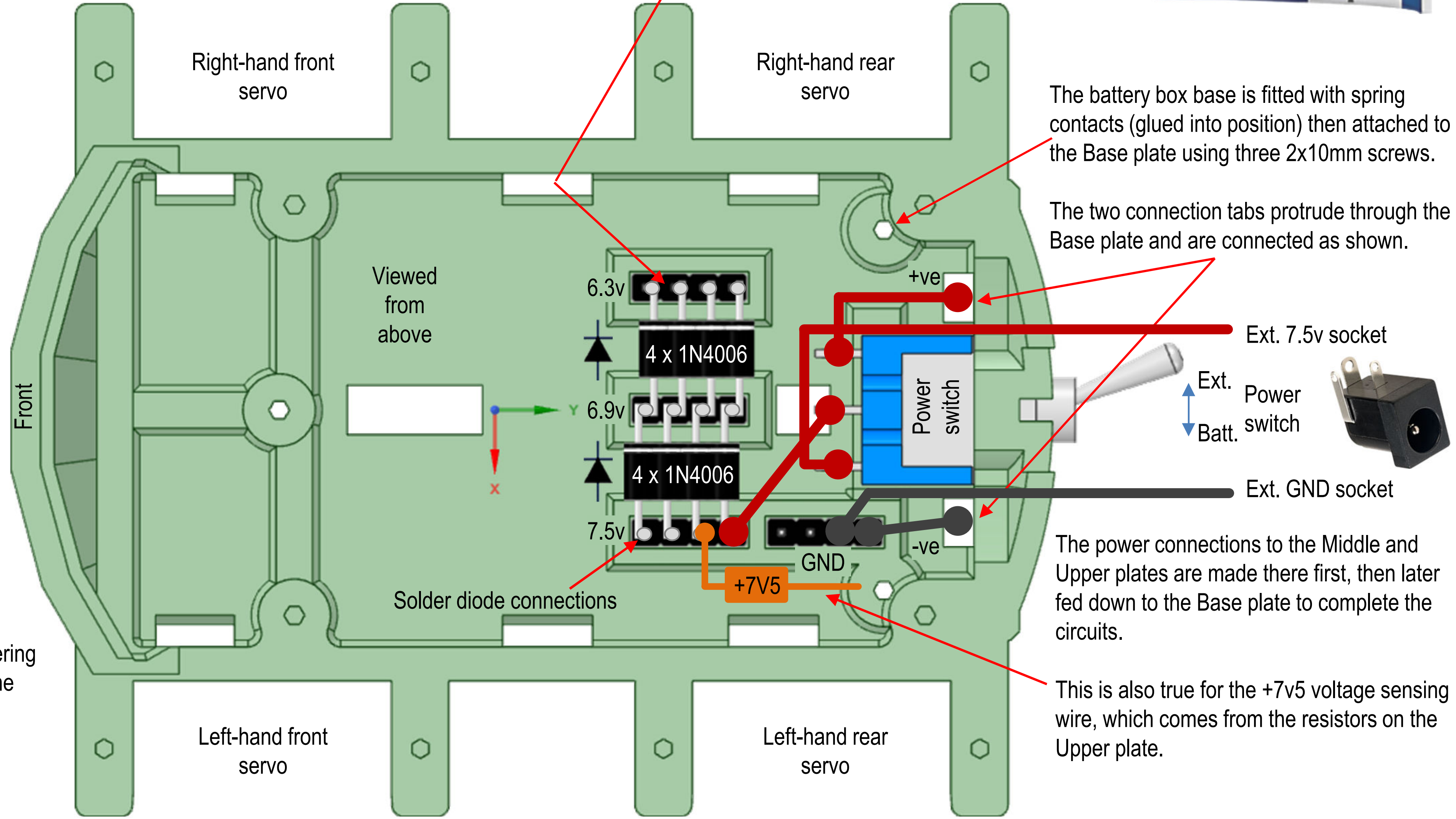




4 x 4-pin strips, with pins wired together, then glued into Base plate as common connection point

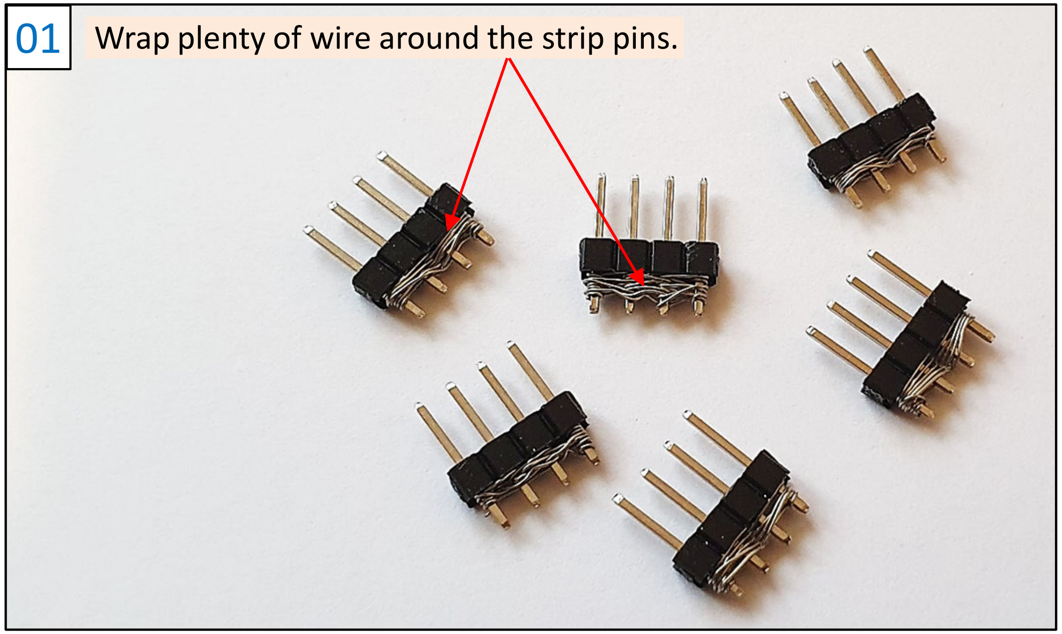
Tin the pins before soldering on diodes.

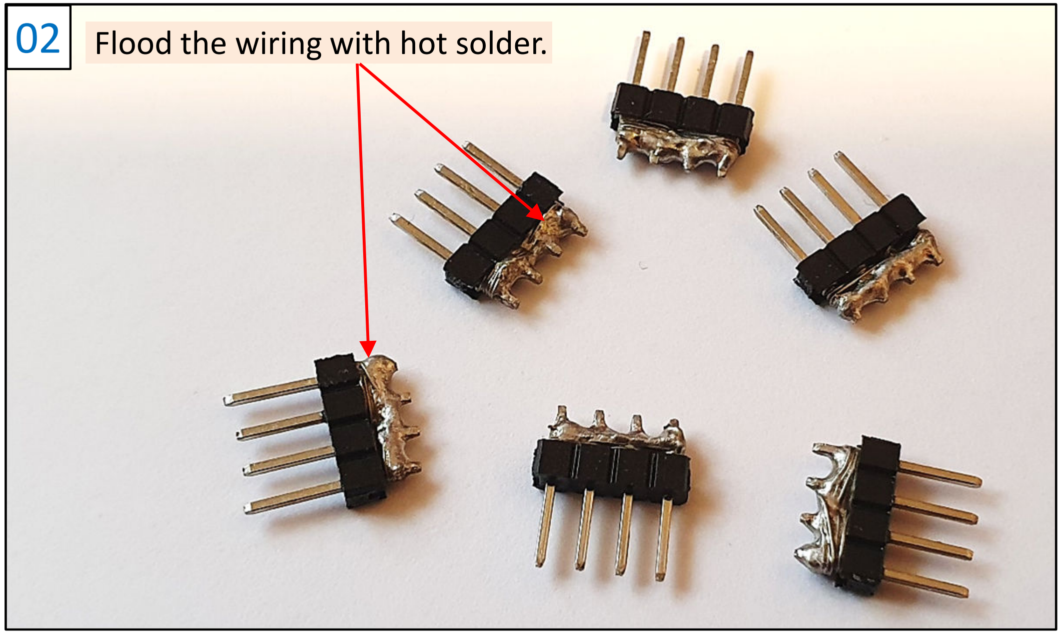


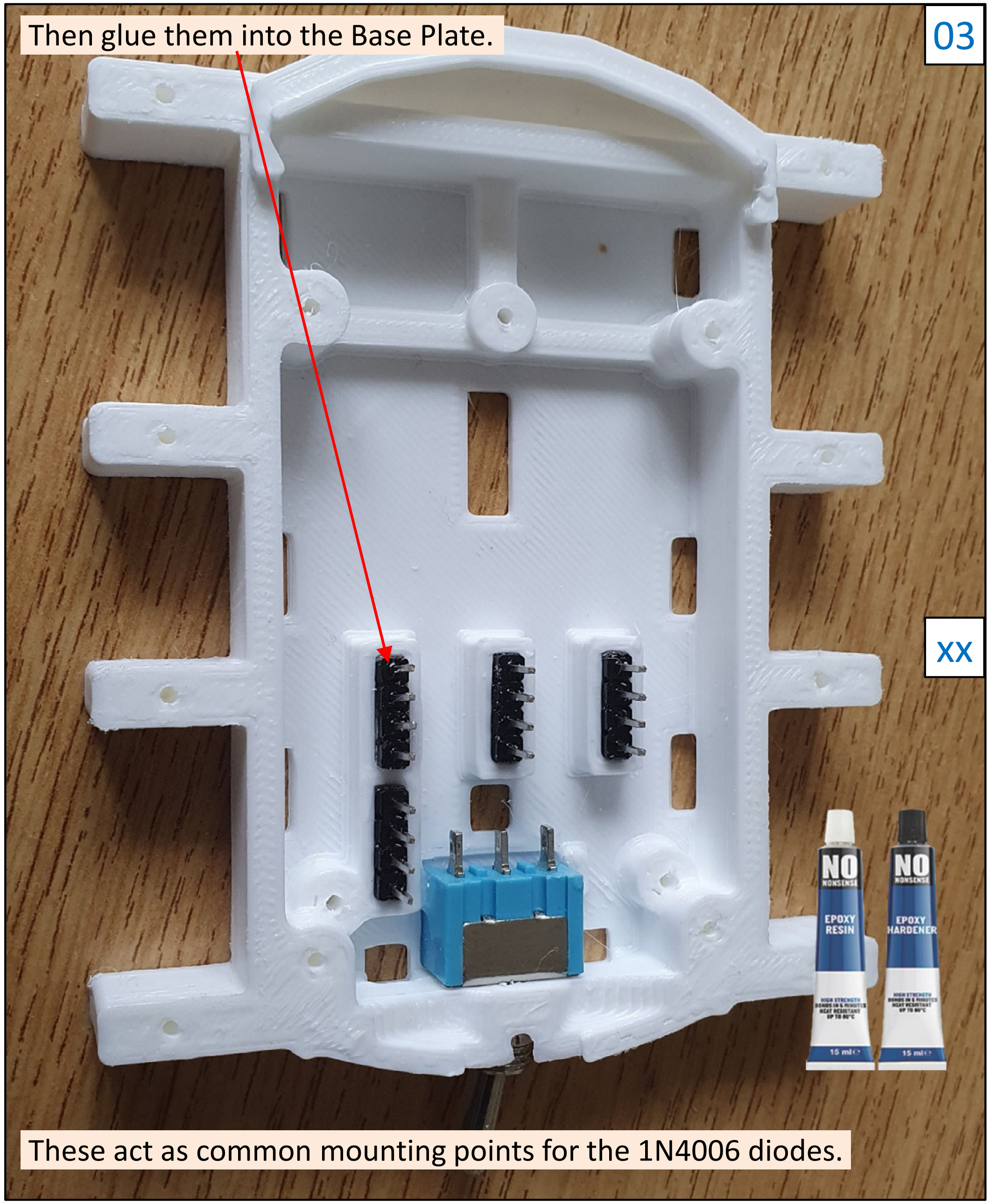


Suggested order for soldering in diodes. Brush flux on the joints before soldering.

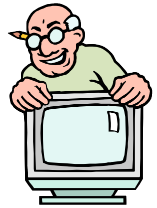
Common Connection Points



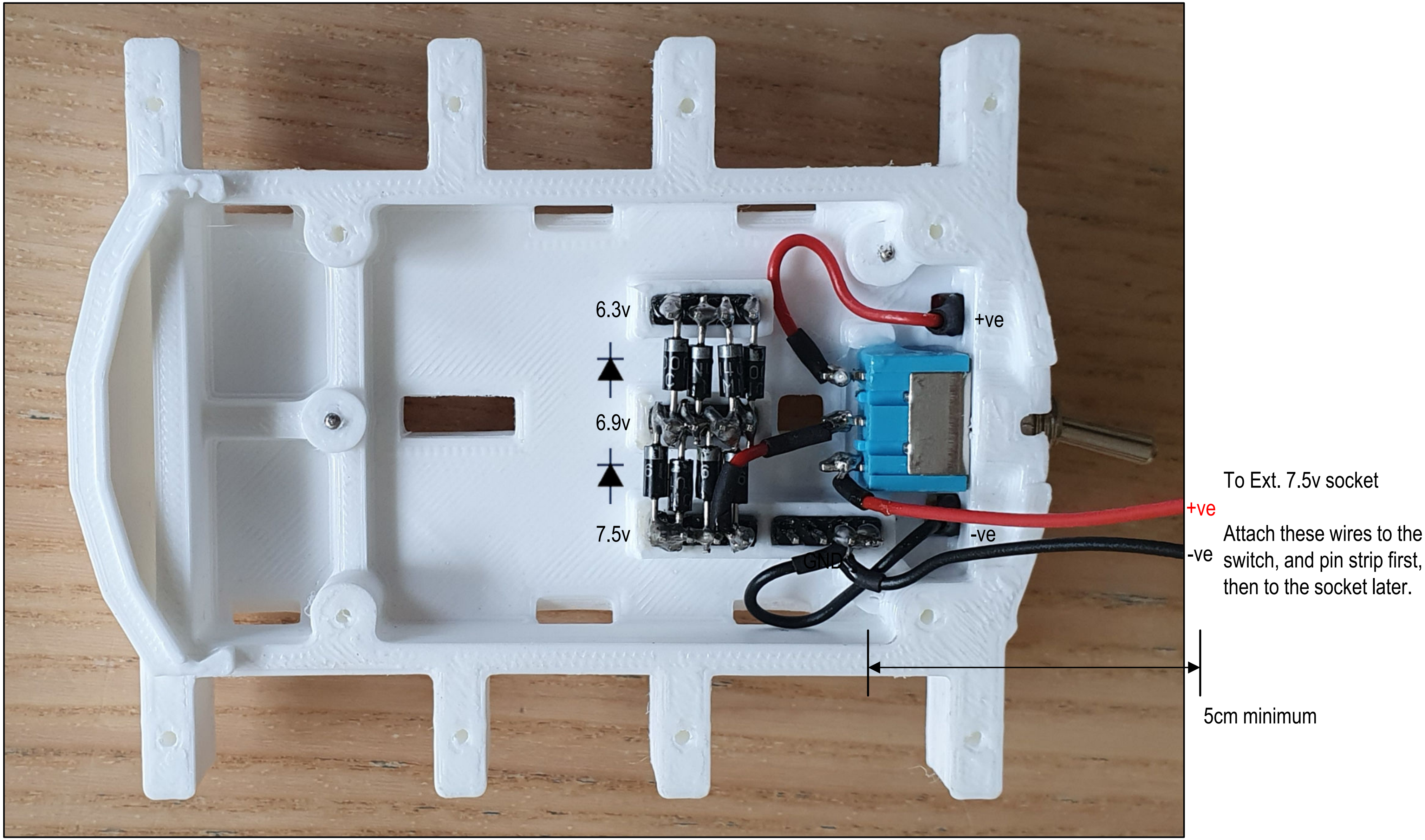




Base Plate Wiring



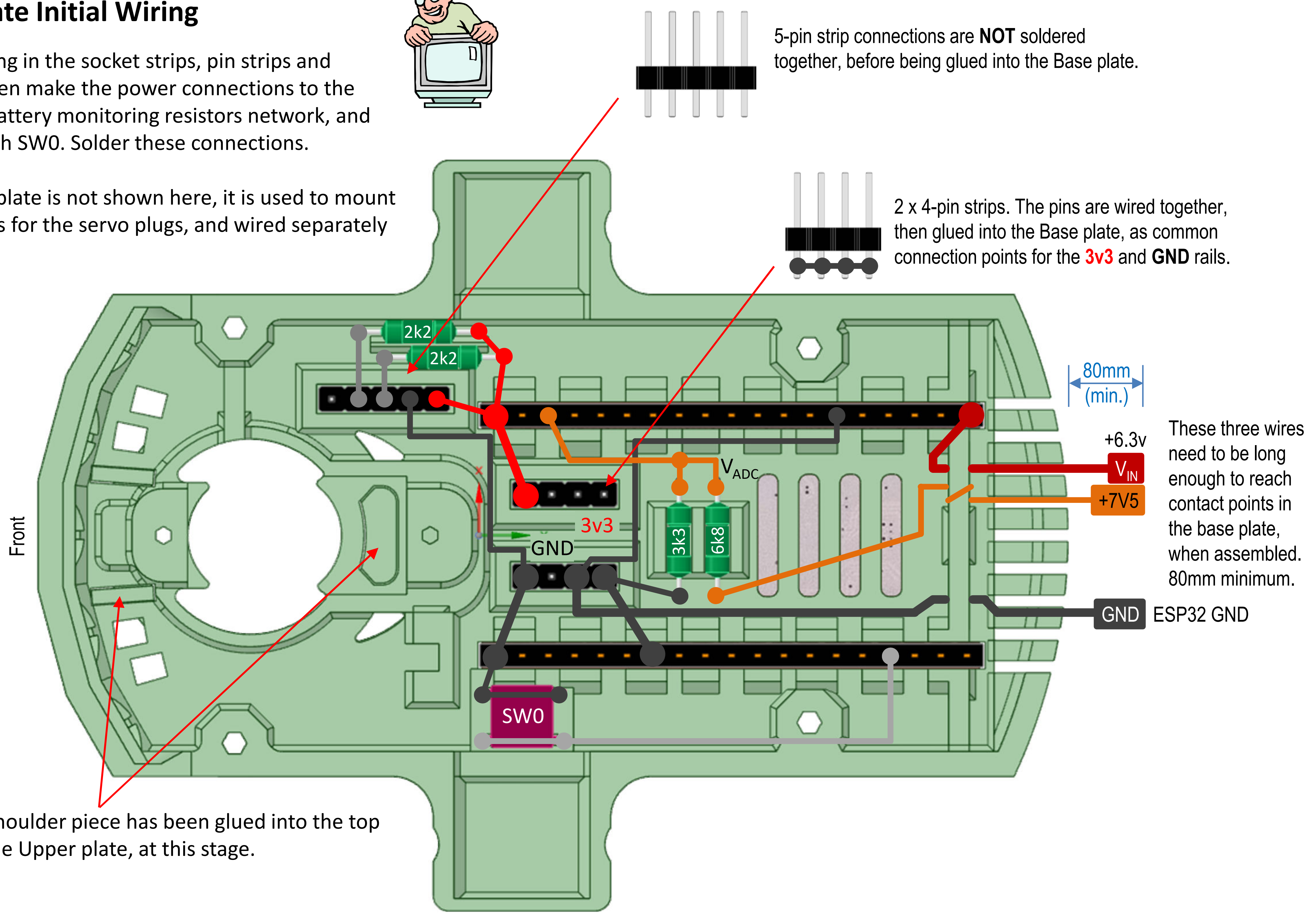
Your Base plate connections should look something like this, once the 8 x 1N4006 diodes, and connecting wires have been soldered into position. The pre-soldered pin-strips act as common connection points.



Upper Plate Initial Wiring

Start by gluing in the socket strips, pin strips and resistors. Then make the power connections to the micro, the battery monitoring resistors network, and button switch SW0. Solder these connections.

The Middle plate is not shown here, it is used to mount the pin strips for the servo plugs, and wired separately initially.



Note neck shoulder piece has been glued into the top surface of the Upper plate, at this stage.

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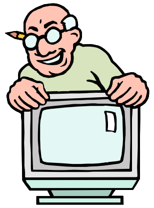
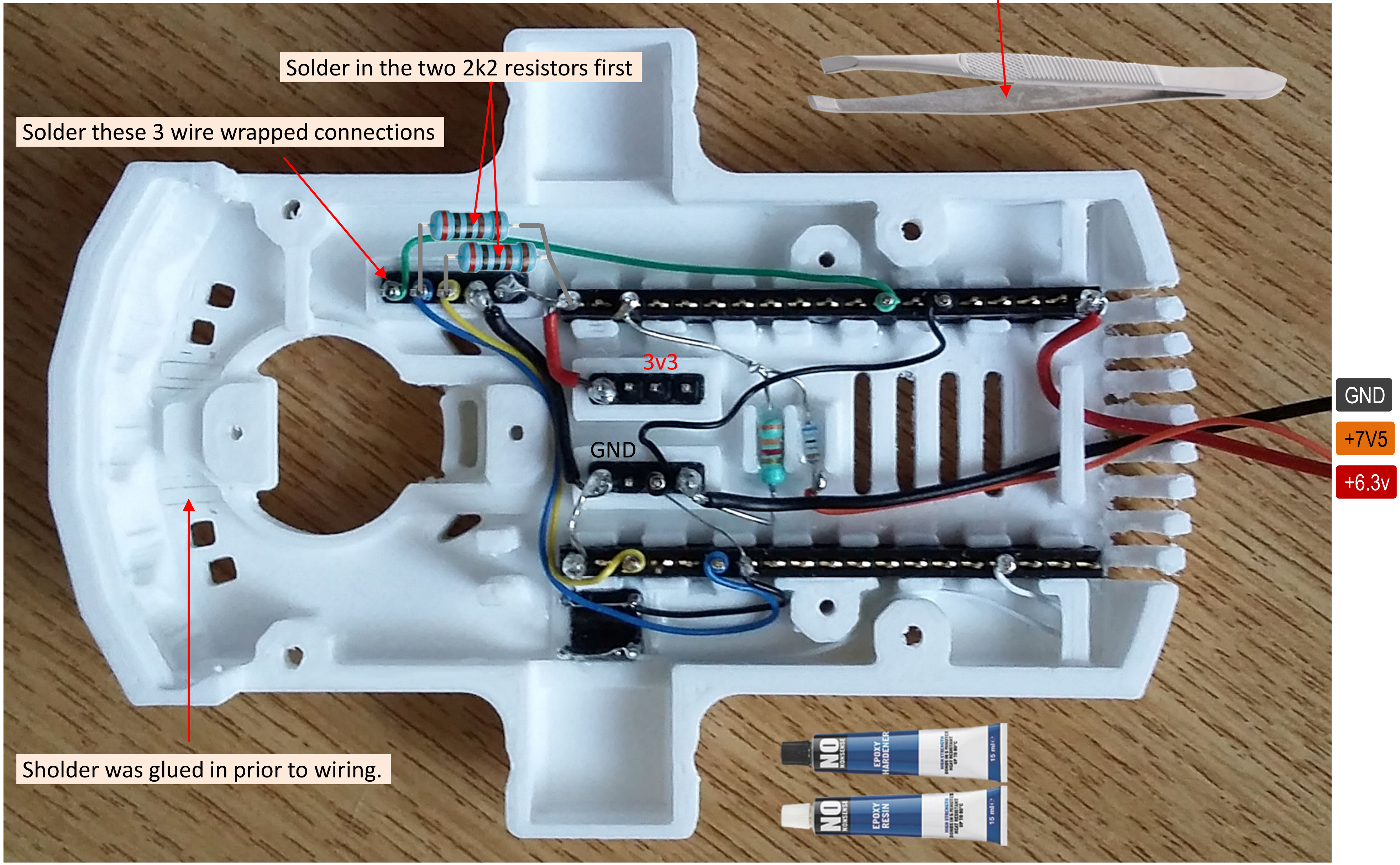
Upper Plate Wiring I2C

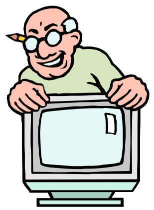
Your initial Upper plate connections should look something like this.
The socket strips, pin strips and resistors are glue in first <u>before</u> wiring.



Use tweezers to help position and form the wire.
See my wire wrap guide for best practise.



WS2812B RGB strip Wiring



The five WS2812B LEDs are difficult to wire up in position, within the front of the Upper Plate. So, to make the task much easier we use a small jig, which holds the LEDs in the correct orientation for wiring. Once wired, we can then simply transfer the assembly to the upper plate, test it and them glue the LEDs into position.

Start by placing the LEDs in the jig, in the correct orientation. We will be attaching wires from the left to the right, by soldering them onto the WS2812B pads. Holding the jig in a small vice can help.

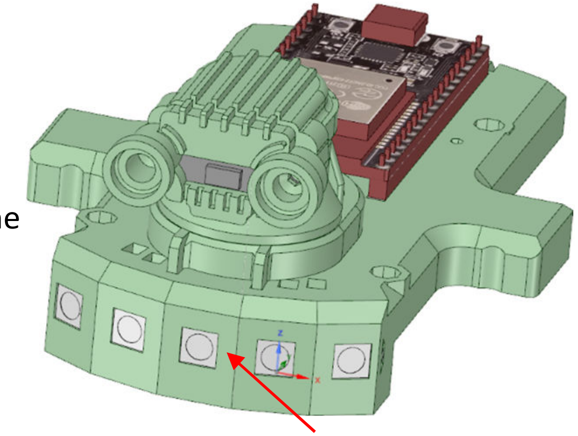
The wires will be of different length, with the green wire being much longer, due to its data loops and the micro connection.

Then solder in the red wire along the 5v pads. The stripped wire needs to exceed the length of the jig, and the insulated portion needs to be able to reach the 5v common pin strip. Crop excess, once soldered onto pads.

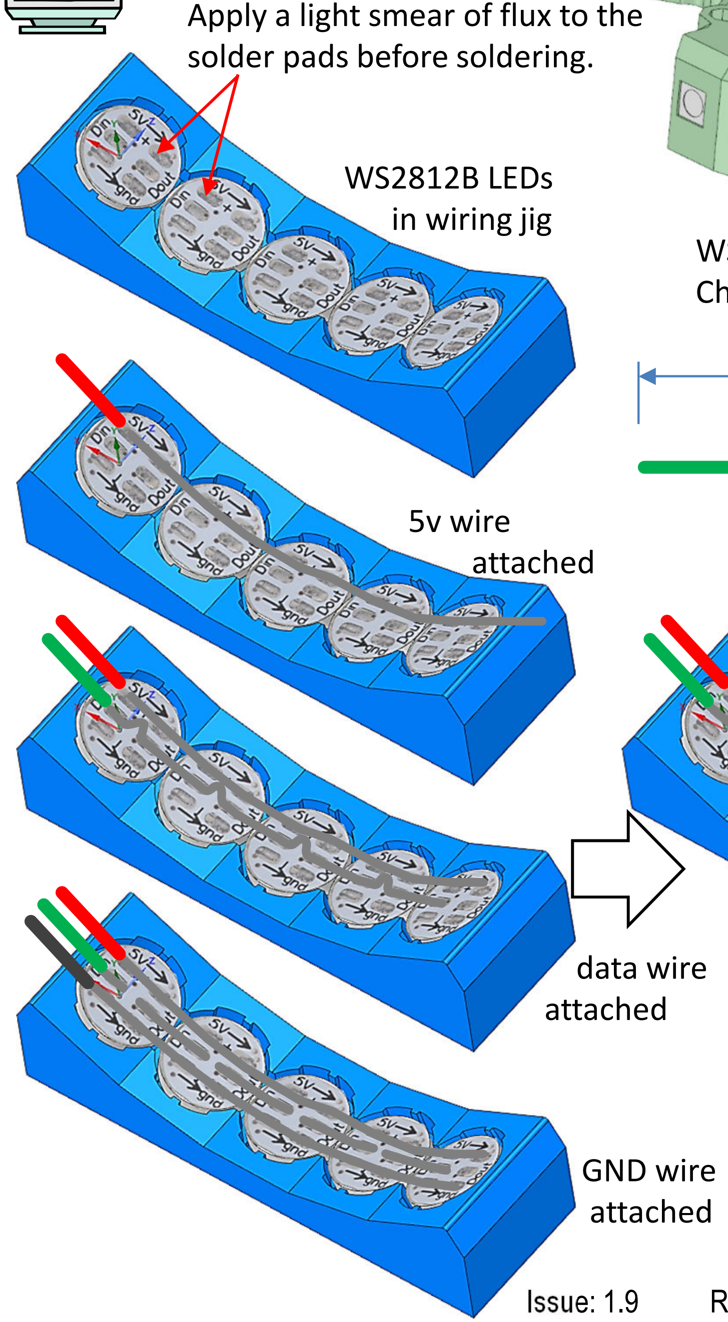
Then solder in the green data wire, raising the wire into a small loop between each data pad on the LED chip, so that this can be cropped off afterwards to break the connection as shown. Inspect the soldered joints before cropping.

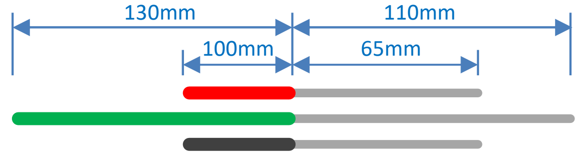
The solder in the black GND wire, connecting all of the GND pads together. Crop excess once soldered.

Transfer the wired components to the robot's upper plate, and wire wrap the three connections. With a micro inserted and programmed, you can test the LED strip before finally gluing in the LEDs. See photos later for more information.

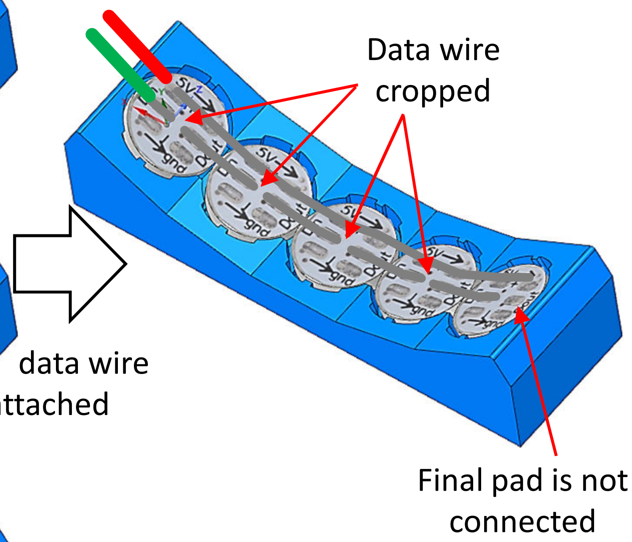


WS2812B LEDs in robot facia. Check/file apertures for clearance.





Minimum wire lengths
Use 30AWG wire-wrap wire.



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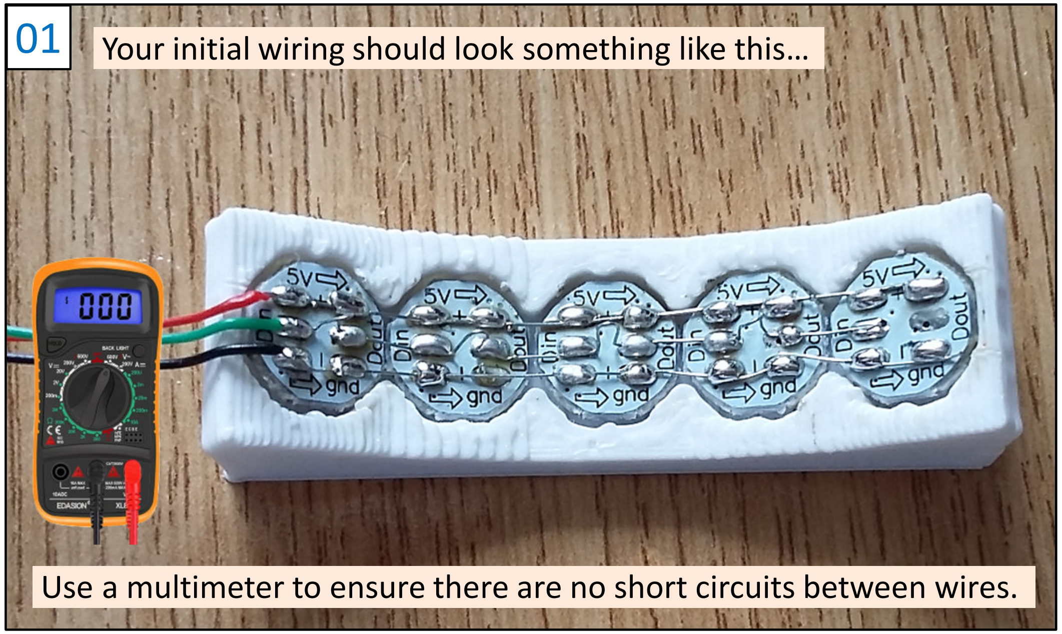
WS2812B RGB strip Wiring

01

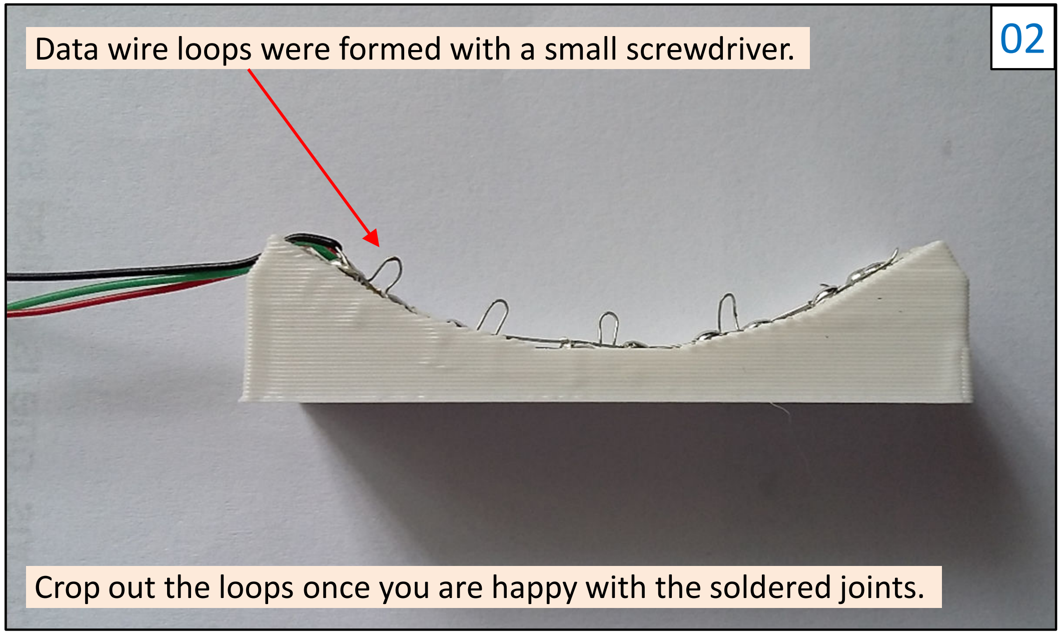
Your initial wiring should look something like this…



Use a multimeter to ensure there are no short circuits between wires.

02

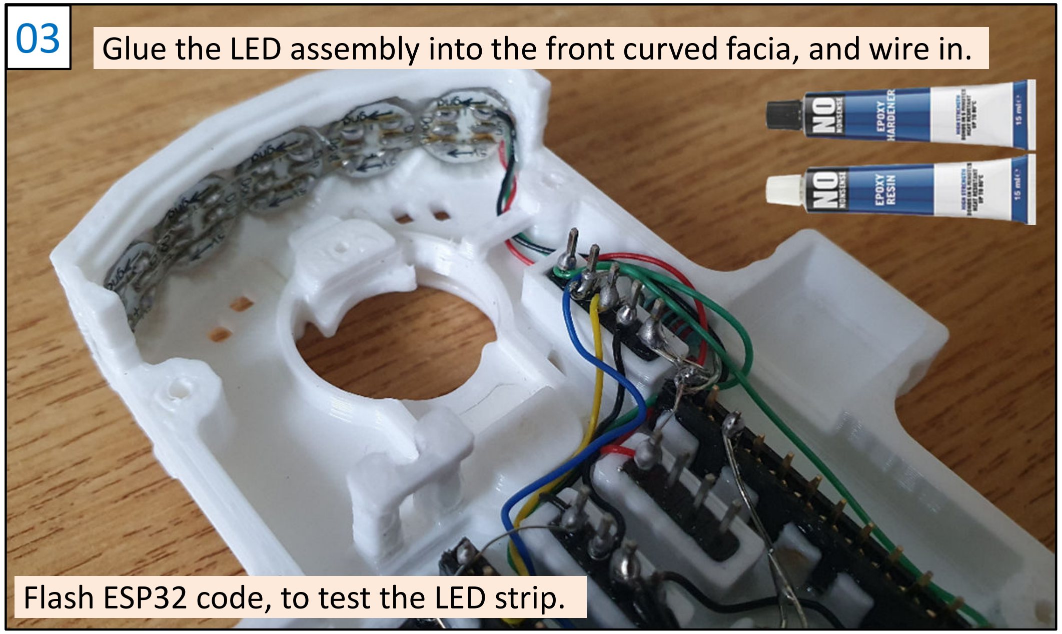
Data wire loops were formed with a small screwdriver.



Crop out the loops once you are happy with the soldered joints.

03

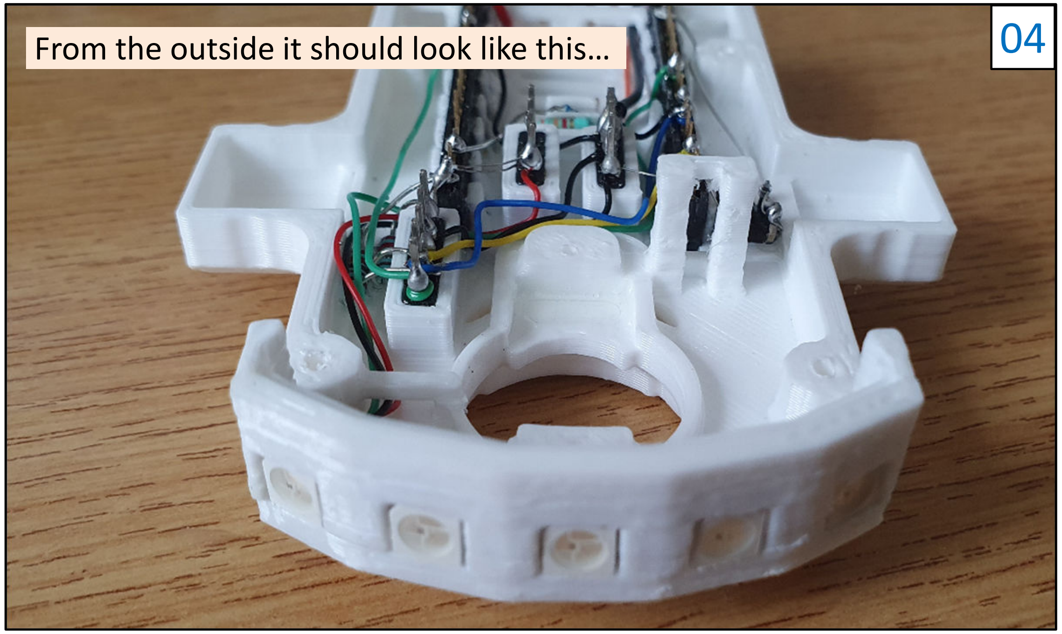
Glue the LED assembly into the front curved facia, and wire in.



Flash ESP32 code, to test the LED strip.

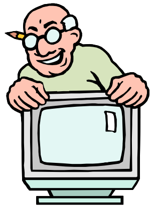
04

From the outside it should look like this…

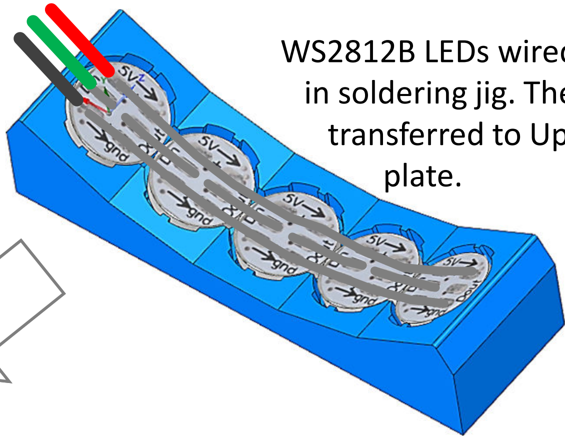


Upper Plate WS2812B Wiring

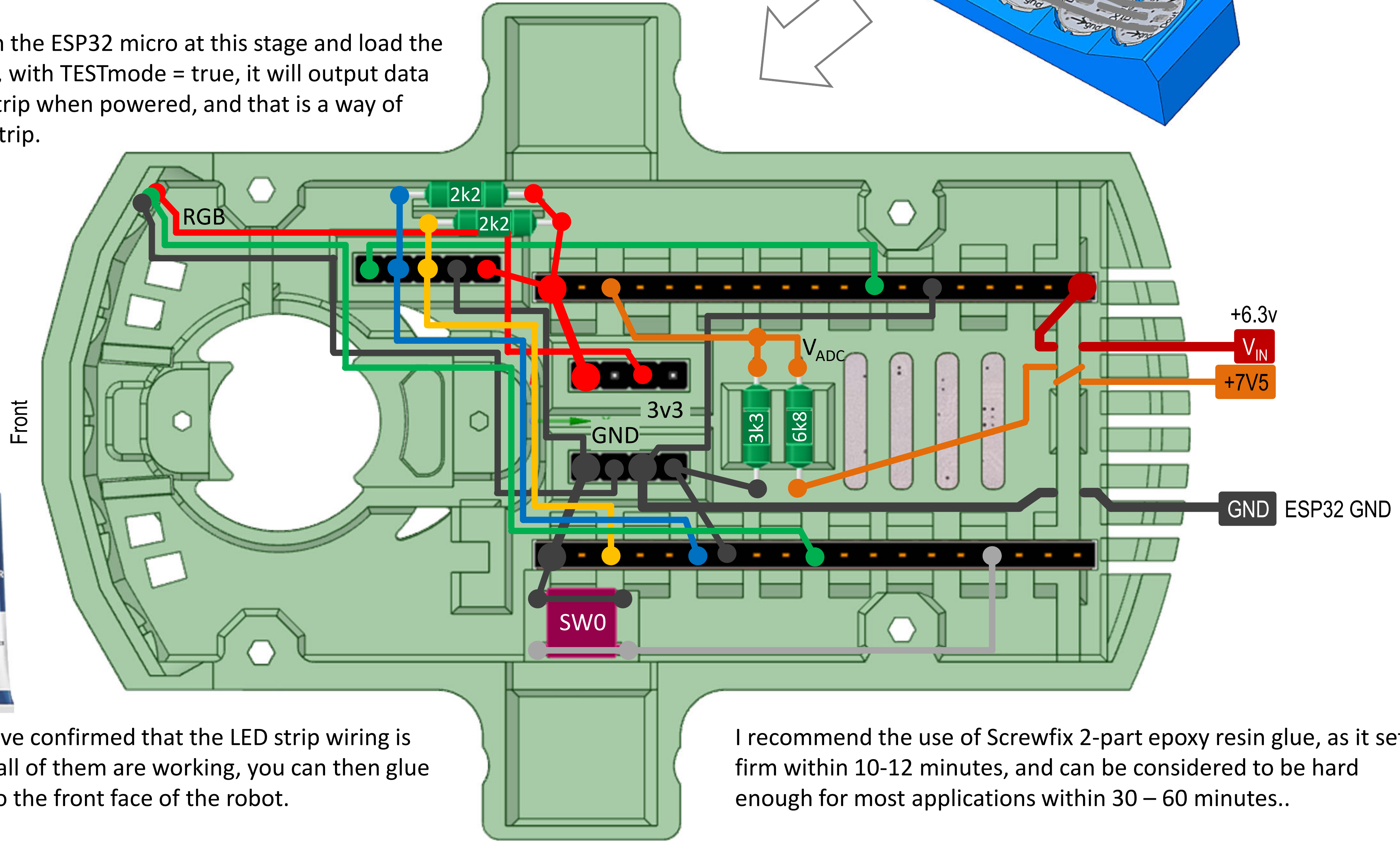
Now we carefully transfer the wired WS2812B LEDs from the soldering jig, into the front face of the Upper plate. From that position we run and terminate the three wire connections.



If you plug in the ESP32 micro at this stage and load the code onto it, with TESTmode = true, it will output data to the LED strip when powered, and that is a way of testing the strip.



WS2812B LEDs wired in soldering jig. Then transferred to Upper plate.

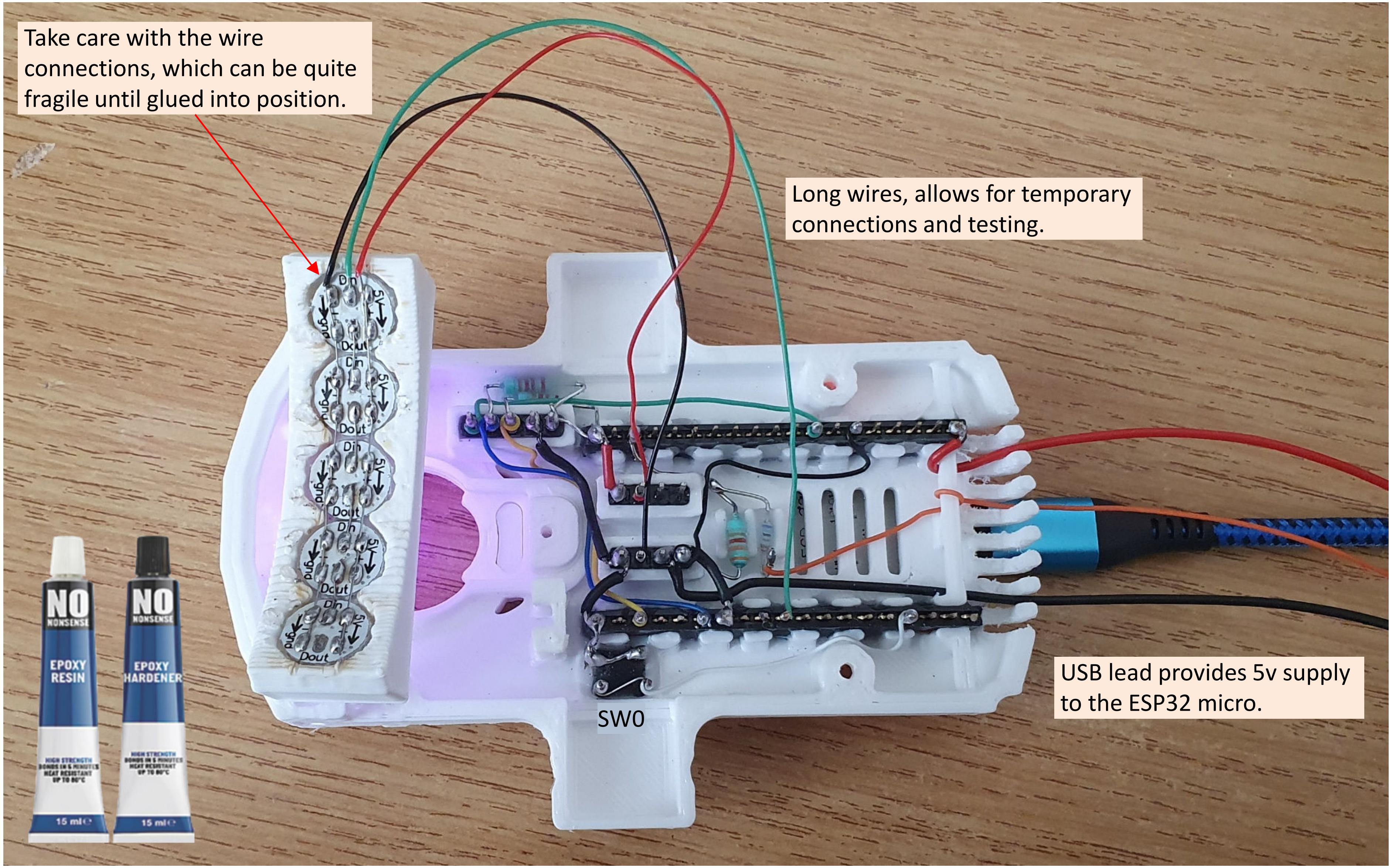


Once you have confirmed that the LED strip wiring is correct and all of them are working, you can then glue the LEDs into the front face of the robot.

I recommend the use of Screwfix 2-part epoxy resin glue, as it sets firm within 10-12 minutes, and can be considered to be hard enough for most applications within 30 – 60 minutes..

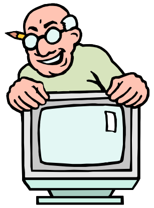
Upper Plate WS2812B Wiring

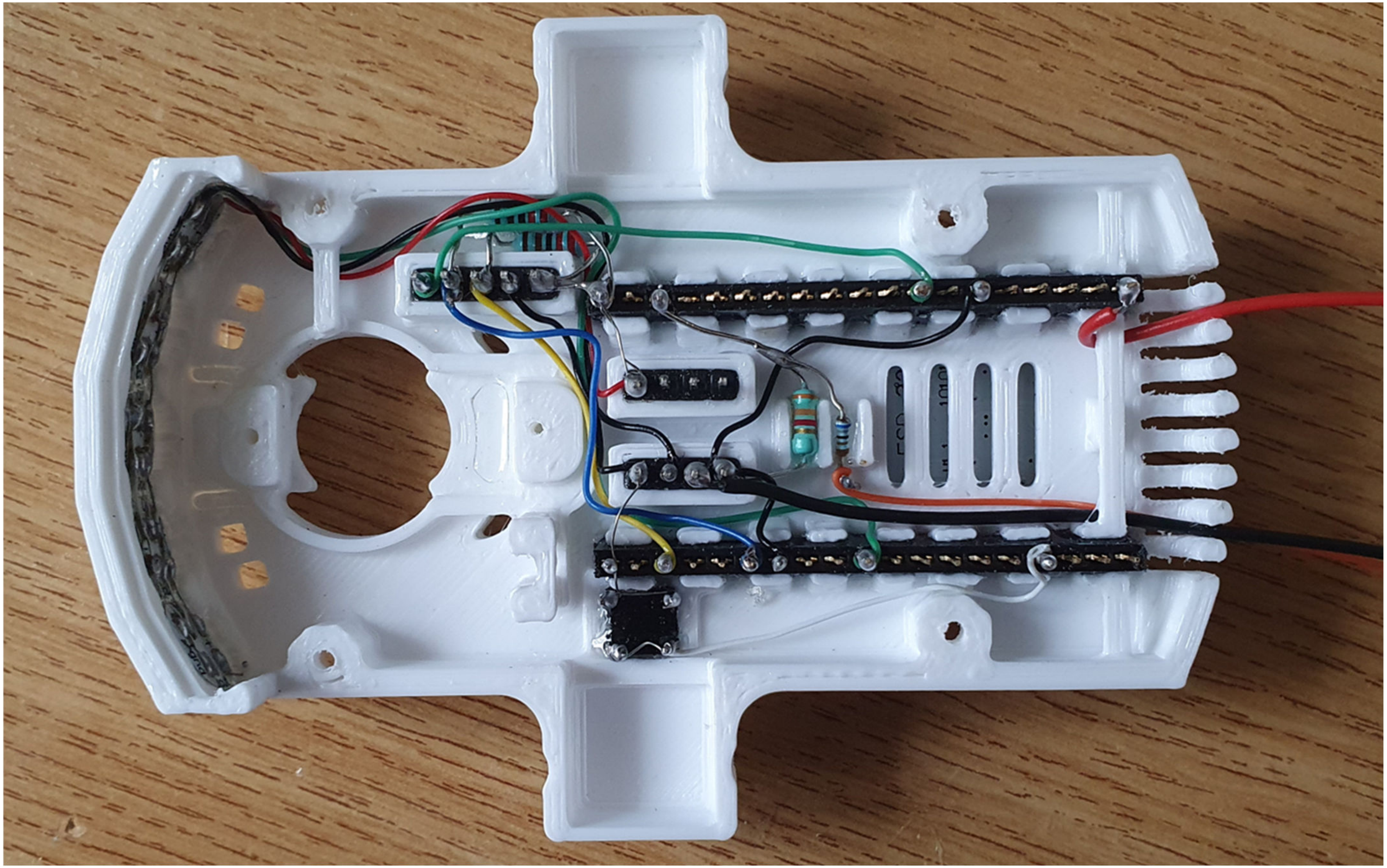
Before removing the connected LEDs, from the support jig, and gluing them into the Top plate, you can temporarily wire them up, flash the ESP32 micro, and run the code off a USB lead, to confirm that all of the LEDs are working as expected. The start-up sequence lights all of the LEDs. You can also test the push button switch connections, which turns the end two LEDs blue..



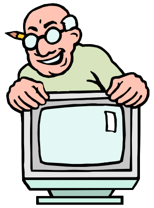
Upper Plate WS2812B Wiring

Your Upper plate connections should now look like this.

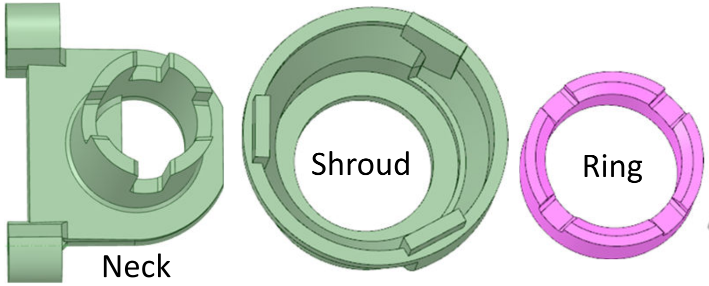




Head assembly

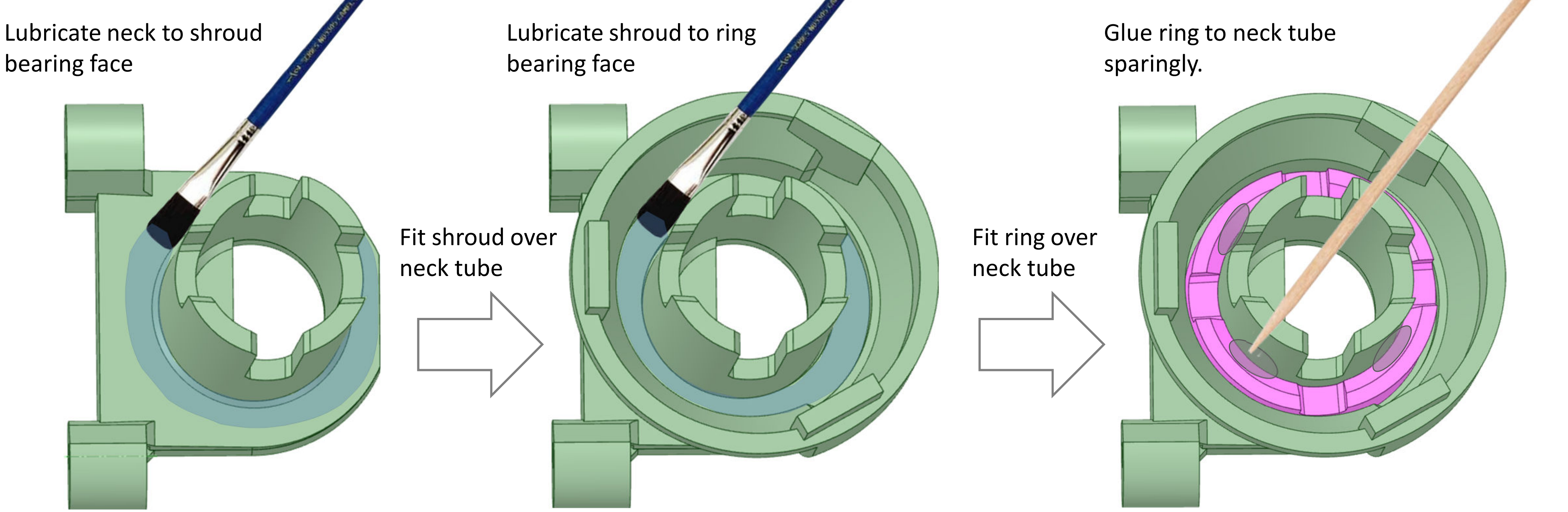


The neck is held into the shroud piece by a retaining ring, which is glued onto the neck tube.



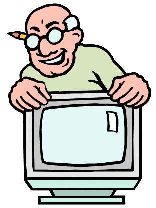
Prior to gluing the components, we apply a small amount of lubricant the load bearing surfaces, to reduce friction and wear. I used Vaseline for this.

Care must be taken to lubricate sliding faces only, whilst not compromising the glued faces. The glue dabs acts to retain the ring on the neck tube; you are not trying to glue the ring fully.



Allow the glue to go firm, then carefully rotate the neck within the shroud, to ensure that it is not glued also. Leaving the tooth pick on the mixing card gives a good indication as to when the glue stiffens. Normally 10-12 minutes depending on room temperature.

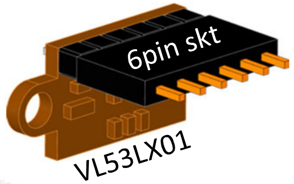
Head VL53L0X LTOF Wiring

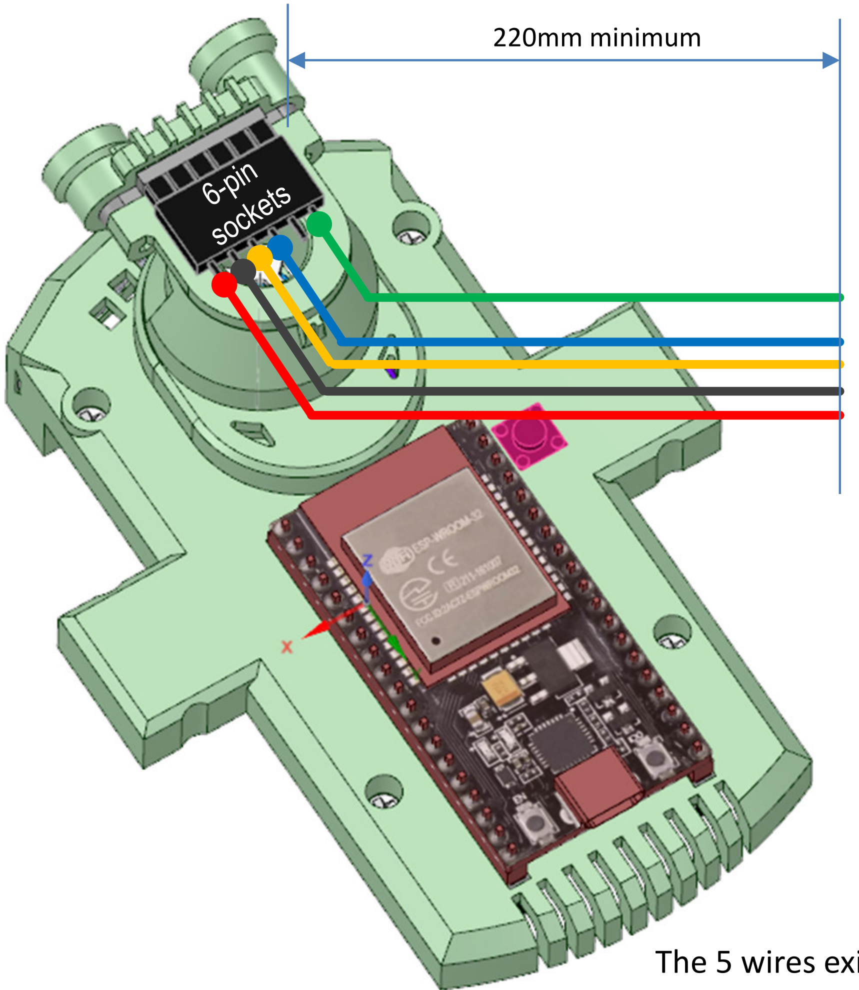


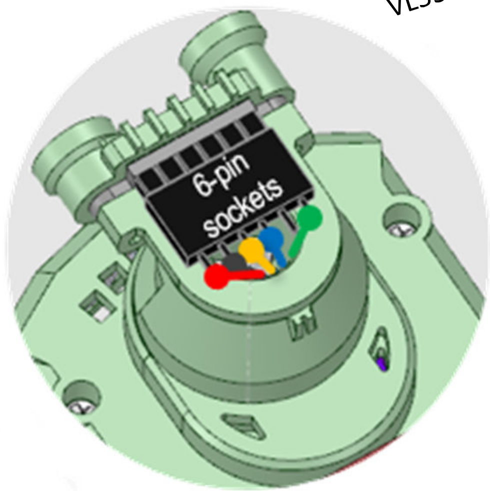
Using the Head Eyelets piece, and 2 screws, attach the sensor onto the neck.

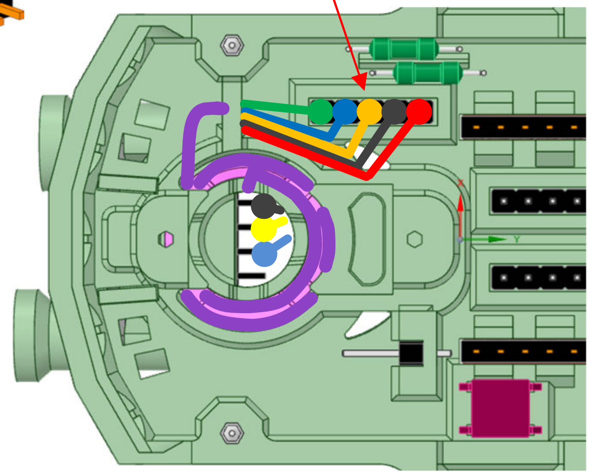
Connect 5 wires to a 6-pin socket strip, as shown; allowing for a minimum length of 220 mm. Solder the connections, then plug this onto the VL53L0X device, whilst feeding the wires down through the neck aperture. The wire length aims to ensure you have more than sufficient.

With the 5 wires wrapped round the neck and exiting the Upper plate as shown, insert the servo with the cross leaver attached, and screw it into position. Then terminate the 5 wire wrap wires as shown. Only solder once tested.

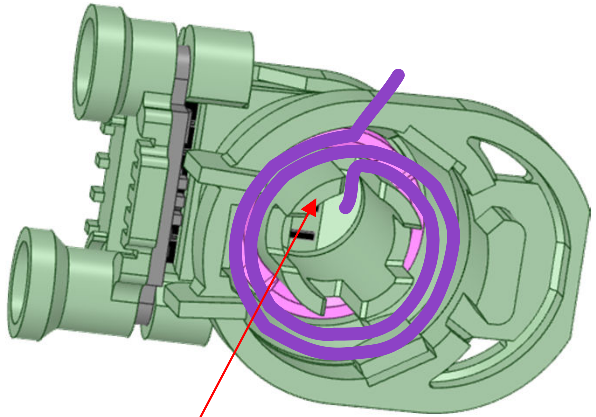


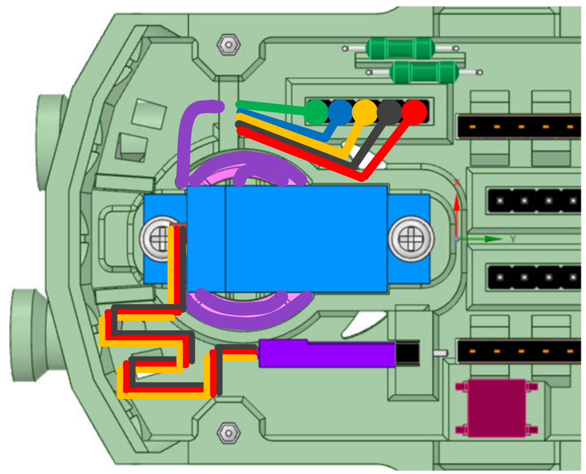






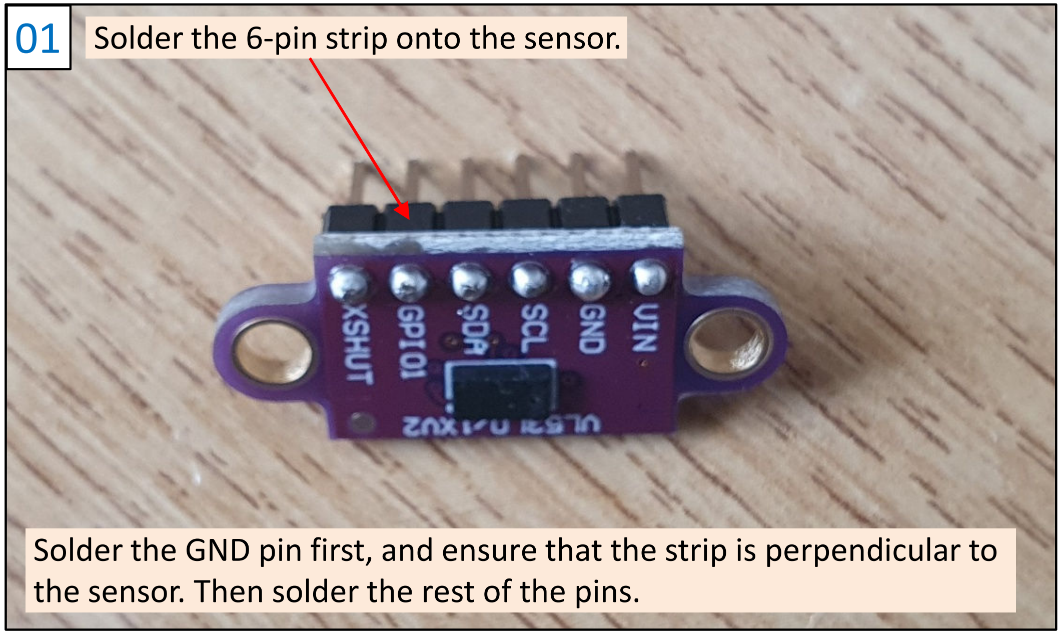
The five wires are represent by one thick purple wire in this diagram.





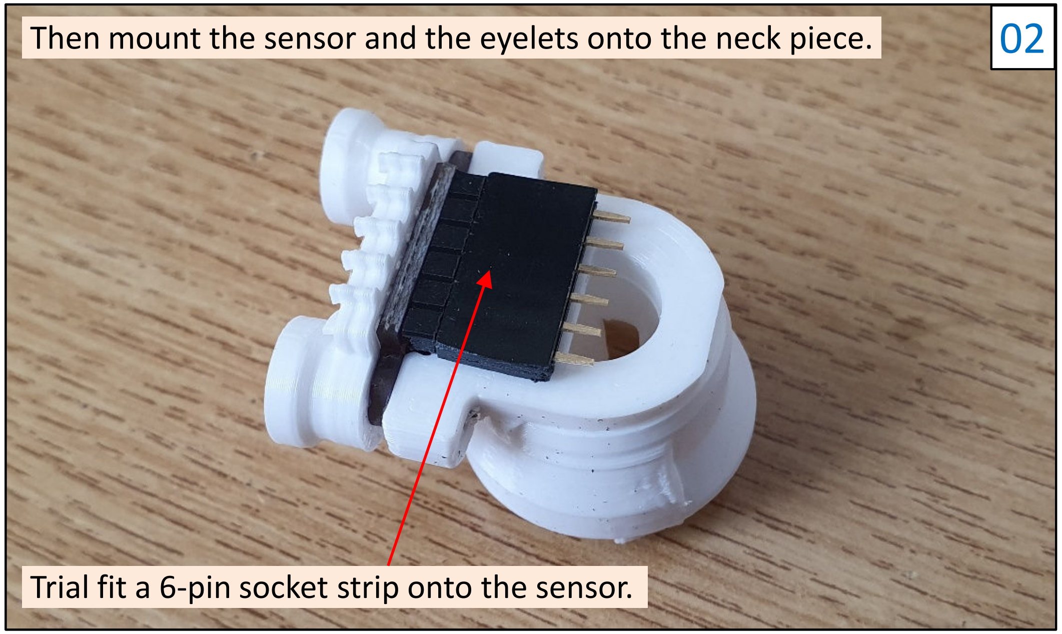
The 5 wires exit the neck here, above the servos drive leaver, and are wrapped twice clockwise around the neck, before exiting through the upper plate aperture.

Build Photos



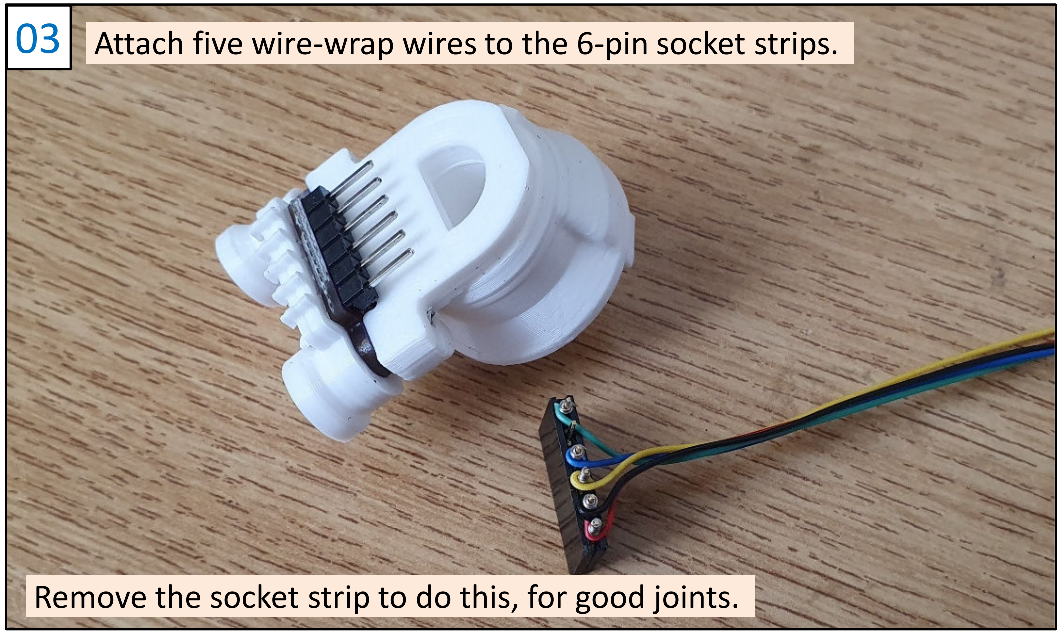
01 Solder the 6-pin strip onto the sensor.

Solder the GND pin first, and ensure that the strip is perpendicular to the sensor. Then solder the rest of the pins.



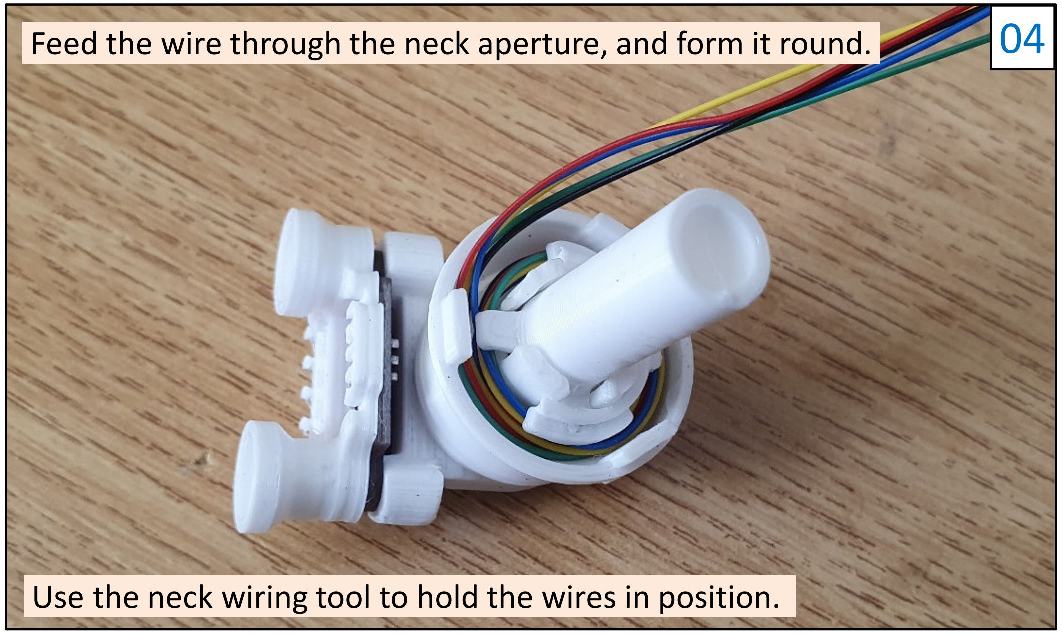
02 Then mount the sensor and the eyelets onto the neck piece.

Trial fit a 6-pin socket strip onto the sensor.



03 Attach five wire-wrap wires to the 6-pin socket strips.

Remove the socket strip to do this, for good joints.

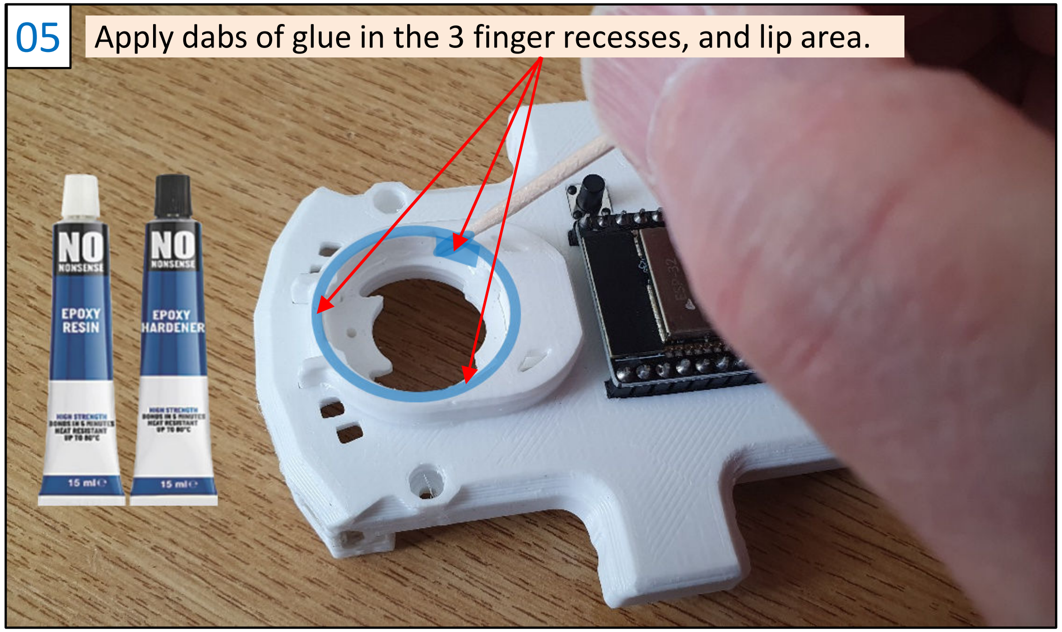


04 Feed the wire through the neck aperture, and form it round.

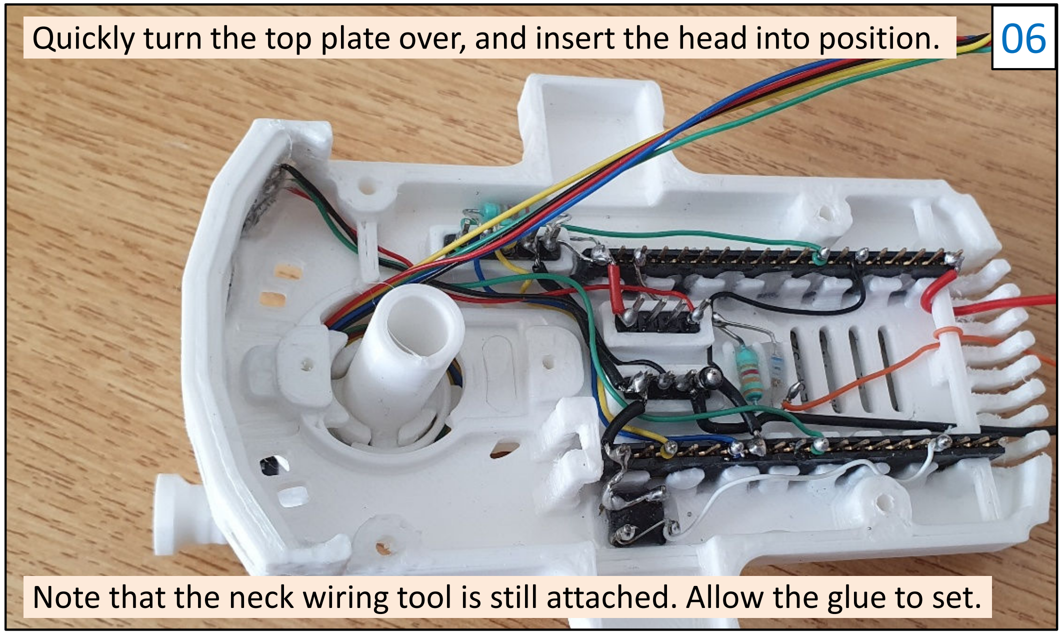
Use the neck wiring tool to hold the wires in position.

Wiring Sequence

05 Apply dabs of glue in the 3 finger recesses, and lip area.

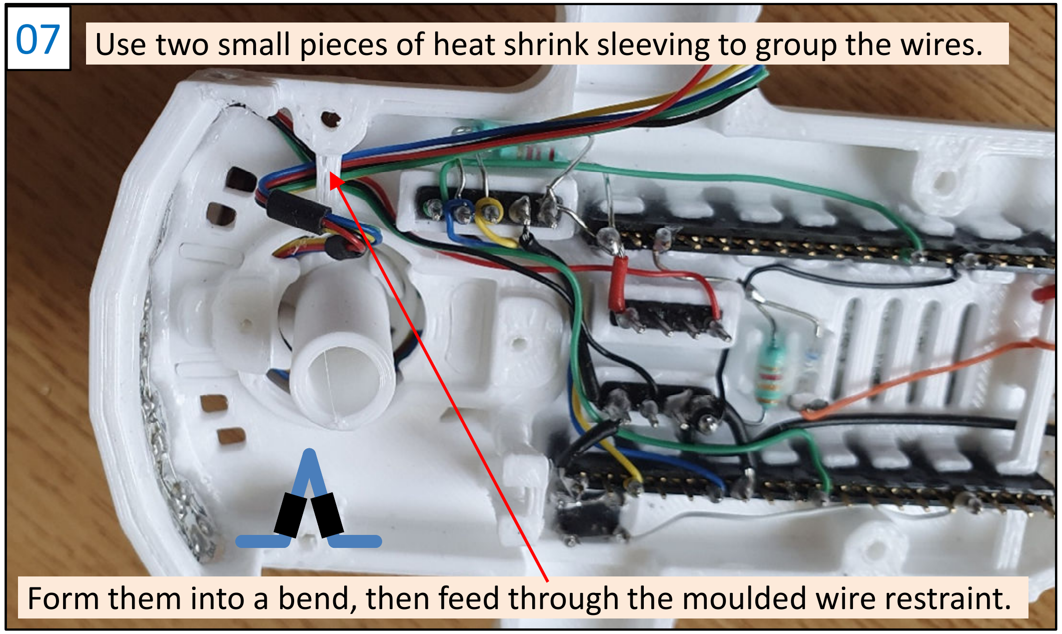


06 Quickly turn the top plate over, and insert the head into position.



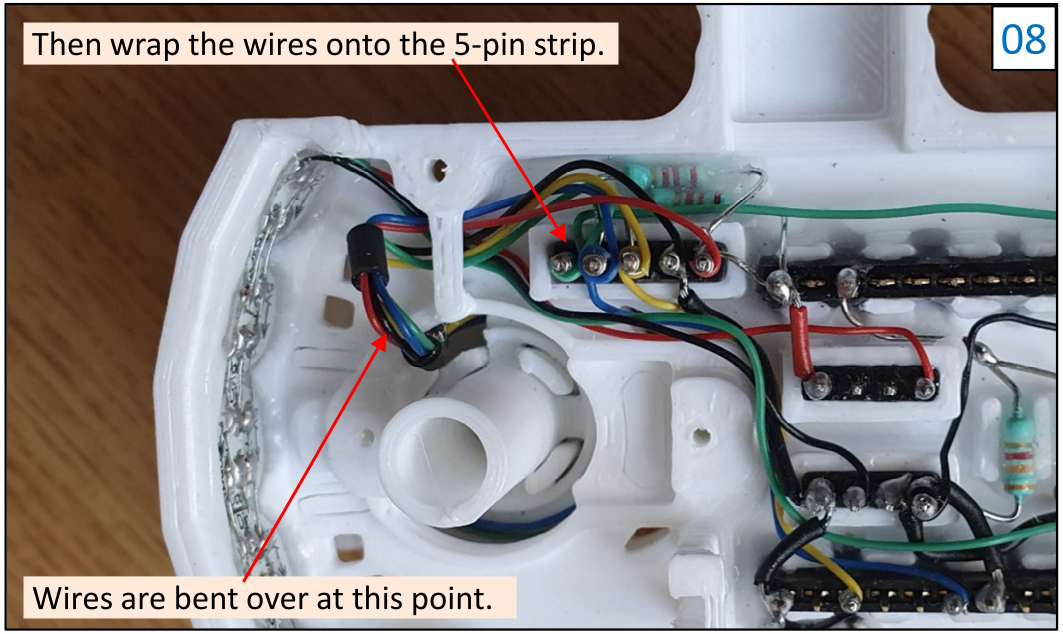
Note that the neck wiring tool is still attached. Allow the glue to set.

07 Use two small pieces of heat shrink sleeving to group the wires.



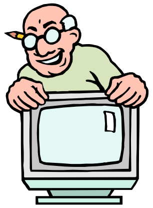
Form them into a bend, then feed through the moulded wire restraint.

08 Then wrap the wires onto the 5-pin strip.



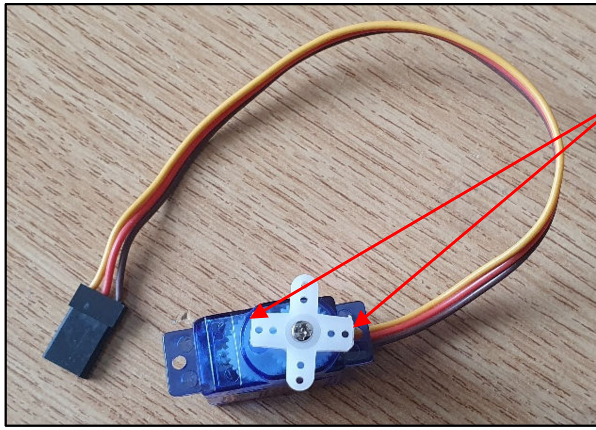
Wires are bent over at this point.

Head VL53L0X LTOF Wiring



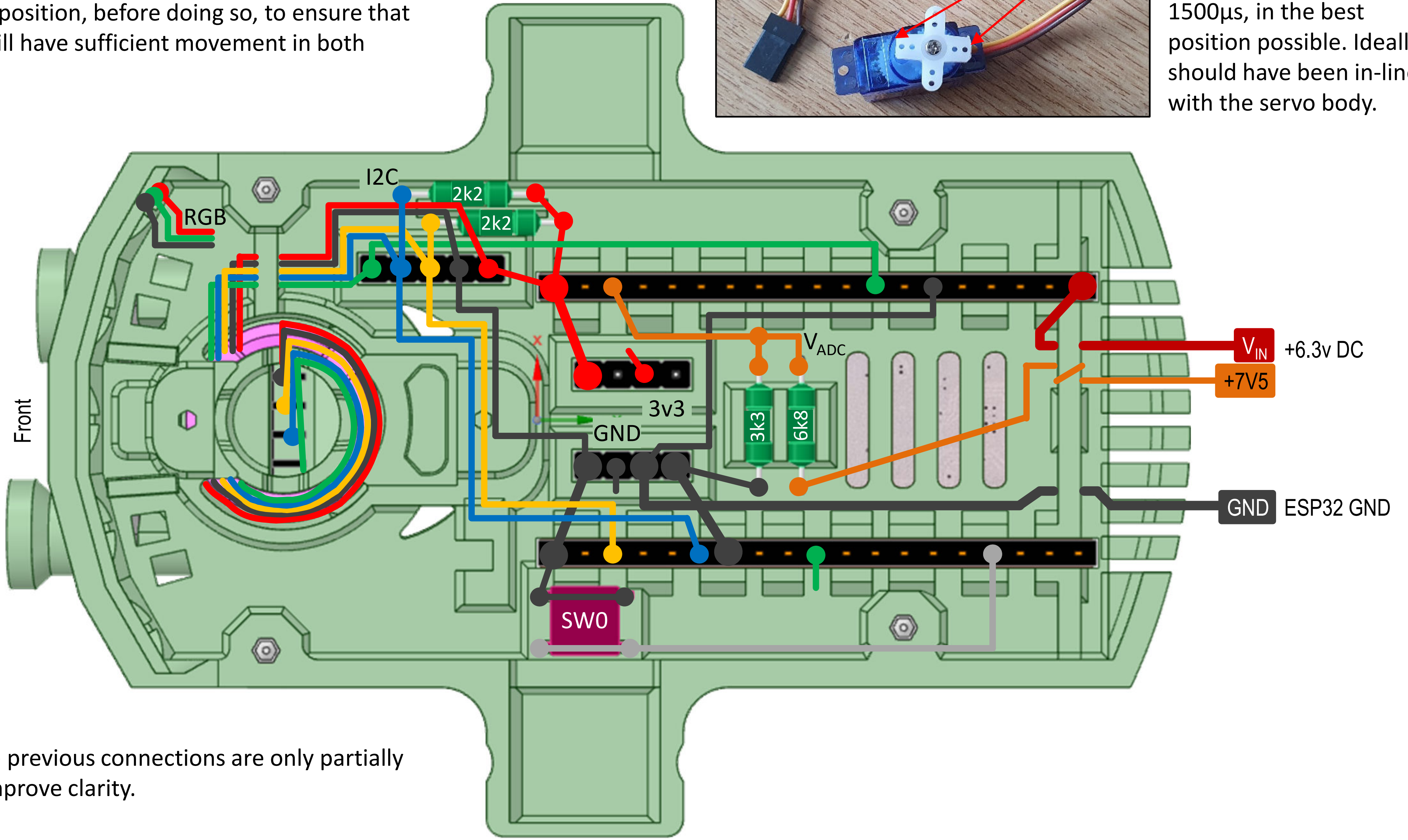
The 5 wires from the VL53L0X sensor are terminated on the 5-pin strip as shown.

Carefully fit the head servo, with its leaver arm set in the 1500µs position, before doing so, to ensure that the servo will have sufficient movement in both directions.



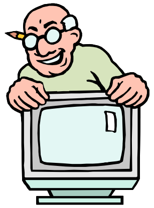
If the cross lever arm supplied with the servo has extended arms, these will need to be cropped off.

This arm was fitted at 1500µs, in the best position possible. Ideally it should have been in-line with the servo body.



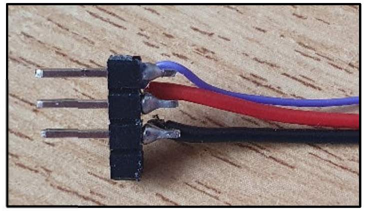
Some of the previous connections are only partially shown to improve clarity.

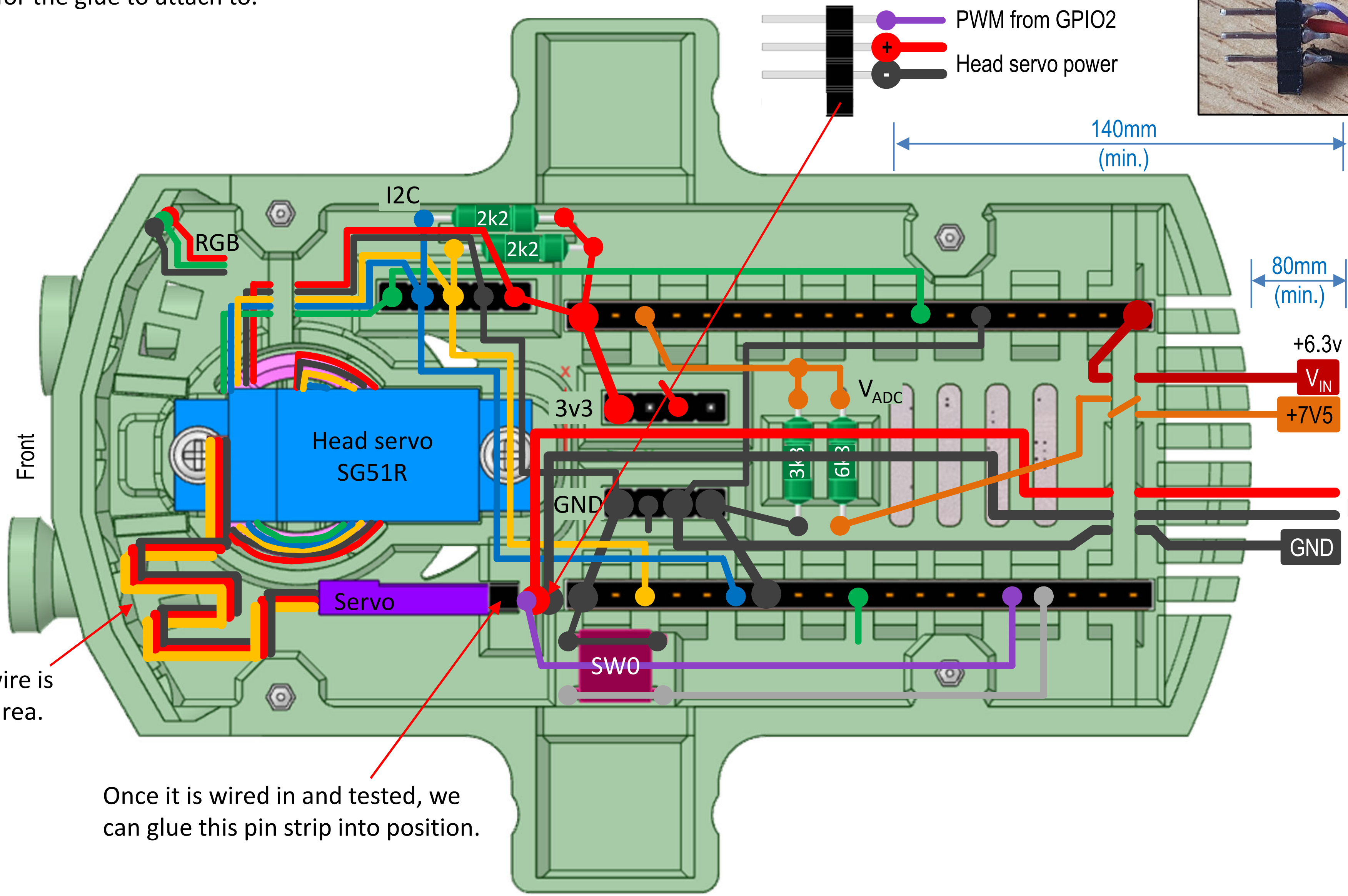
Head servo Wiring



We now attach wires to a 3-pin strip (actually 4-pin), to connect to the servo plug. The unused pin position helps to raise the pin strip off the Upper plate, and gives more for the glue to attach to.

A 4-pin strip, with one end pin removed, is pre-wired as shown, before gluing it into the Upper plate. Test for s/c. The head servo plugs onto these pins.



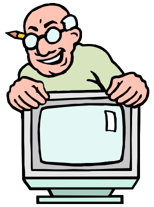


Excess servo wire is folded in this area.

Once it is wired in and tested, we can glue this pin strip into position.

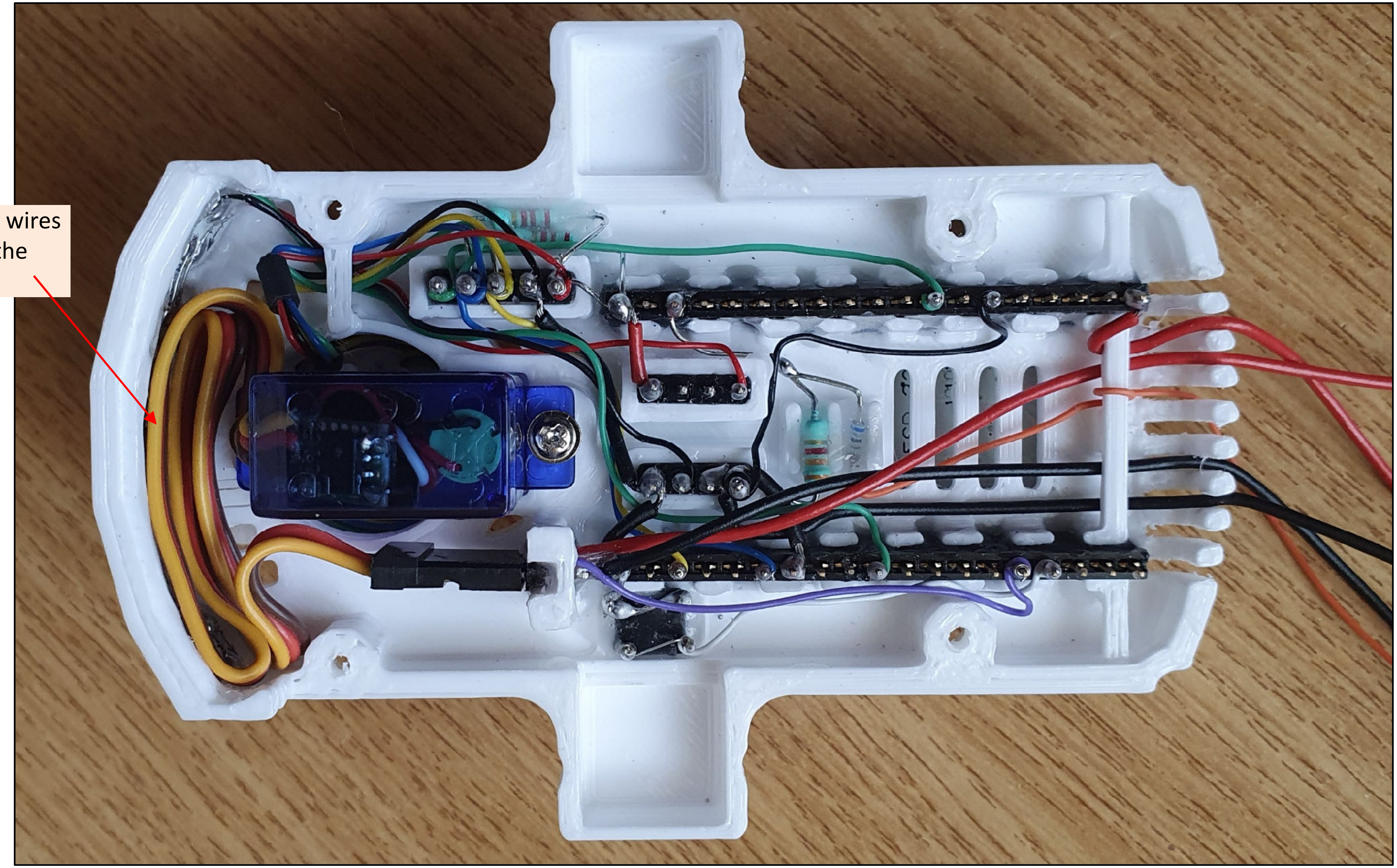
Upper Plate Servo Wiring

Your Upper plate connections should look like this.



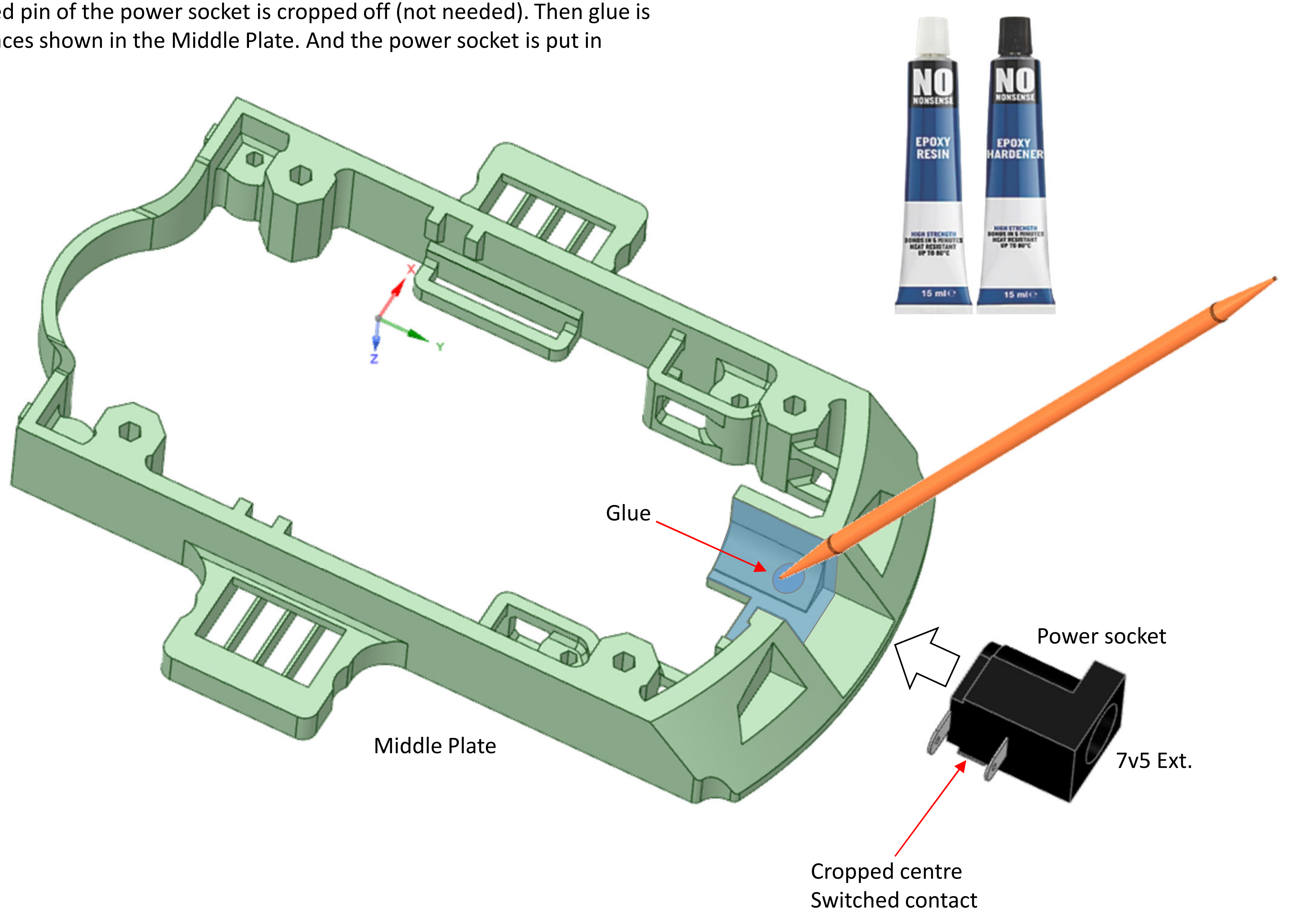
With the head servo motor fully installed. Note, that the power for this servo will come from the lower plate connections.

Tuck servo wires in behind the front face.



Middle Plate Components

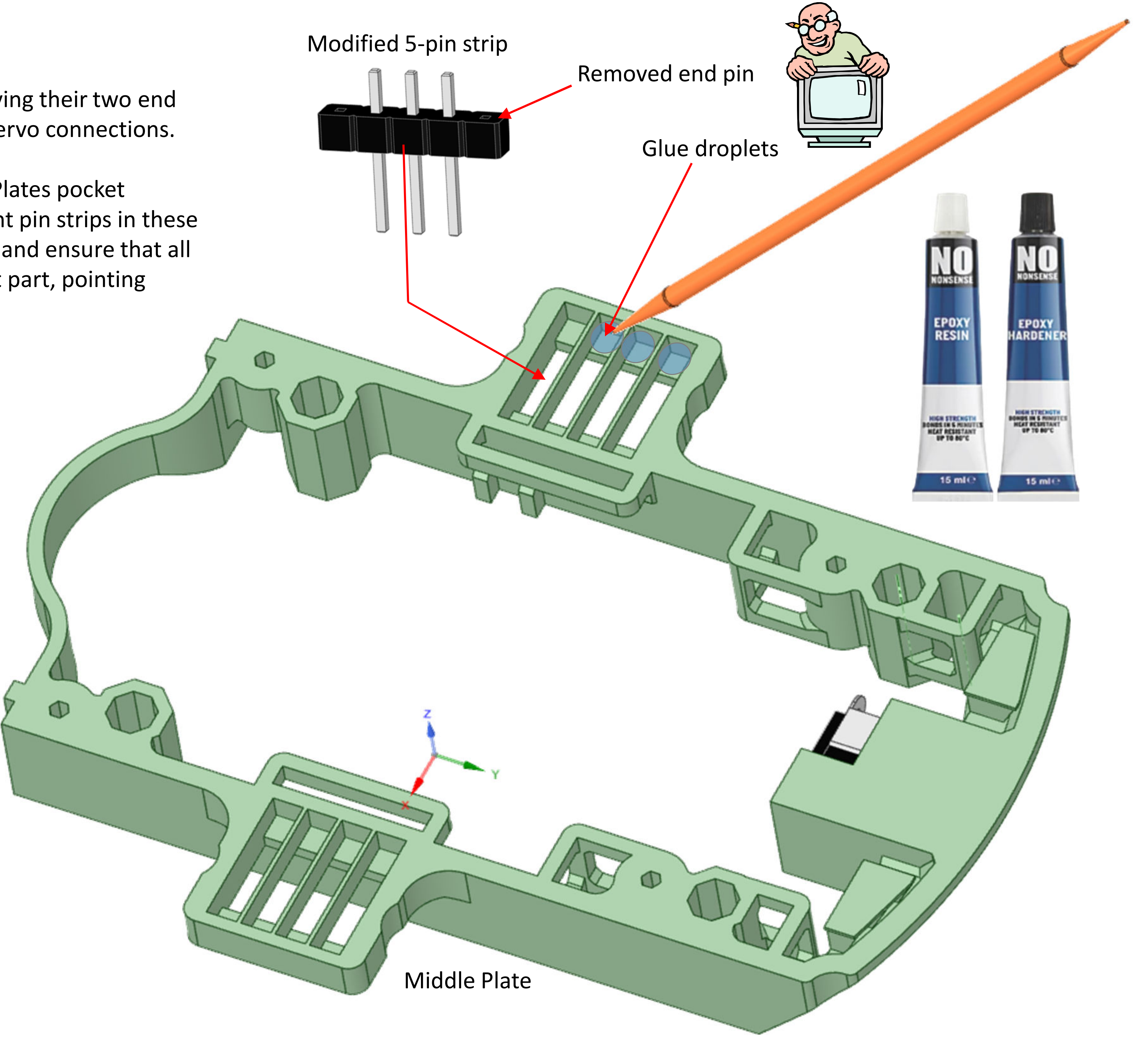
The centre, switched pin of the power socket is cropped off (not needed). Then glue is applied to the surfaces shown in the Middle Plate. And the power socket is put in position.



Middle Plate Components

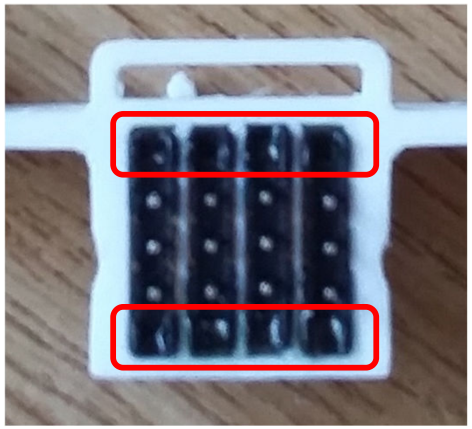
Eight, 5-pin strips are modified, by removing their two end pints, to make eight 3-pin strips for the servo connections.

Put small droplets of glue in the Middle Plates pocket recesses (16 in total). Then place the eight pin strips in these locations. Avoid getting glue on the pins, and ensure that all of the pins are vertical, with their longest part, pointing downwards.



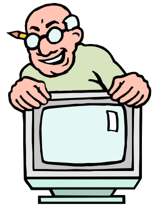
Then smear a small quantity of glue across the ends of the row of pin strips, to strengthen the bond. Again, avoid getting glue on the metal contacts.

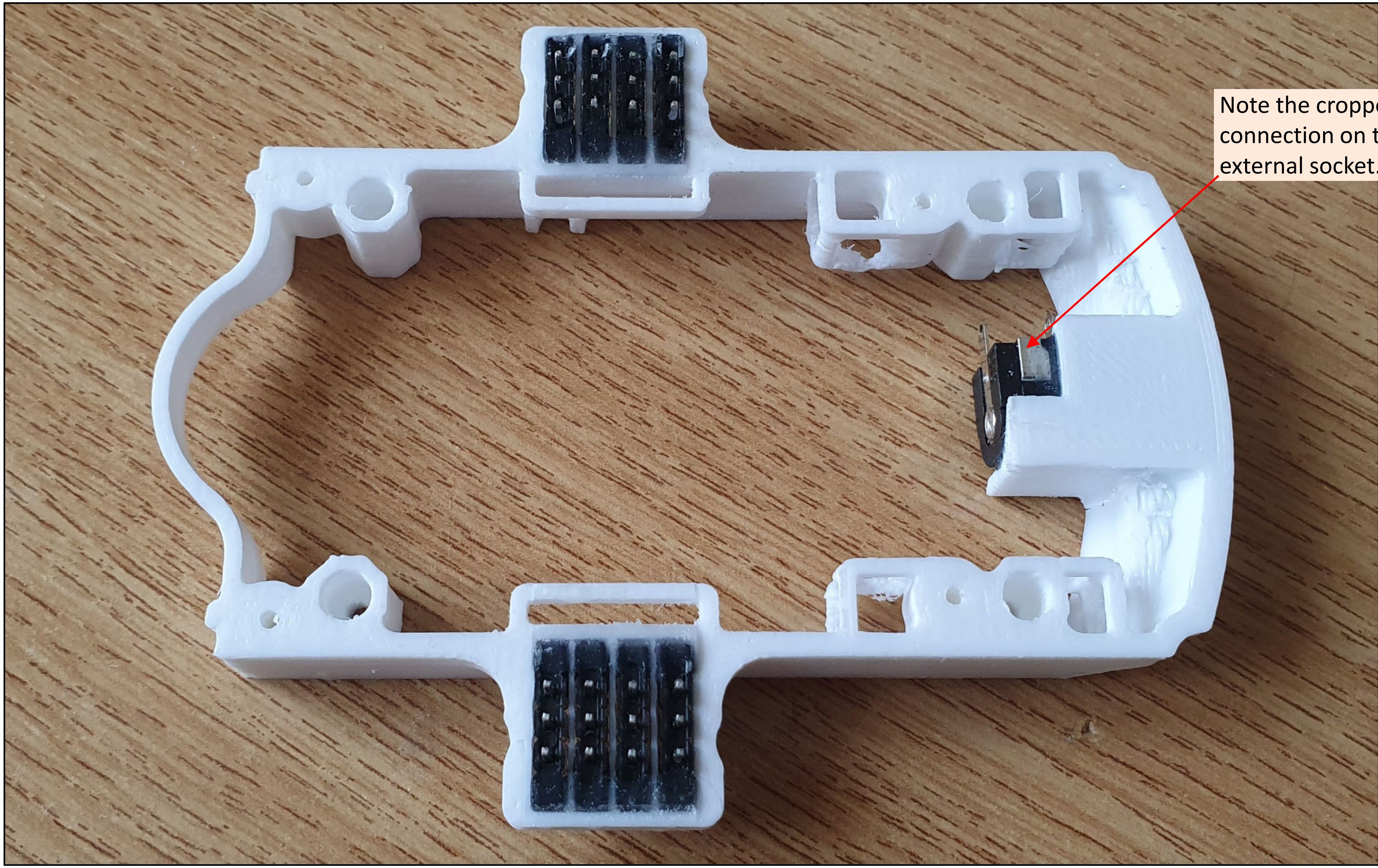
Once the glue has hardened, you can remove any excess, with a needle file.



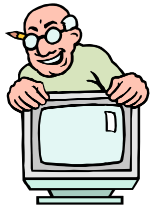
Middle Plate Components

Your Middle plate should then look like this.



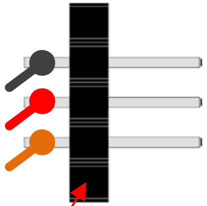


Middle Plate Wiring



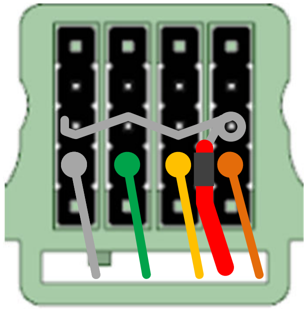
The servo Vcc and GND wire loops work like a ring main, acting to improve current distribution in the servo power wiring.

Servo 5-pin strips have their end pins removed, making them 3-pin, with the modified end pieces being used as glued supports. Ensure that the glue has set before wiring.

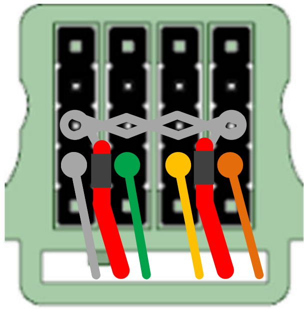


Start by wire wrapping the PWM pins, ensuring that there is sufficient length to reach the ESP32 pins on the upper plate, when folded back. Solder those connections, then solder in the power wires. Use wire lengths of at least 220mm.

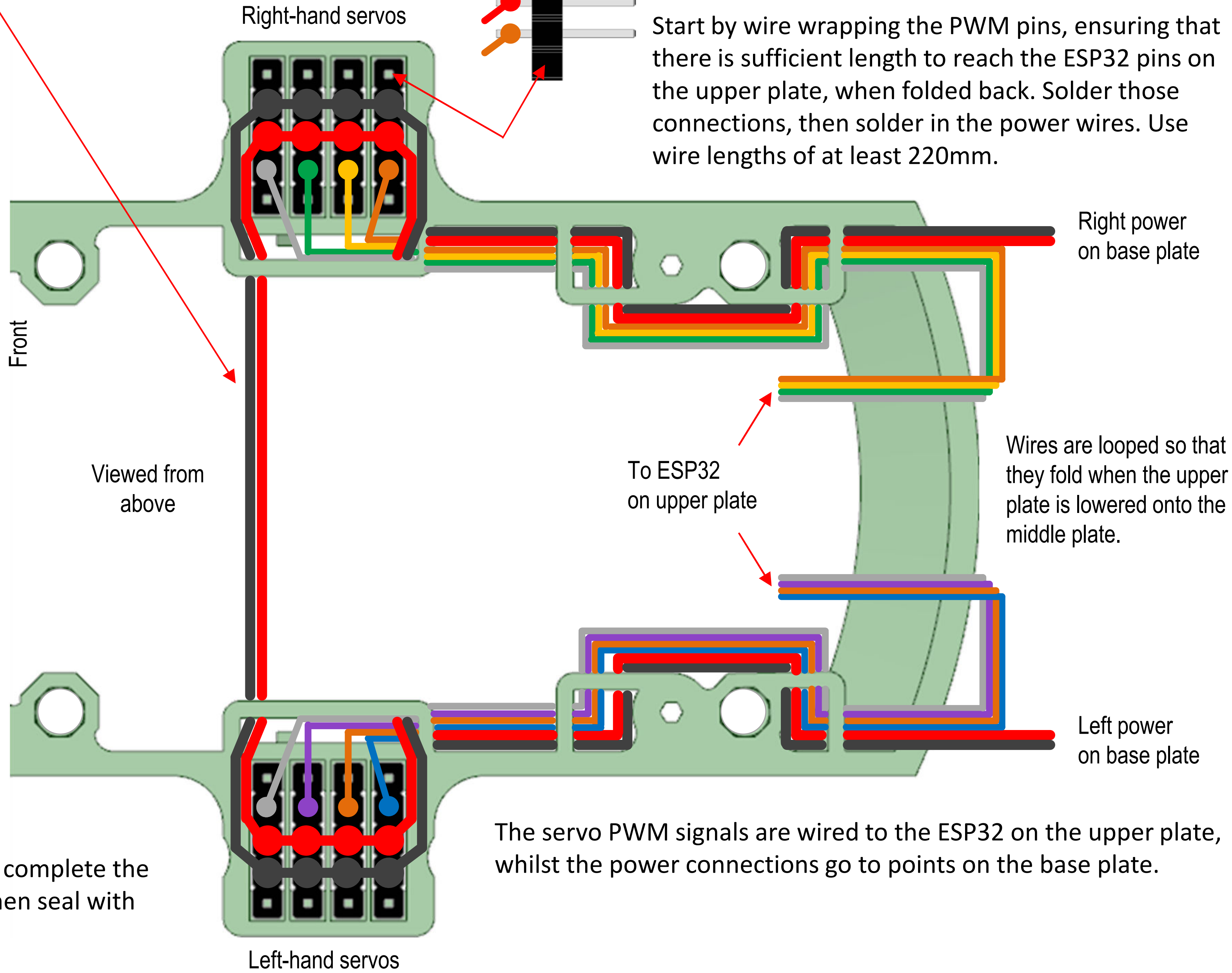
Having soldered the wire wrapped connections, connect the power leads. Shrink sleaving is used to prevent the wire from melting back.



Use the first wire to link all 4 pins, then make the second connection at the other end. Take care soldering, and check for shorts at each stage.



Repeat this process for the GND wire to complete the task. Check for s/c with a multimeter. Then seal with glue

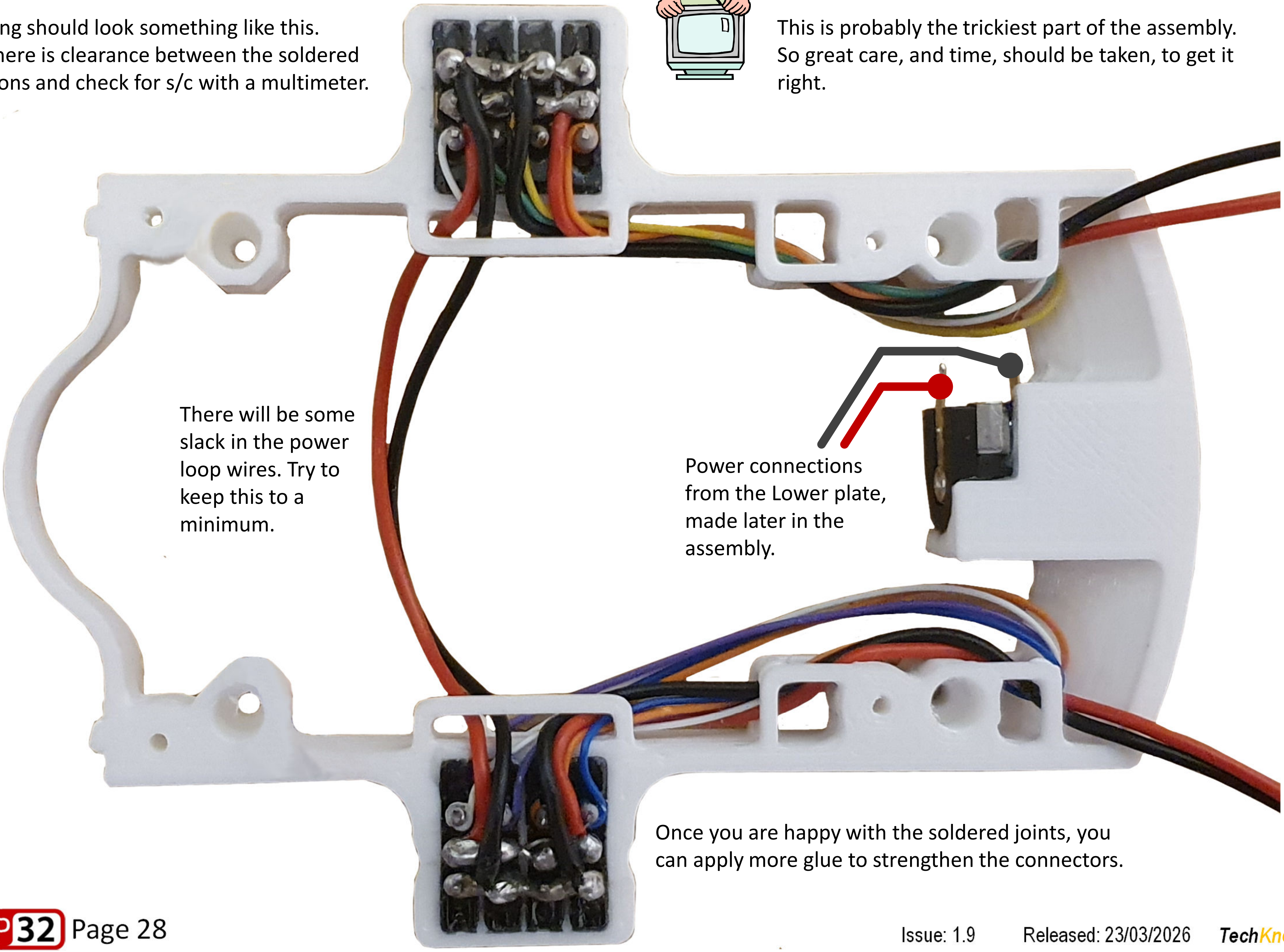


The servo PWM signals are wired to the ESP32 on the upper plate, whilst the power connections go to points on the base plate.

Middle Plate Wiring

Your wiring should look something like this. Ensure there is clearance between the soldered connections and check for s/c with a multimeter.

This is probably the trickiest part of the assembly. So great care, and time, should be taken, to get it right.

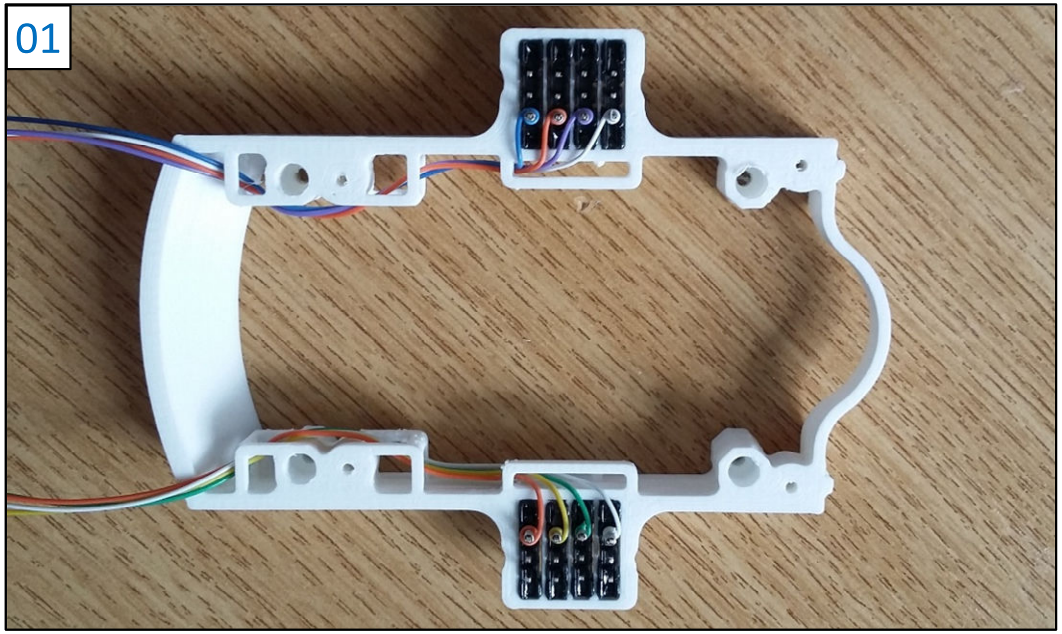


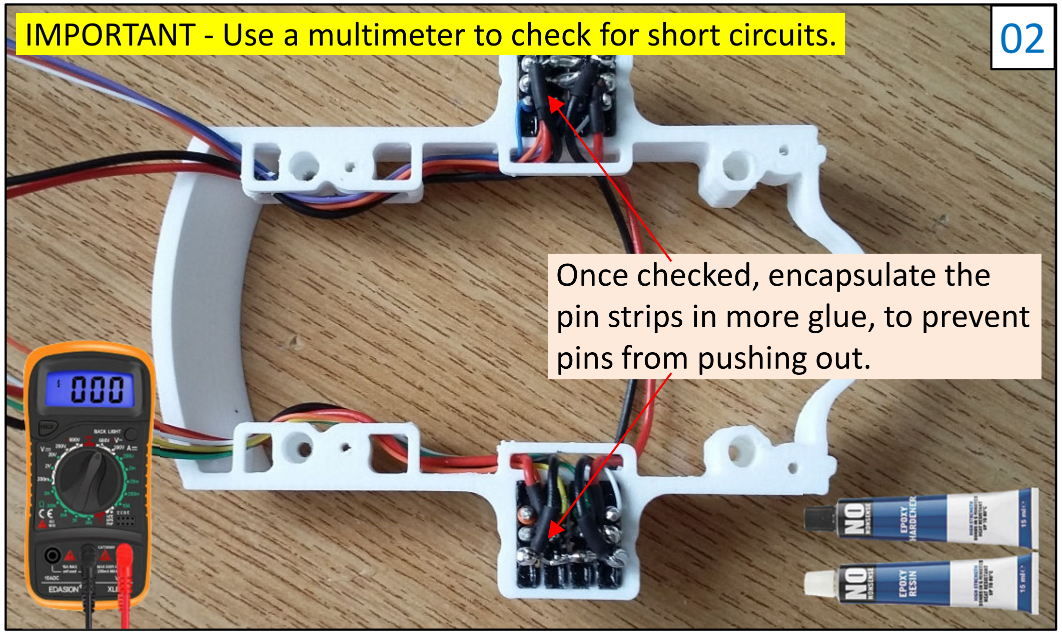
There will be some slack in the power loop wires. Try to keep this to a minimum.

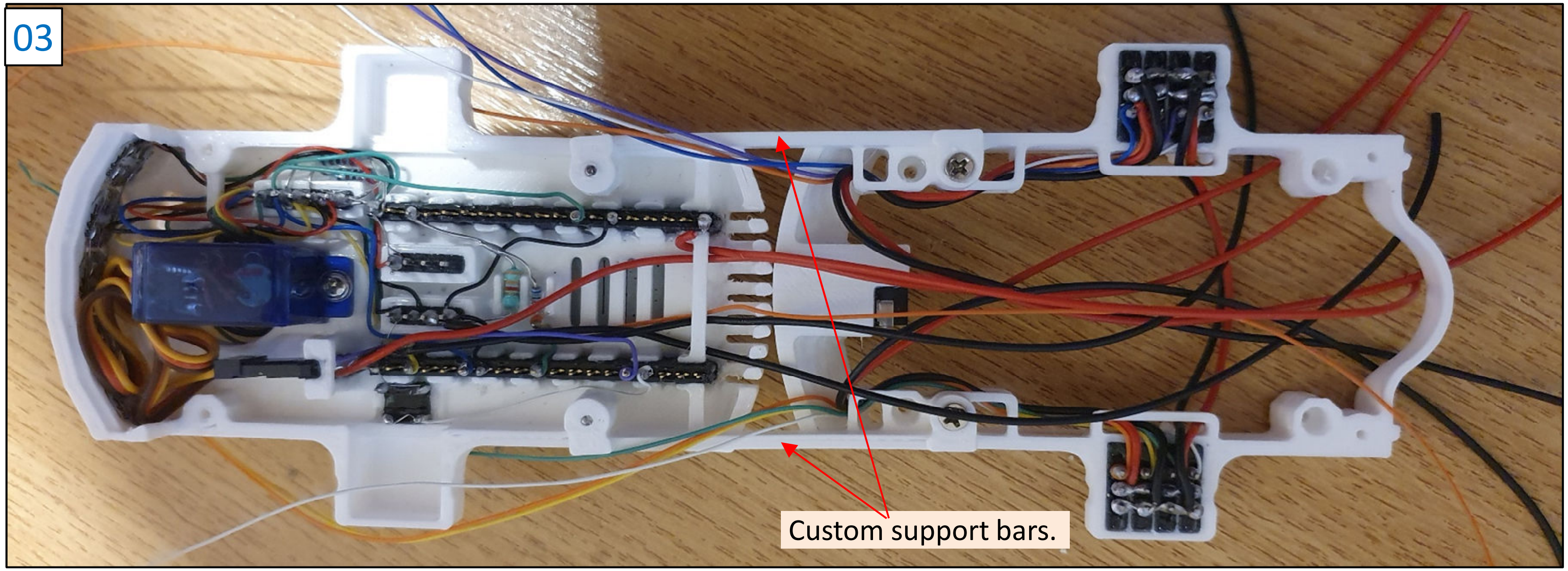
Power connections from the Lower plate, made later in the assembly.

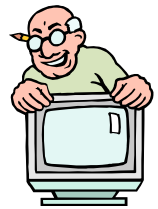
Once you are happy with the soldered joints, you can apply more glue to strengthen the connectors.

Wiring Sequence





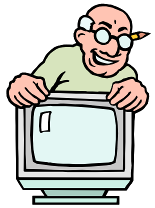


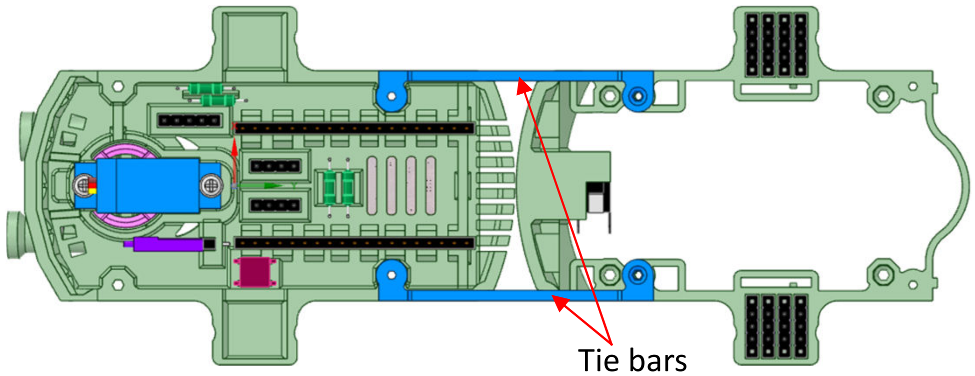


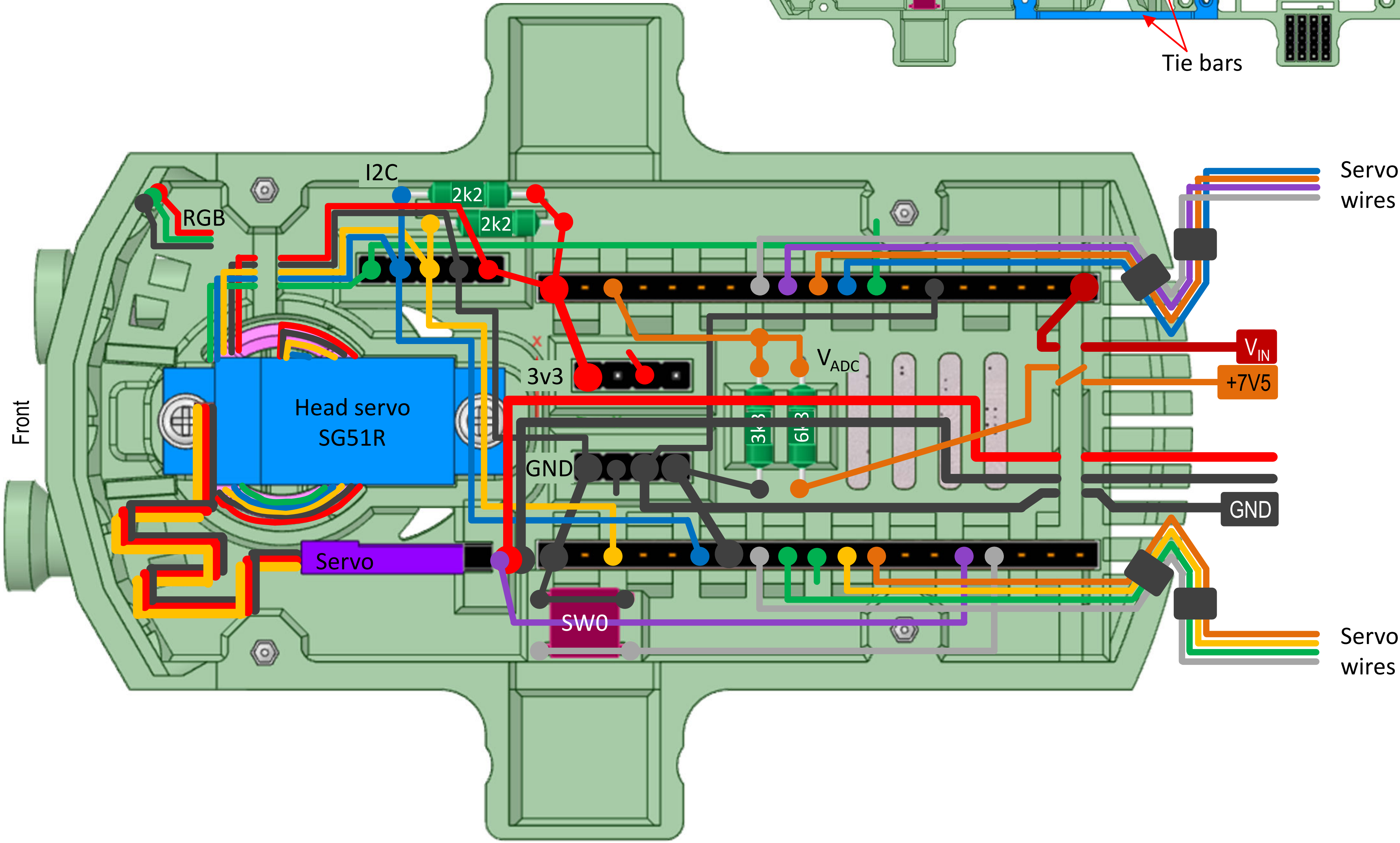
You can now use the custom support bars to connect the Middle plate to the Upper plate. This will make the wiring of the 8 servo connections to the micro much simpler to do.

Leg servo Wiring

With the Middle Plate connected to the Upper Plate, using the two custom tie bars, you can then terminate the wires coming from the leg servo pins, as shown here.







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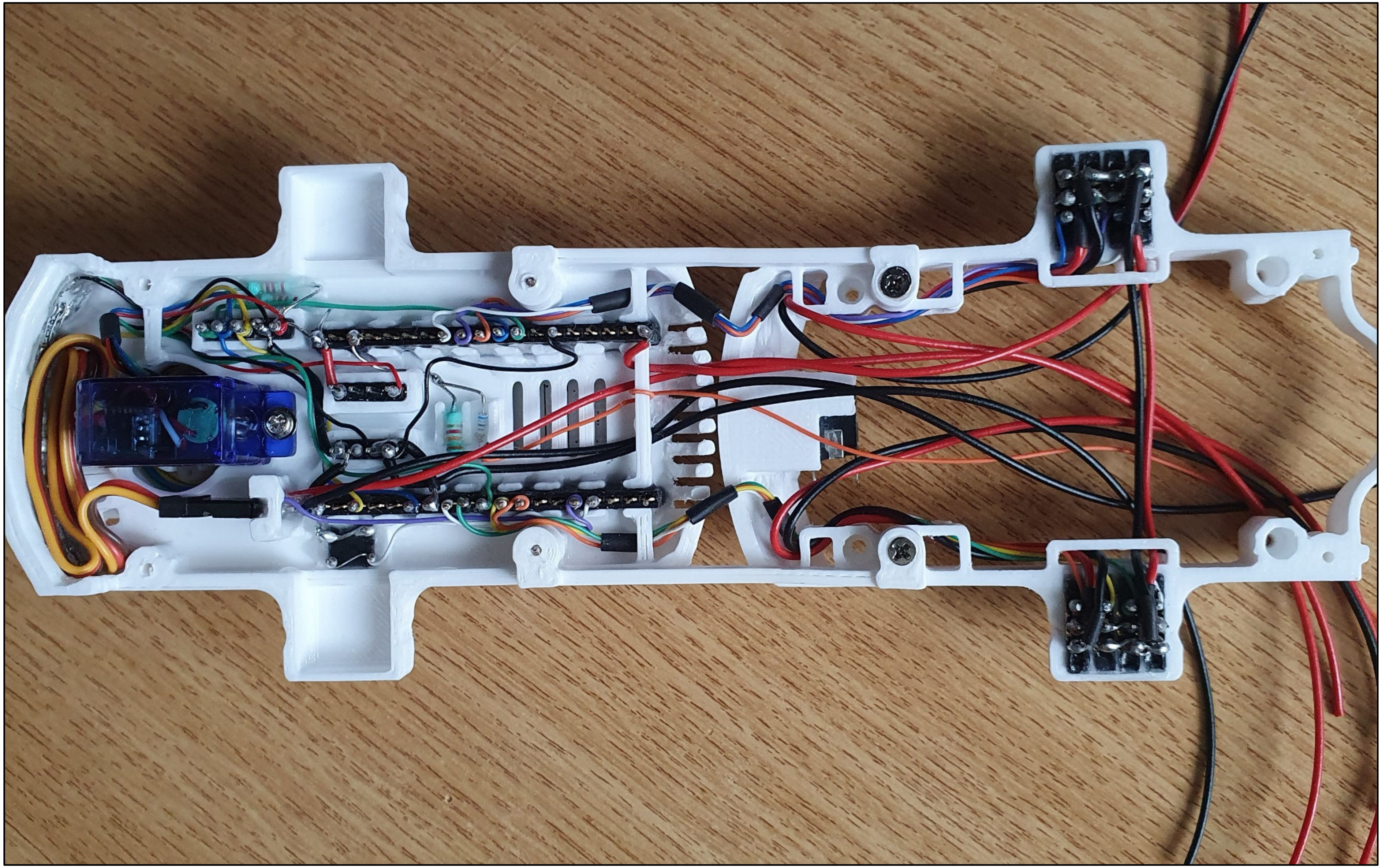
Leg Servo Wiring Completed



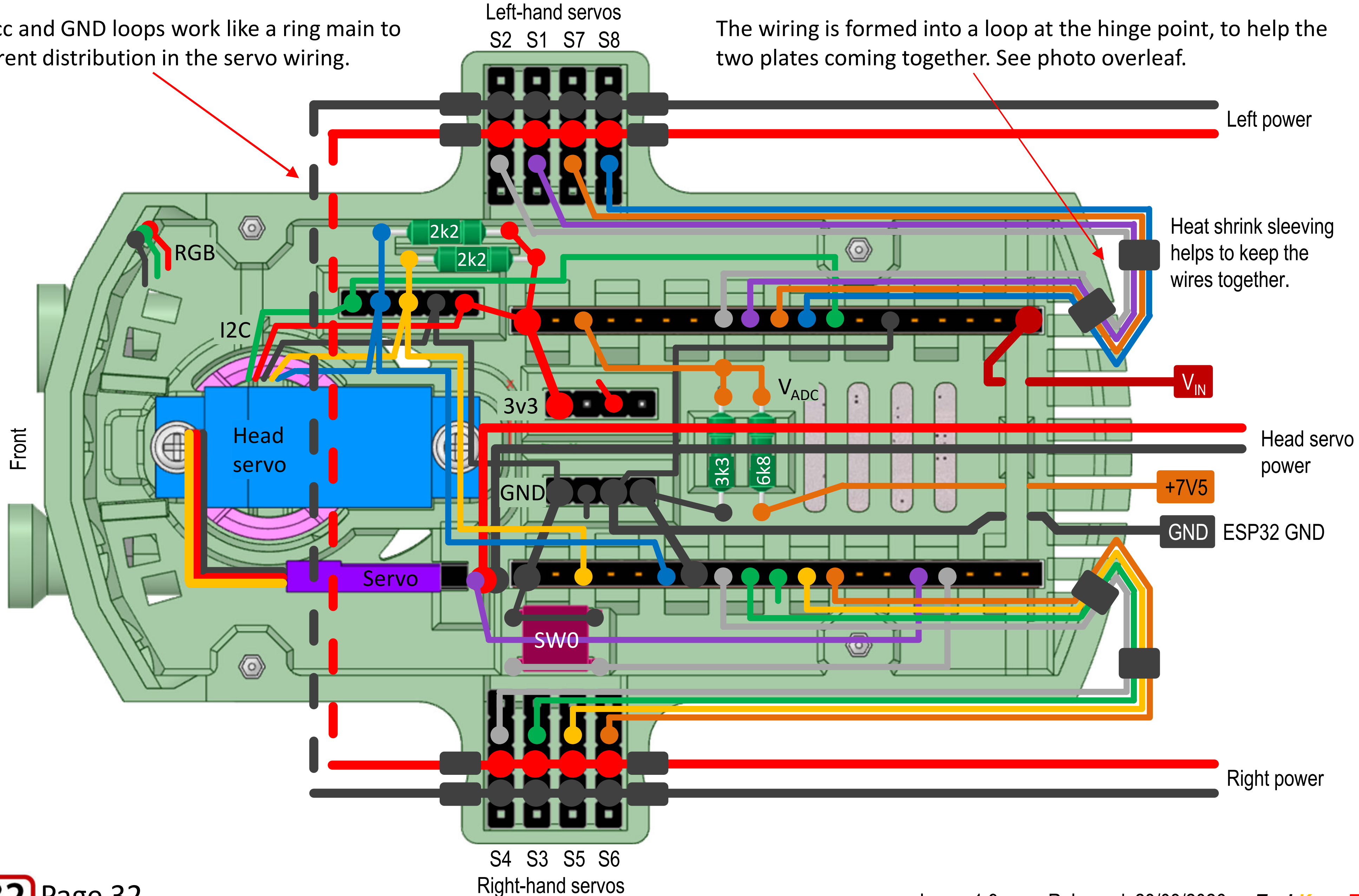
Upper/Middle Plate Wiring

Middle plate is not shown here, but is used to mount the pin strips for the servo plugs, which are shown.

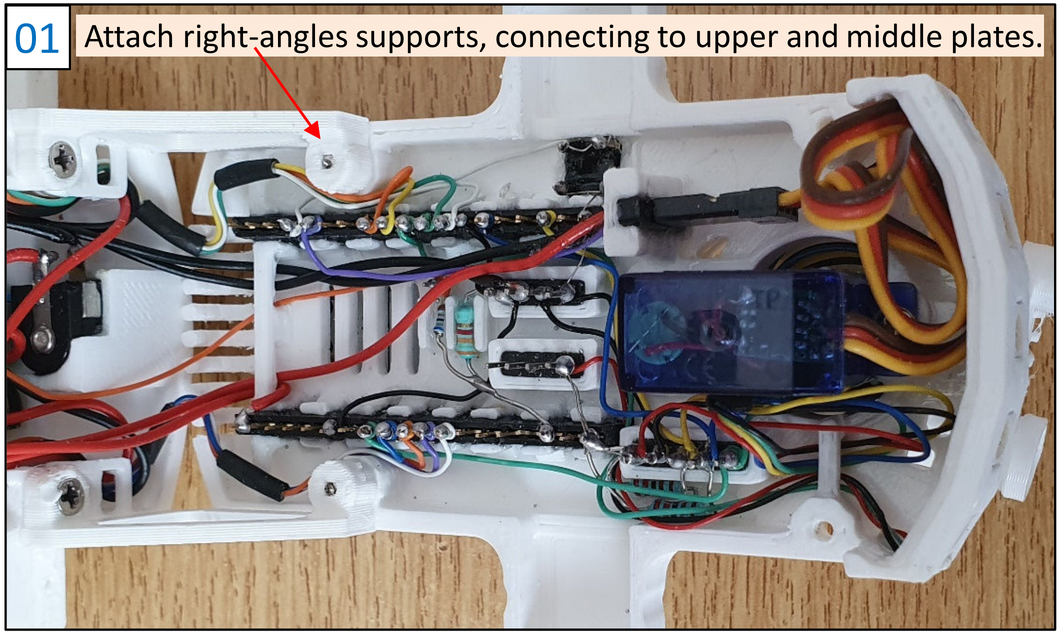
The servo Vcc and GND loops work like a ring main to improve current distribution in the servo wiring.

Use the custom brackets, that are designed to tie the Upper plate to the Middle plate whilst wiring.

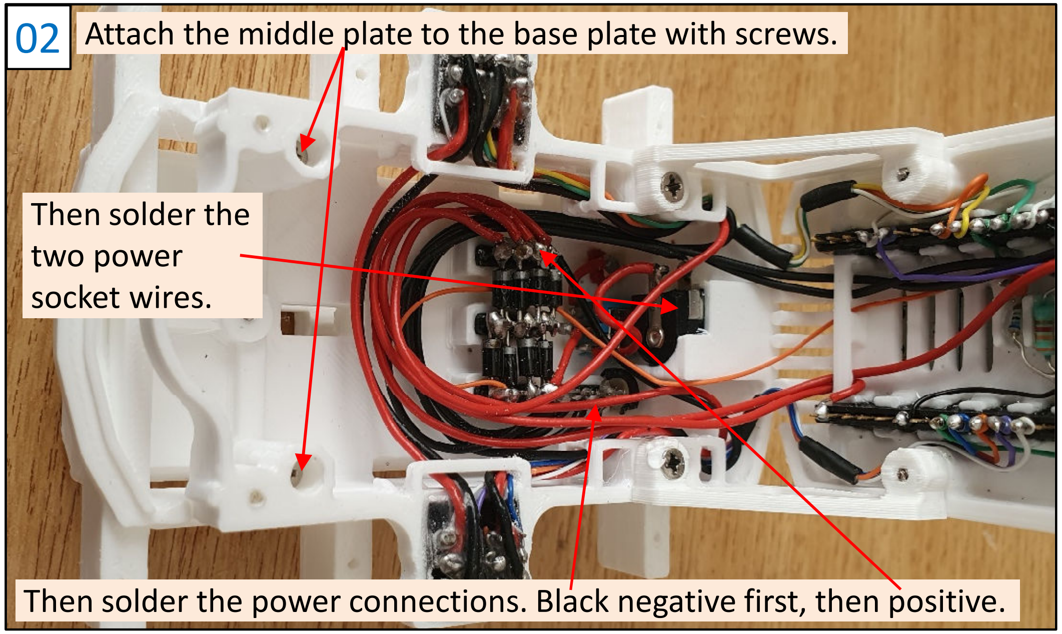
The wiring is formed into a loop at the hinge point, to help the two plates coming together. See photo overleaf.



Wiring Sequence



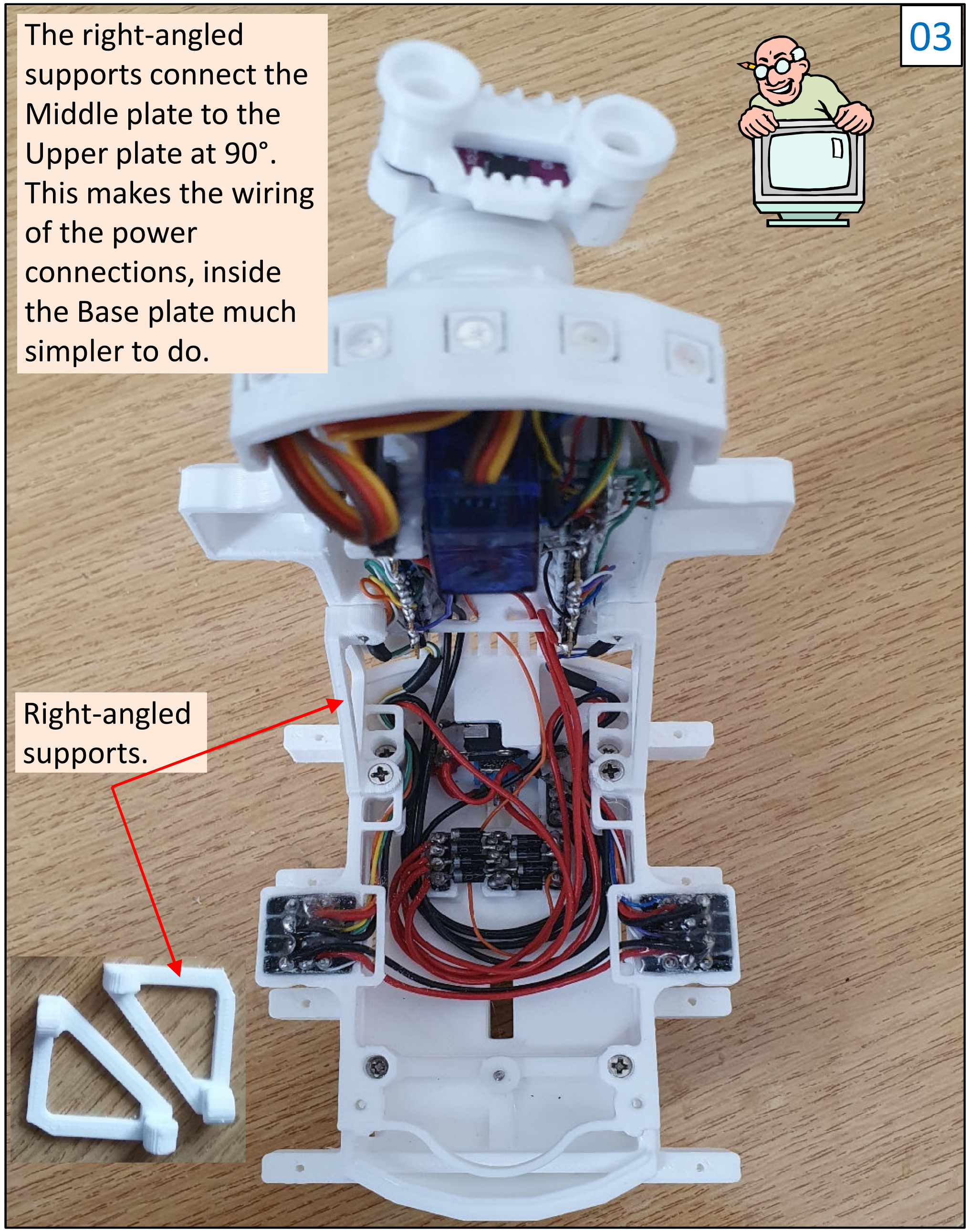
01 Attach right-angles supports, connecting to upper and middle plates.



02 Attach the middle plate to the base plate with screws.

Then solder the two power socket wires.

Then solder the power connections. Black negative first, then positive.

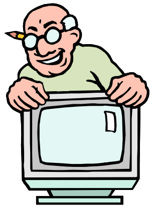


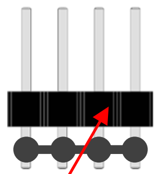
03 The right-angled supports connect the Middle plate to the Upper plate at 90°. This makes the wiring of the power connections, inside the Base plate much simpler to do.

Right-angled supports.

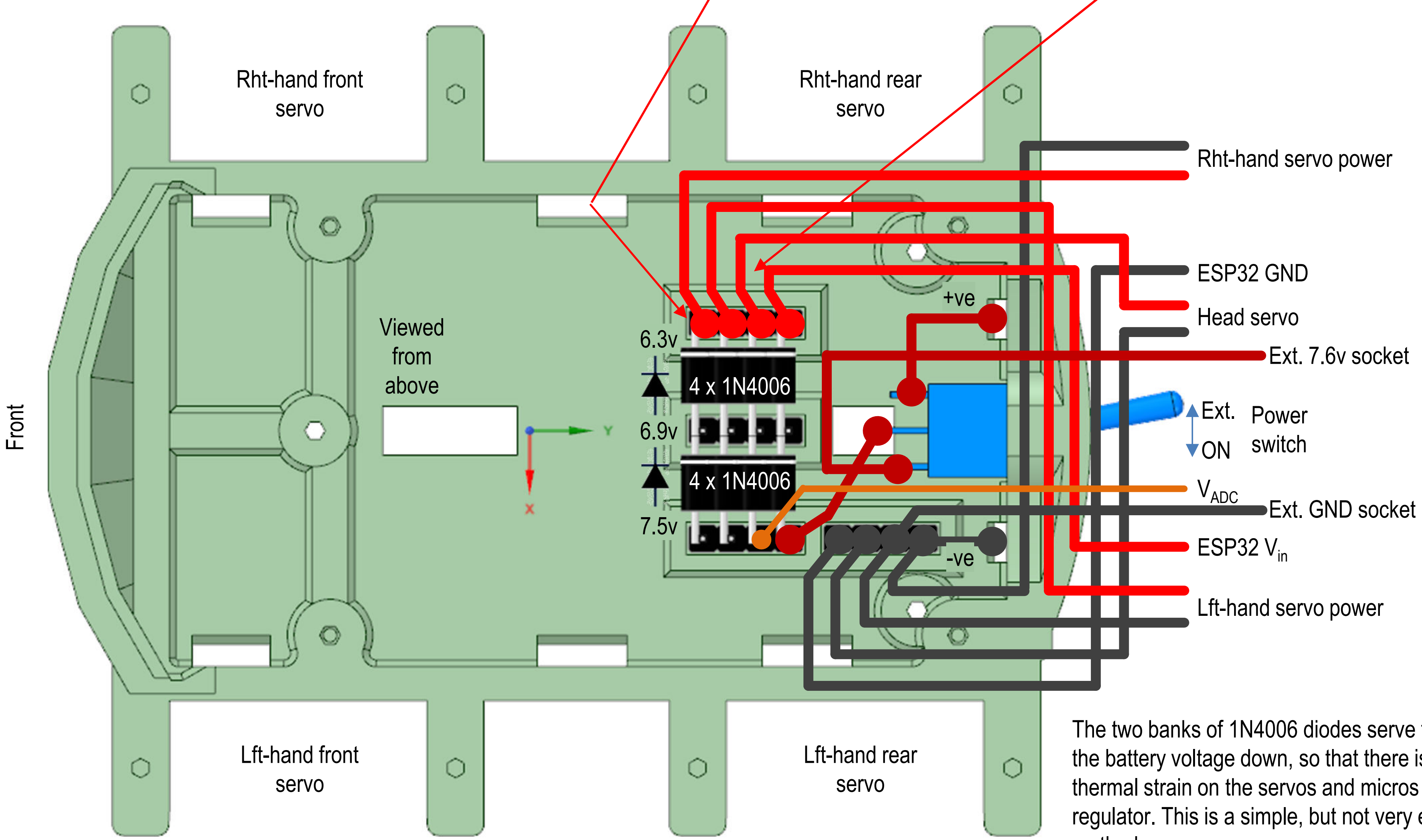
Base Plate Wiring

The Base plate connects to the battery case and distributes power connections to both the Middle (servo) and Upper (micro) plates.





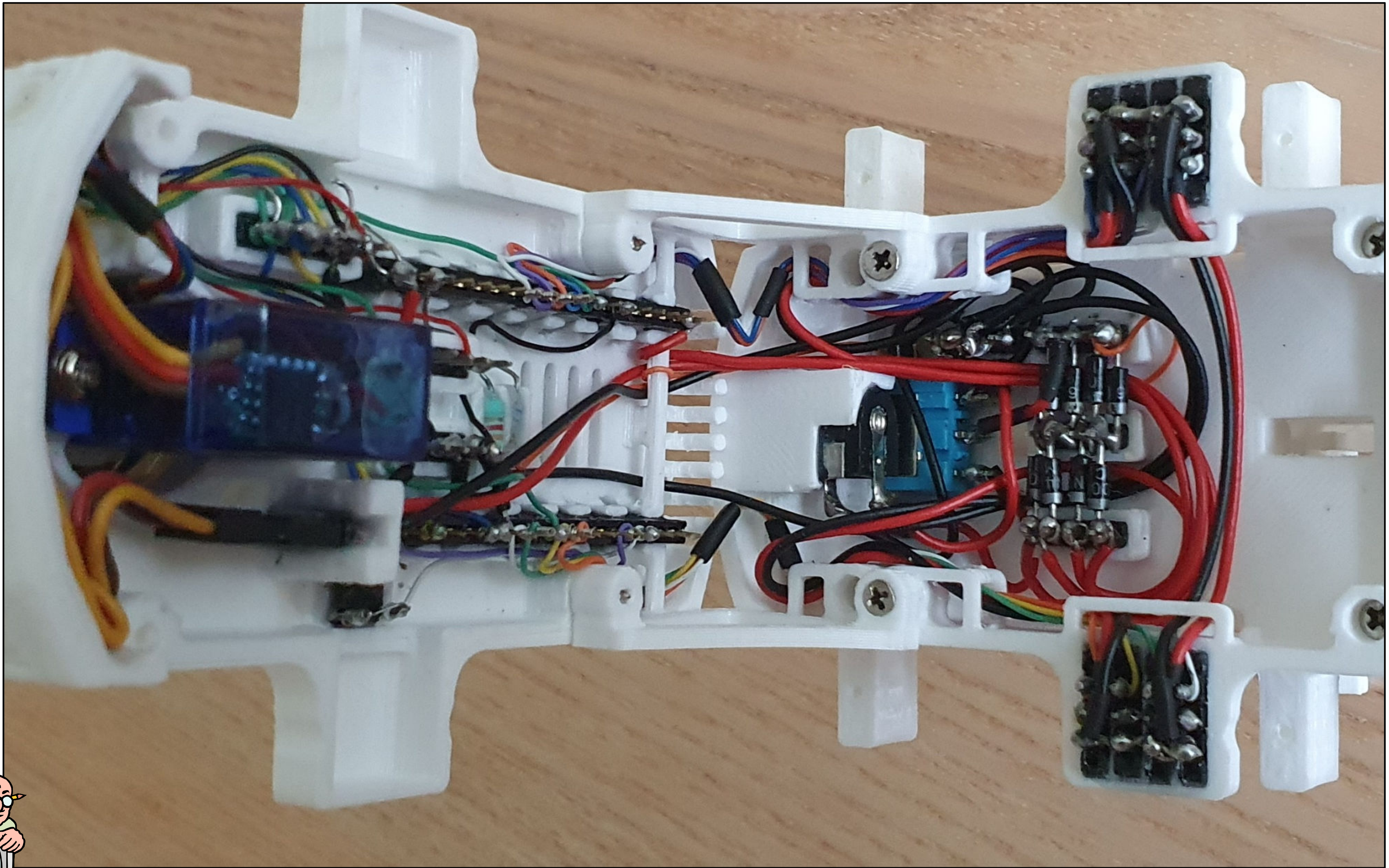
4 x 4-pin strips
Pins wired together, then glued into Base plate

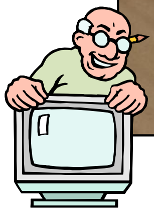


The two banks of 1N4006 diodes serve to drop the battery voltage down, so that there is less thermal strain on the servos and micros 3v3 regulator. This is a simple, but not very efficient method.

This is how the power connections to the Base plate will be completed.

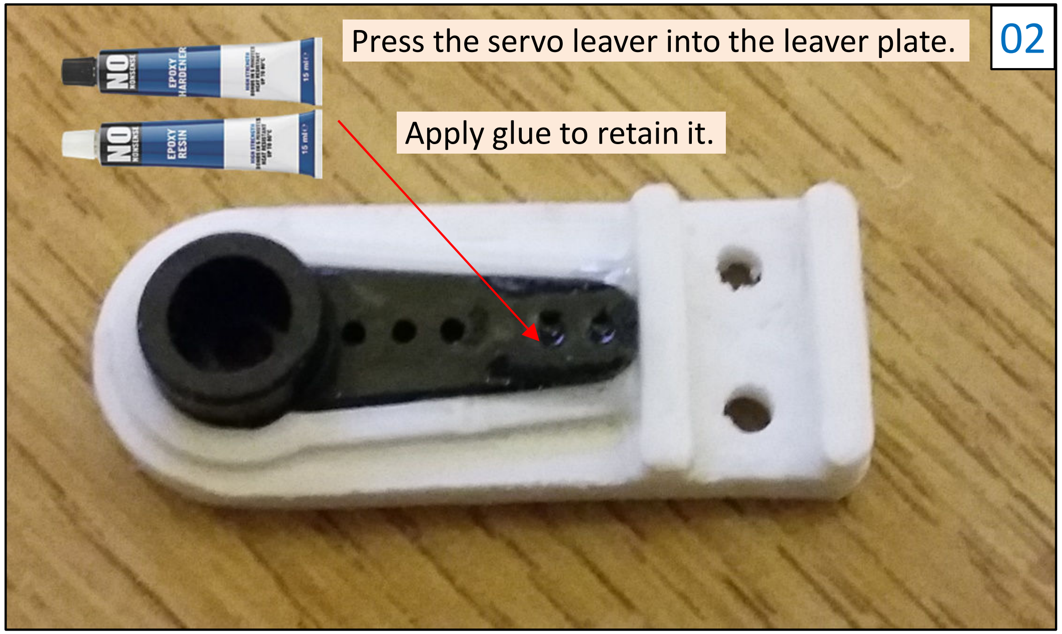
Internal Wiring Completed

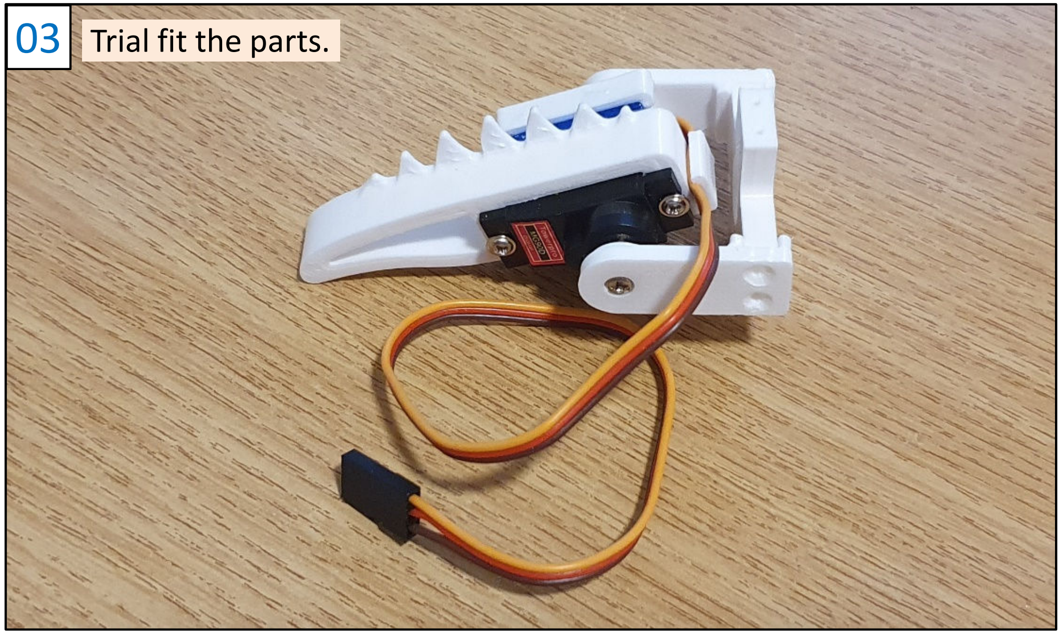


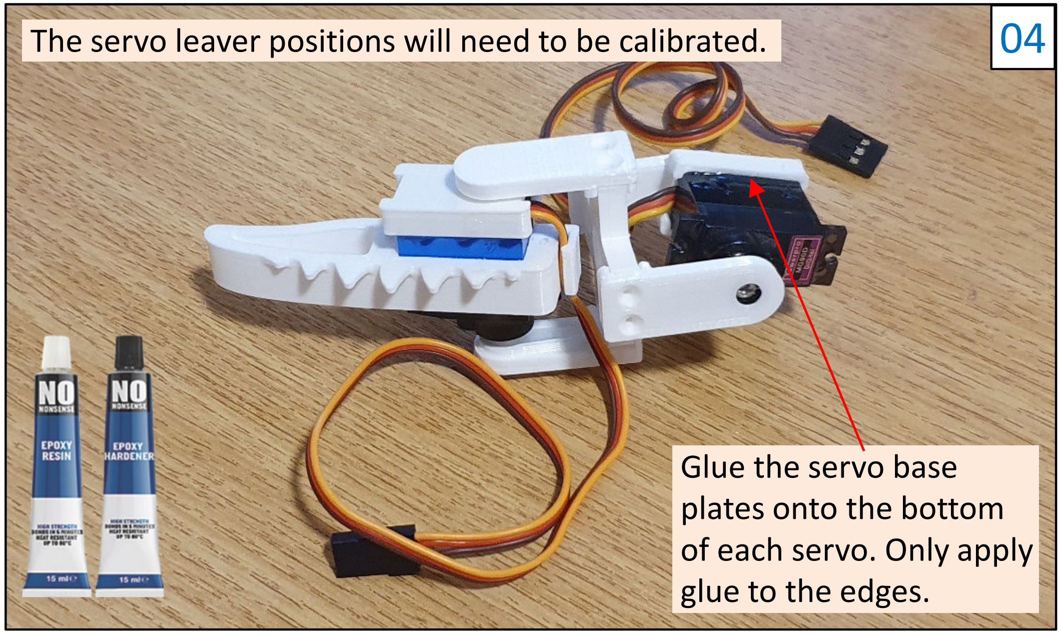


You can now apply power, preferably using a 7.5v mains adapter, to check that all of the functions are working.
Then refer to the Calibration document during the process of attaching the leg servos, and setting them up.

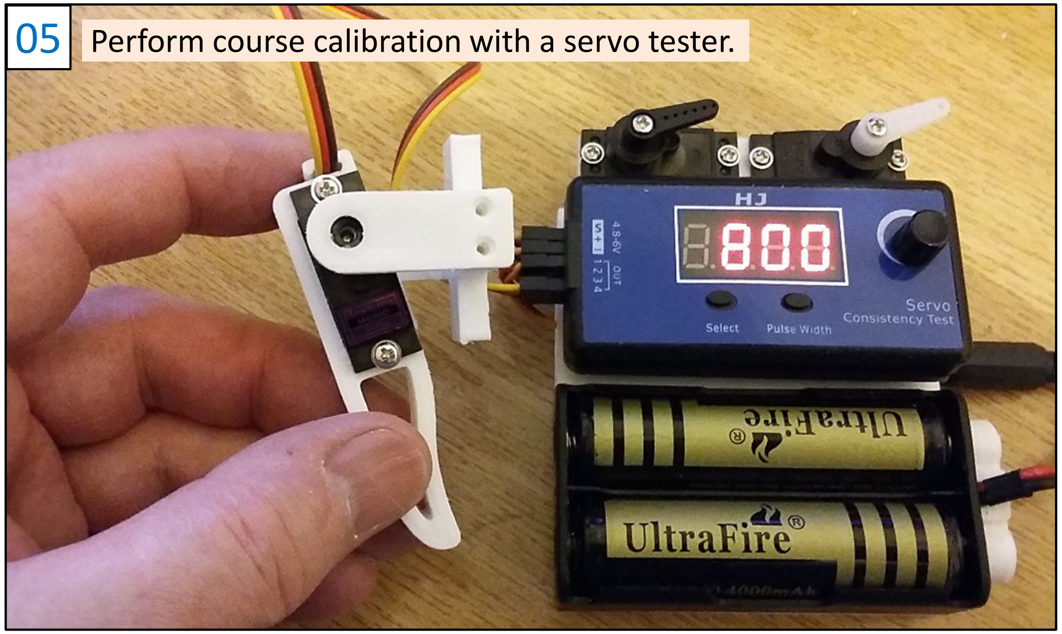
Build Sequence Photos – note some images are from a previous build. Use the latest 3-D models.



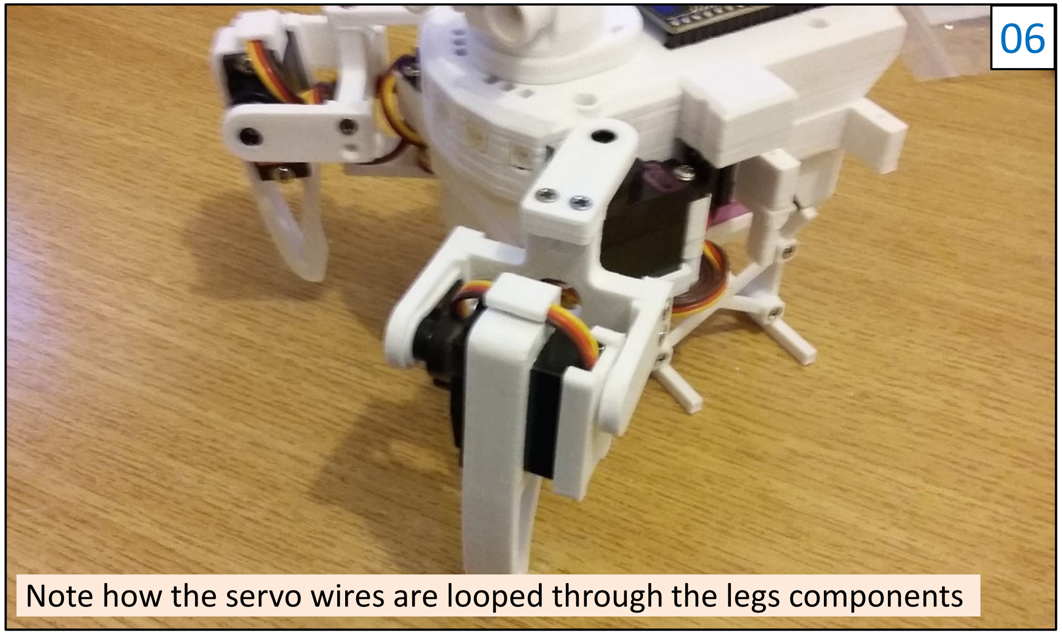




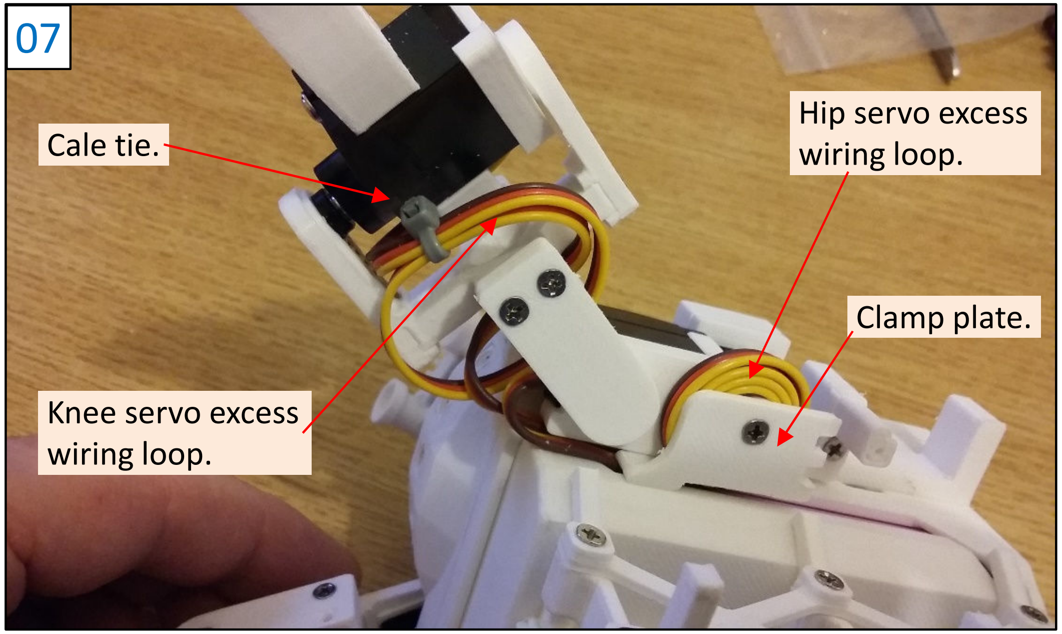
Build Sequence Photos – these images are from a previous build. Use the latest 3-D models.



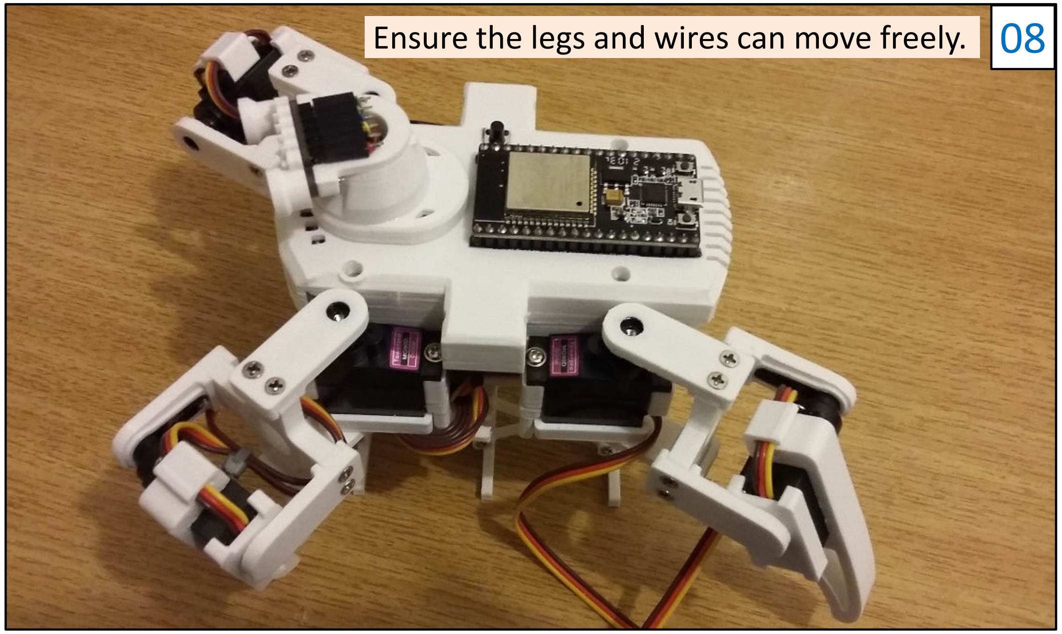
05 Perform course calibration with a servo tester.



06 Note how the servo wires are looped through the legs components

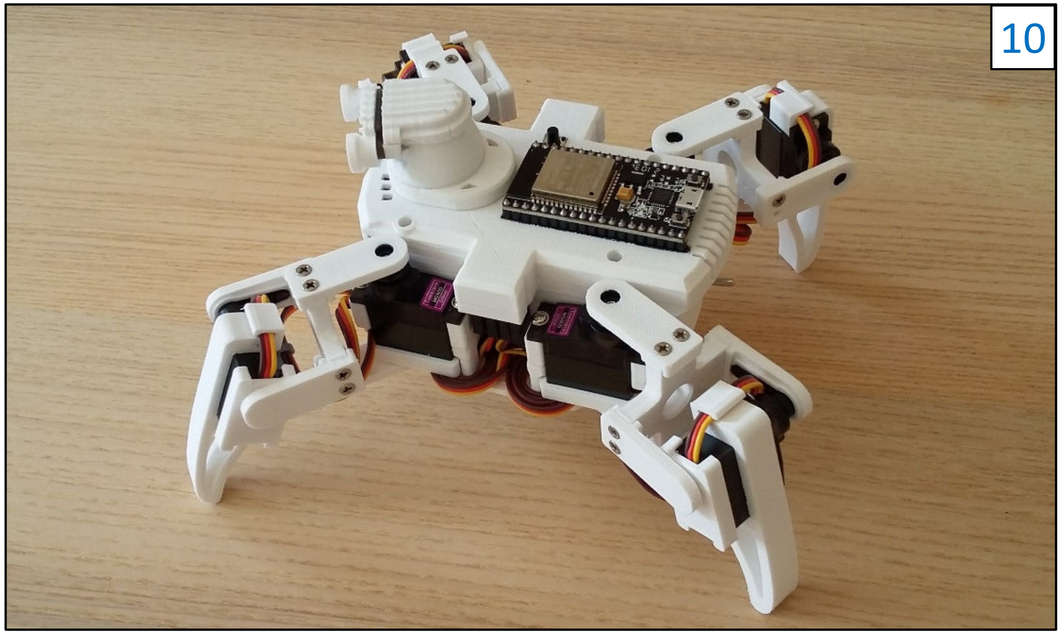


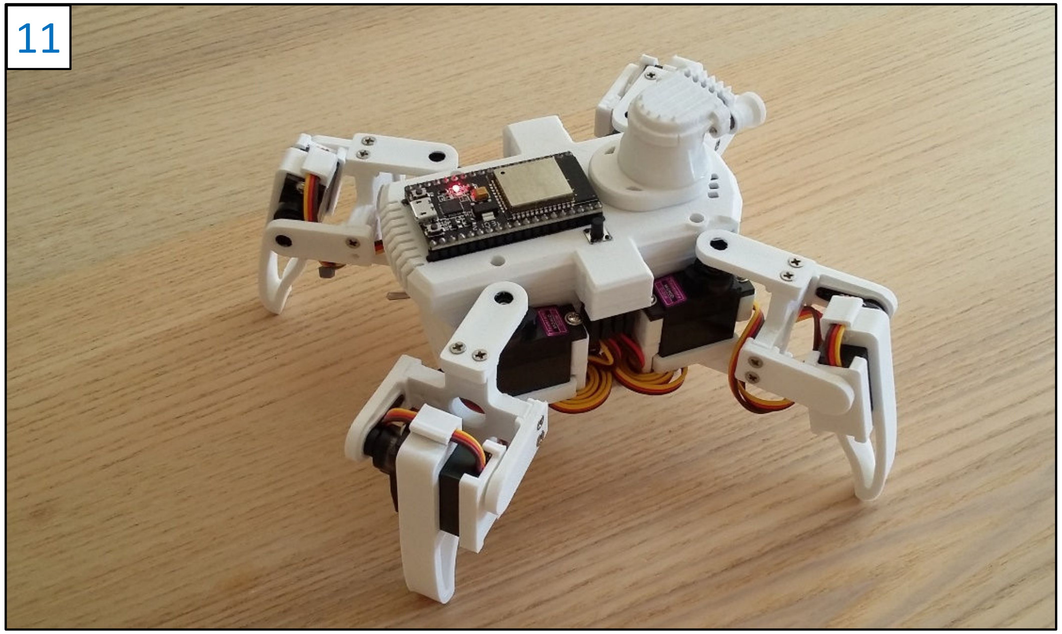
07

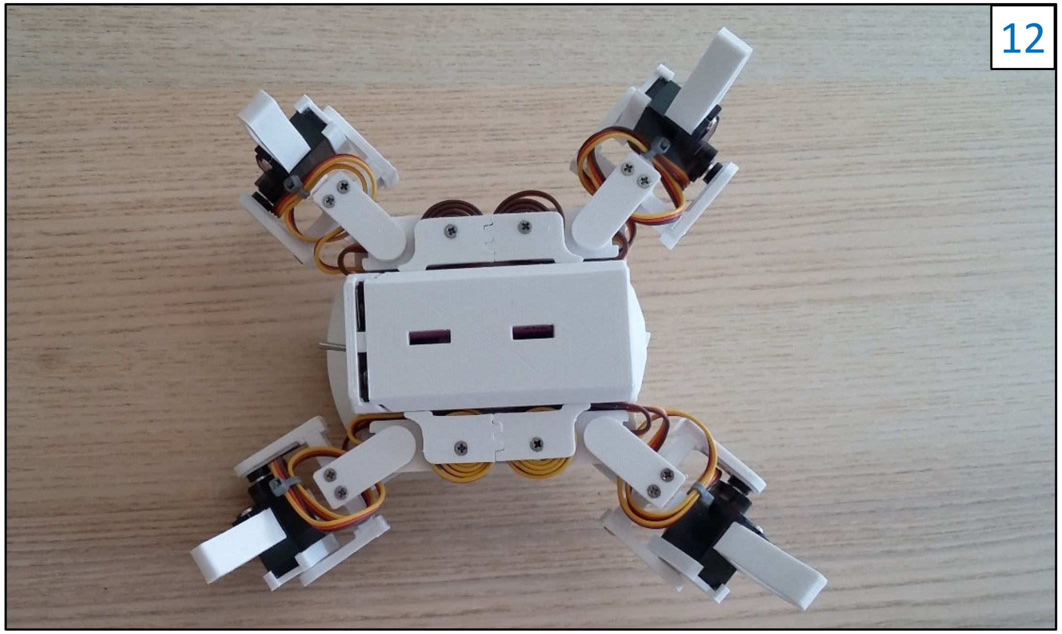


08 Ensure the legs and wires can move freely.

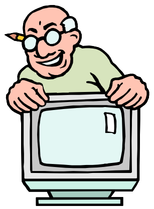
Build Sequence Photos Note: these photos do not show the latest leg joints.







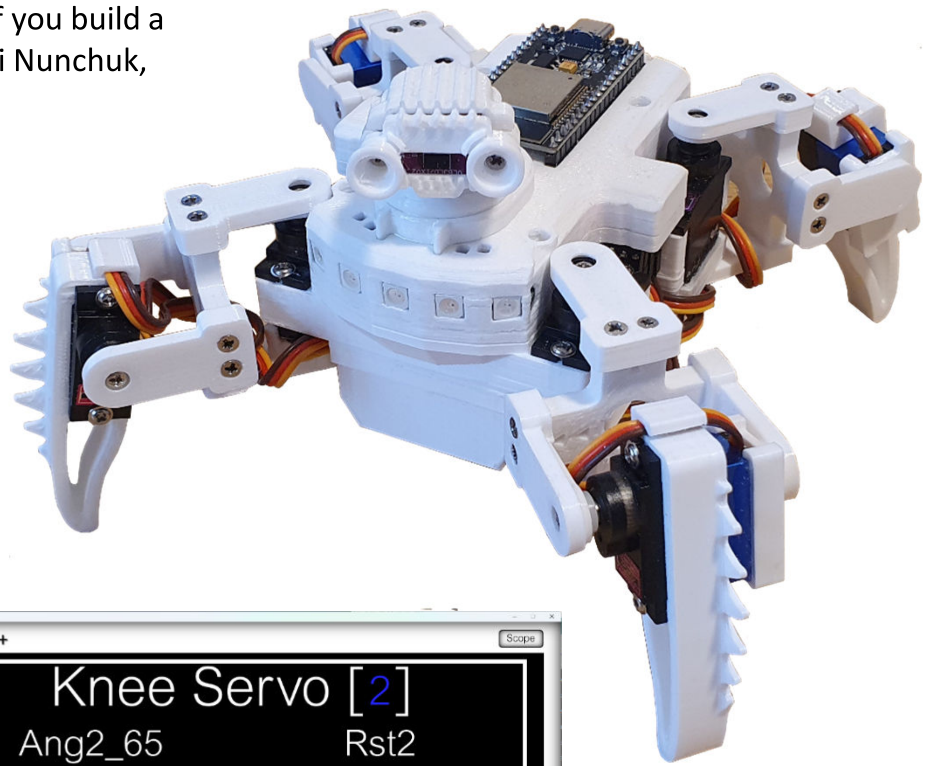
Servo Calibration

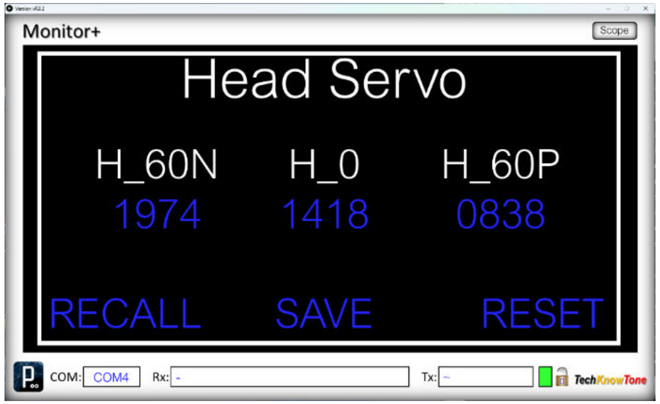


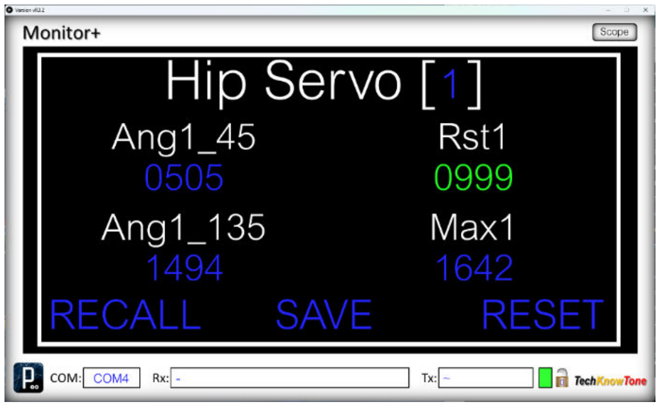
Use the information in the Calibration document to determine, set and store the servo limits. The default values in the supplied code are sub-optimal, and need to be set precisely for good walking performance. In the worst case you may need to reposition the servo arms, in order to achieve the desired range of leg movements.

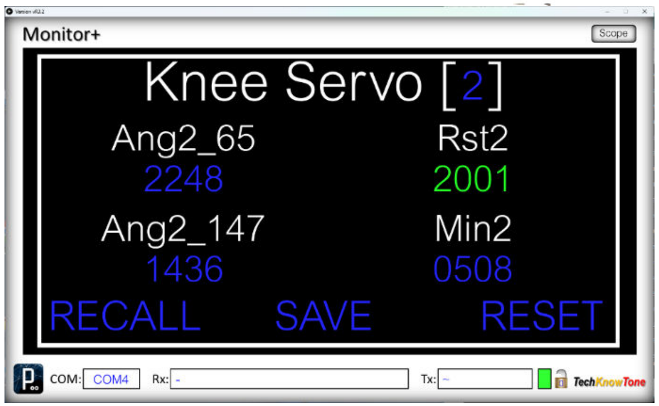
Servo calibration values are now stored in EEPROM, using the SAVE options in the Monitor+ app. This makes the C++ code universal, rather than being unique to each project.

Refer to the Demo Function card for information on how to control your robot. If you build a wireless transceiver, this document explains functions available when using a Wii Nunchuk, and Classic controllers.





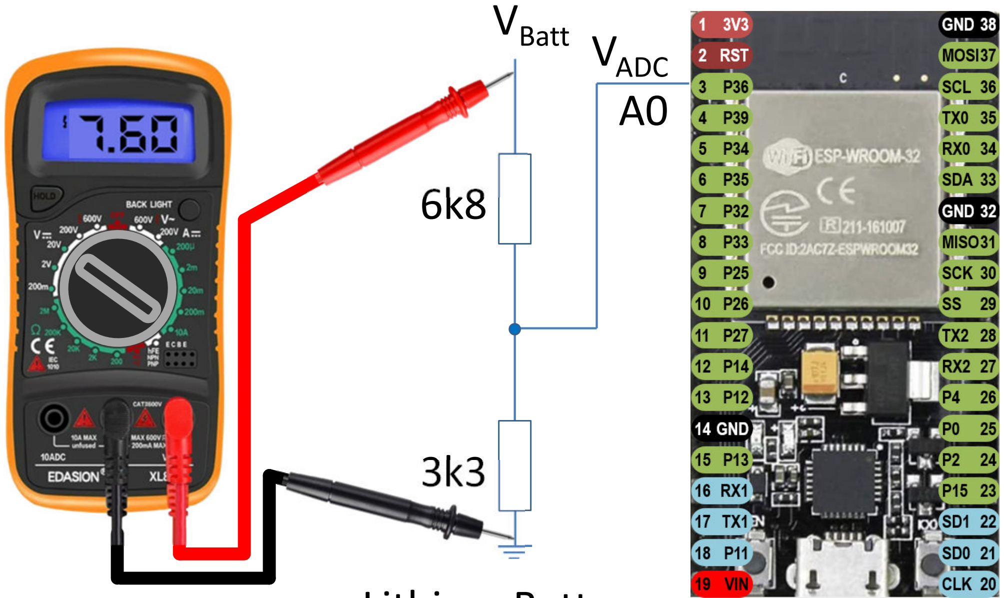




Battery Voltage Calibration

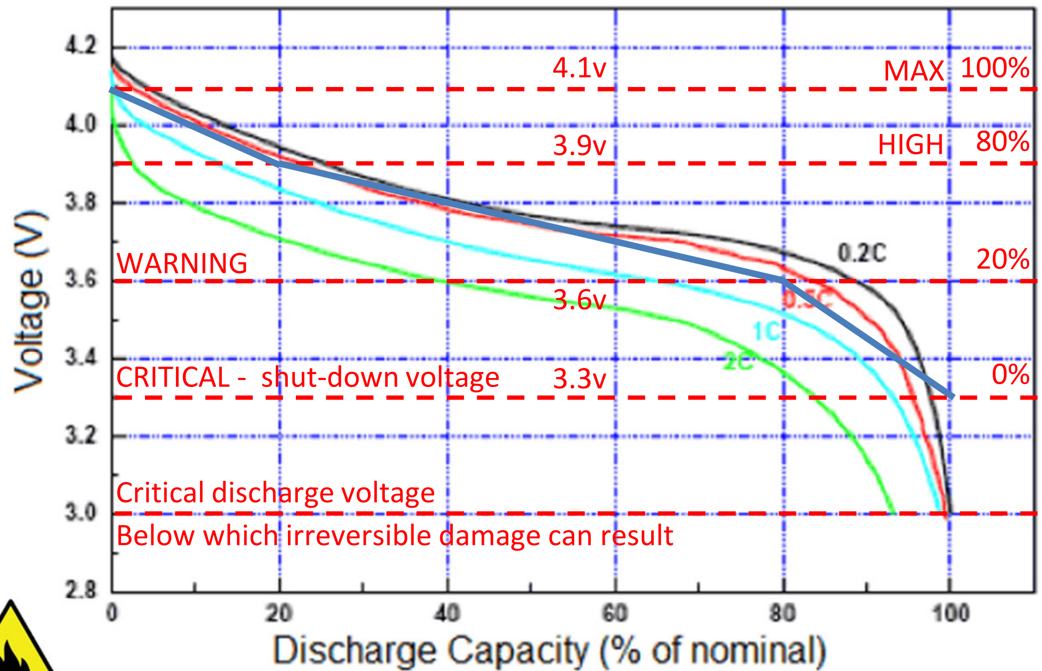
See Lithium discharge curve obtained from the internet. In this analysis the lipo battery consists of two identical batteries connected in series.
Assume fully charged 8.2v battery max voltage is V_{BM} >= 8.4v max (charging)
Set battery warning point at V_{BW} = 7.2v (2 x 3.6v)
Set battery critical point at V_{BC} = 6.6v (2 x3.3v), don't go below this!

The ESP32 is powered via a 3v3 voltage regulator, connected to the 3v3 pin. But the 6k8 supply sampling resistor is connected to source V_{Batt} or Ext. supply.
For ESP32 V_{ADC} == 4095 on 12-bit converter (4095 max).
If we use a 6k8 resistor feeding A0 and a 3k3 resistor to GND, we get a conversion factor of 10.1v == 4095, or 2.47mV/bit, or 405.4 bit/v
Place the droid in TEST mode. Using a Multimeter and a variable DC supply, determine the following V_{ADC} values for corresponding threshold voltages:



MAX. O.C	V_{OC} = 8.4v, gave A0 = 3295 On V_{ADC} (2 x 4.2v)
MAX: (100%)	V_M = 8.2v, gave A0 = 3200 on V_{ADC} (2 x 4.1v)
HIGH: (80%)	V_H = 7.8v, gave A0 = 2997 on V_{ADC} (2 x 3.9v)
WARNING: (20%)	V_{BW} = 7.2v, gives A0 = 2762 on V_{ADC} (2 x 3.6v)
CRITICAL: (0%)	V_{BC} = 6.6v, gives A0 = 2513 on V_{ADC} (2 x 3.3v)

Lithium Battery
Discharge Profile



Discharge: 3.0V cutoff at room temperature.

The code will sample the battery voltage on power-up to ensure it is sufficient, then at every 40ms interval, calculating an average (1/50) to remove noise. Then converts ADC values to voltage in the getBatV() function.

In the code I have assumed a discharge curve ranging from 8.2v (100%) to 6.6v (0%) capacity, using the blue overlay line shown. The voltage is monitored and used to predict the remaining capacity of the battery in use.

Note: If connected to USB port with internal battery switched OFF the ADC will read a value 5 volts (A0 = 1919) or less. So, if the micro starts with such a low reading it knows that it is on USB power, which limits functions available.