QuadAuto MKII (ESP32)
Circuits & Wiring

VL53L0X
Laser range finder
VL53L0/1XV2
VIN GND SCL SDA GPIO1 XSHUT

Tower Pro SG51R Micro servo
S0

Left-hand servos

S2

S1

S7

S8

12 x MG90D

2kΩ
2kΩ

En

V_{ADC}

ESP-WROOM-32

1	3V3		GND	38	
2	RST		P23	37	
3	P36		P22 SCL	36	
4	P39		P01 TX0	35	
5	P34		RX0	34	
6	P35		P21 SDA	33	
7	P32		GND	32	
8	P33		P19	31	
9	P25		P18	30	
10	P26		P05	29	
11	P27		TX2 P17	28	
12	P14		RX2 P16	27	
13	P12		P4	26	
14	GND		P0	25	
15	P13		P2	24	
16	P09 RX1		P15	23	
17	P10 TX1		P08	22	
18	P11		P07	21	
19	VIN		P06	20	

FCC ID:2ACTZ-ESPWROOM32
211-161007

Right-hand servos

S4

S3

S5

S6

SW0

+7.5v

3k3
6k8

+7.5v

+6.3v

2 x 4 x 1N4006

ON   OFF

Ext. 7.6v

GND

5 x WS2812B

CAUTION LITHIUM BATTERY

CAUTION LITHIUM BATTERY

∞ + ESP32

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

Lithium batteries can be <u>extremely</u> dangerous, if not handled and cared for properly. This design does not include any form of current limiting circuit, like a fuse. So, care <u>must</u> 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
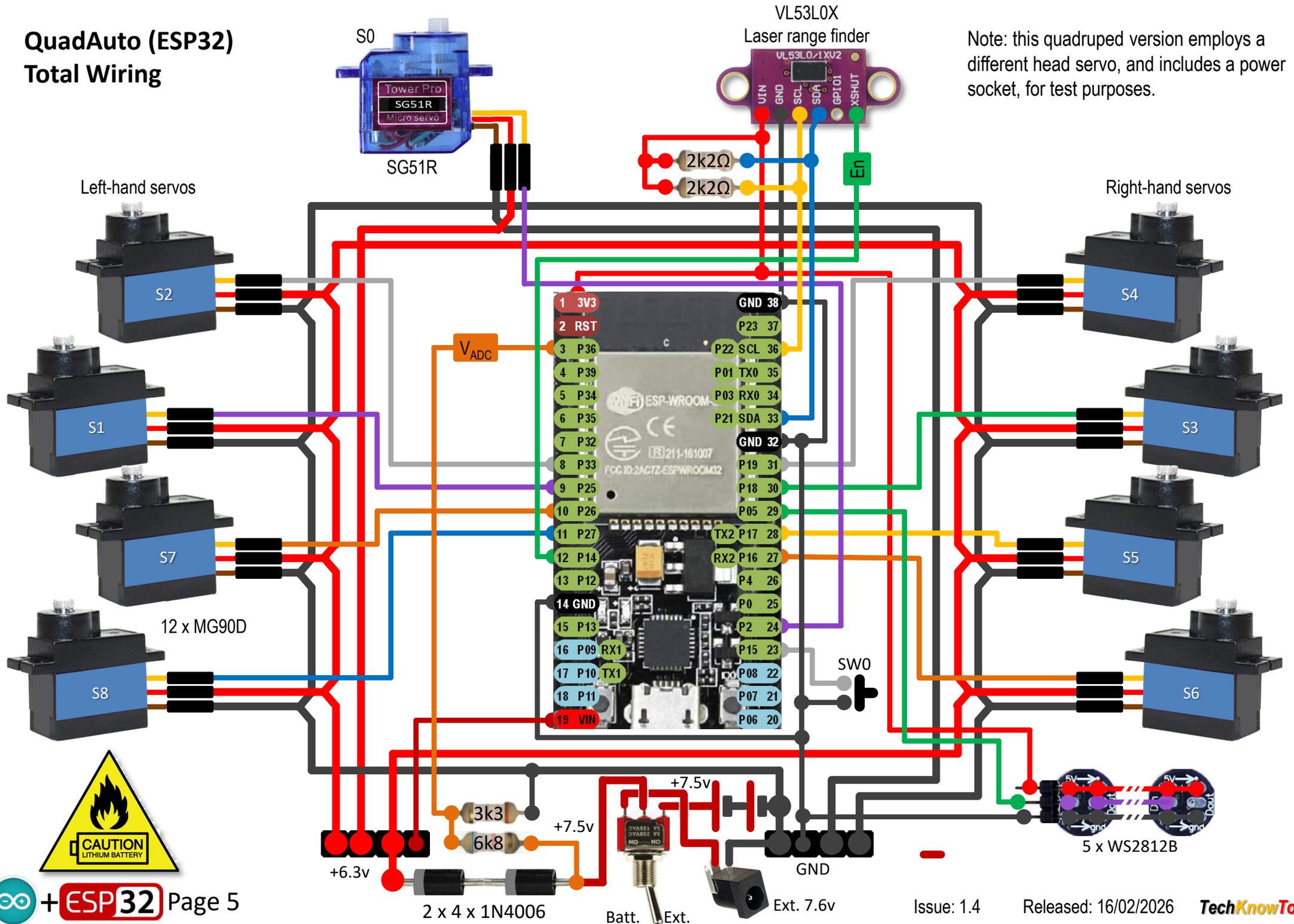Tweezers
Wire wrapping tool
Wire wrapping wire 30 AWG
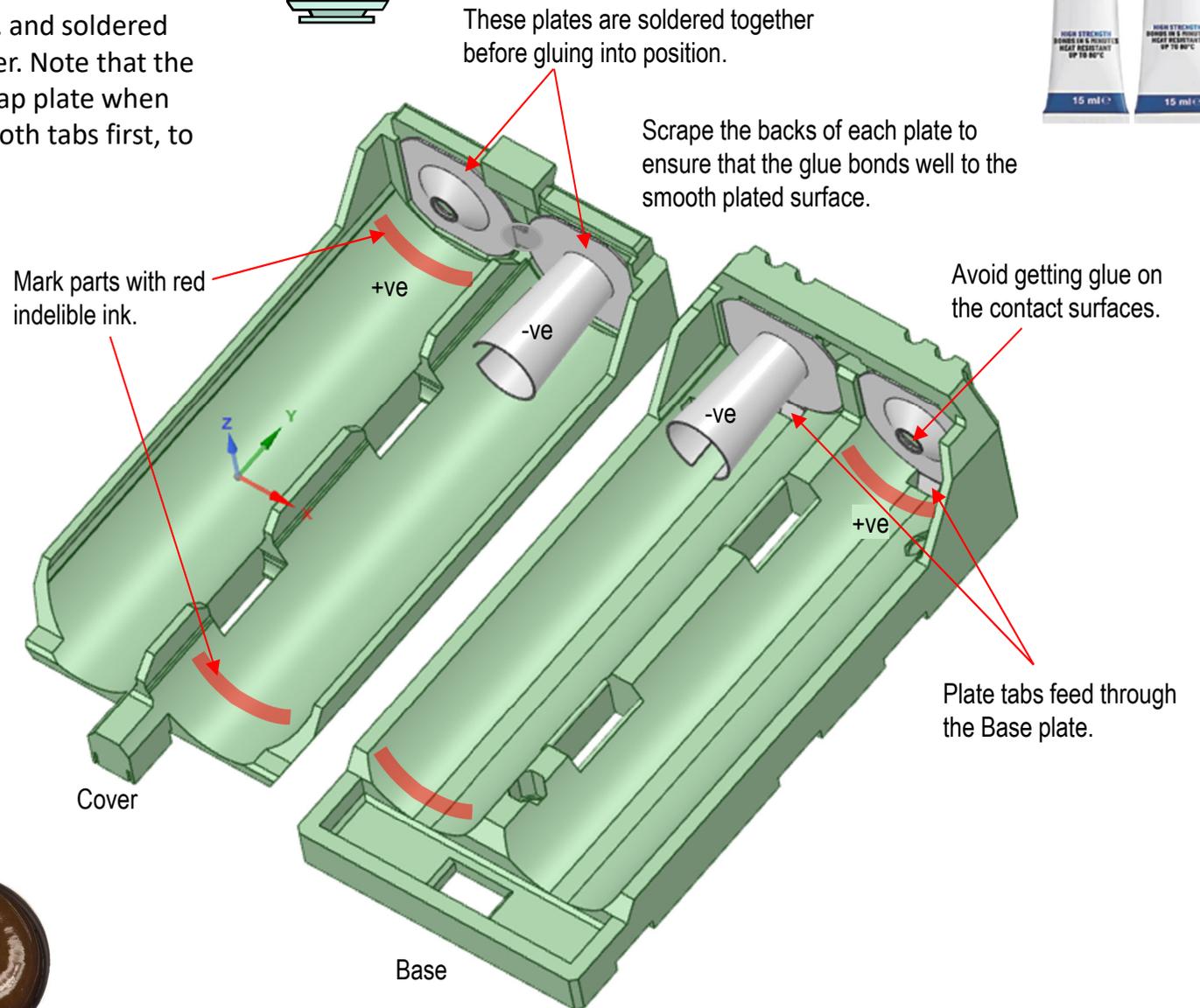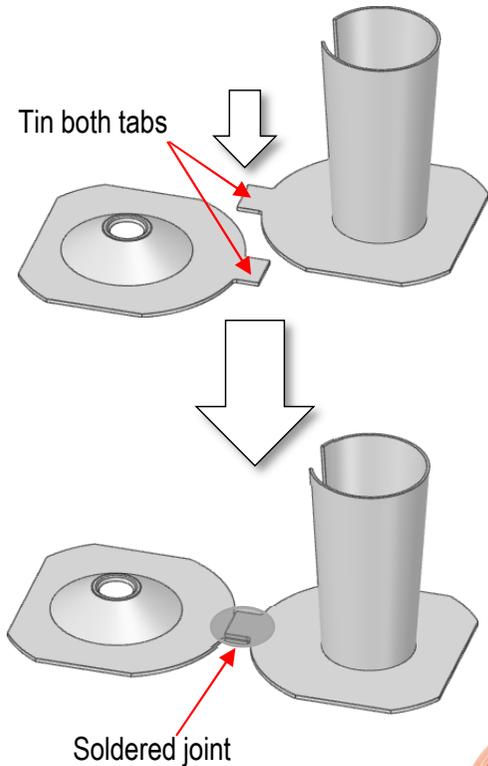24 AWG stranded wire (red, black & yellow)
Multimeter

QuadAuto (ESP32)
Total Wiring

S0

SG51R

VL53L0X
Laser range finder

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

Left-hand servos

Right-hand servos

2k2Ω

2k2Ω

En

S2

S4

V_{ADC}

1	3V3		GND	38
2	RST		P23	37
		c	P22 SCL	36
3	P36		P01 TX0	35
4	P39		P03 RX0	34
5	P34		P21 SDA	33
6	P35		GND	32
7	P32		P19	31
8	P33		P18	30
9	P25		P05	29
10	P26		TX2 P17	28
11	P27		RX2 P16	27
12	P14		P4	26
13	P12		P0	25
14	GND		P2	24
15	P13		P15	23
16	P09 RX1		P08	22
17	P10 TX1		P07	21
18	P11		P06	20
19	VIN			

S1

S3

S7

S5

S8

S6

12 x MG90D

SW0

+6.3v

3k3

6k8

+7.5v

+7.5v

+7.5v

GND

Ext. 7.6v

Batt. Ext.

2 x 4 x 1N4006

5 x WS2812B

Issue: 1.4

Released: 16/02/2026

TechKnowTone

CAUTION LITHIUM BATTERY

+ ESP32 Page 5

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, <u>before</u> 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.

These plates are soldered together before gluing into position.

Scrape the backs of each plate to ensure that the glue bonds well to the smooth plated surface.

Mark parts with red indelible ink.

Tin both tabs

Soldered joint

+ve

-ve

Cover

Avoid getting glue on the contact surfaces.

-ve

+ve

Plate tabs feed through the Base plate.

Base

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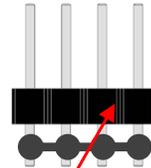
4 x 4-pin strips, with pins wired together, then glued into Base plate as common connection point

Tin the pins before soldering on diodes.

Right-hand front servo

Right-hand rear servo

The battery box base is fitted with spring contacts (glued into position) then attached to the Base plate using three 2x10mm screws.

The two connection tabs protrude through the Base plate and are connected as shown.

8 3 7 4

2 5 1 6

Viewed from above

Front

6.3v

4 x 1N4006

6.9v

4 x 1N4006

7.5v

+ve

Power switch

Ext. 7.5v socket

Ext. Power switch

Ext.
Batt.

Ext. GND socket

-ve

Solder diode connections

+7V5

GND

The power connections to the Middle and Upper plates are made there first, then later fed down to the Base plate to complete the circuits.

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

Left-hand front servo

Left-hand rear servo

Common Connection Points

01 Wrap plenty of wire around the strip pins.

03 Then glue them into the Base Plate.

02 Flood the wiring with solder.

xx

These act as common mounting points for the 1N4006 diodes.
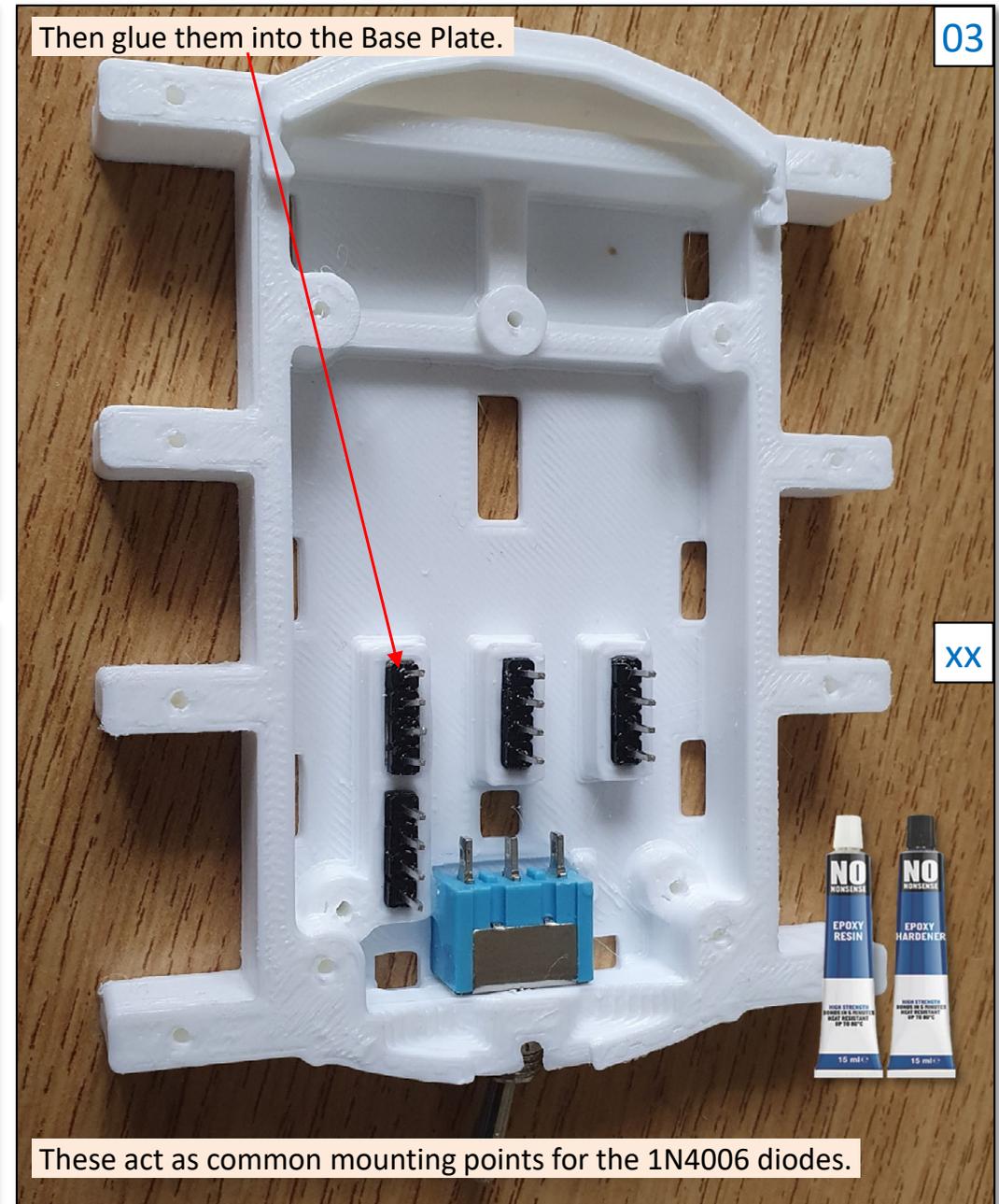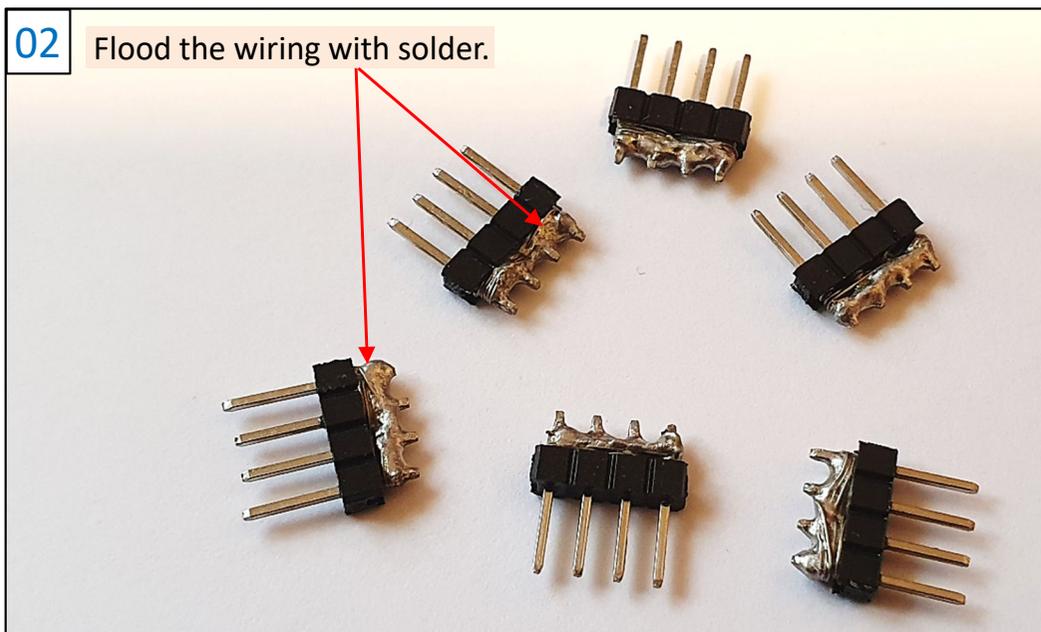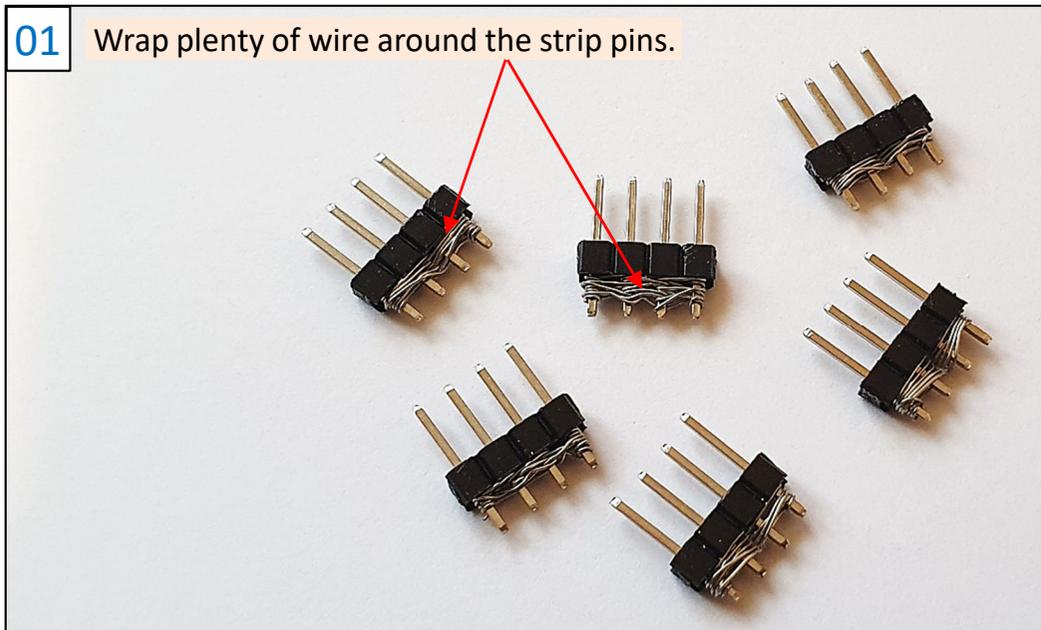
Base Plate Wiring

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.
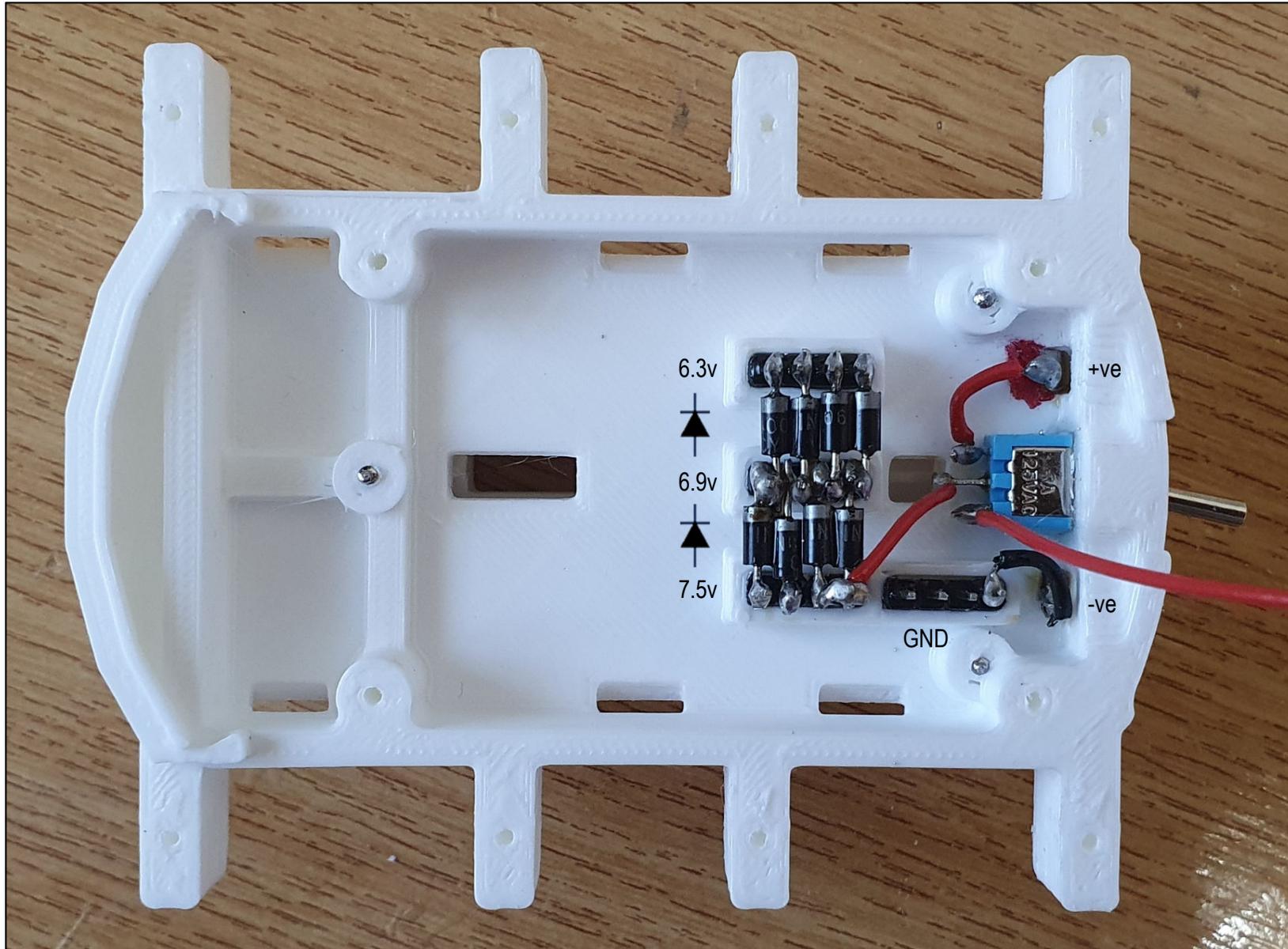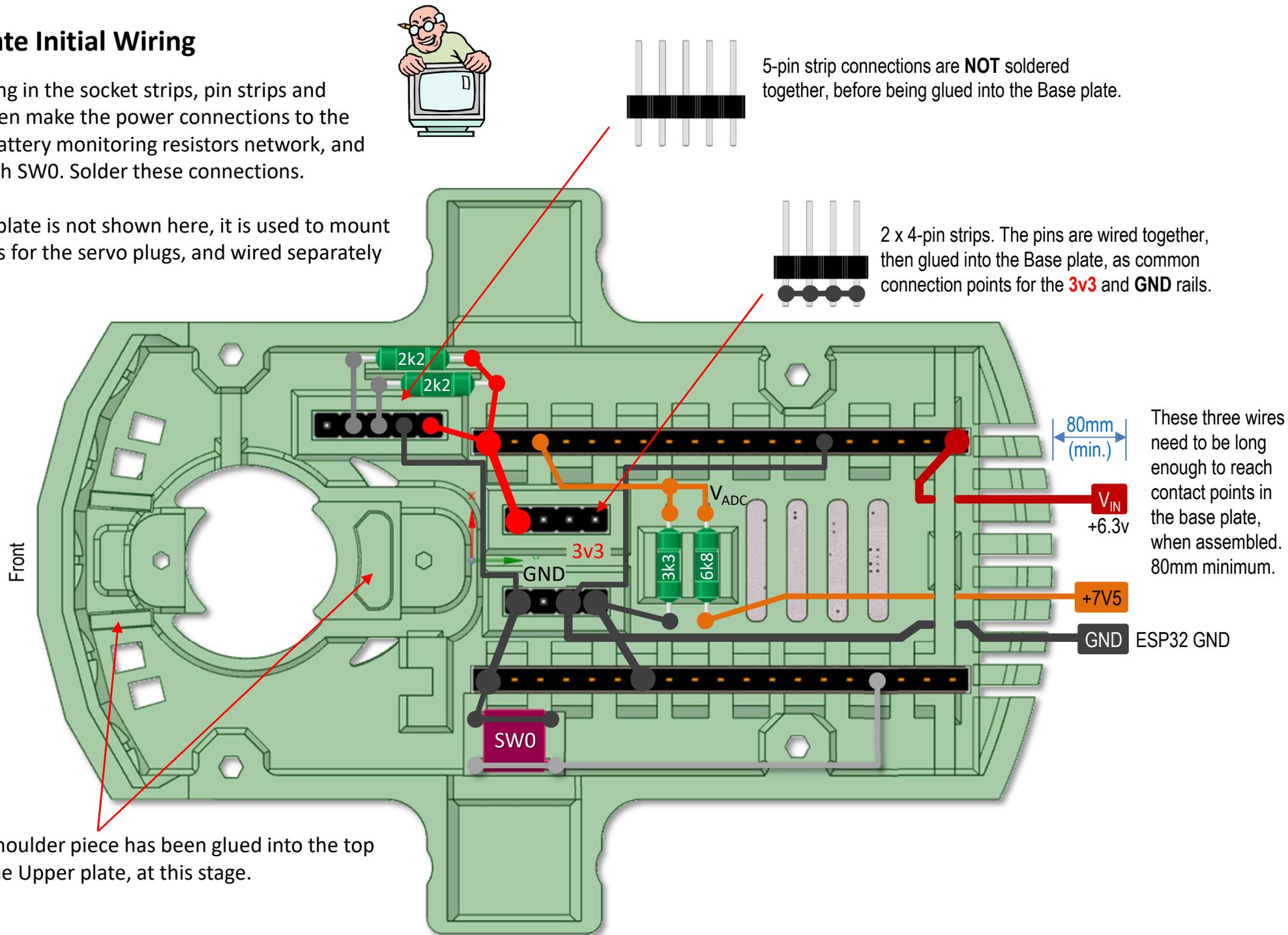
UPDATE

Ext. 7.5v socket

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.

5-pin strip connections are **NOT** soldered together, before being glued into the Base plate.

2 x 4-pin strips. The pins are wired together, then glued into the Base plate, as common connection points for the **3v3** and **GND** rails.

These three wires need to be long enough to reach contact points in the base plate, when assembled. 80mm minimum.

80mm (min.)

2k2
2k2

V_{ADC}

3v3

GND

3k3 6k8

V_{IN}
+6.3v

+7V5

GND ESP32 GND

SW0

Front

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

Upper Plate Wiring I2C

We now move on to wiring in the I2C connections for the laser range finder.

The 5-pin I2C pin strip acts as terminal posts for the individual signal paths.

These three wires need to be long enough to reach contact points in the base plate when assembled. 80mm minimum.

80mm (min.)

V_{IN} +6.3v

+7V5

GND   ESP32 GND

3v3

GND

V_{ADC}

2k2

2k2

3k3

6k8

SW0

Front
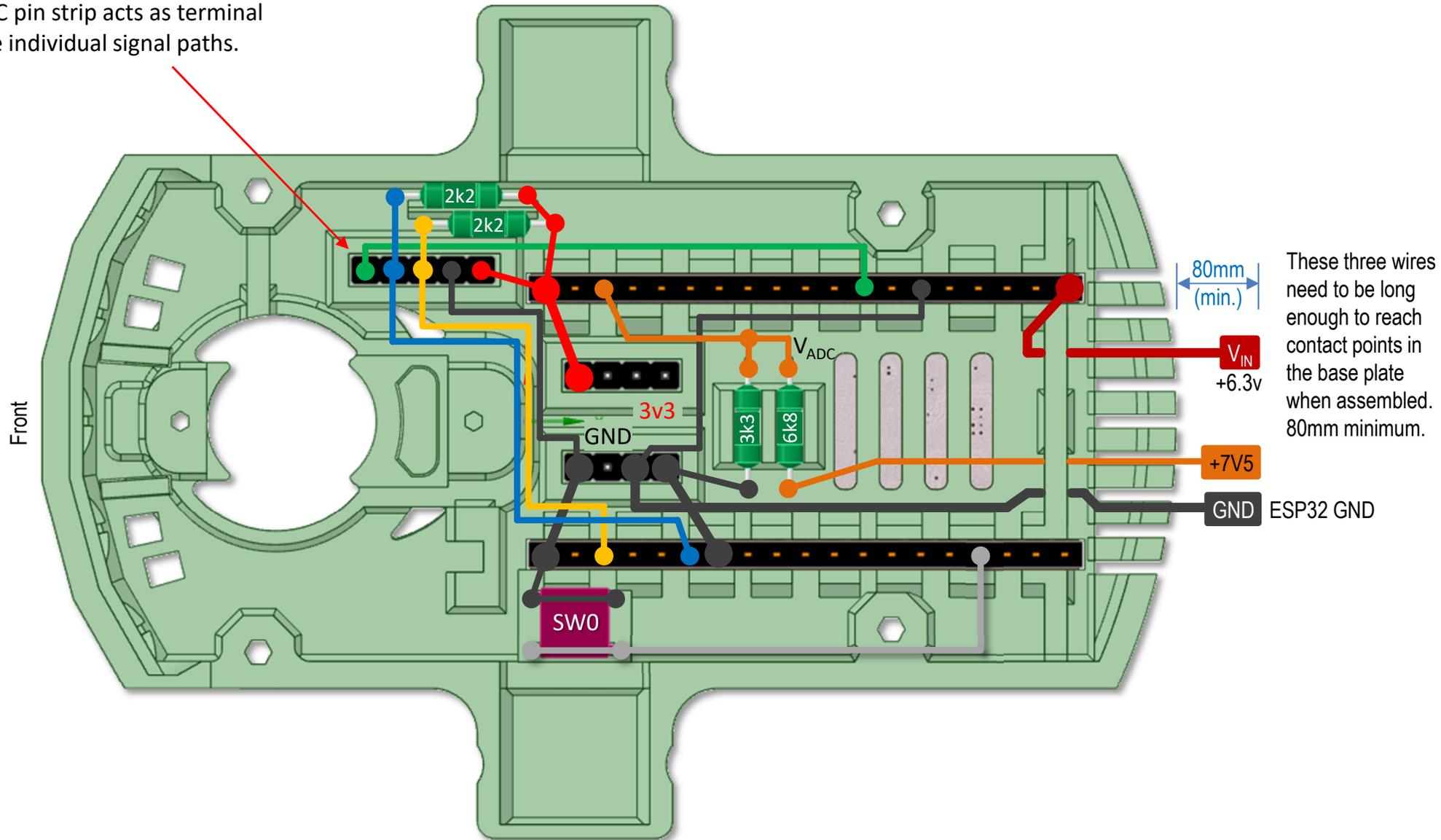
Upper Plate Wiring I2C

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.

Solder in the two 2k resistors first

Solder these 3 wire wrapped connections

3v3

GND

GND

+7V5

+6.3v

Sholder was glued in prior to wiring.
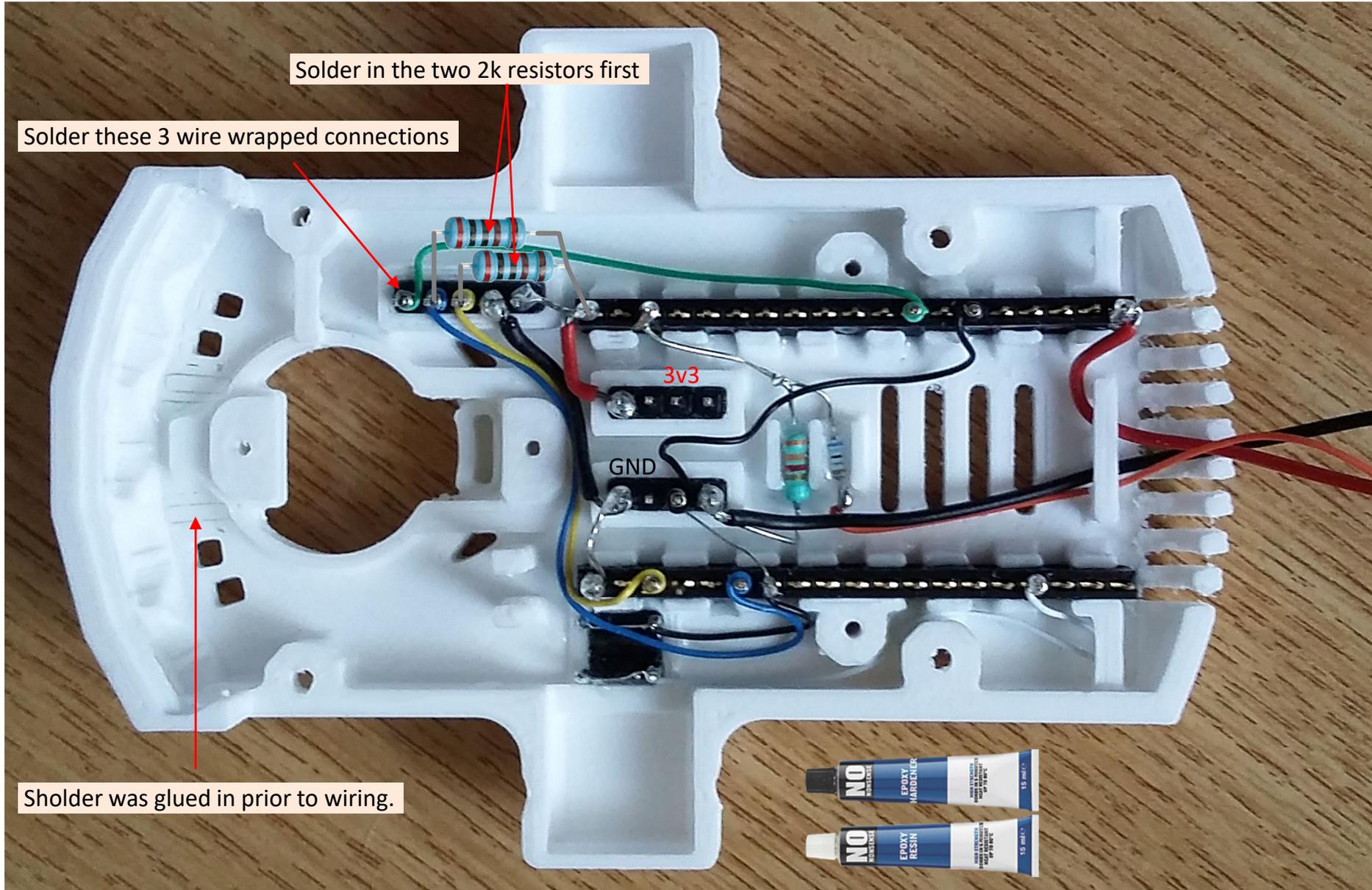
WS2812B RGB strip Wiring

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.

Apply a light smear of flux to the solder pads before soldering.

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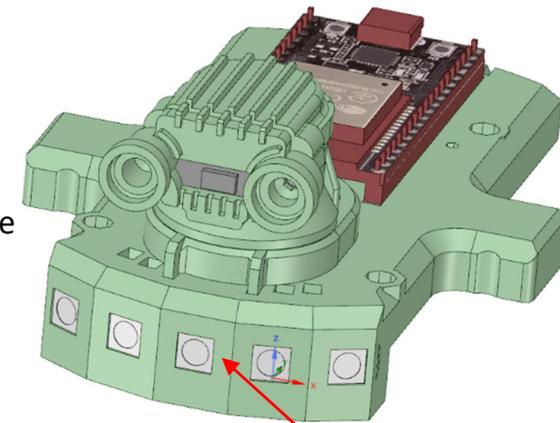
WS2812B LEDs in robot facia. Check/file apertures for clearance.

130mm
110mm
100mm
65mm

Minimum wire lengths
Use 30AWG wire-wrap wire.

5v wire attached

Data wire cropped

data wire attached

GND wire attached
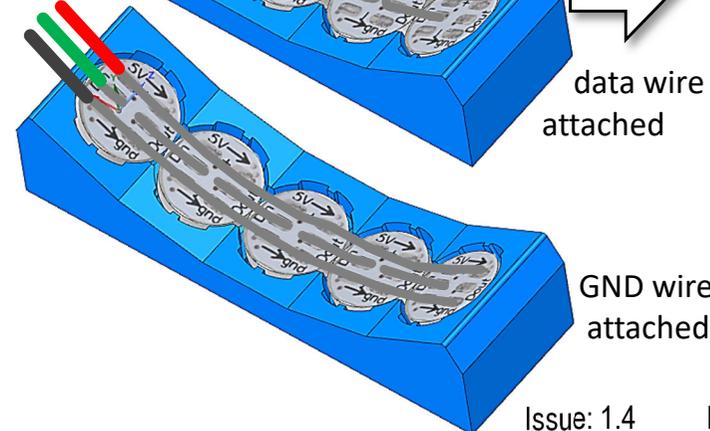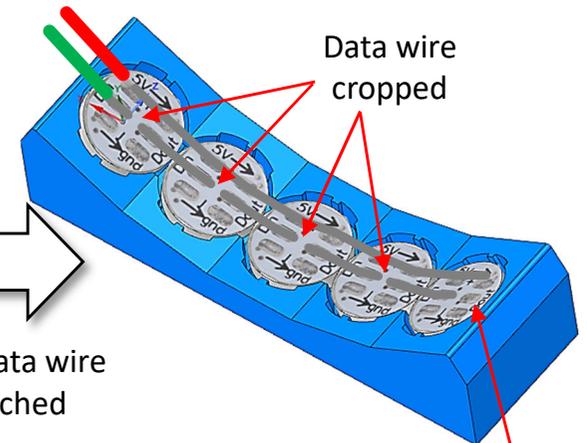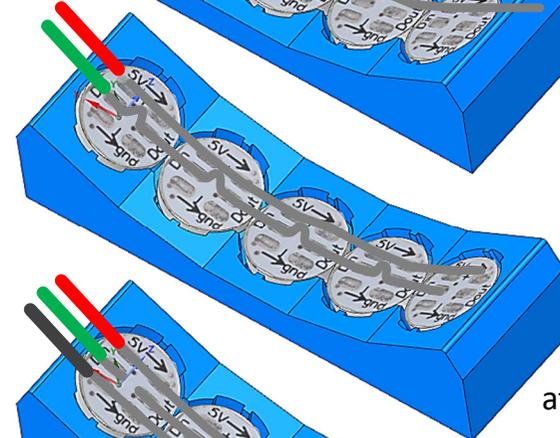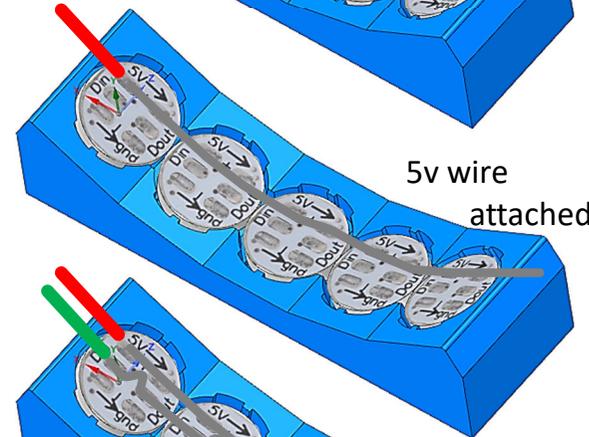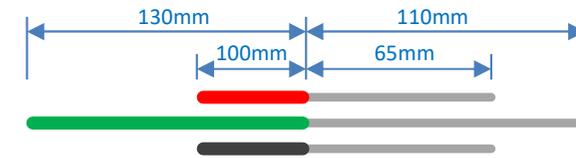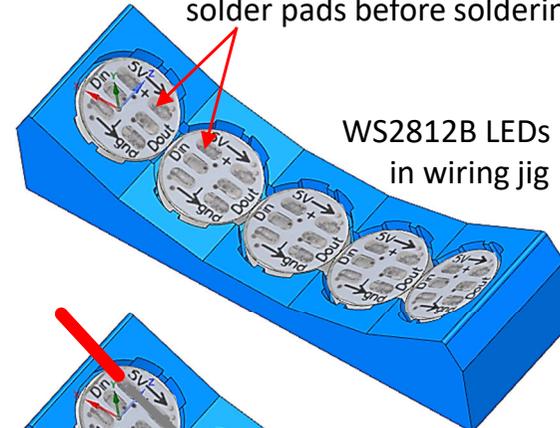
Final pad is not connected

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.

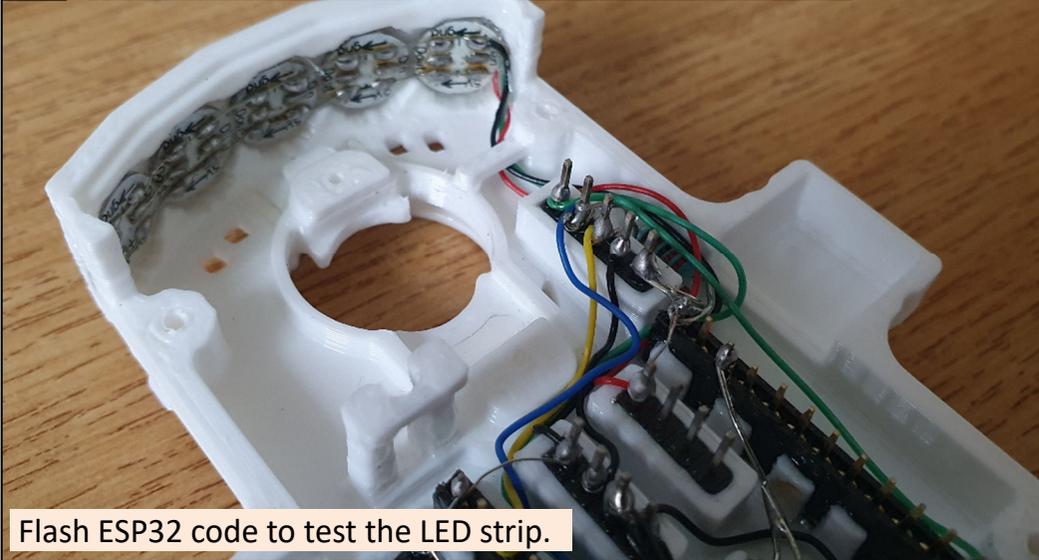**02** Data wire loops were formed with a small screwdriver.

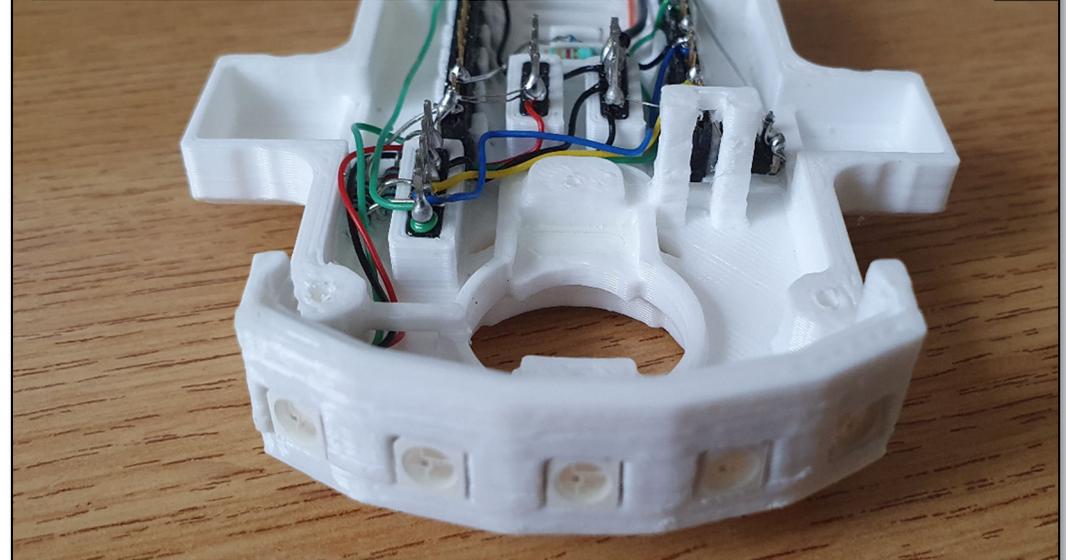Crop out the loops once you are happy with the soldered joints.

03 Insert the wired assembly into the front curved facia.

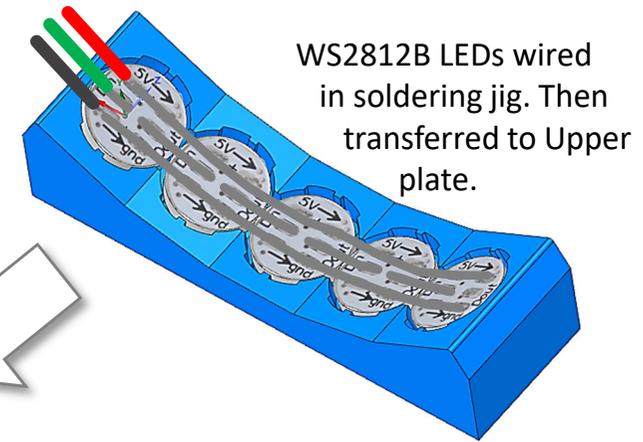Flash ESP32 code to test the LED strip.

**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.

RGB

2k2
2k2

V_{ADC}

V_{IN}
+6.3v

3v3

3k3   6k8

GND

+7V5

GND   ESP32 GND

Front

SW0
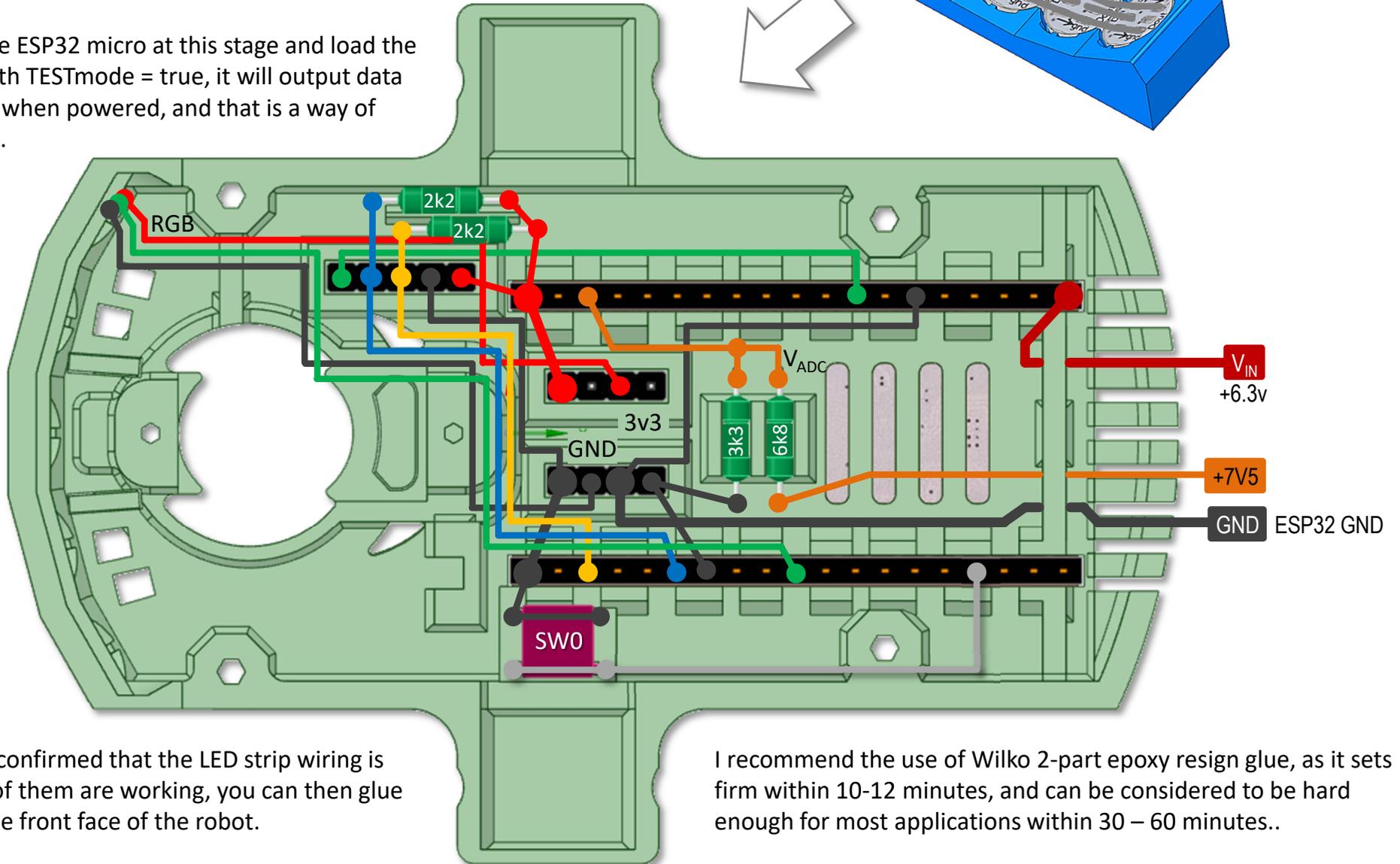
Once you have confirmed that the LED strip wiring is correct and all of them are working, you can then glue the LEDs into the front face of the robot.

I recommend the use of Wilko 2-part epoxy resign 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

Your Upper plate connections should now look like this.
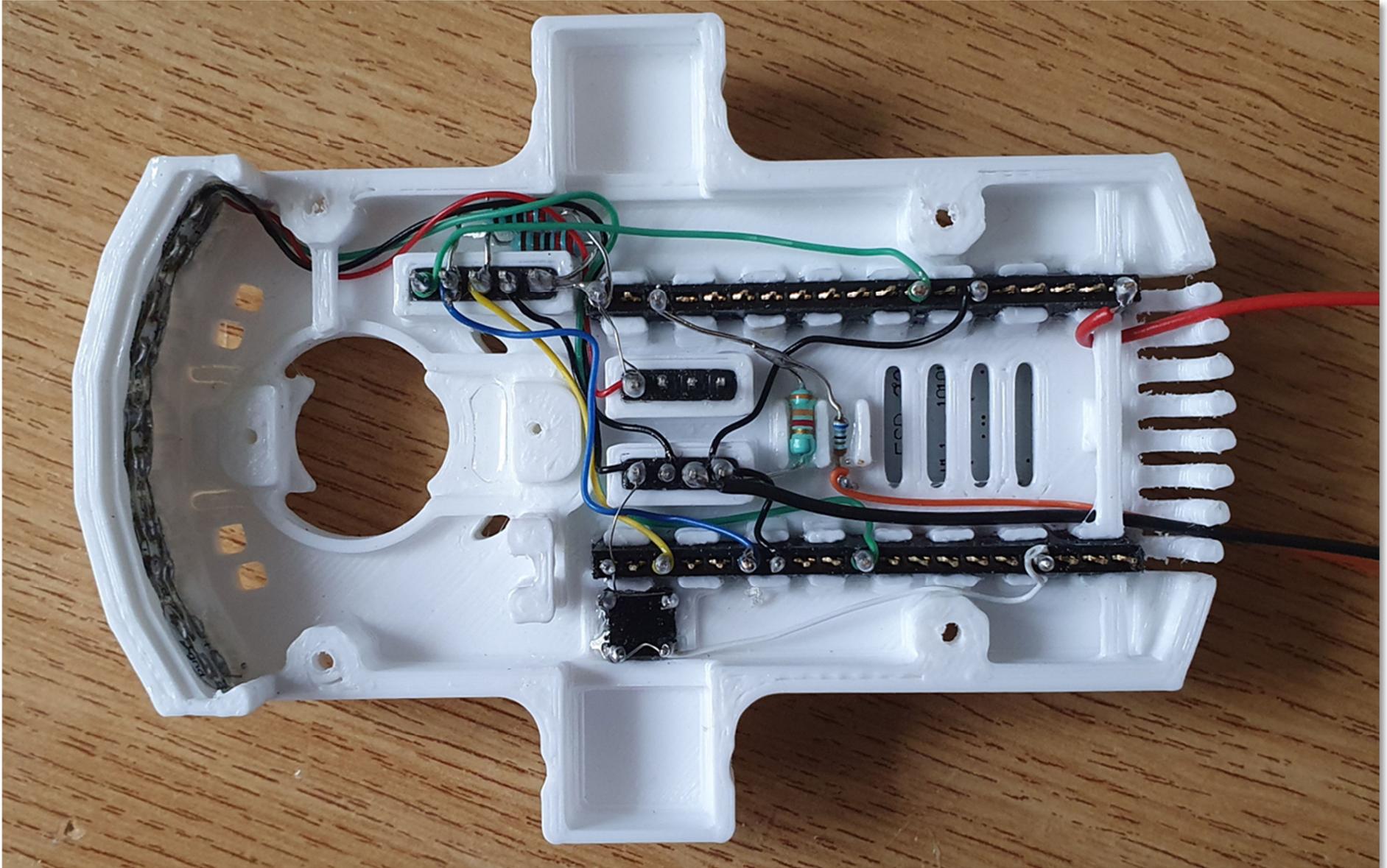
Head assembly

The neck is held into the shroud piece by a retaining ring, which is glued onto the neck tube.
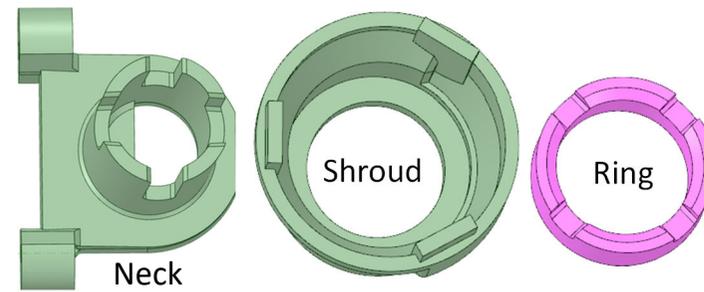
Prior to gluing the components, we apply a small amount of lubricant the load bearing surfaces, to reduce friction and wear. I used Vaseline for this.
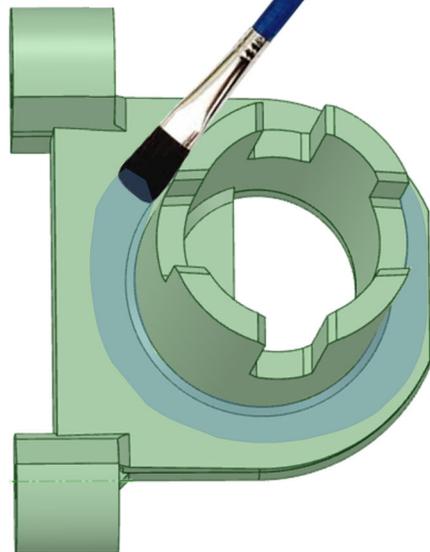
Care must be taken to lubricate sliding faces only, whilst not compromising the glued faces. The glue dabs acts to retain the ring on the neck tube; you are not trying to glue the ring fully.

Neck   Shroud   Ring

Lubricate neck to shroud bearing face

Fit shroud over neck tube

Lubricate shroud to ring bearing face

Fit ring over neck tube

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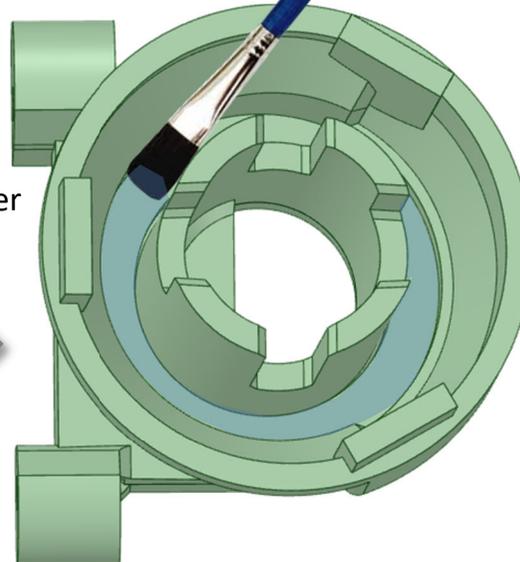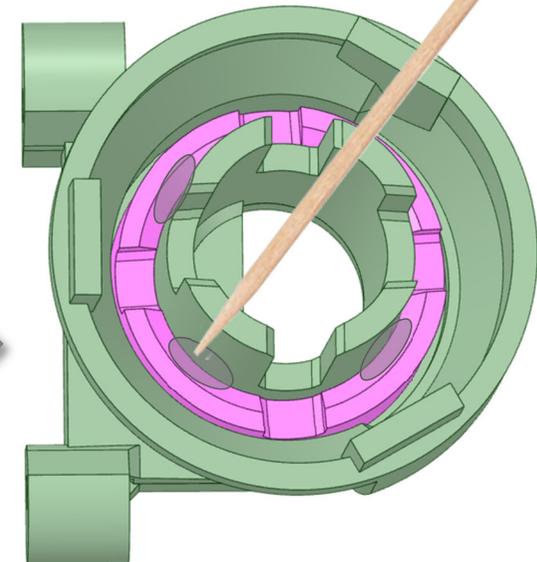
Allow the glue to go firm, then carefully rotate the neck within the shroud, to ensure that it is not glued also. Leaving the tooth pick on the mixing card gives a good indication as to when the glue stiffens. Normally 10-12 minutes depending on room temperature.

Issue: 1.4   Released: 16/02/2026   TechKnowTone

Head VL53L0X LTOF Wiring

Using the Head Eyelets piece and 2 screws, attach the sensor onto the neck. Then glue the Head Shroud into the neck on the Upper plate.
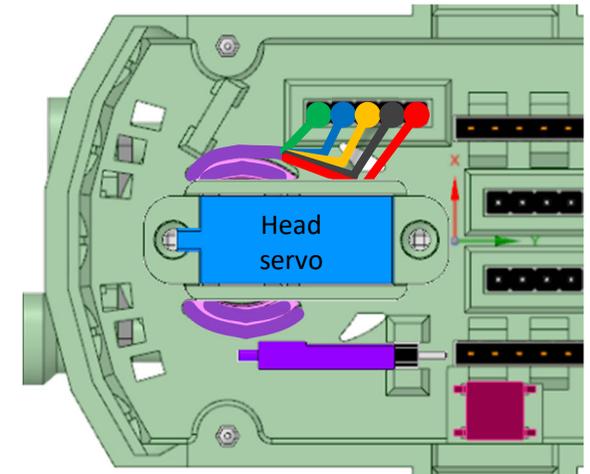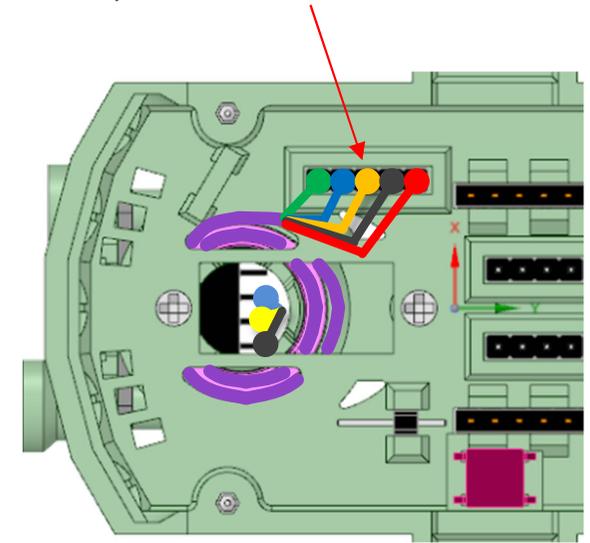
Once the glue has set, connect 5 wires to a 6-pin socket strip, as shown; allowing for a minimum length of 200 mm. Solder the connections, then plug this onto the VL53L1X device whilst feeding the wires down through the neck aperture. The wire length aims to ensure you have sufficient.

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.

220mm minimum

6-pin sockets

6-pin sockets
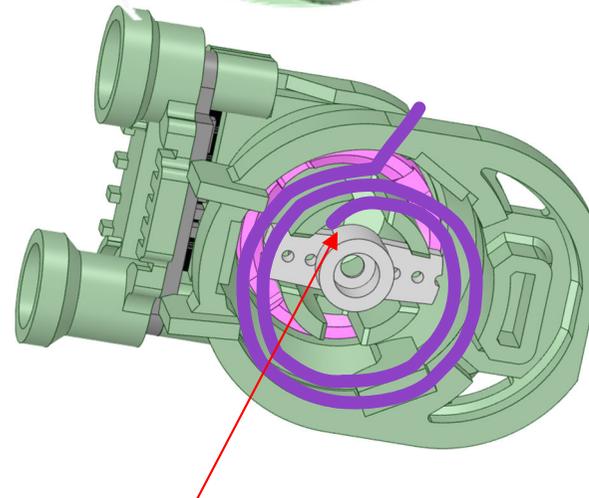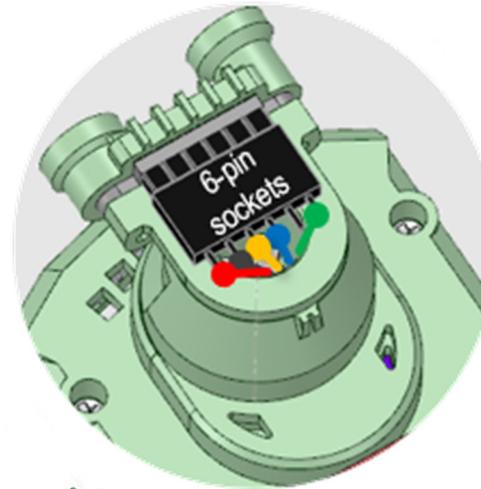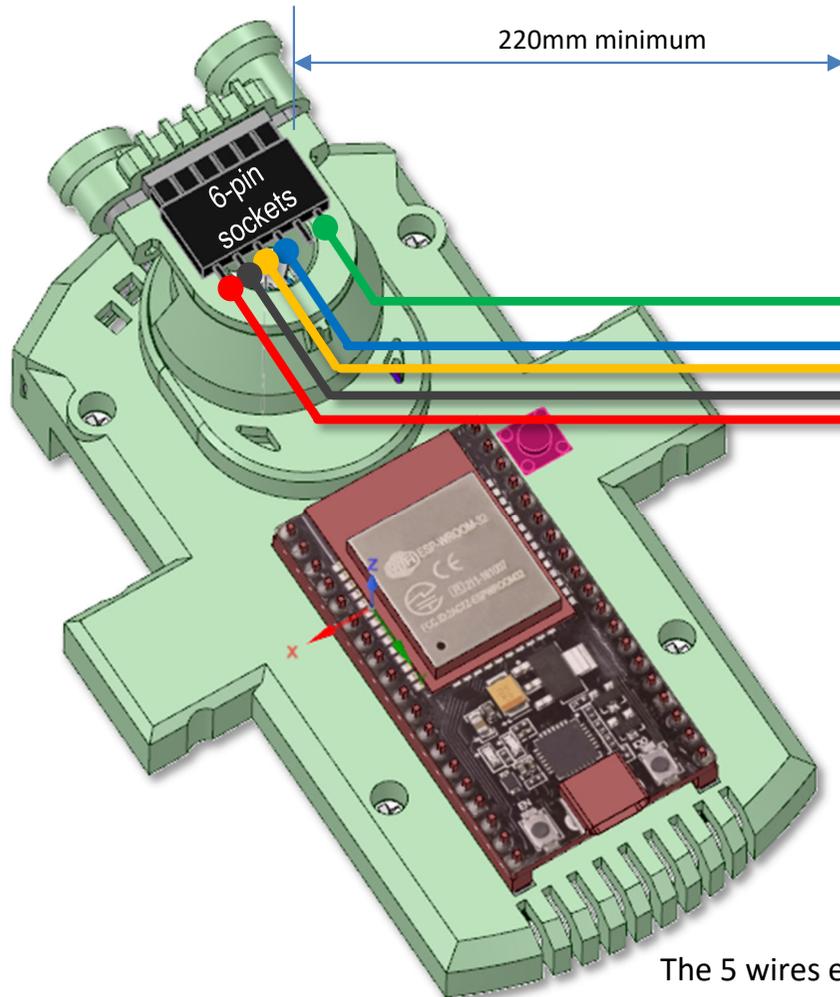
Head servo

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.

Issue: 1.4   Released: 16/02/2026   TechKnowTone

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.

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. The head servo plugs onto these pins.

PWM

Head servo power
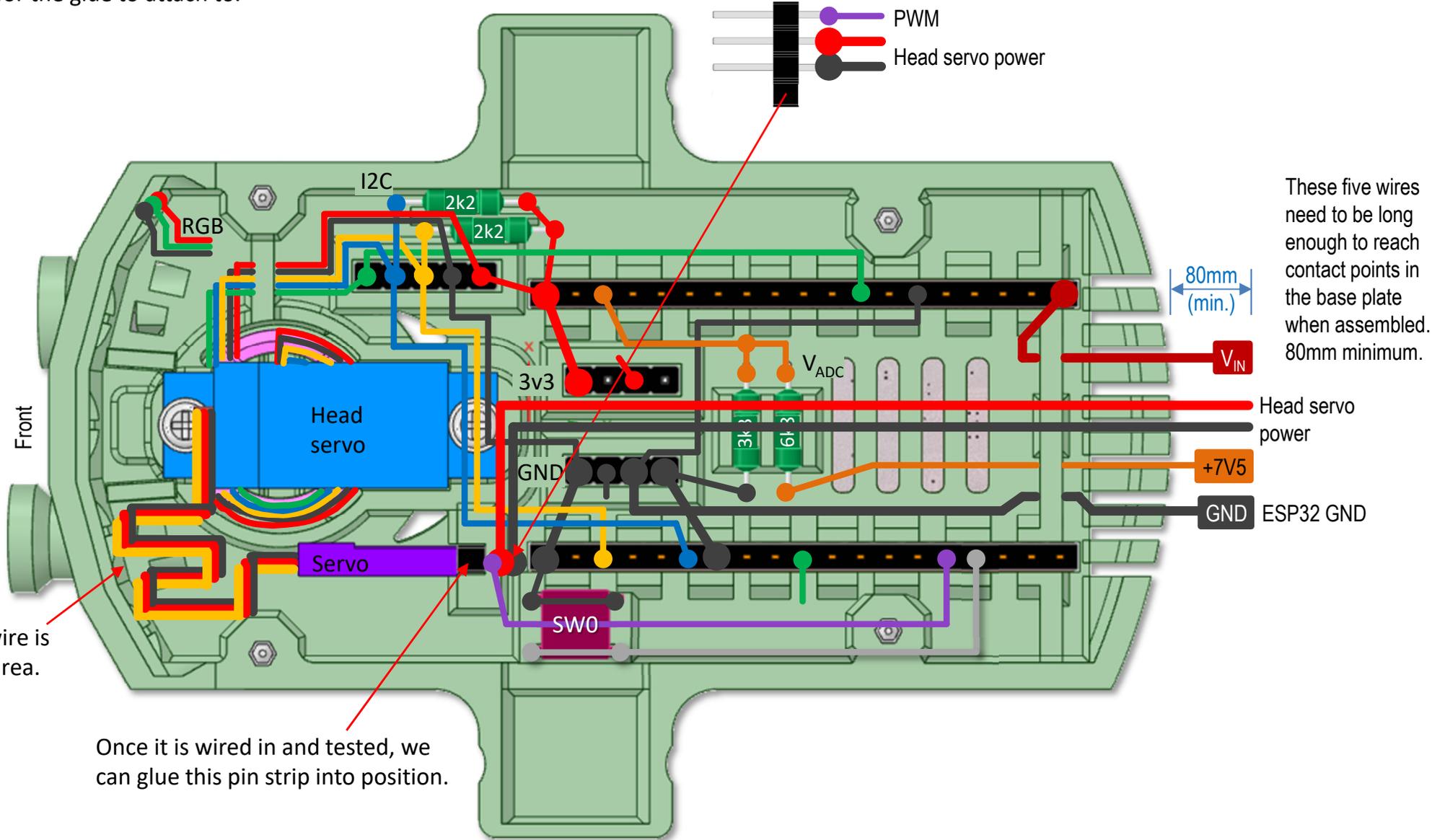
These five wires need to be long enough to reach contact points in the base plate when assembled. 80mm minimum.

80mm (min.)

I2C

2k2

2k2

RGB

3v3

V_{ADC}

V_{IN}

Front

Head servo

Head servo power

GND

+7V5

Servo

GND ESP32 GND

SW0

Excess servo wire is folded in this area.

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

EPOXY RESIN

EPOXY HARDENER

Upper Plate Servo Wiring

Your Upper plate connections should look like this.

Issue: 1.4   Released: 16/02/2026   *TechKnowTone*
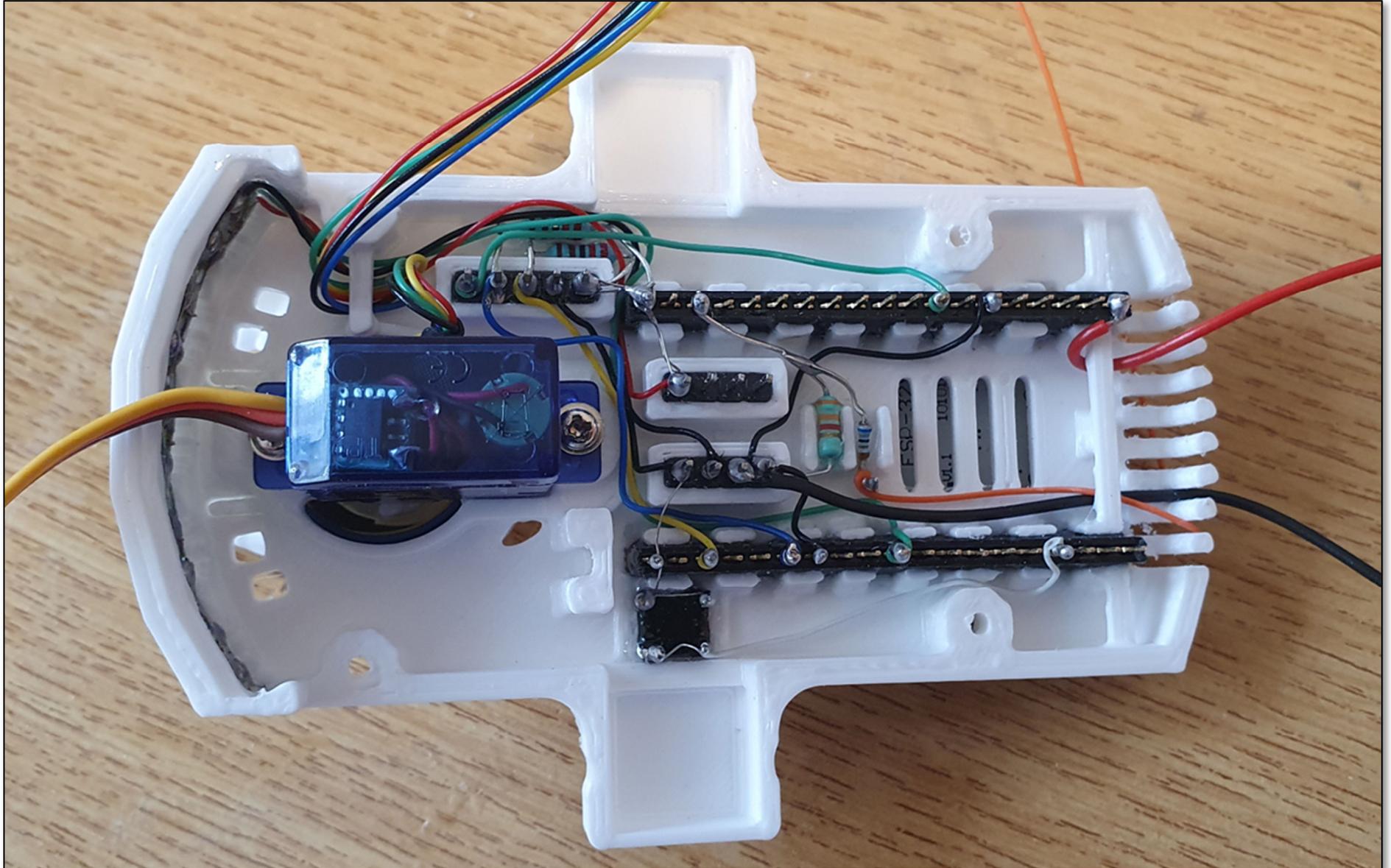
Middle Plate Components

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.

Glue

Power socket

Middle Plate

Cropped centre
Switched contact
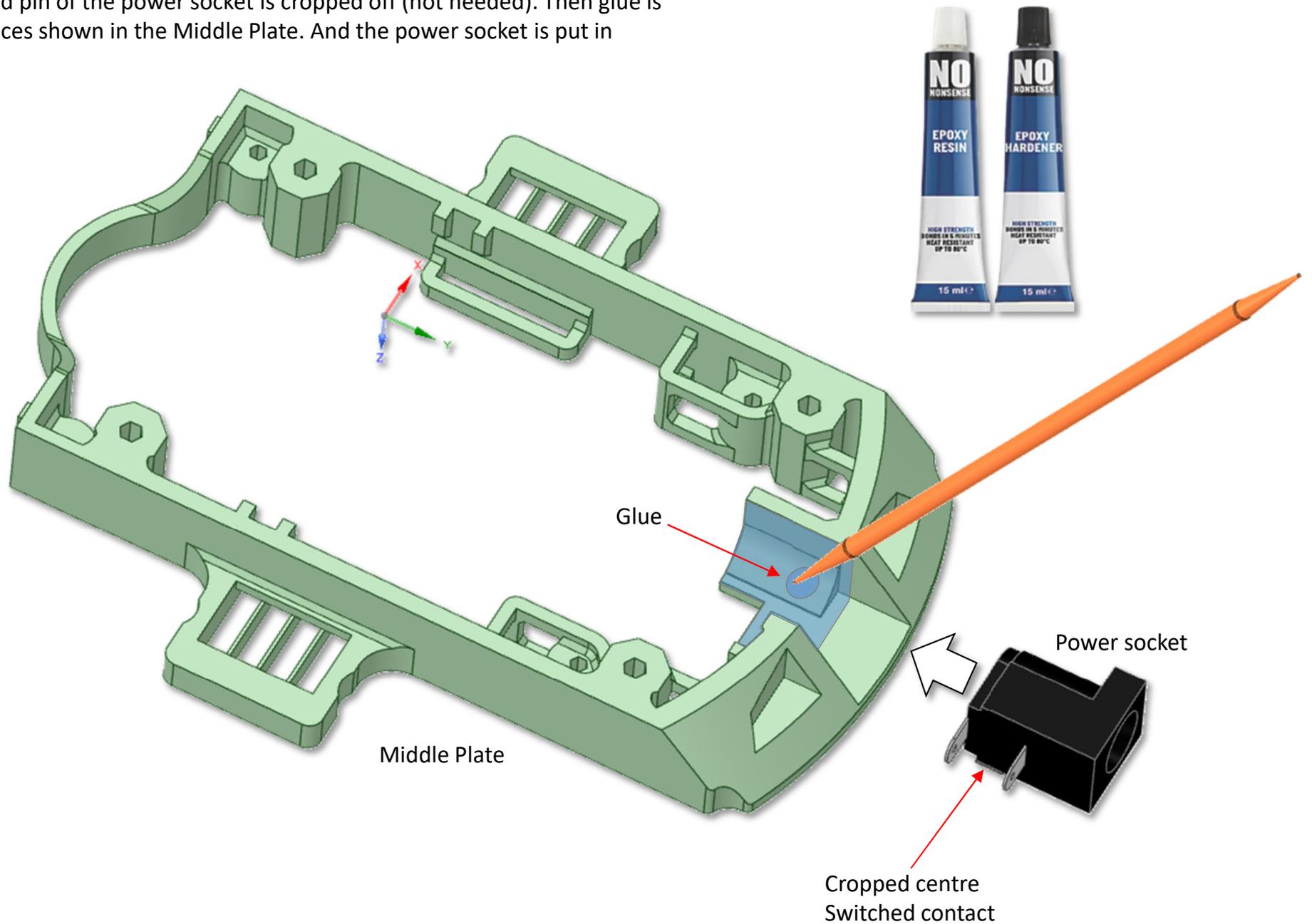
Middle Plate Components

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.

Modified 5-pin strip

Removed end pin

Glue droplets
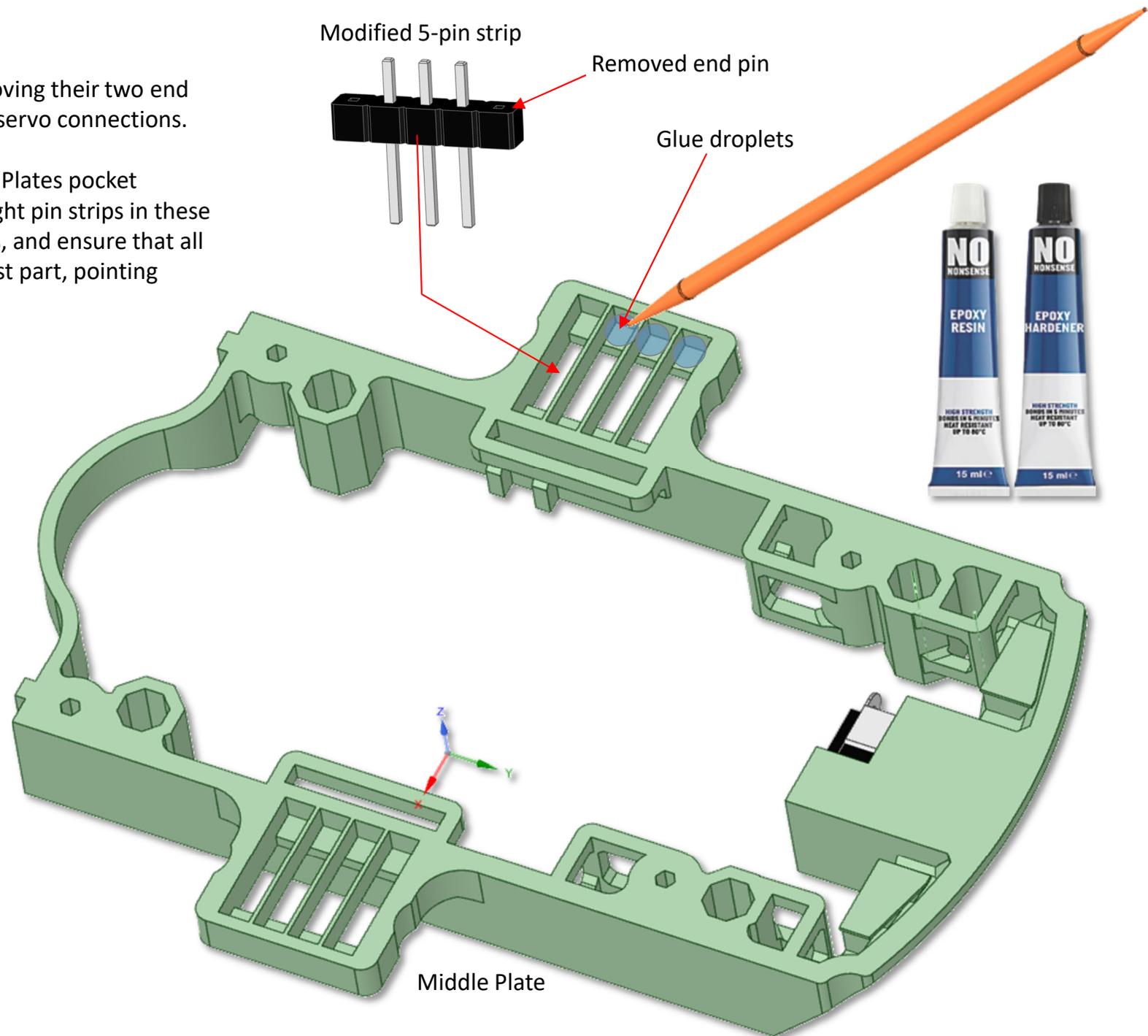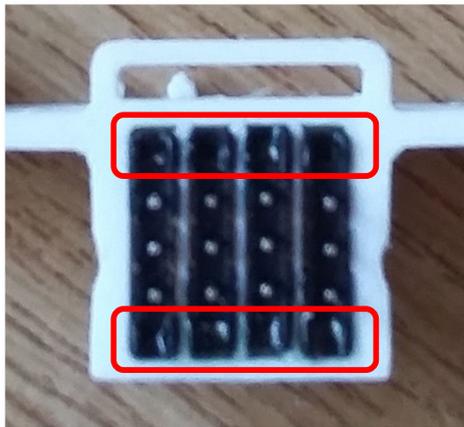
Middle Plate

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.
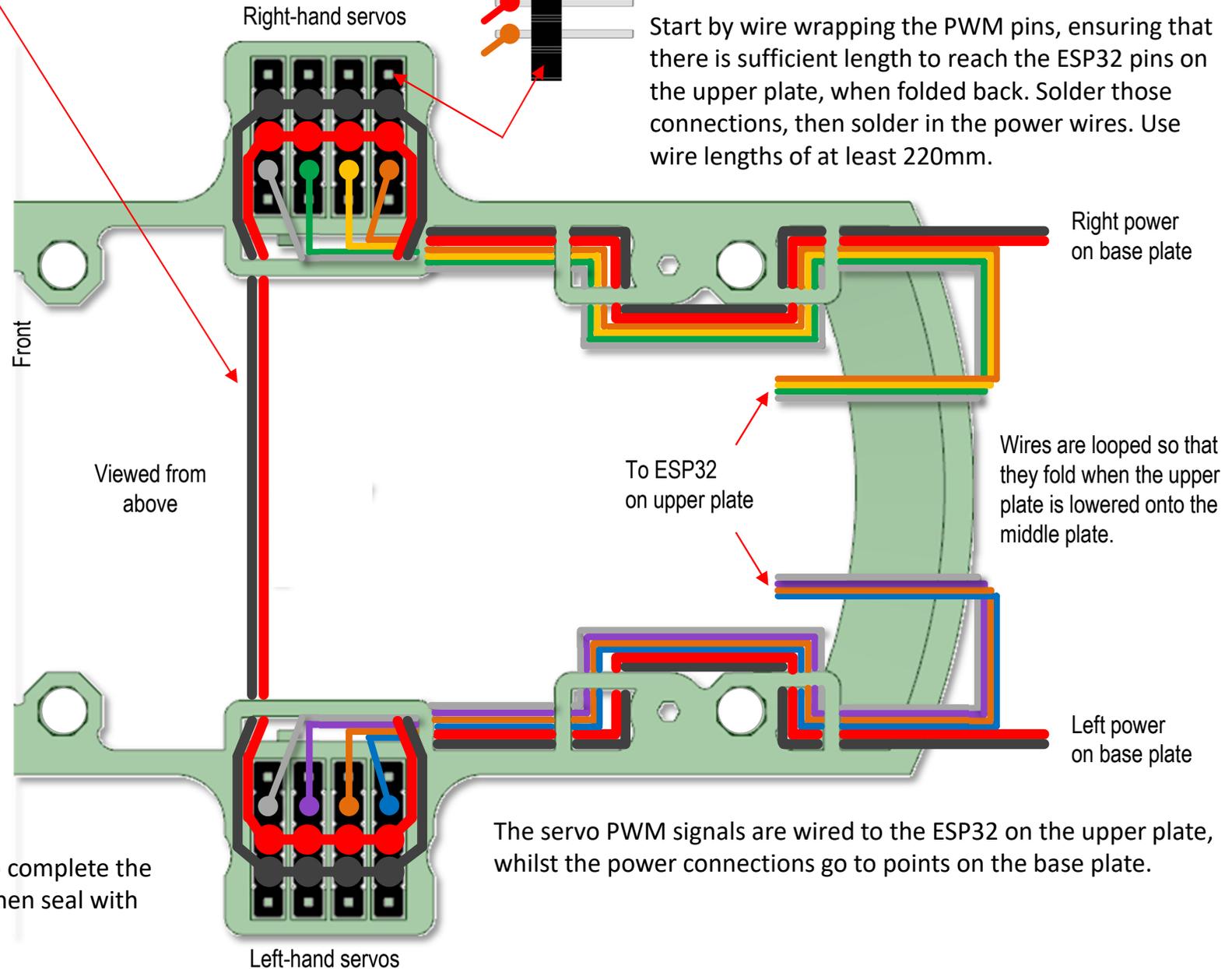
Having soldered the wire wrapped connections, connect the power leads. Shrink sleaving is used to prevent the wire from melting back.
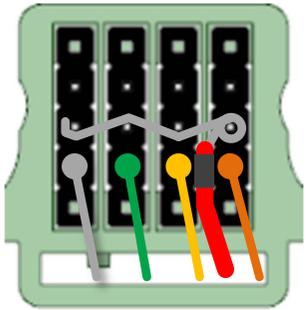
Use the first wire to link all 4 pins, then make the second connection at the other end. Take care soldering, and check for shorts at each stage.
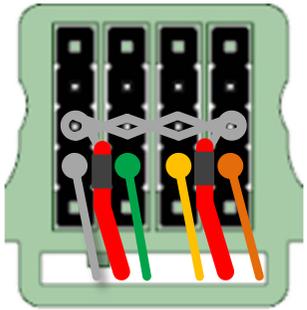
Repeat this process for the GND wire to complete the task. Check for s/c with a multimeter. Then seal with glue

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.

Right-hand servos

Front

Viewed from above

Right power on base plate

To ESP32 on upper plate

Wires are looped so that they fold when the upper plate is lowered onto the middle plate.

Left power on base plate

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

Left-hand servos

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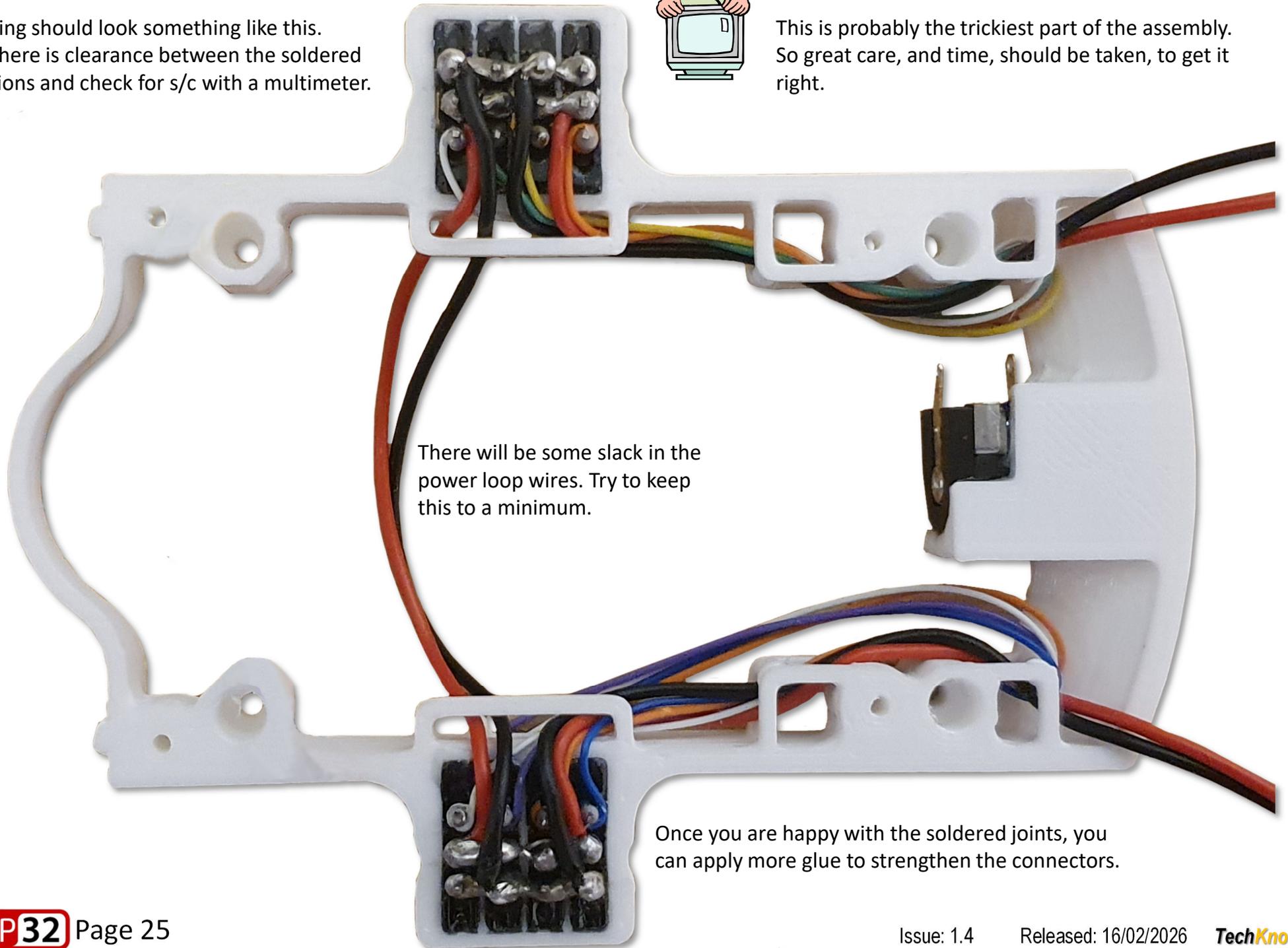
There will be some slack in the power loop wires. Try to keep this to a minimum.

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

Wiring Sequence

01

02

Once checked, encapsulate the pin strips in glue, to prevent pins from pushing out.

03
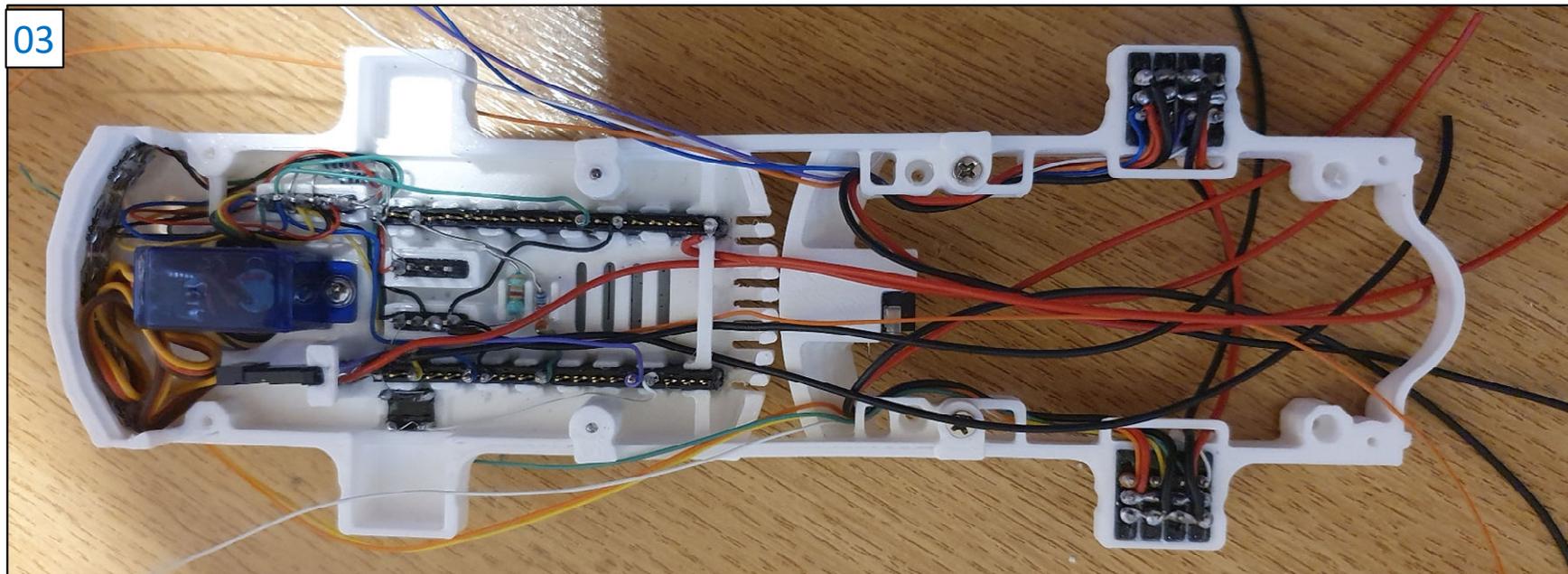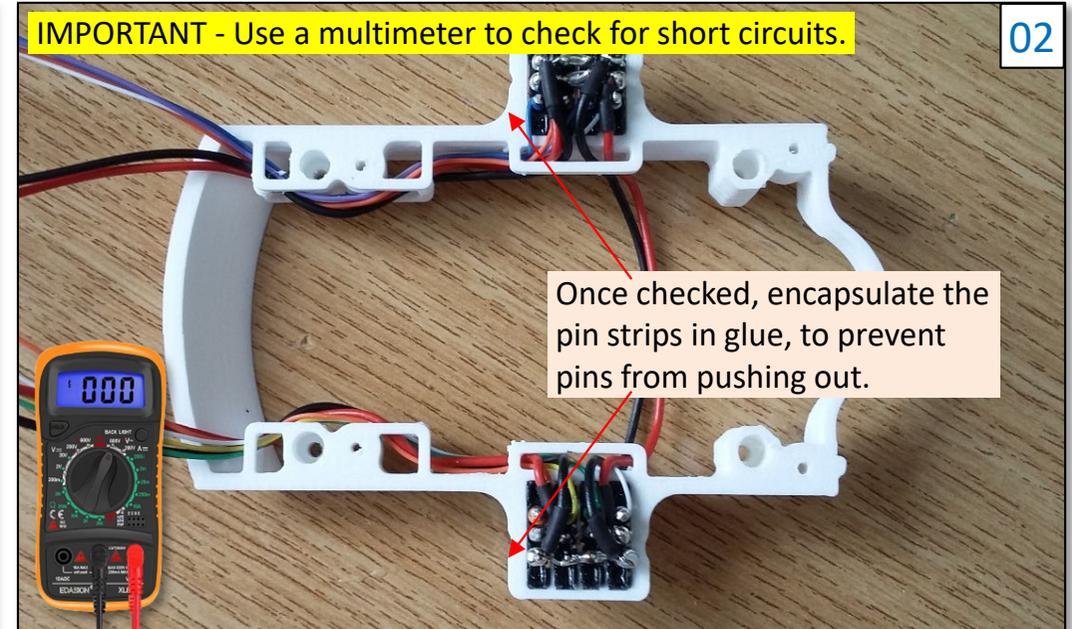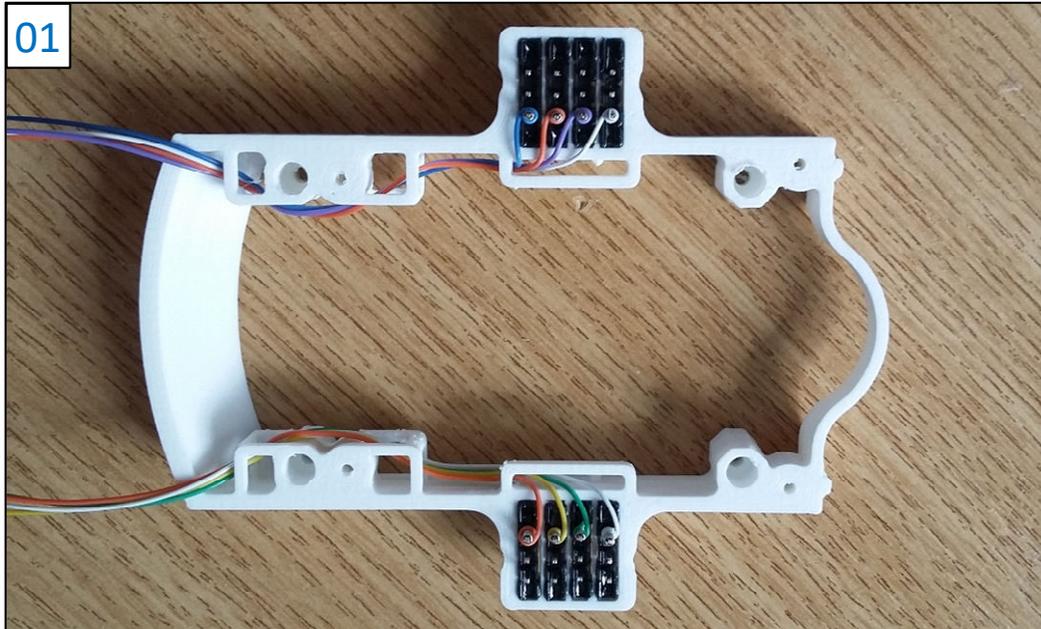
You can now use the custom support bars to connect the Middle plate to the Upper plate. This will make the wiring of the 8 servo connections much simple to do.
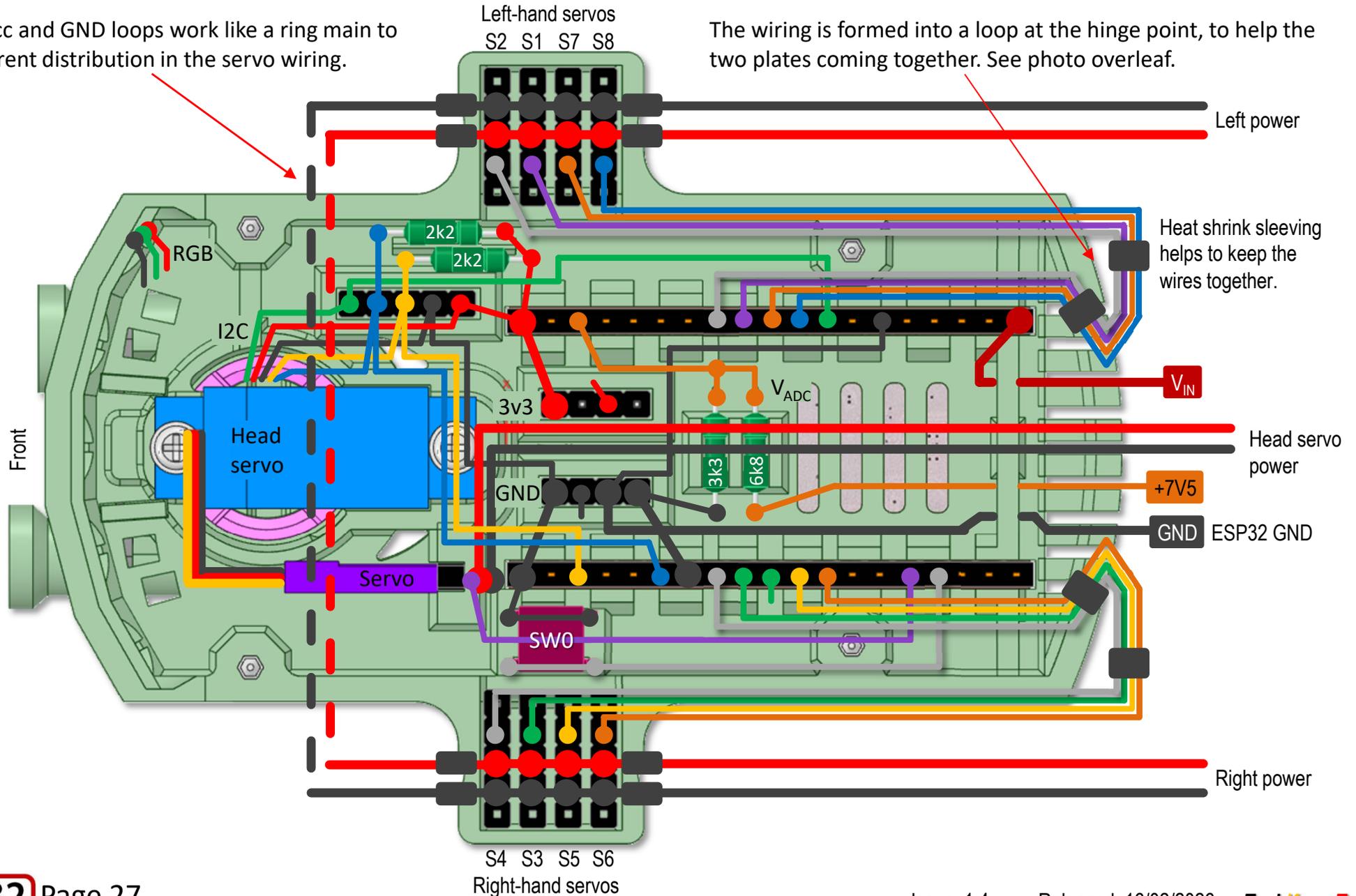
Upper/Middle Plate Wiring

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

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

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

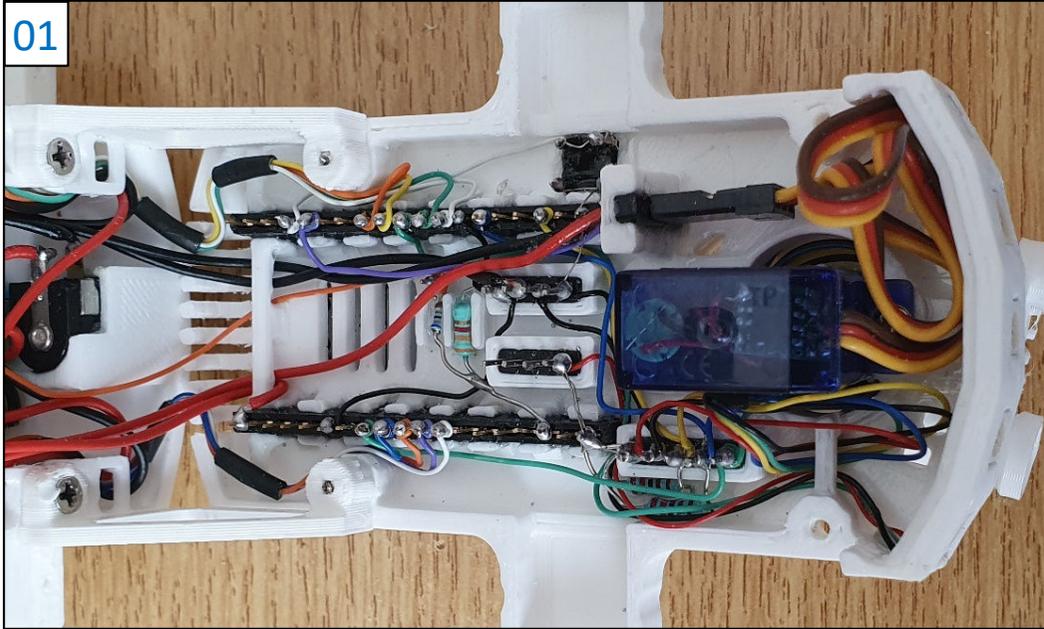The wiring is formed into a loop at the hinge point, to help the two plates coming together. See photo overleaf.

Left-hand servos
S2   S1   S7   S8

Left power

Heat shrink sleeving helps to keep the wires together.

RGB

2k2

2k2

I2C

V_{ADC}

3v3

V_{IN}

Head servo

Head servo power

3k3   6k8

GND

+7V5

Servo

GND   ESP32 GND

SW0
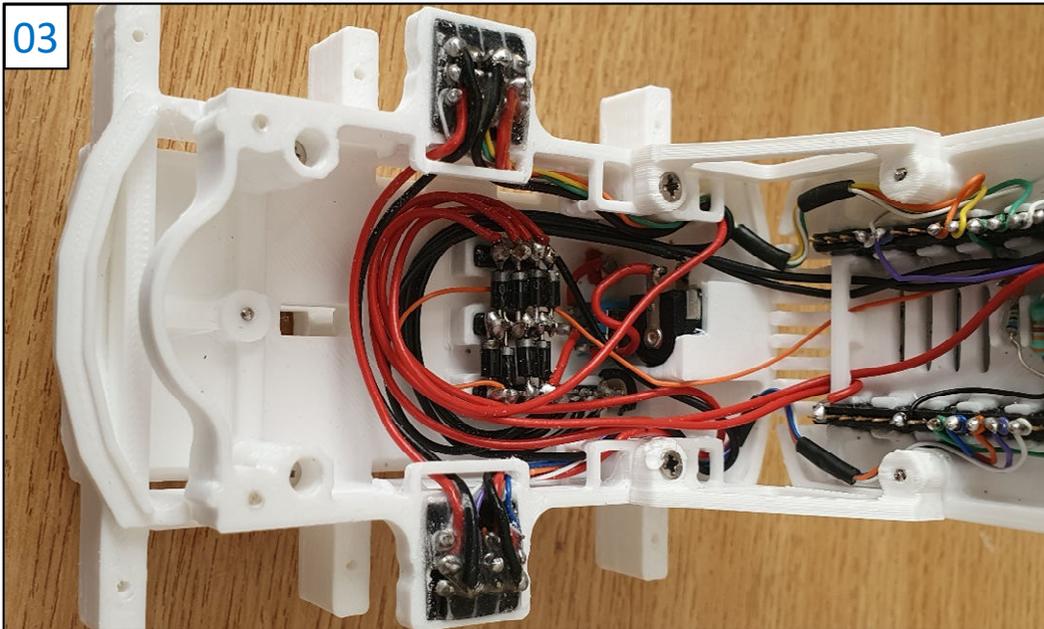
Right power

S4   S3   S5   S6

Right-hand servos
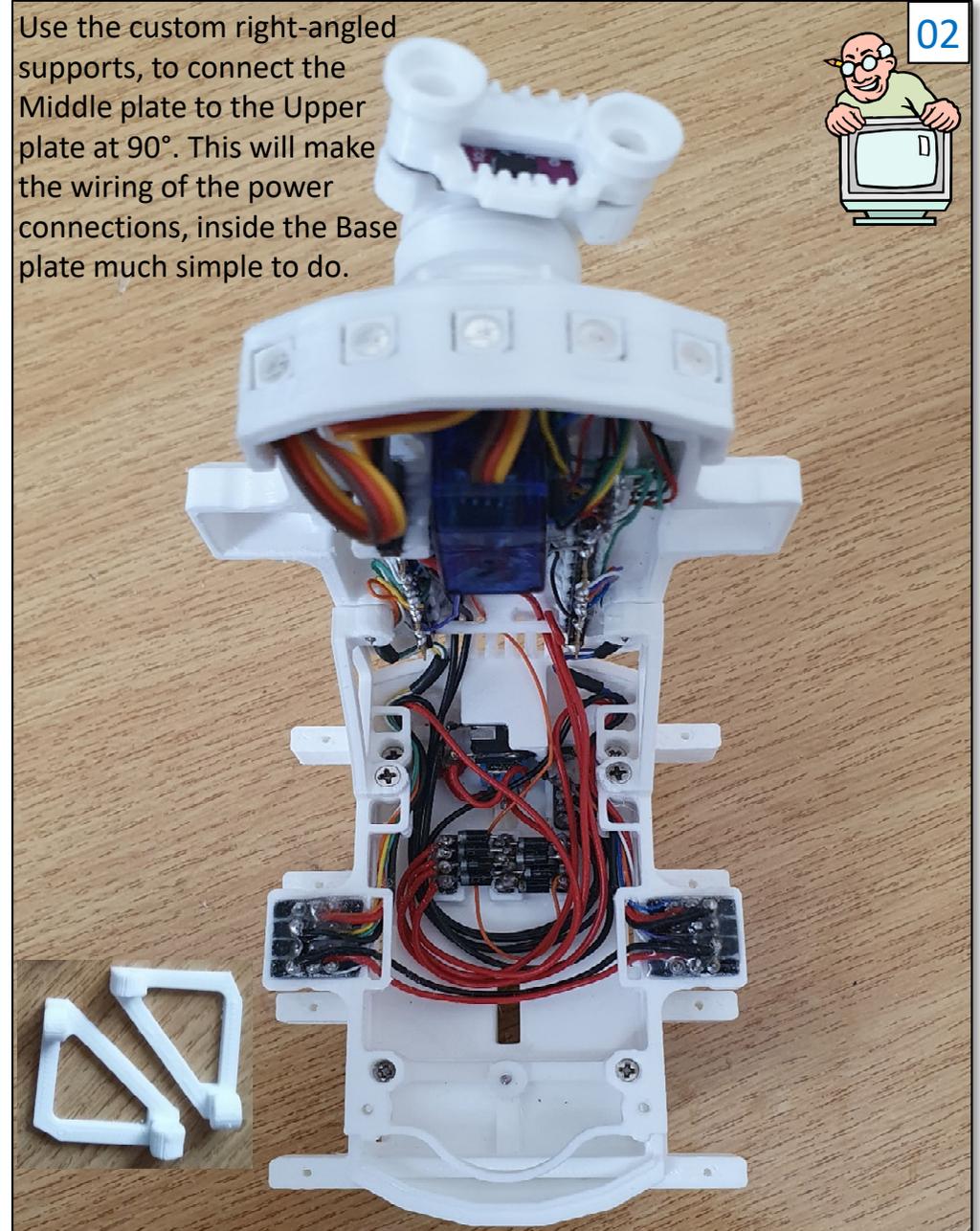
Wiring Sequence

01

02

Use the custom right-angled supports, to connect the Middle plate to the Upper plate at 90°. This will make the wiring of the power connections, inside the Base plate much simple to do.
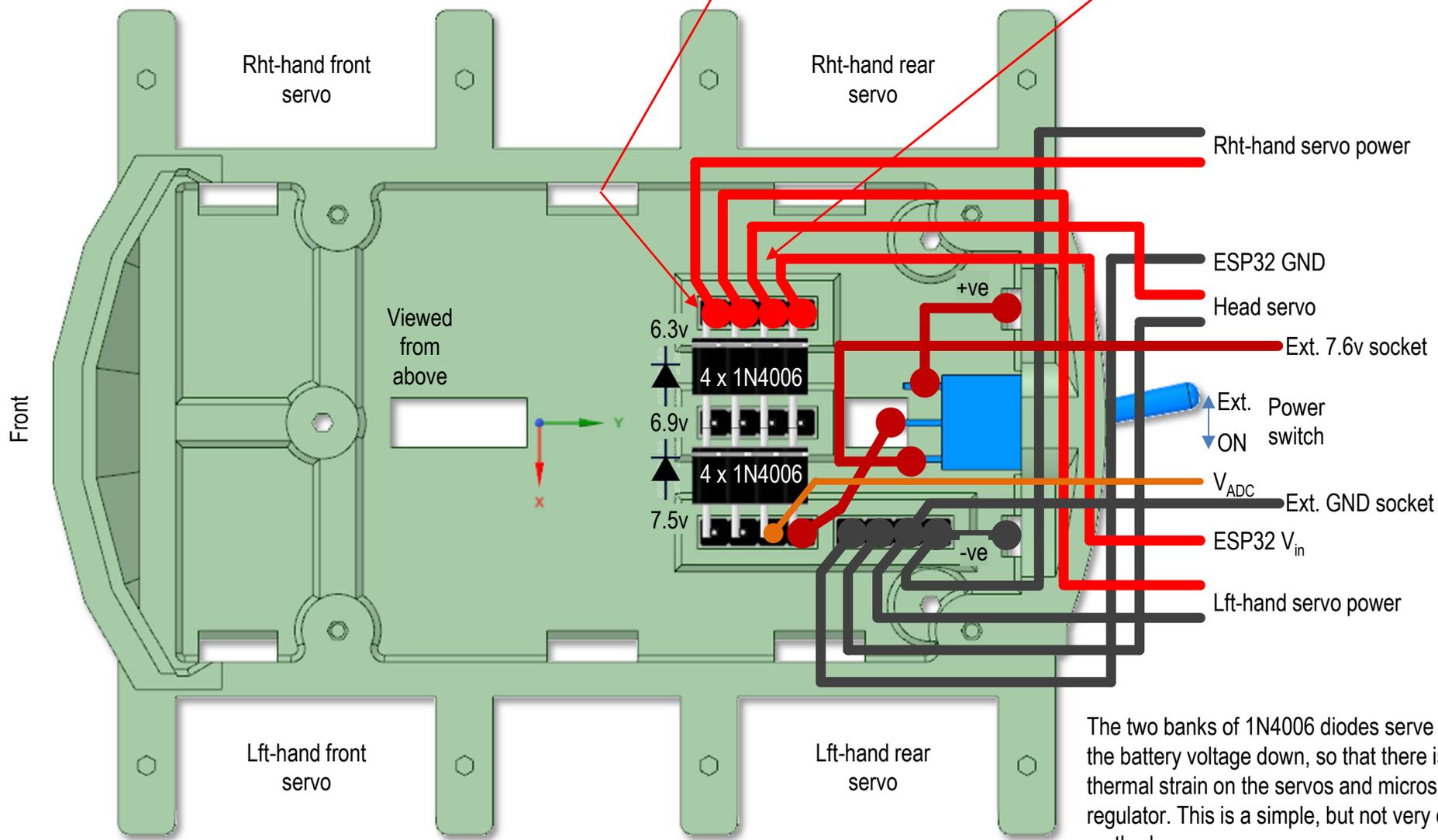

03

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
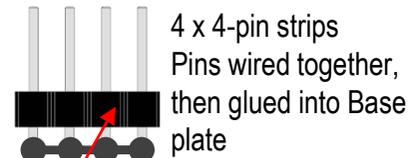
The power wires are looped round and soldered, as if from the front, so that they can move forward a little as the Upper plate is turned over and lowered onto the Base plate.

Rht-hand front servo

Rht-hand rear servo

Viewed from above

Front

6.3v

4 x 1N4006

6.9v

4 x 1N4006

7.5v

+ve

-ve

V_{ADC}

Rht-hand servo power

ESP32 GND

Head servo

Ext. 7.6v socket

Ext. Power switch

ON

Ext. GND socket

ESP32 V_{in}

Lft-hand servo power

Lft-hand front servo
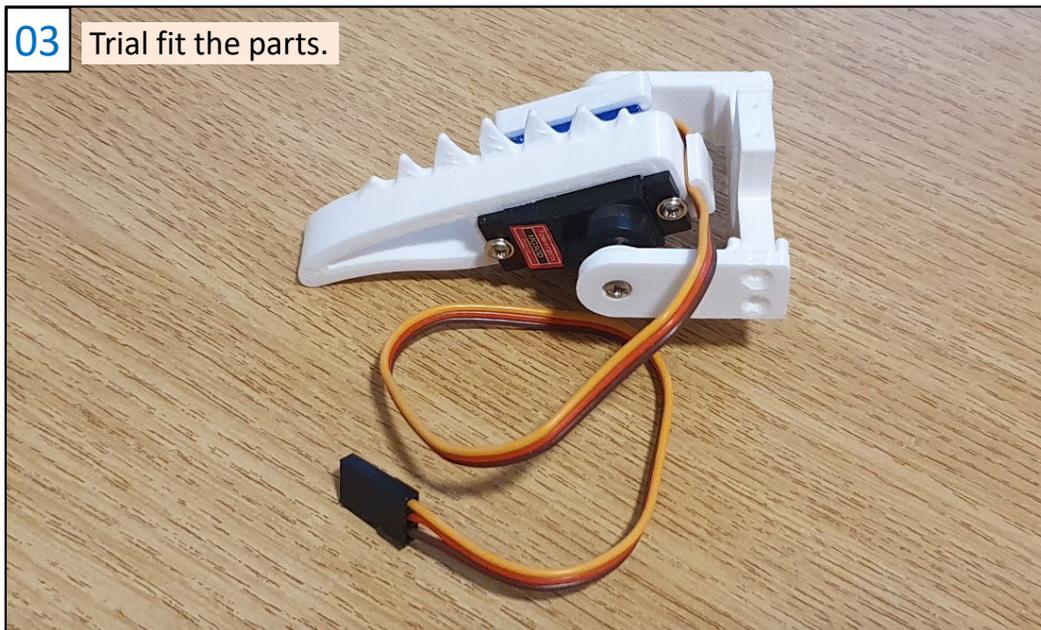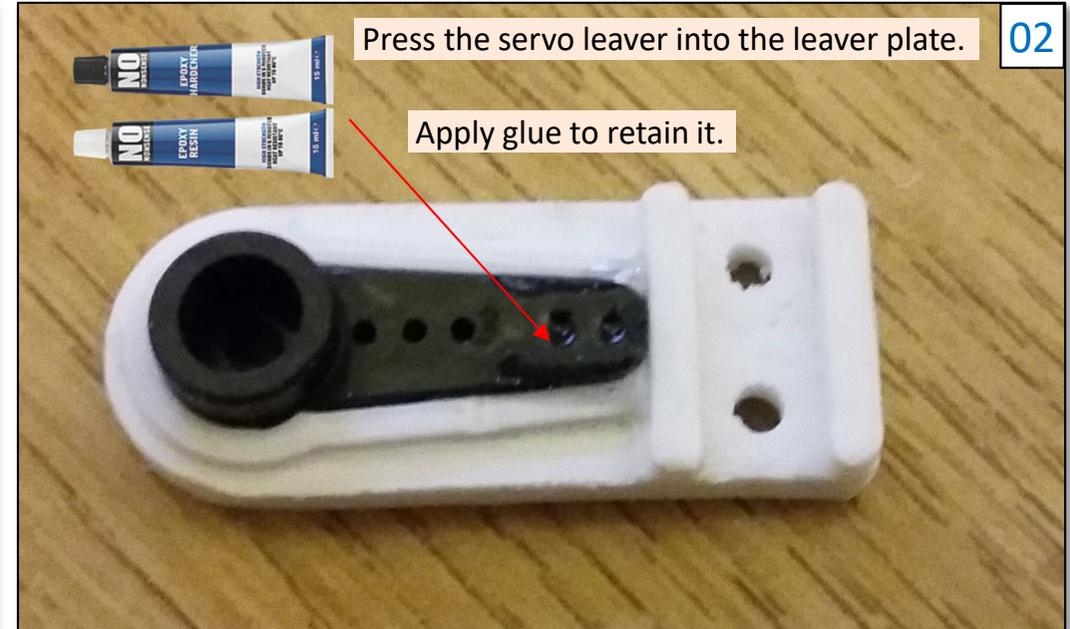
Lft-hand rear servo

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.
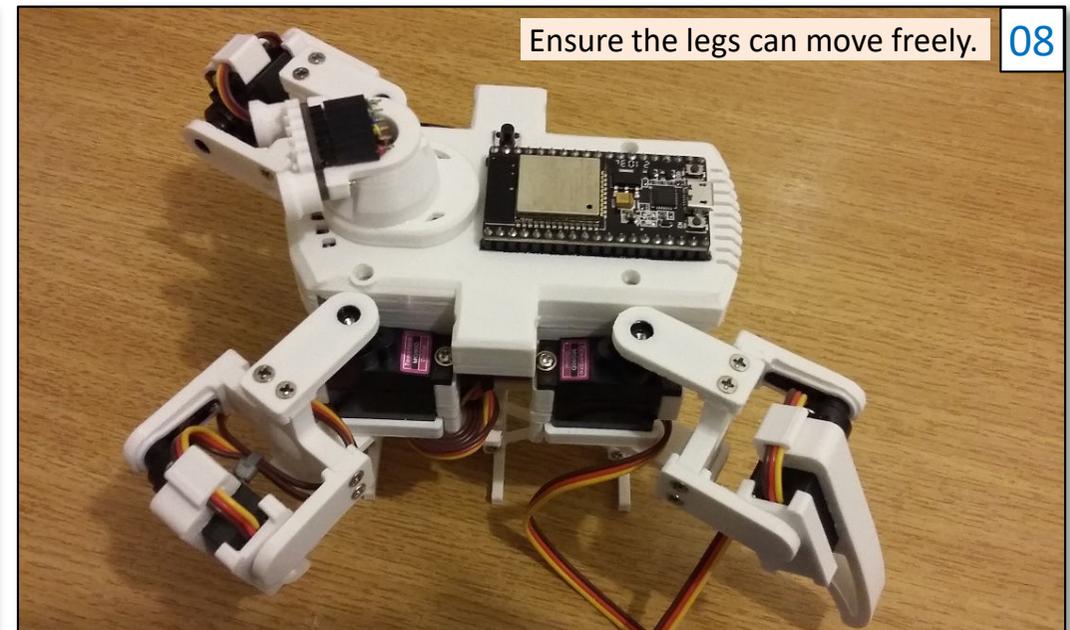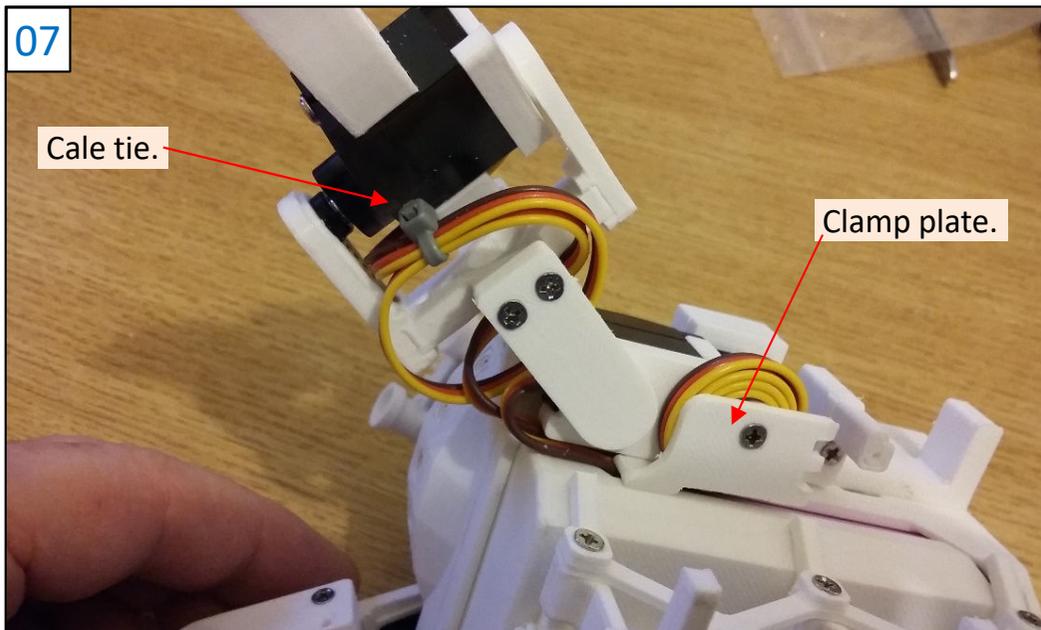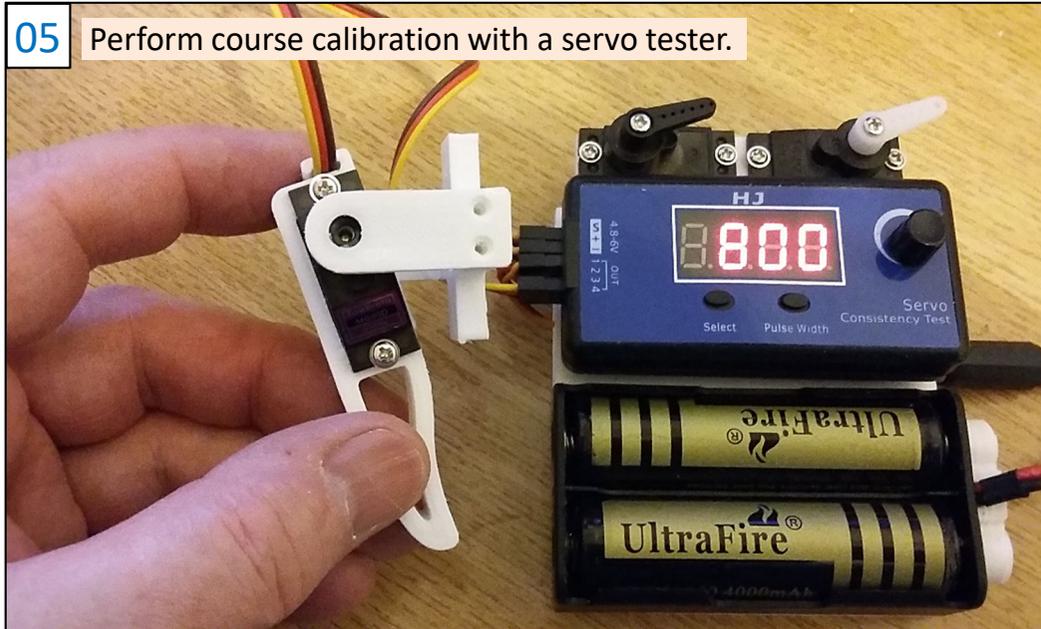
CAUTION LITHIUM BATTERY

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

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

01 Some parts shown here have been updated.

02 Press the servo leaver into the leaver plate.

Apply glue to retain it.

03 Trial fit the parts.

04 The servo leaver positions will need to be calibrated.

Issue: 1.4   Released: 16/02/2026   TechKnowTone

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

Cale tie.

Clamp plate.

08 Ensure the legs can move freely.
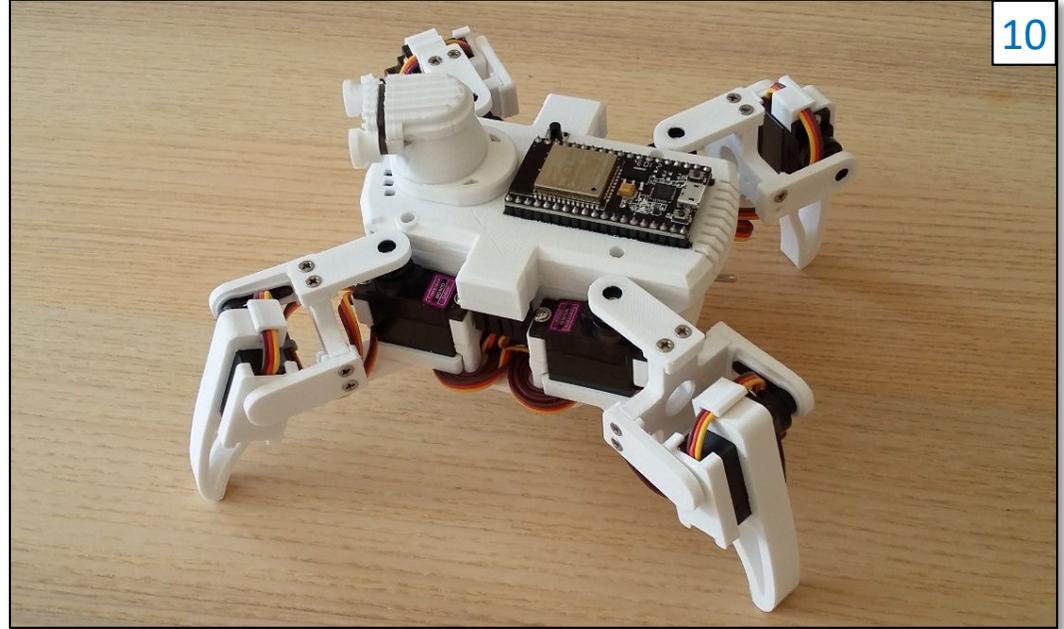
Build Sequence Photos
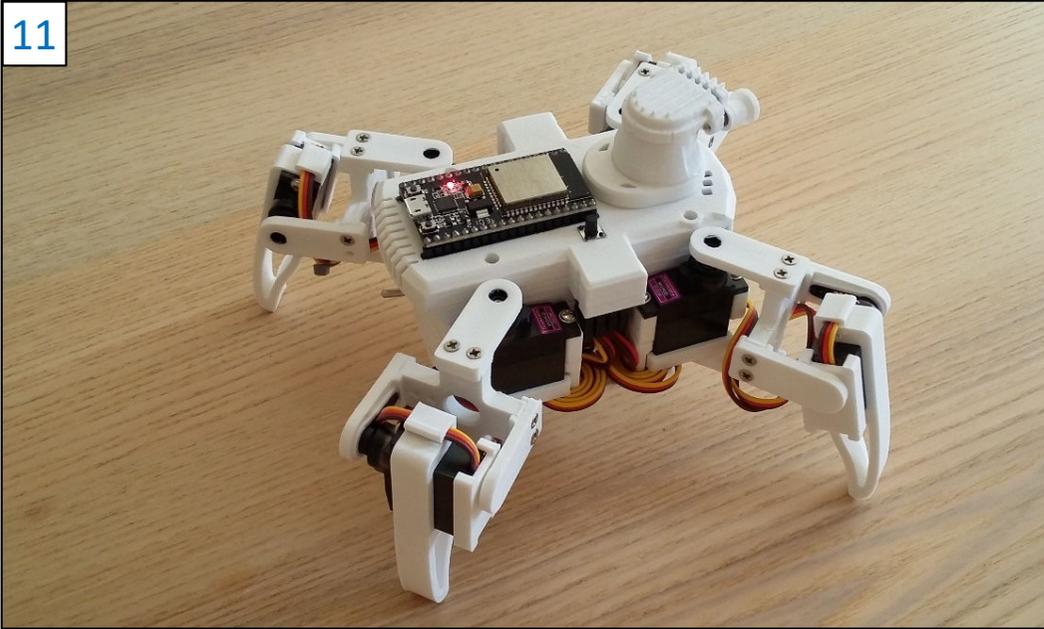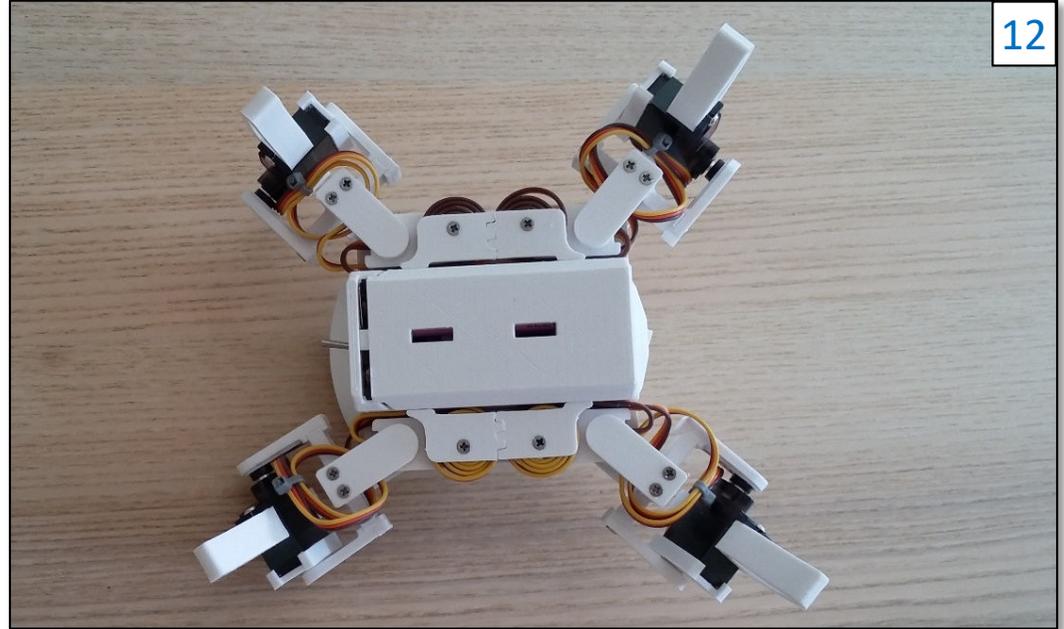
Battery Voltage Calibration

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)

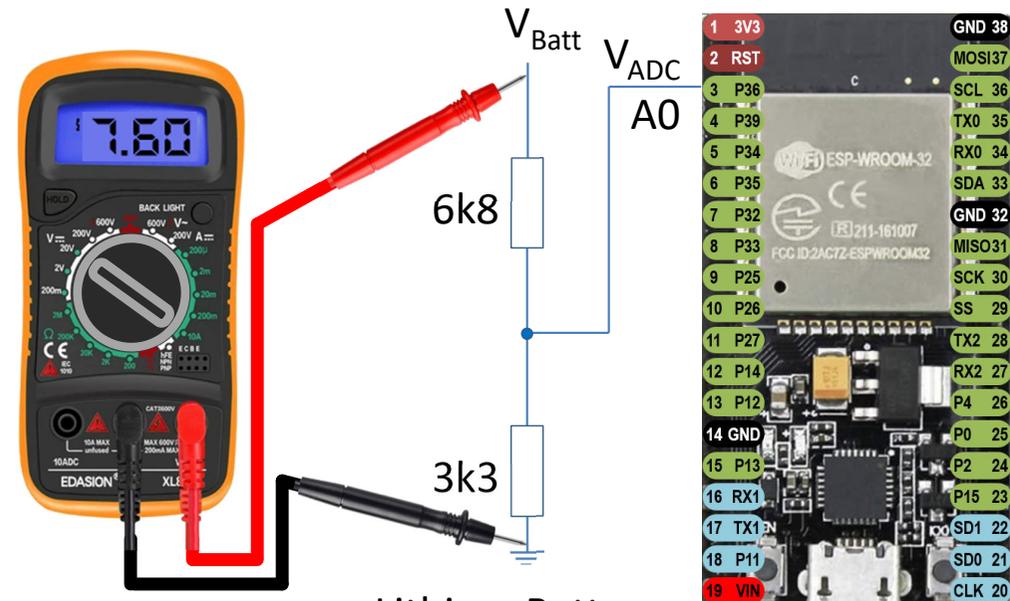HIGH: (80%) V_{H} = 7.8v, gave A0 = 2997 on V_{ADC} (2 x 3.9v)

WARNING: (20%) V_{BW} = 7.2v, gives A0 = 2762 on V_{ADC} (2 x 3.6v)

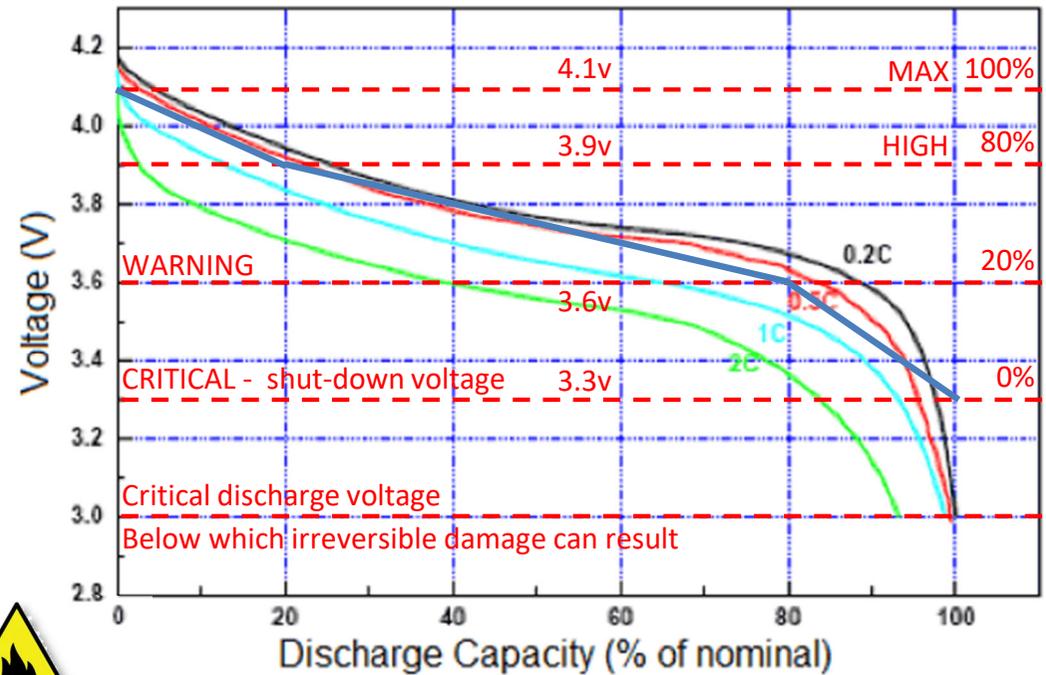CRITICAL: (0%) V_{BC} = 6.6v, gives A0 = 2513 on V_{ADC} (2 x 3.3v)

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.

V_{Batt} V_{ADC}
A0
6k8
3k3

Lithium Battery Discharge Profile

4.1v — MAX 100%
3.9v — HIGH 80%
WARNING
3.6v — 20%
CRITICAL - shut-down voltage   3.3v — 0%
Critical discharge voltage
Below which irreversible damage can result

Discharge: 3.0V cutoff at room temperature.

CAUTION LITHIUM BATTERY