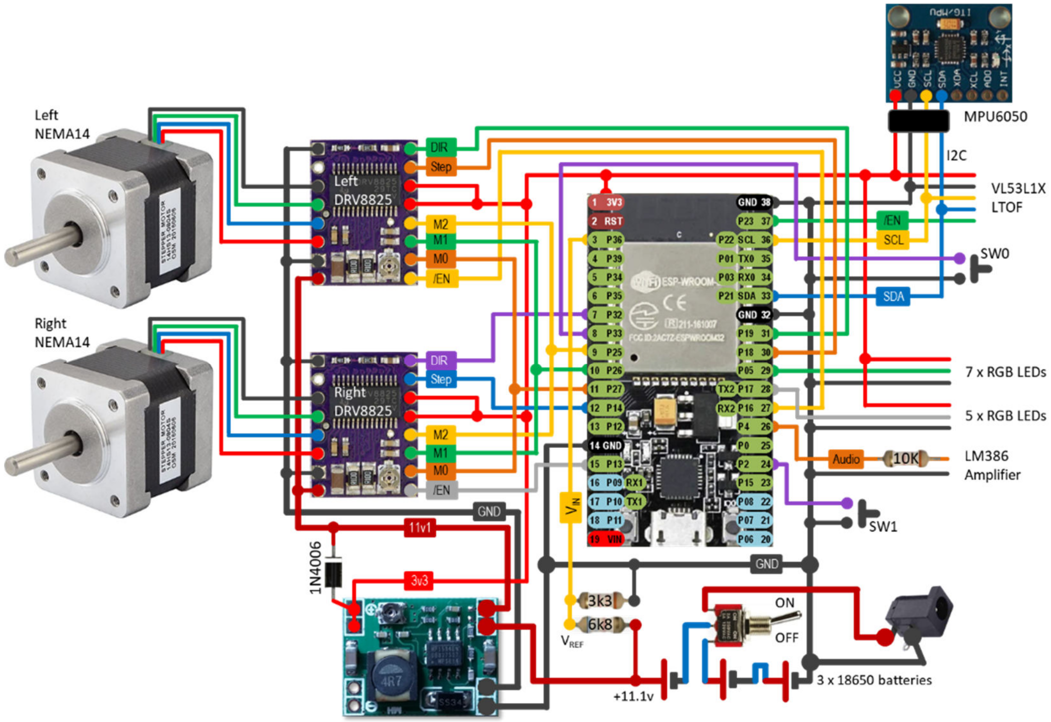
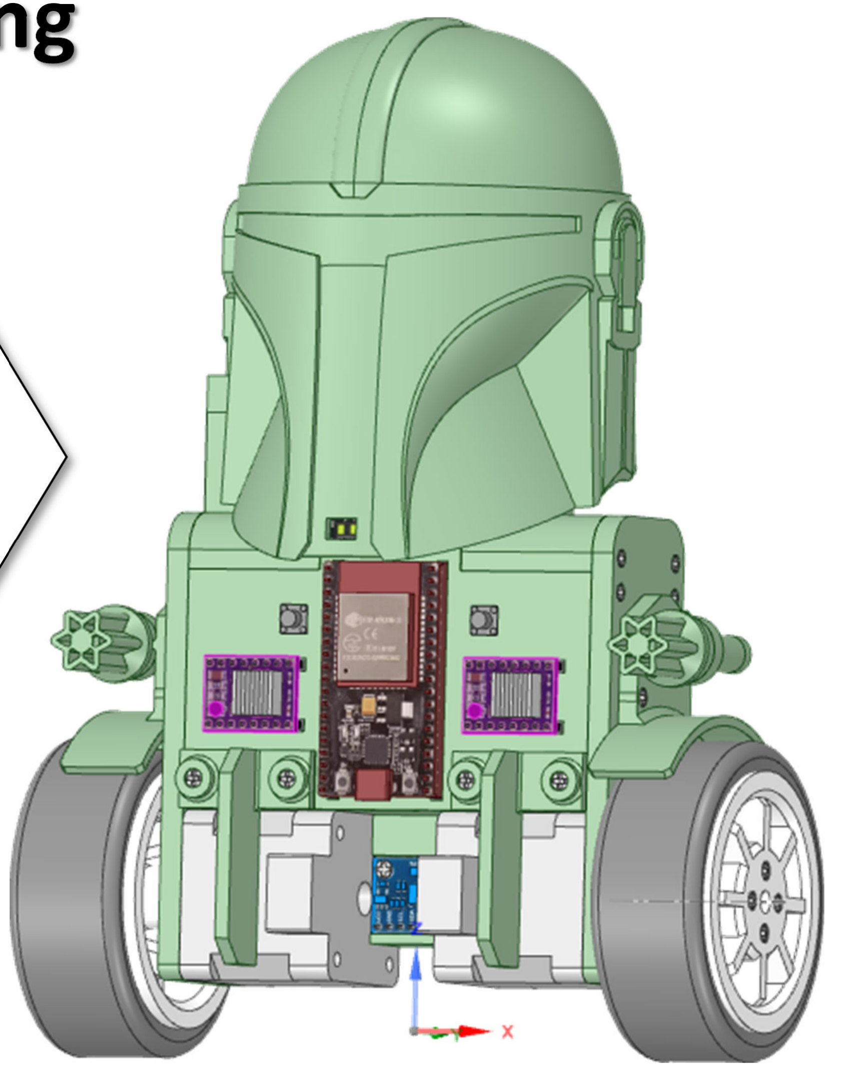
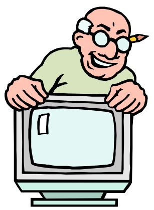
Project MandalBot BLE

Circuits & Wiring







Read through this documentation completely <u>before</u> attempting this project.

Issue: 1.0 Released: 21/10/2023 TechKnowTone

Hand Tools:

Recommended:
- Fine Nosed Pliers
- Side Cutters
- 1.5 mm Drill
- 2.0 mm Drill
- 2.4 mm Drill
- 4.0 mm Drill
- M3 Tap
- Needle Files
- Screwdrivers
- Craft Knife

Note: Not all items needed are shown here.

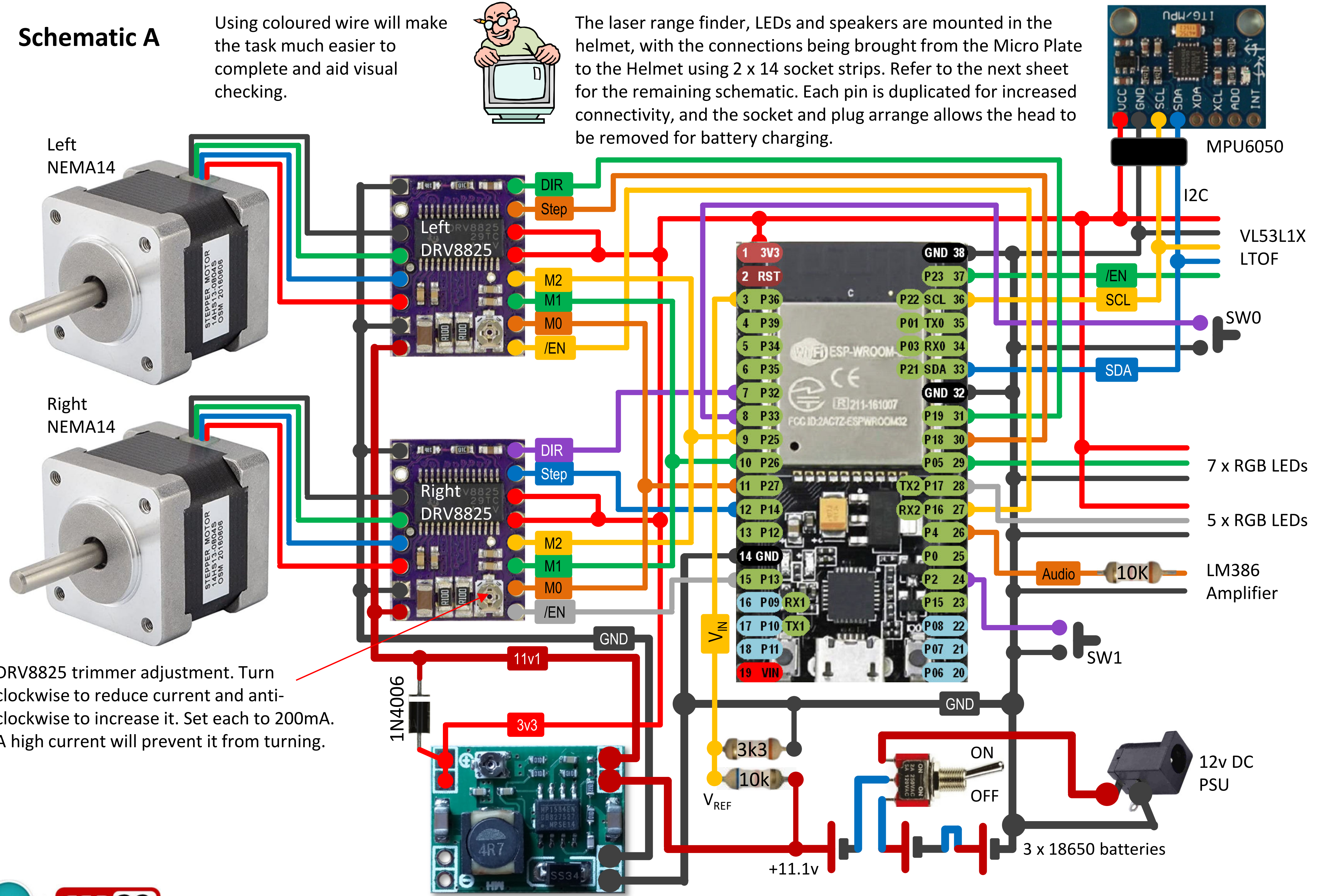
Tools & Materials:

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

Schematic A

Using coloured wire will make the task much easier to complete and aid visual checking.

The laser range finder, LEDs and speakers are mounted in the helmet, with the connections being brought from the Micro Plate to the Helmet using 2 x 14 socket strips. Refer to the next sheet for the remaining schematic. Each pin is duplicated for increased connectivity, and the socket and plug arrange allows the head to be removed for battery charging.

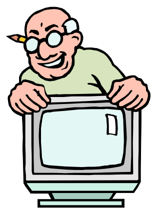


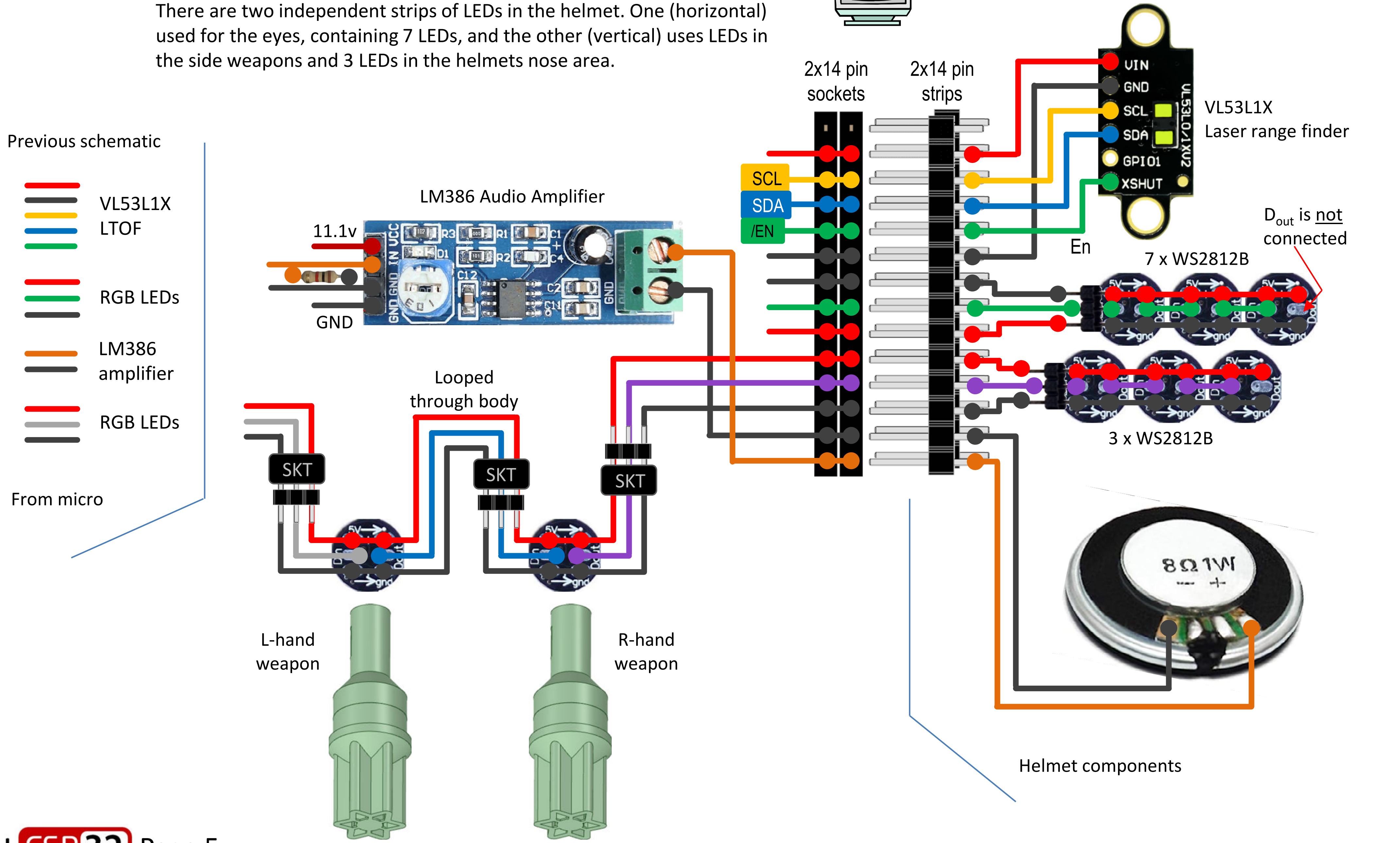
DRV8825 trimmer adjustment. Turn clockwise to reduce current and anti-clockwise to increase it. Set each to 200mA. A high current will prevent it from turning.

Schematic B

A number of components are mounted within the Mandalorian helmet. They are fed from a connector, which concentrates all of the wires coming up through the micro plate.

There are two independent strips of LEDs in the helmet. One (horizontal) used for the eyes, containing 7 LEDs, and the other (vertical) uses LEDs in the side weapons and 3 LEDs in the helmets nose area.





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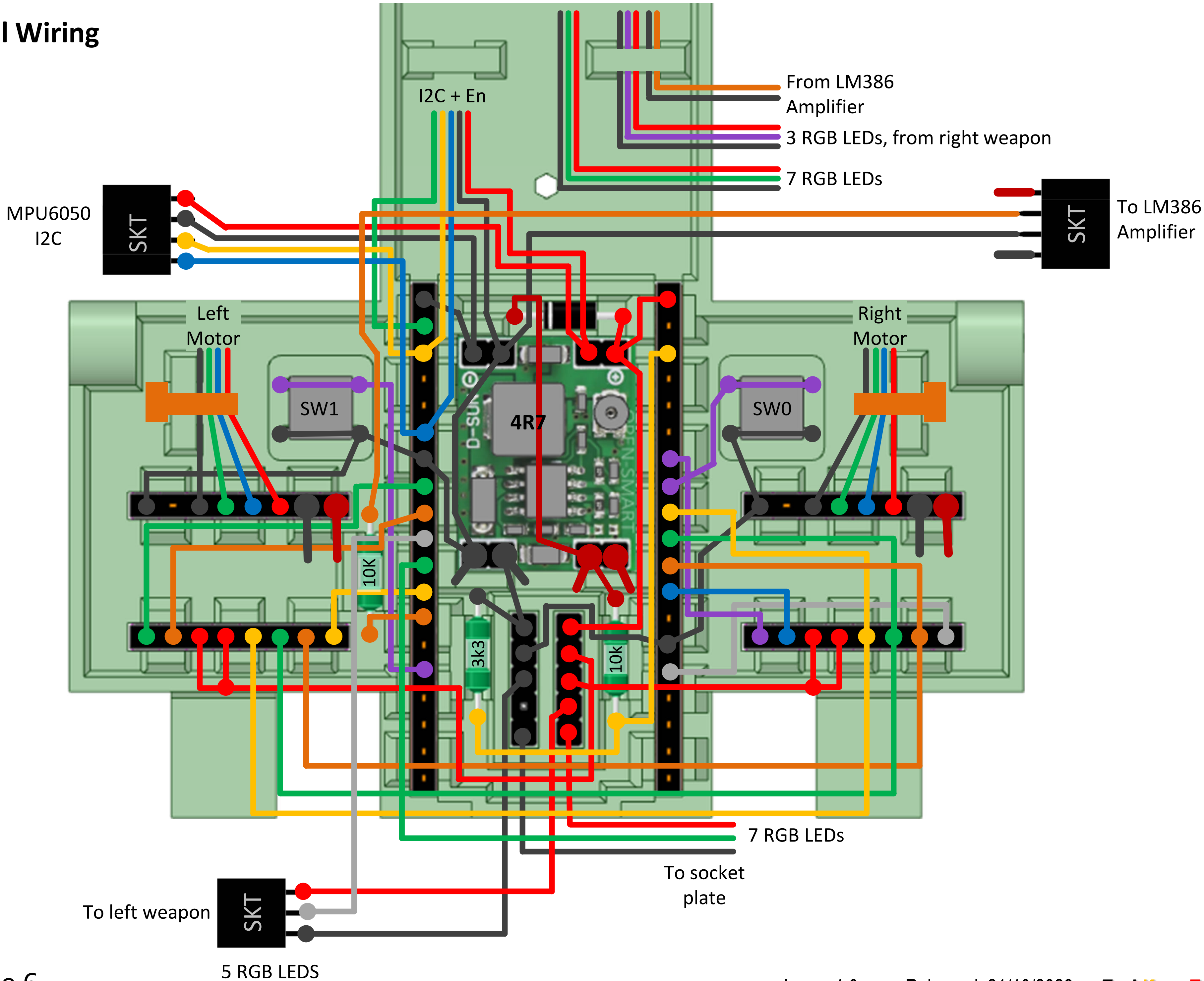
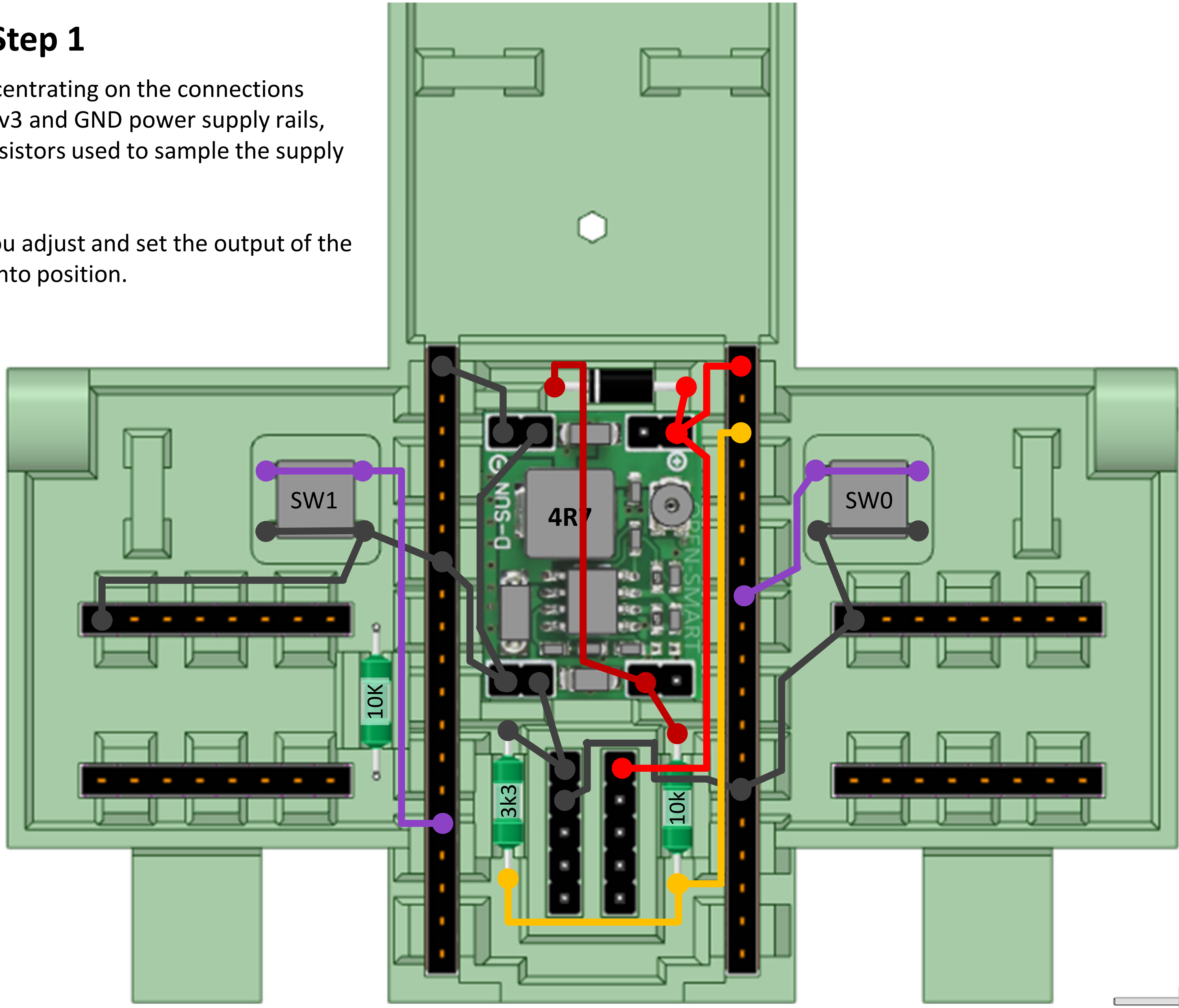
Micro Plate Total Wiring

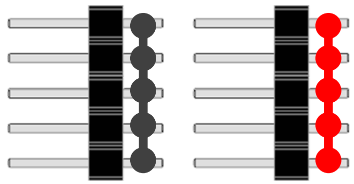


Micro Plate Wiring - Step 1

Start the wiring process by concentrating on the connections shown here. This includes the 3v3 and GND power supply rails, plus the button switches and resistors used to sample the supply voltage.

Note it is recommended that you adjust and set the output of the 3v3 regulator prior to gluing it into position.

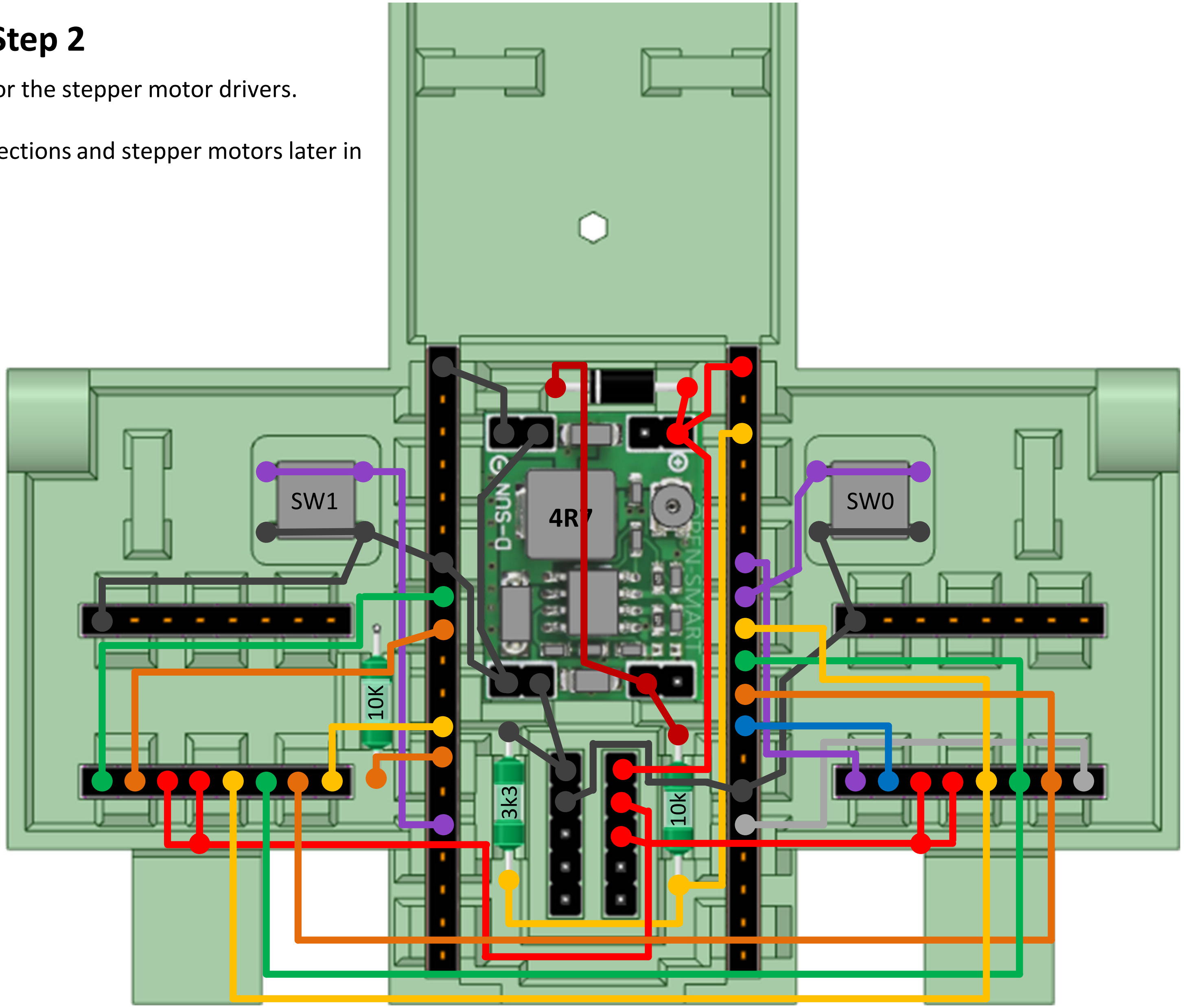




Micro Plate Wiring - Step 2

Now wire in the control wires for the stepper motor drivers.

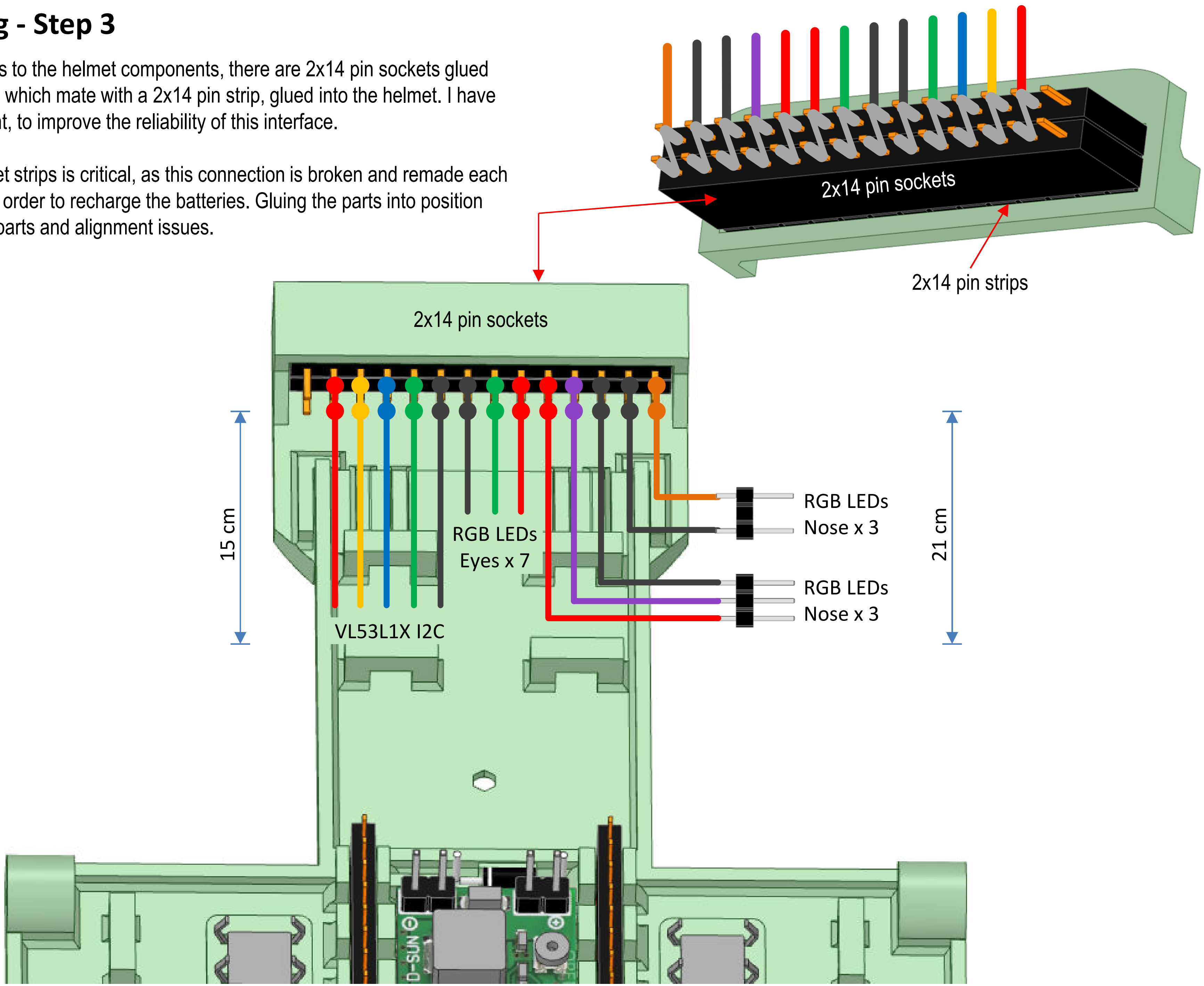
We will wire in the power connections and stepper motors later in the process.



Micro Plate Wiring - Step 3

To carry the circuit connections to the helmet components, there are 2x14 pin sockets glued into the end of the micro plate, which mate with a 2x14 pin strip, glued into the helmet. I have used a double pin arrangement, to improve the reliability of this interface.

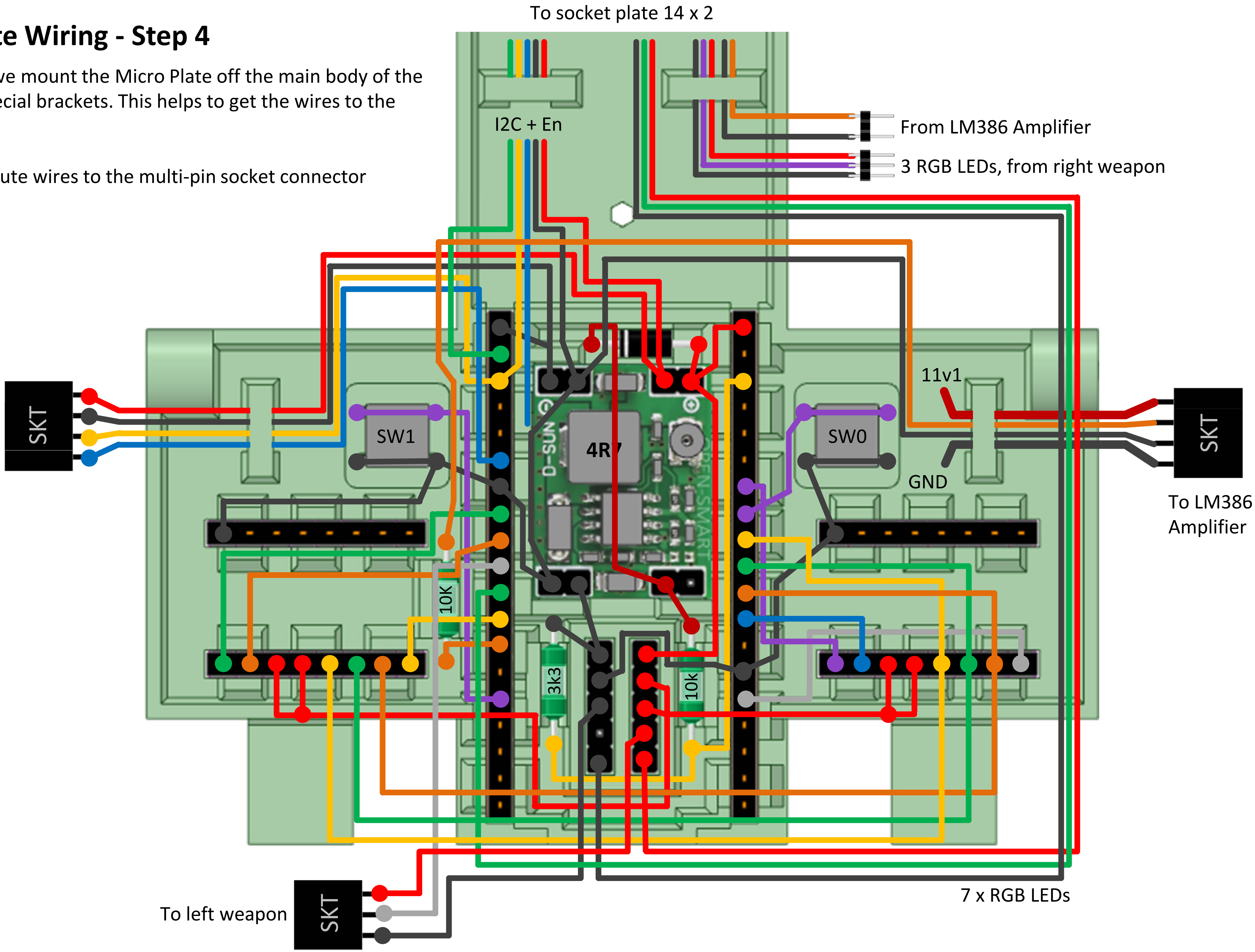
Alignment of the pin and socket strips is critical, as this connection is broken and remade each time the helmet is removed, in order to recharge the batteries. Gluing the parts into position allows for overall tolerance in parts and alignment issues.



Micro Plate Wiring - Step 4

For this stage we mount the Micro Plate off the main body of the robot using special brackets. This helps to get the wires to the correct length.

Now we can route wires to the multi-pin socket connector



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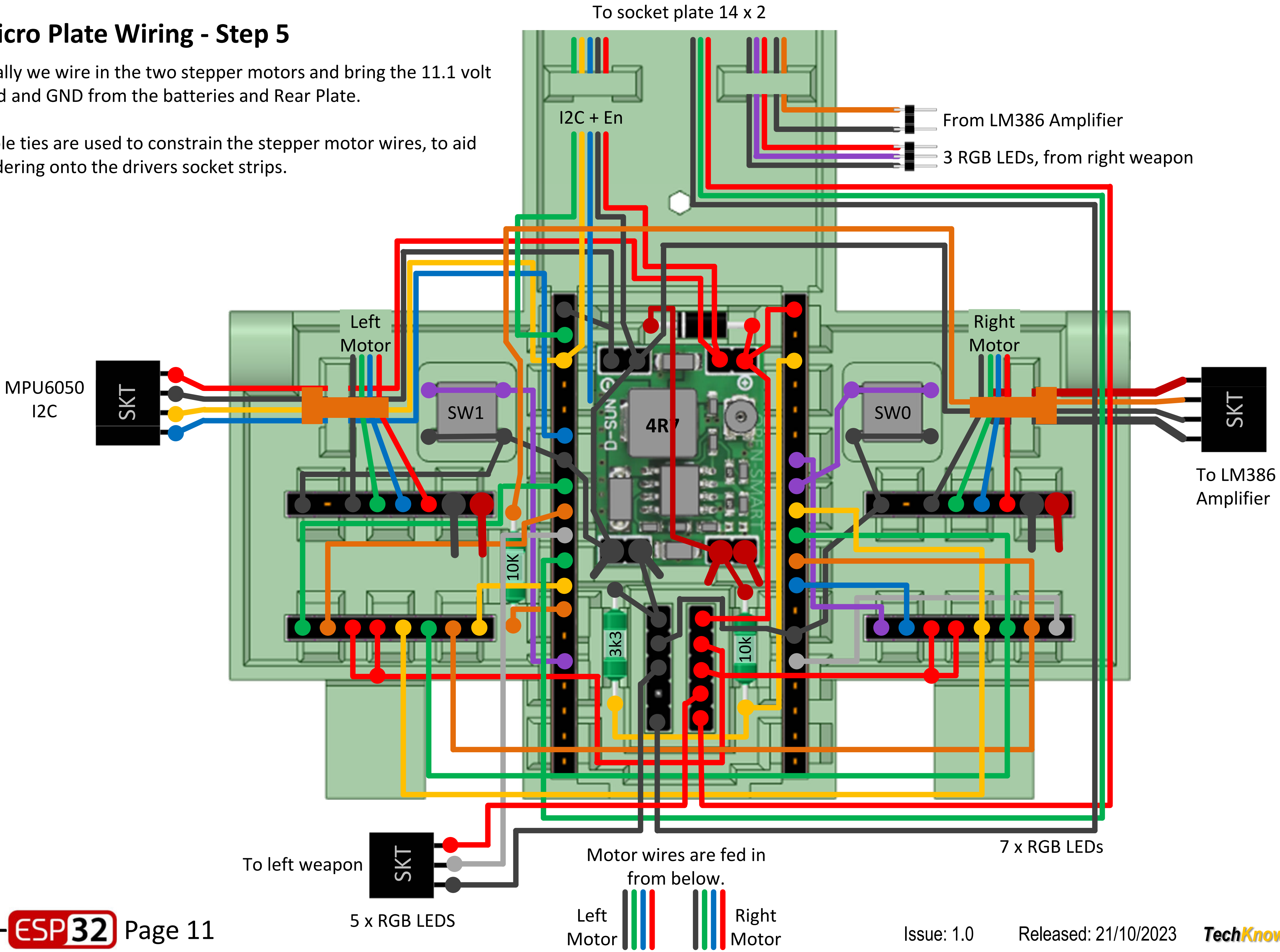
Micro Plate Wiring - Step 5

Finally we wire in the two stepper motors and bring the 11.1 volt feed and GND from the batteries and Rear Plate.

Cable ties are used to constrain the stepper motor wires, to aid soldering onto the drivers socket strips.



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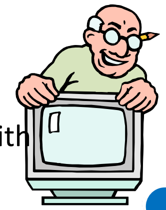
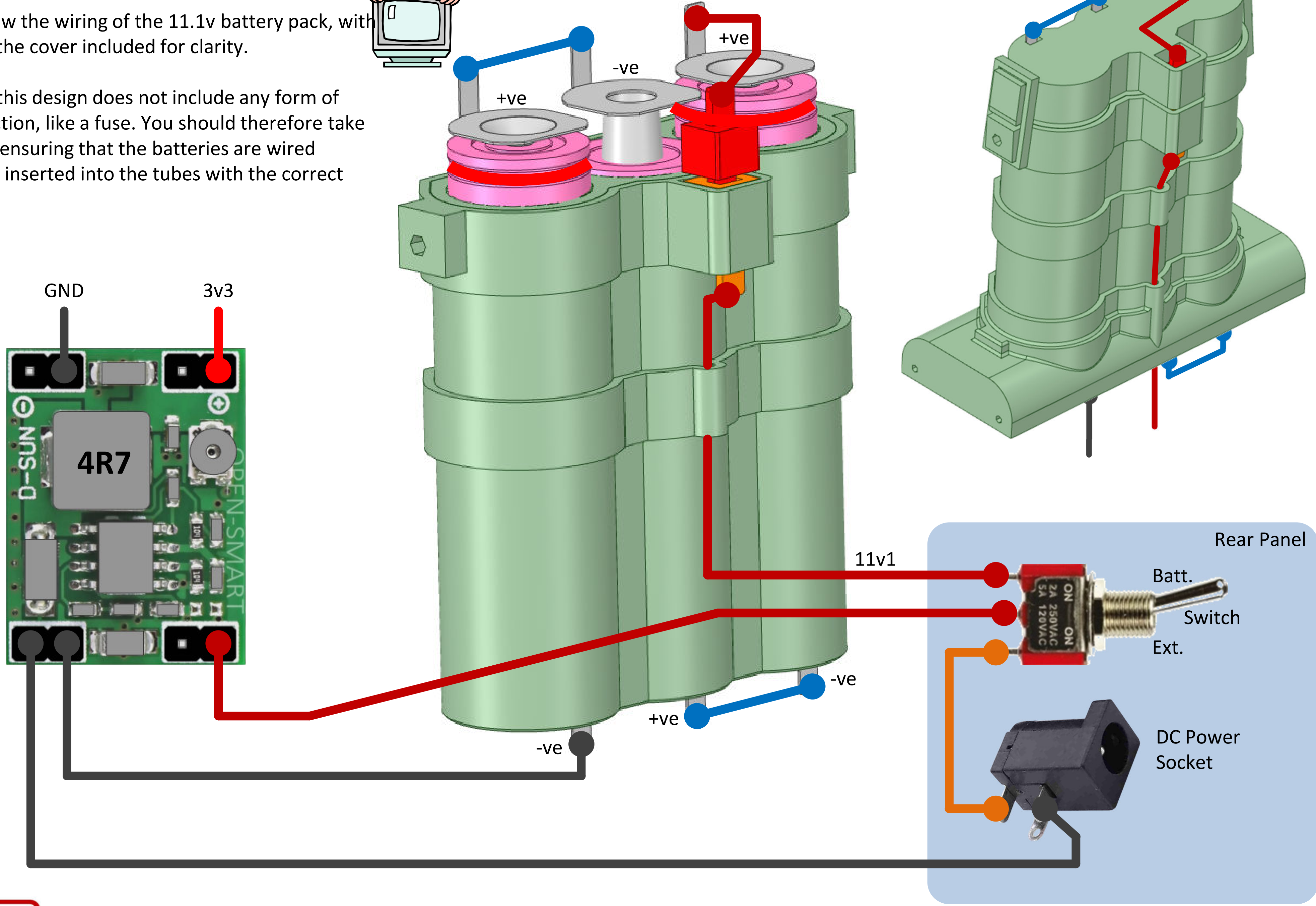
Battery Pack Wiring

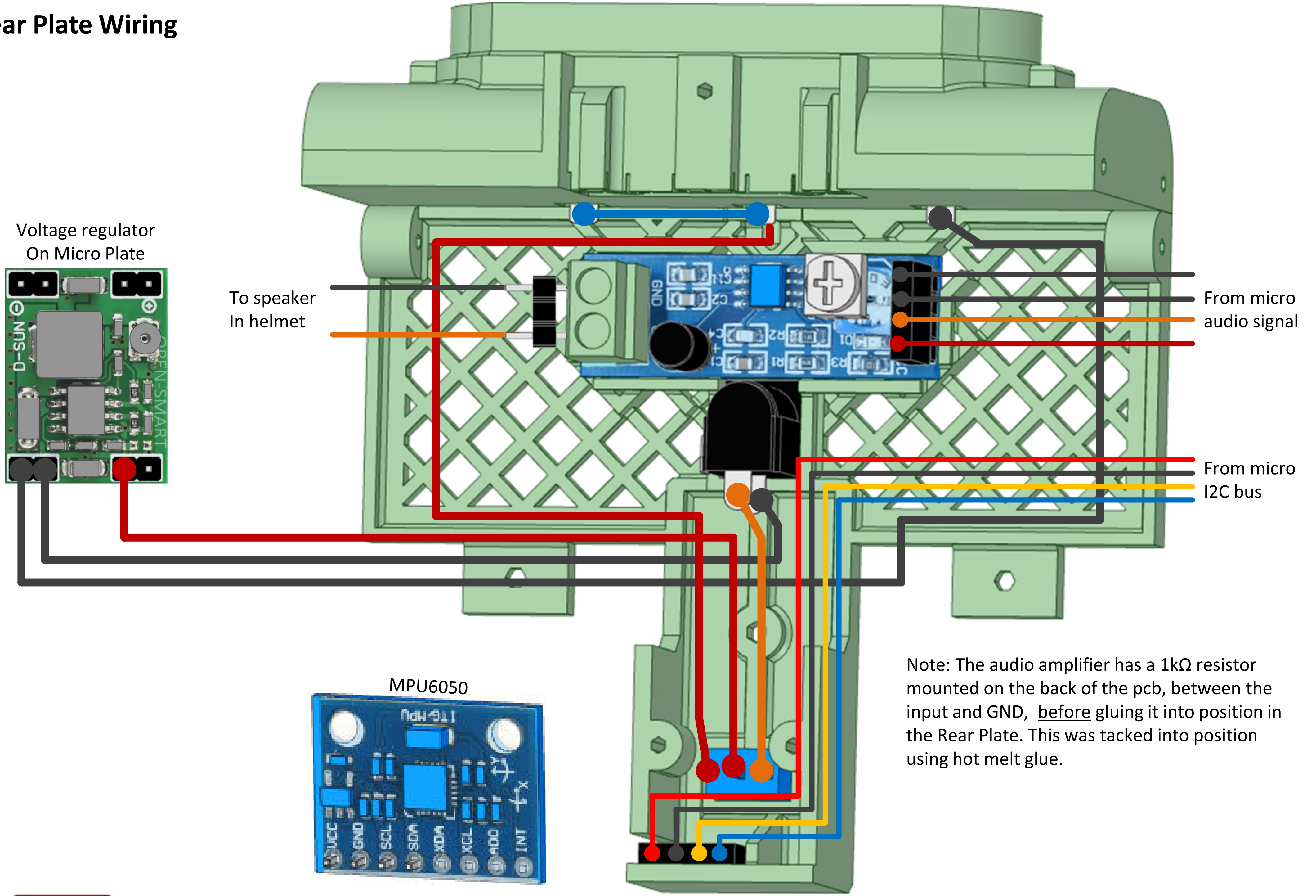
This slide show the wiring of the 11.1v battery pack, with and without the cover included for clarity.

WARNING – this design does not include any form of circuit protection, like a fuse. You should therefore take great care in ensuring that the batteries are wired correctly and inserted into the tubes with the correct polarity.



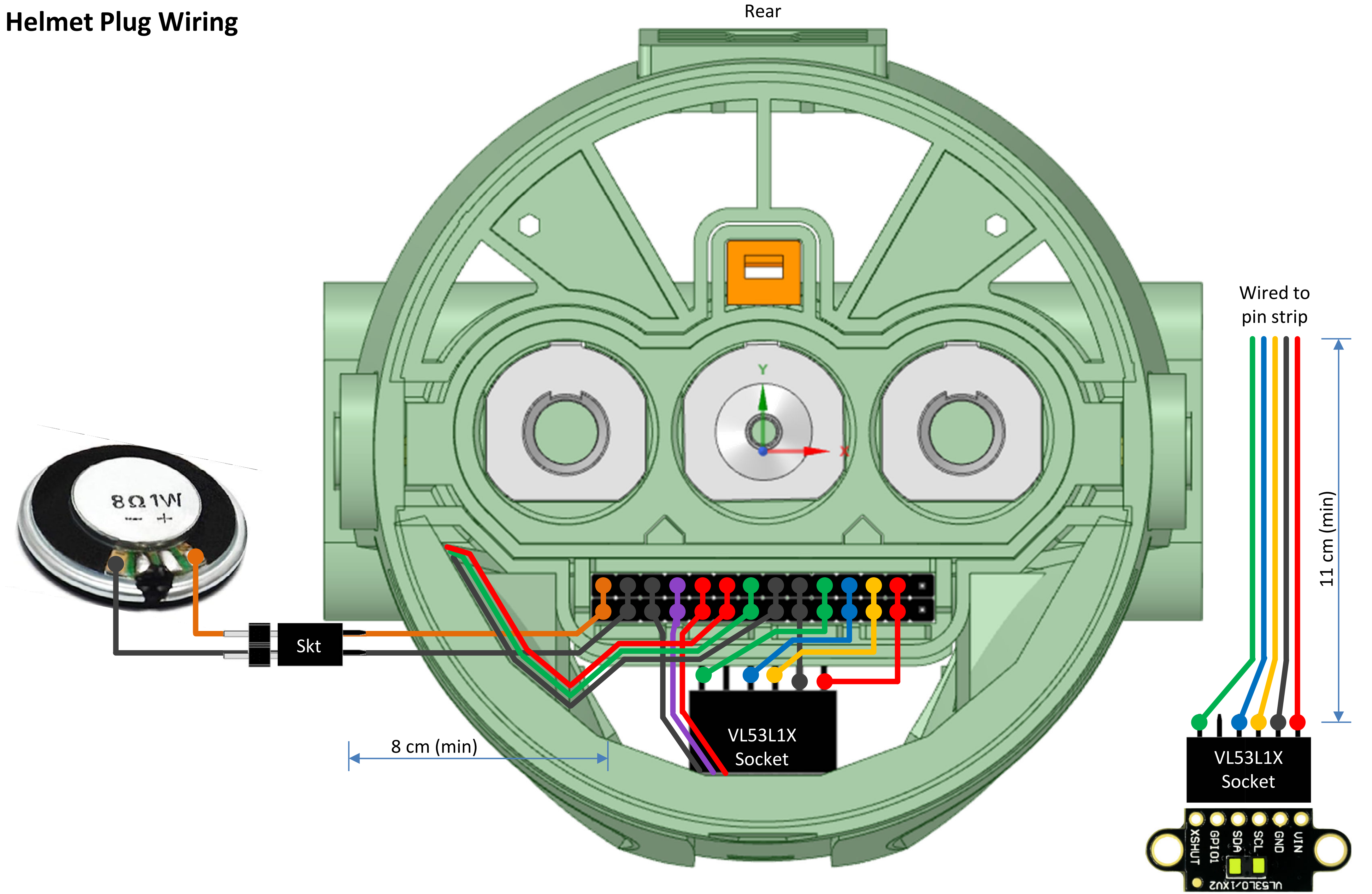


Rear Plate Wiring



Note: The audio amplifier has a 1kΩ resistor mounted on the back of the pcb, between the input and GND, <u>before</u> gluing it into position in the Rear Plate. This was tacked into position using hot melt glue.

Helmet Plug Wiring



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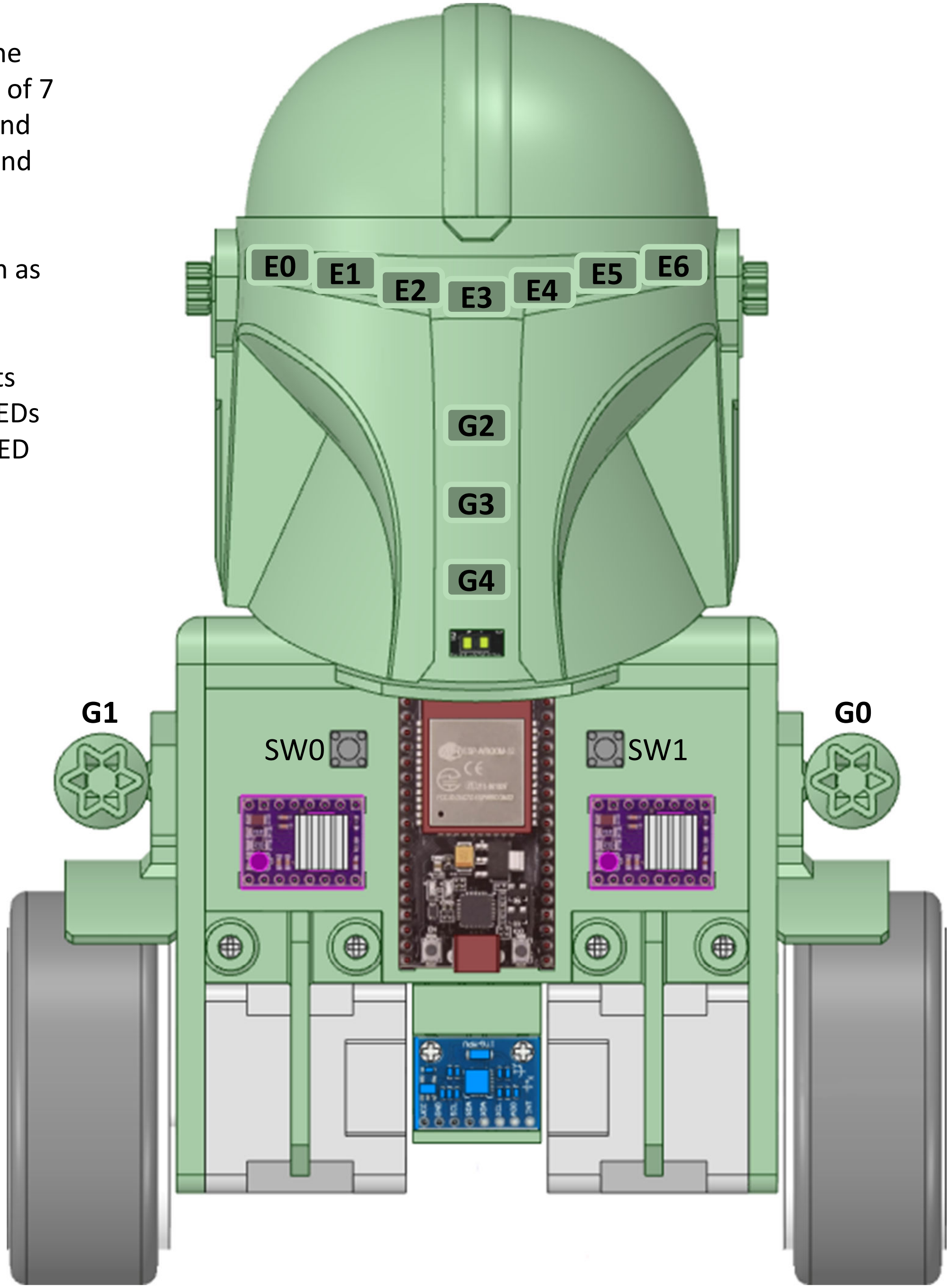
LED Assignments

The LED strips are driven by the ESP32 code as two separate FastLED entities, albeit normally updated at the same time; but not always. The code defines two strips of 7 LEDs in each. One is defined as the Guns_LED[] array, and the other as the Eyes_LED[] array. The left and right-hand gun LEDs are in the same strip as are those in the nose/mouth region. And the Guns_LED[] strip is only 5 LEDs long, not 7; but for simplicity the code treats them as if there were 7 LEDs in that strip.

Given the wiring inside the helmet, the LED assignments are as shown here. Where En references refer to eye LEDs and Gn references refer to gun references. So the G0 LED refers to the FastLED reference Guns_LED[0].

It is important that you understand this, if you wish to write LED sequences for your robot.



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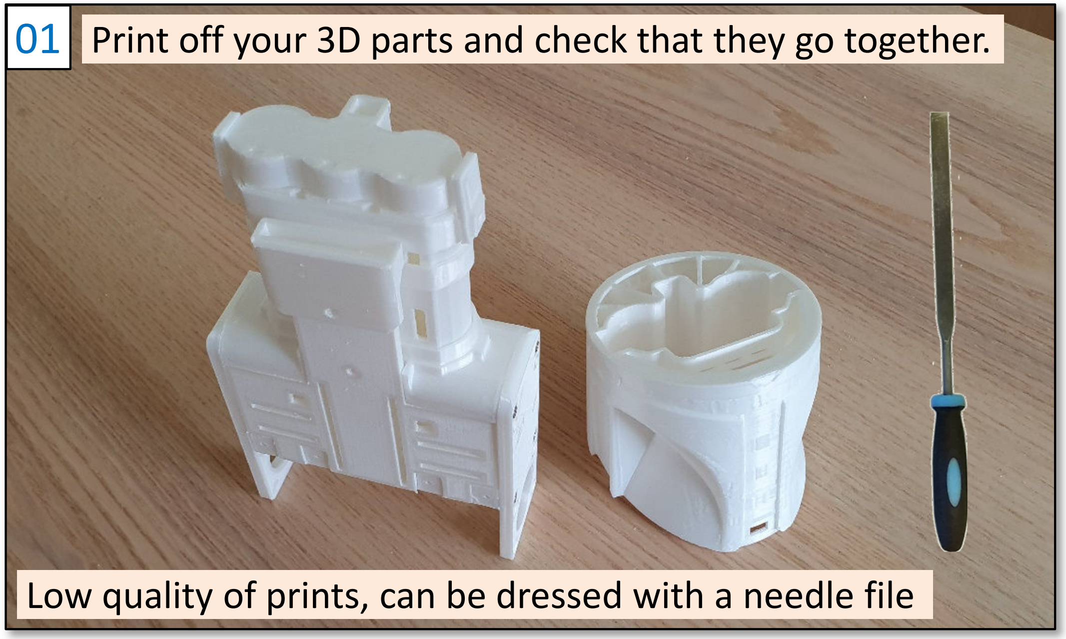

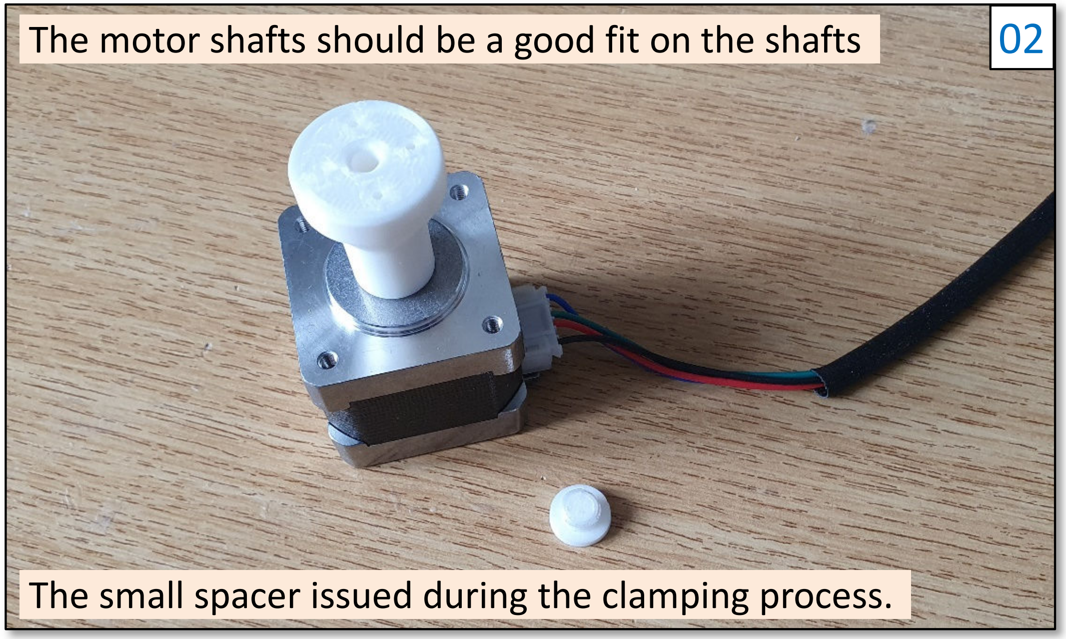

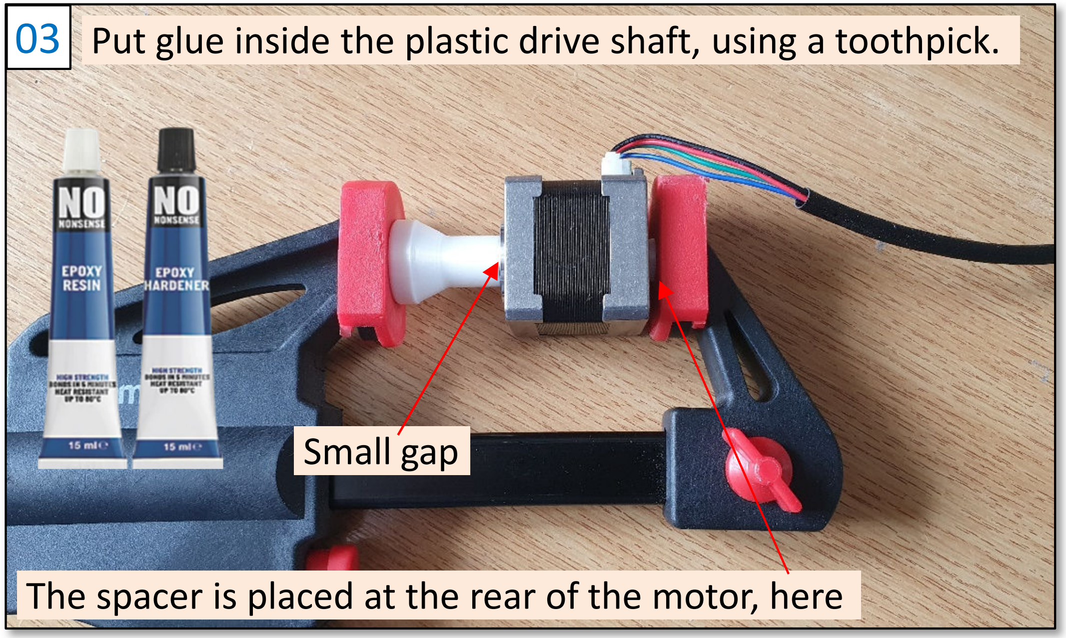

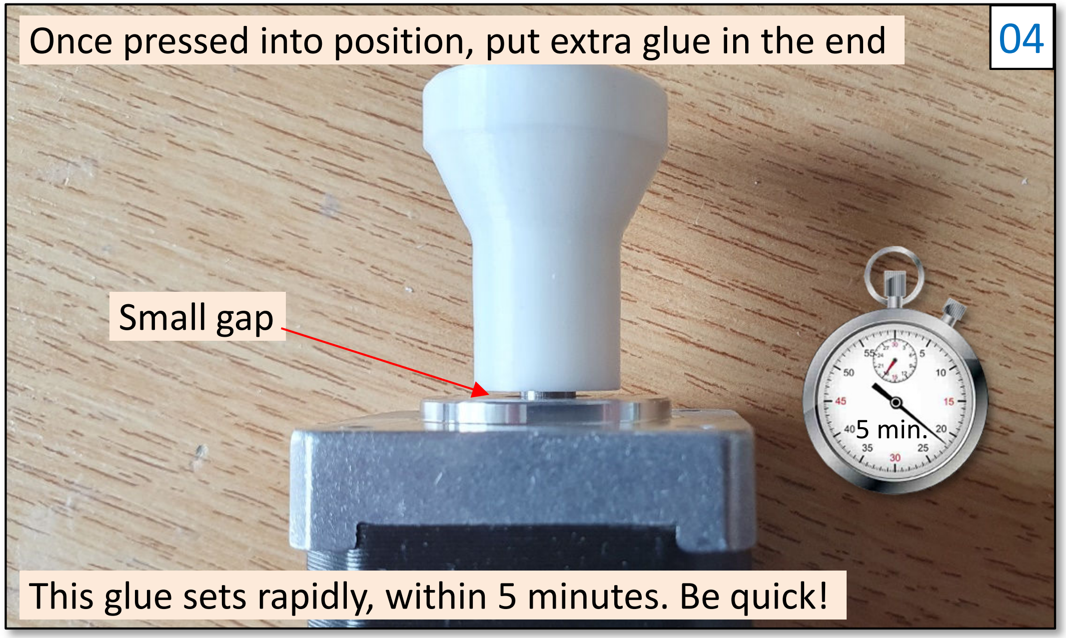

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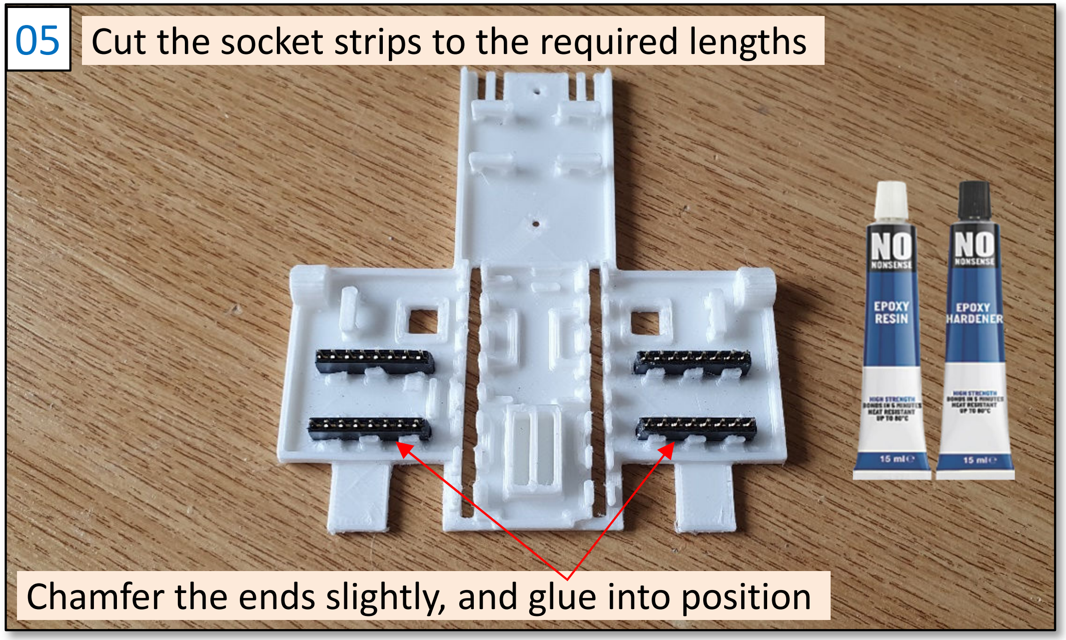
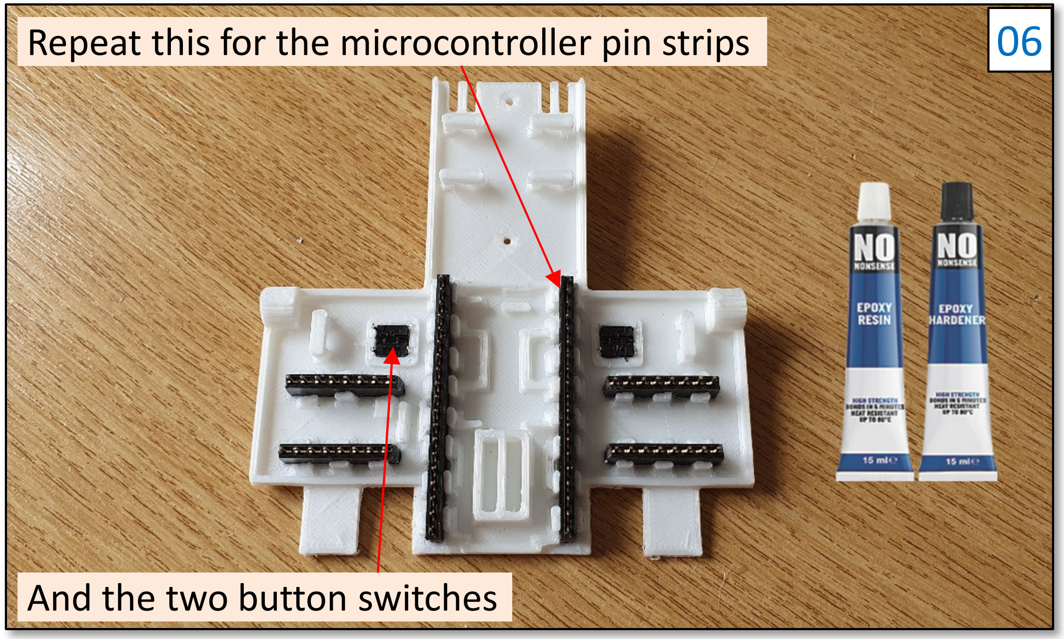
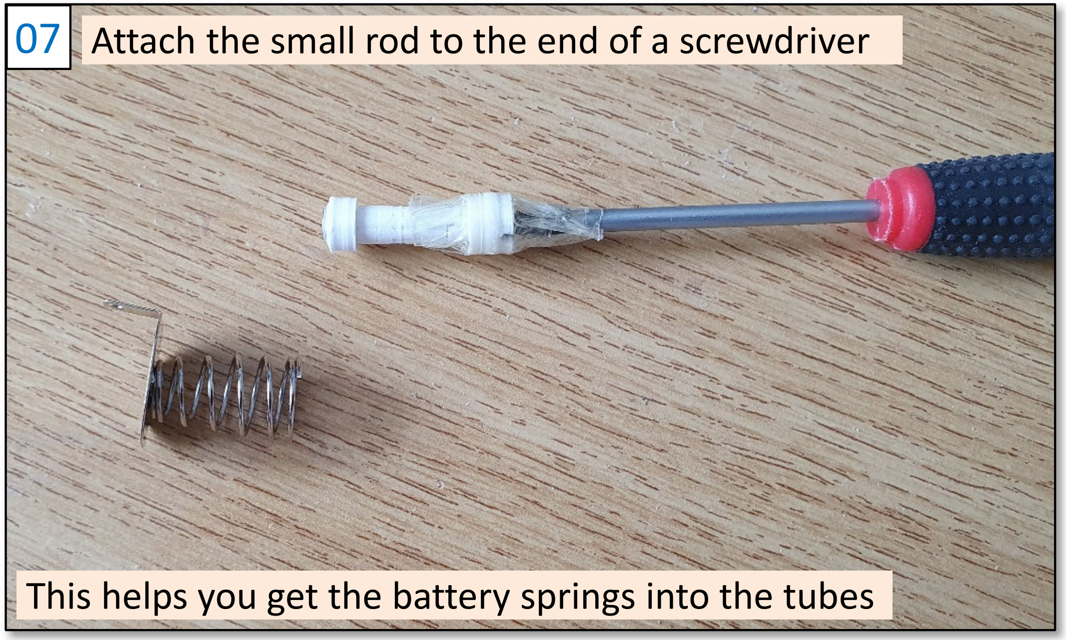
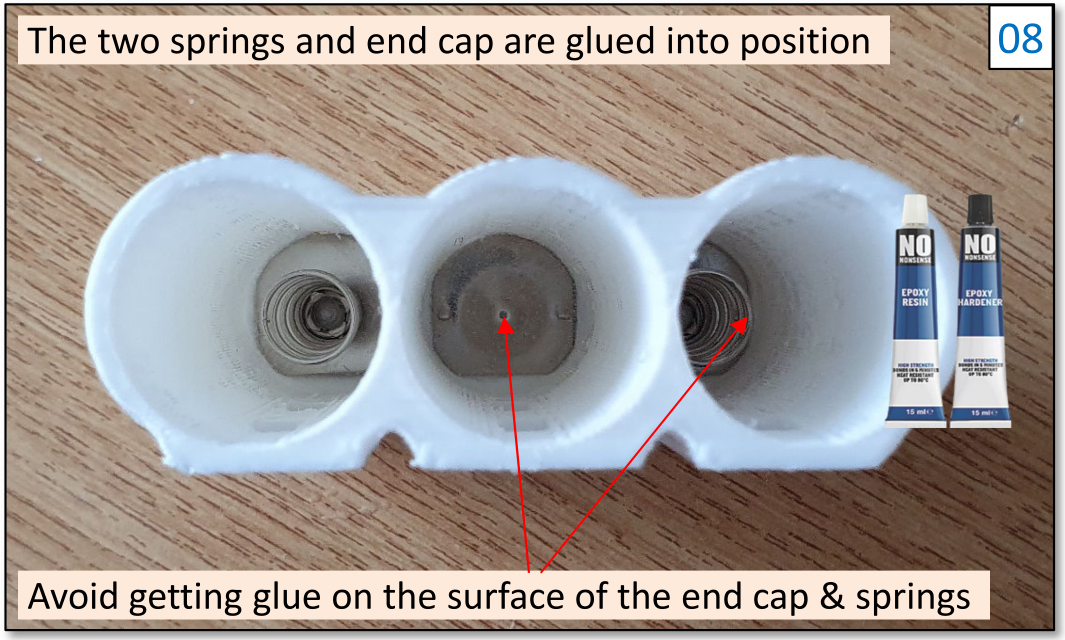


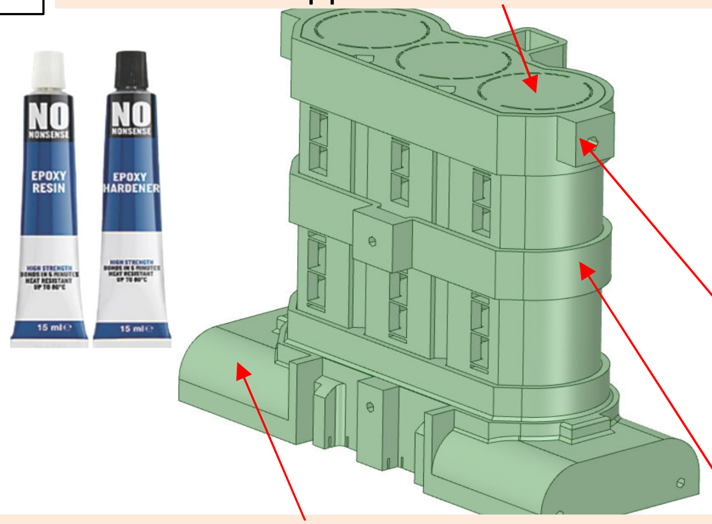






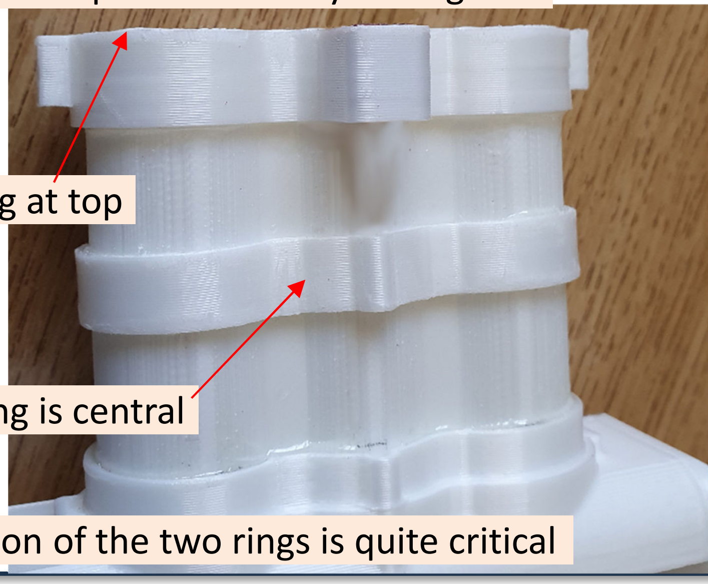
Build Images

09 Remove the support material in the battery tubes



Glue tubes into shoulder, & glue on the middle & clamp rings

10 This shows the parts after they were glued

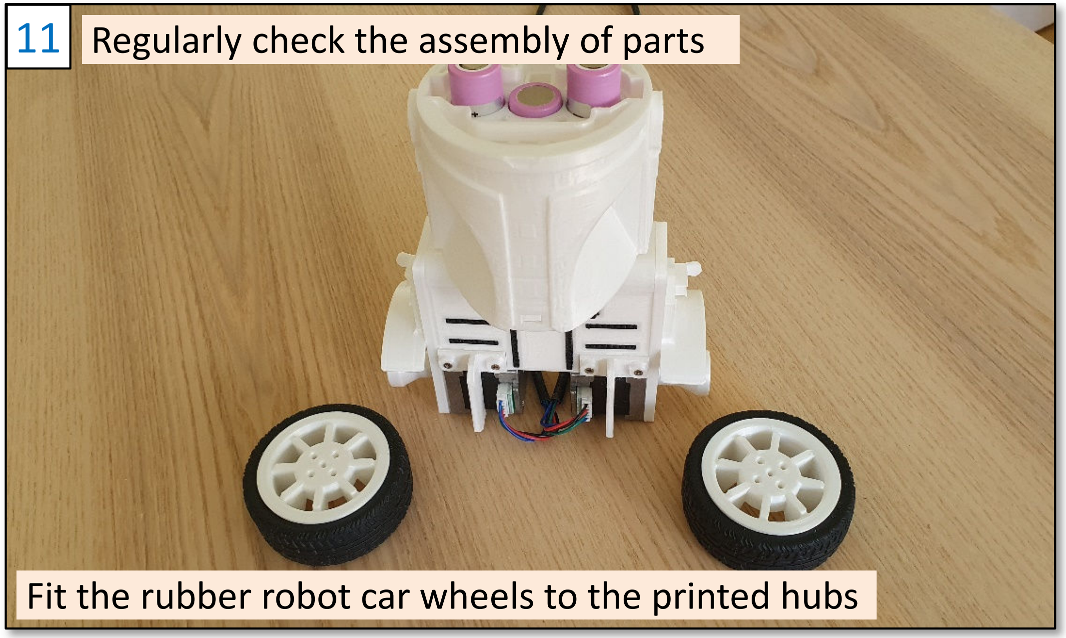


Clamp ring at top

Middle ring is central

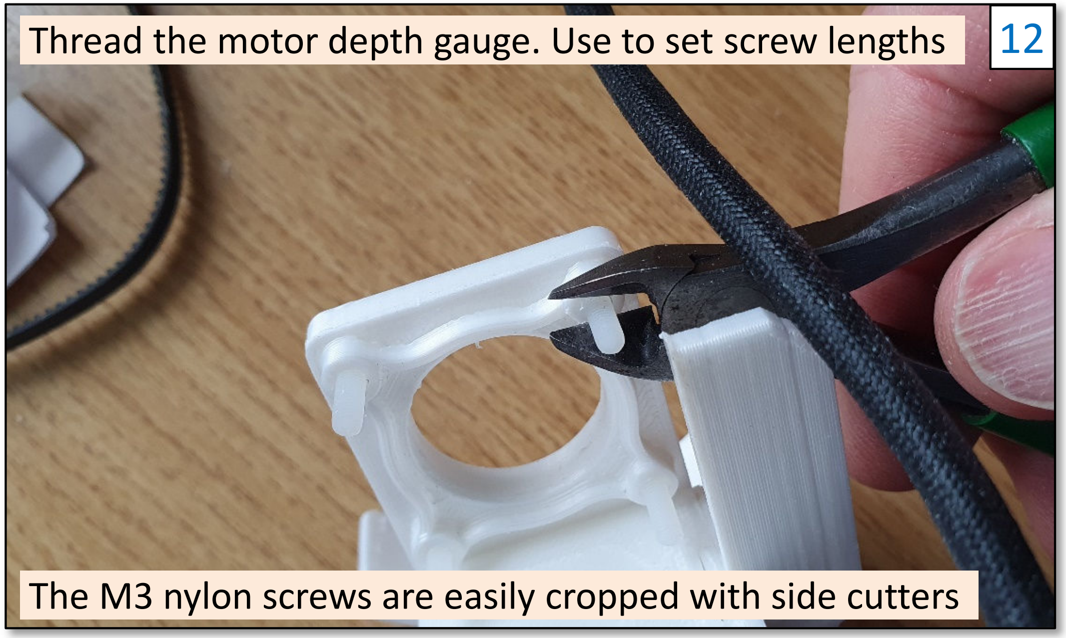
The position of the two rings is quite critical

11 Regularly check the assembly of parts



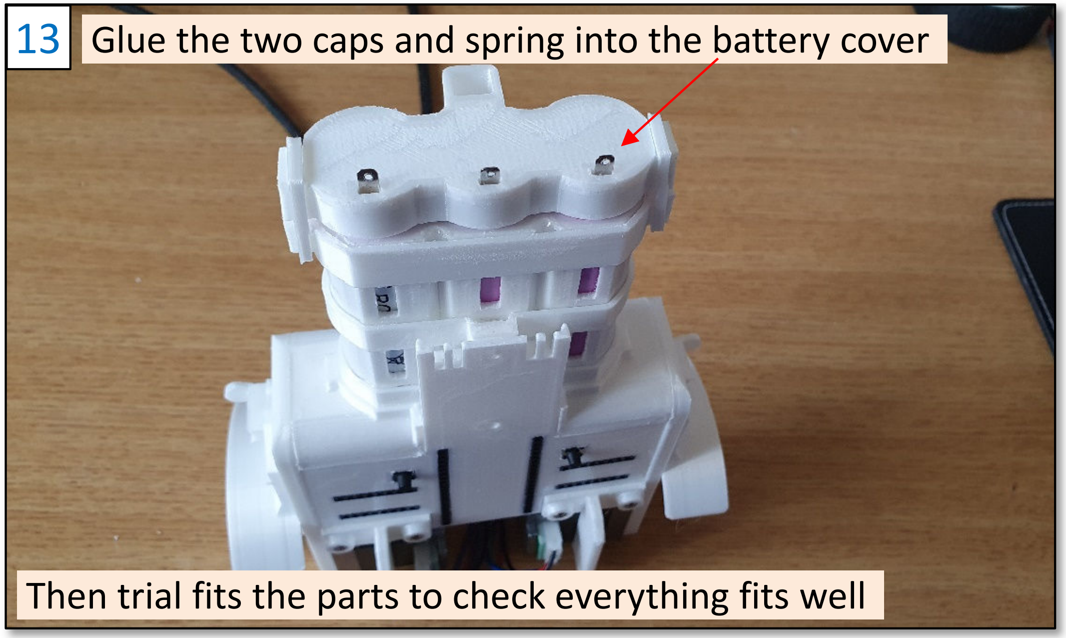
Fit the rubber robot car wheels to the printed hubs

12 Thread the motor depth gauge. Use to set screw lengths



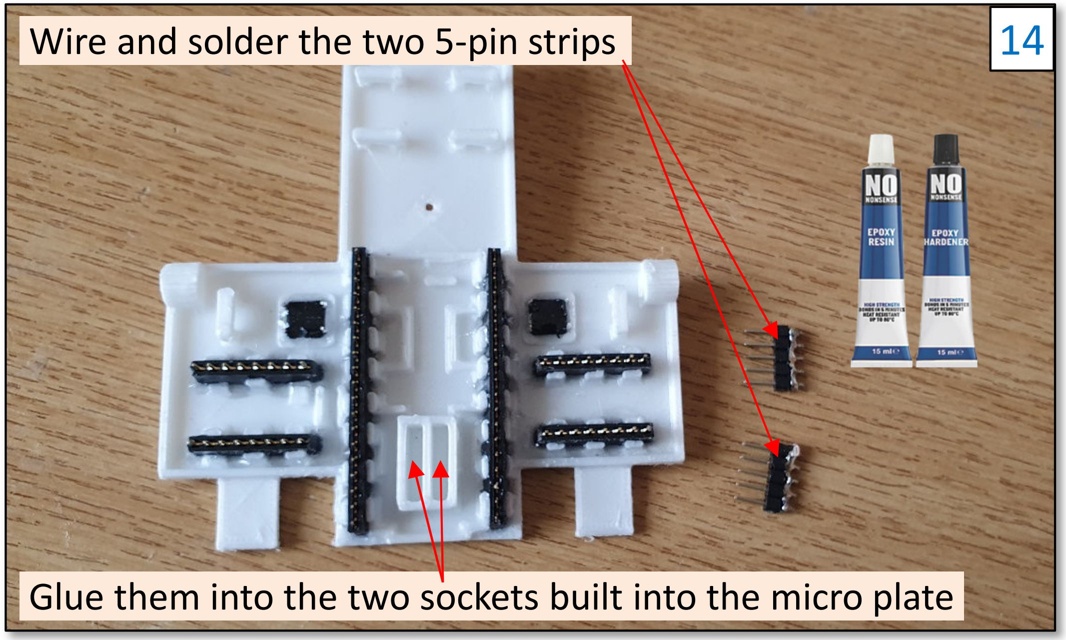
The M3 nylon screws are easily cropped with side cutters

Build Images



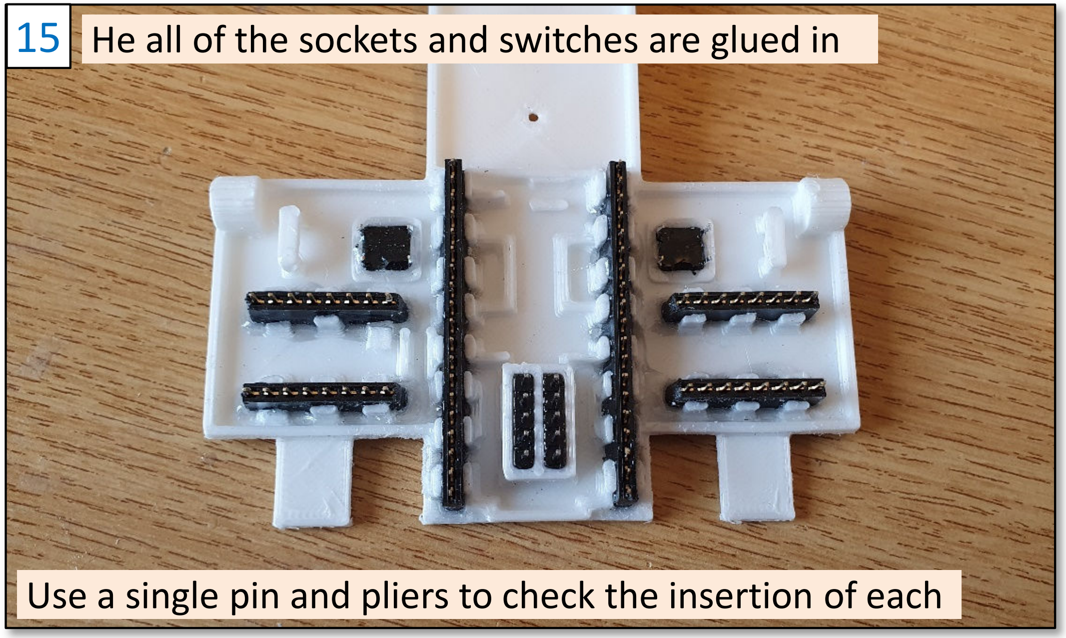
13 Glue the two caps and spring into the battery cover

Then trial fits the parts to check everything fits well



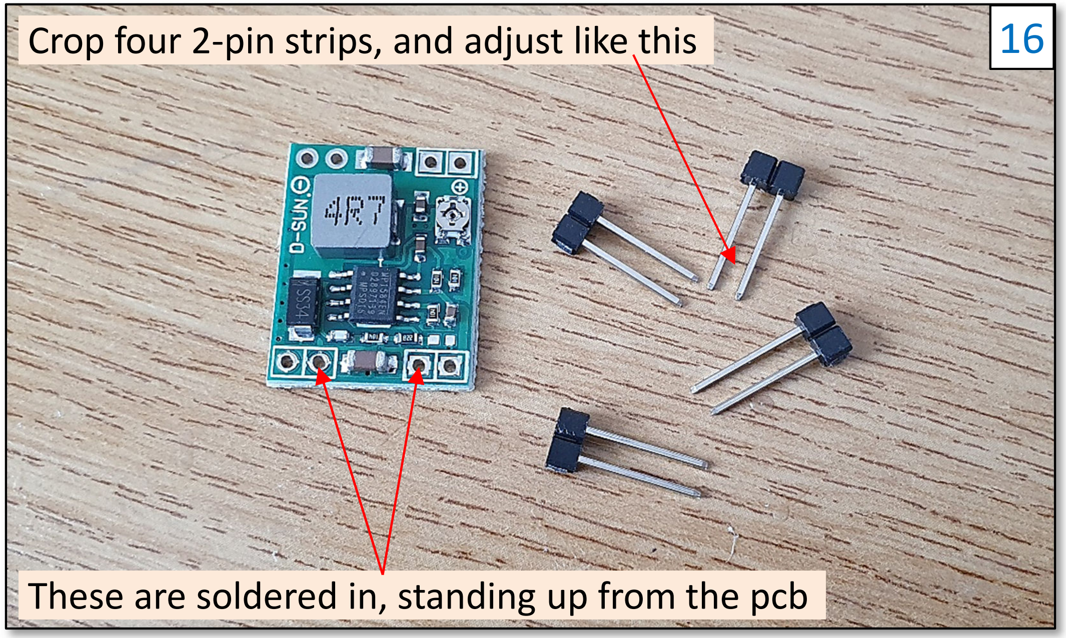
14 Wire and solder the two 5-pin strips

Glue them into the two sockets built into the micro plate



15 He all of the sockets and switches are glued in

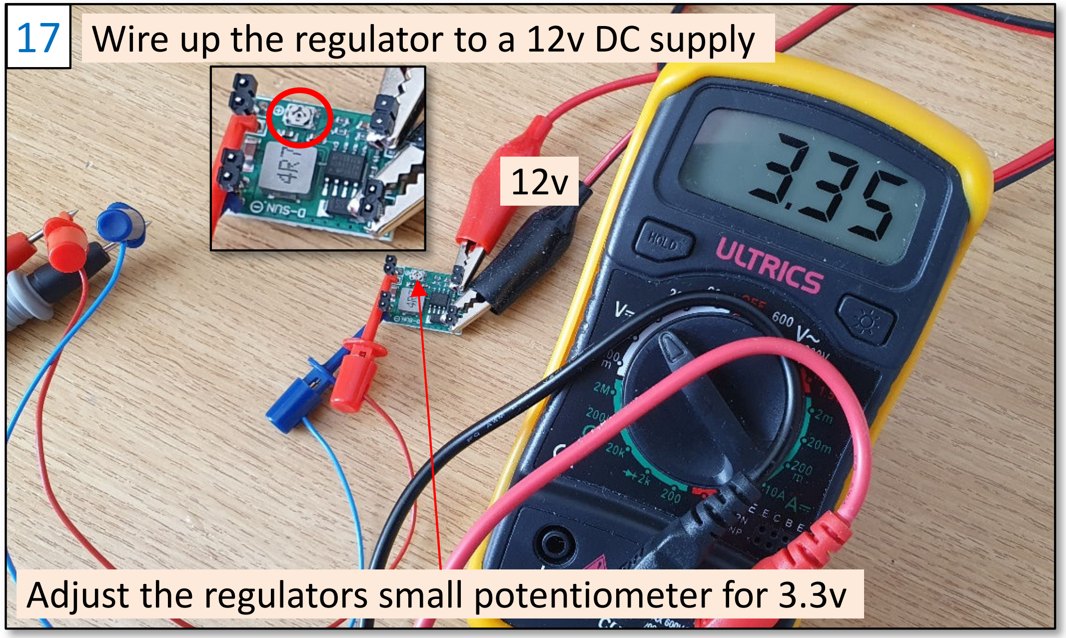
Use a single pin and pliers to check the insertion of each



16 Crop four 2-pin strips, and adjust like this

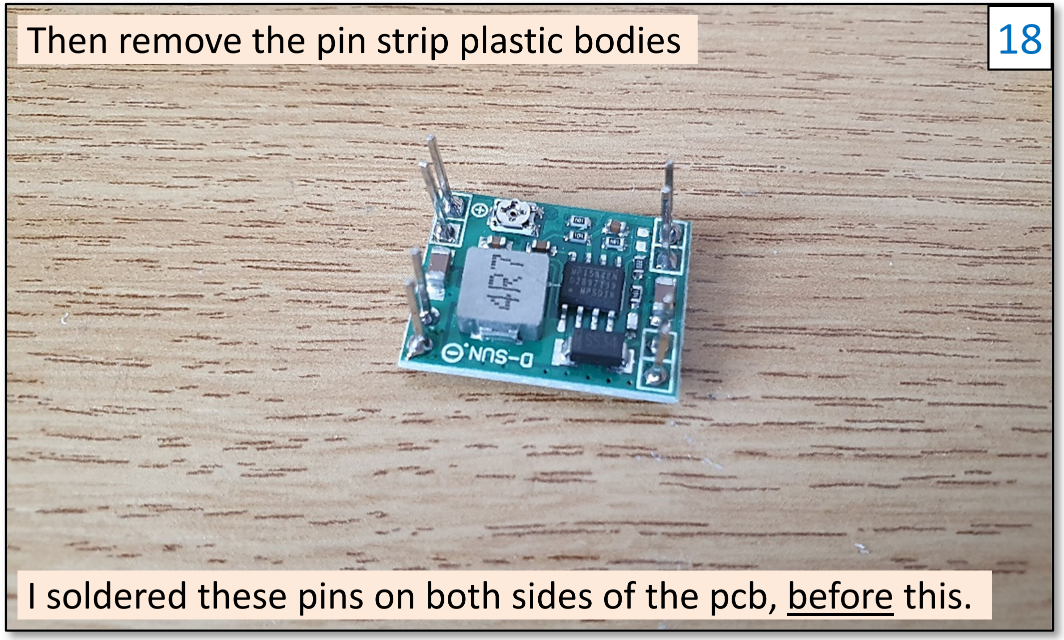
These are soldered in, standing up from the pcb

Build Images

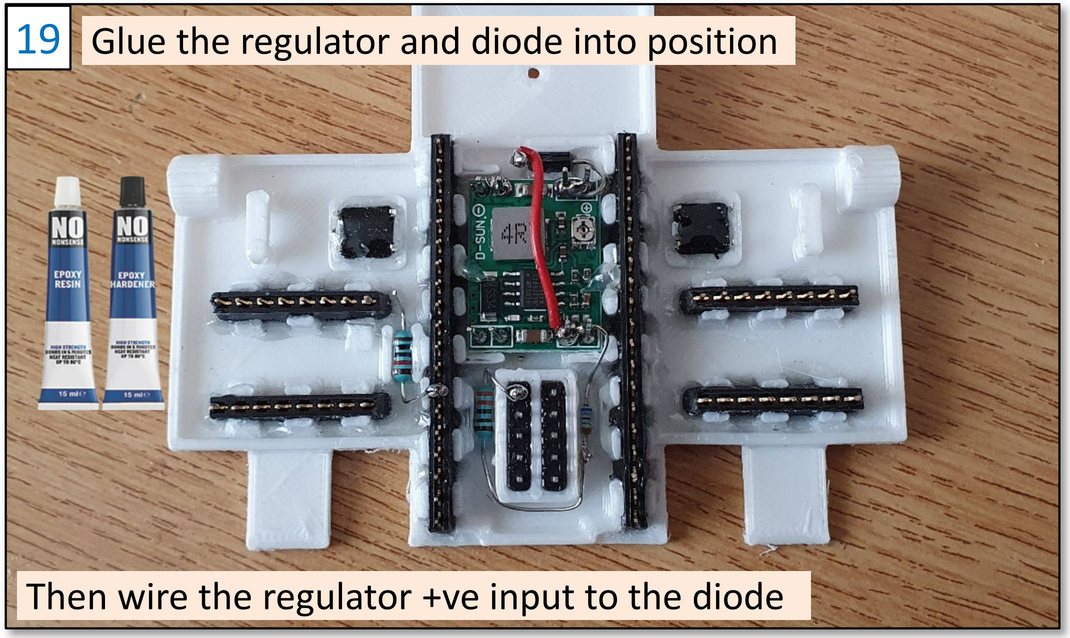


17 Wire up the regulator to a 12v DC supply

Adjust the regulators small potentiometer for 3.3v

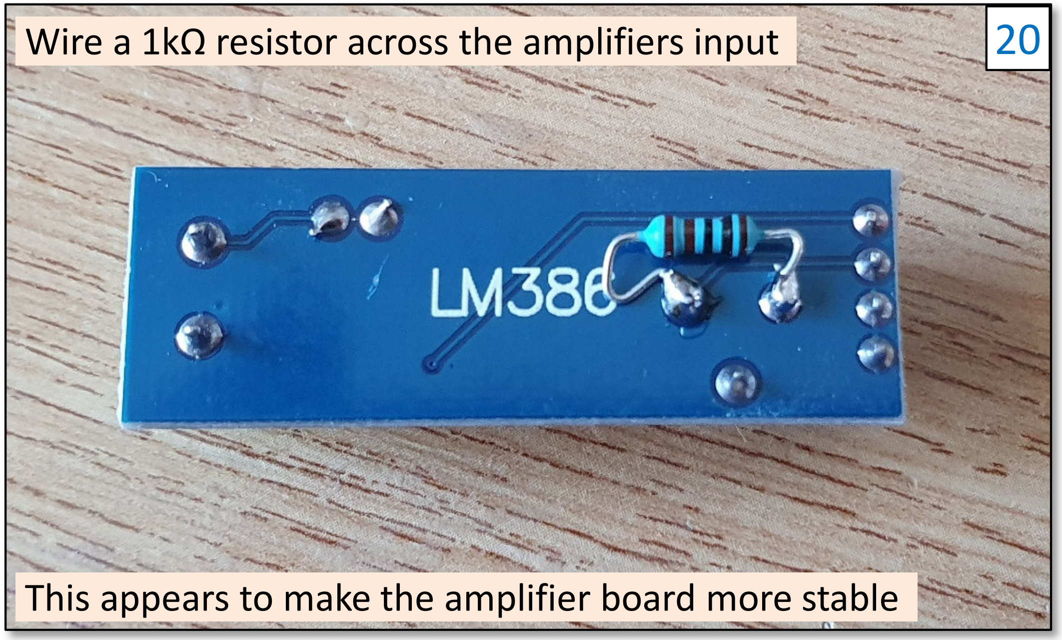

18 Then remove the pin strip plastic bodies

I soldered these pins on both sides of the pcb, <u>before</u> this.



19 Glue the regulator and diode into position

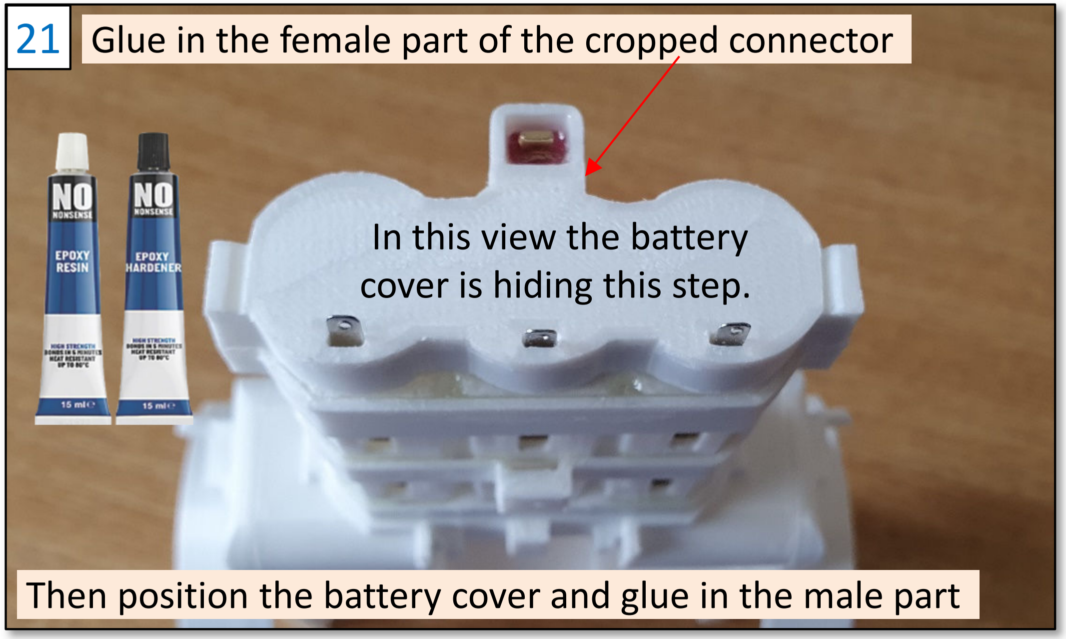
Then wire the regulator +ve input to the diode

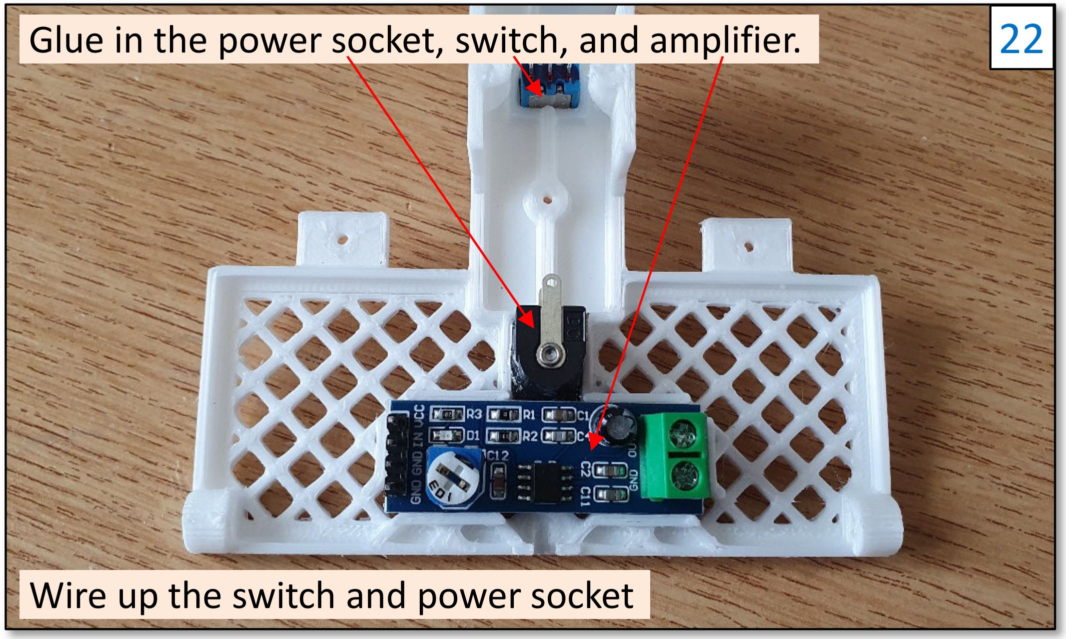


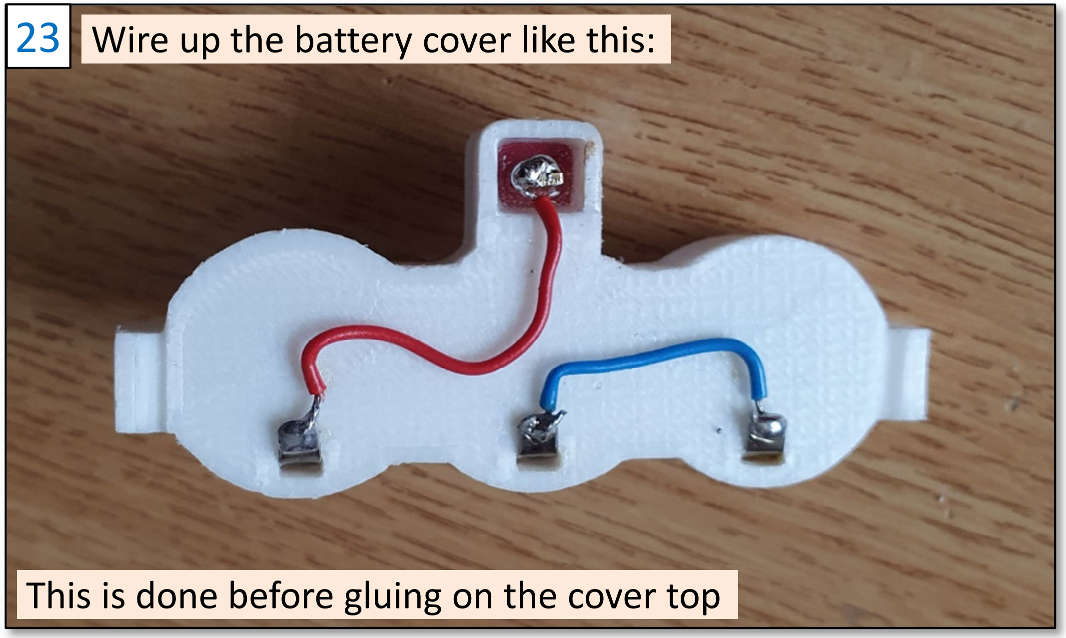
20 Wire a 1kΩ resistor across the amplifiers input

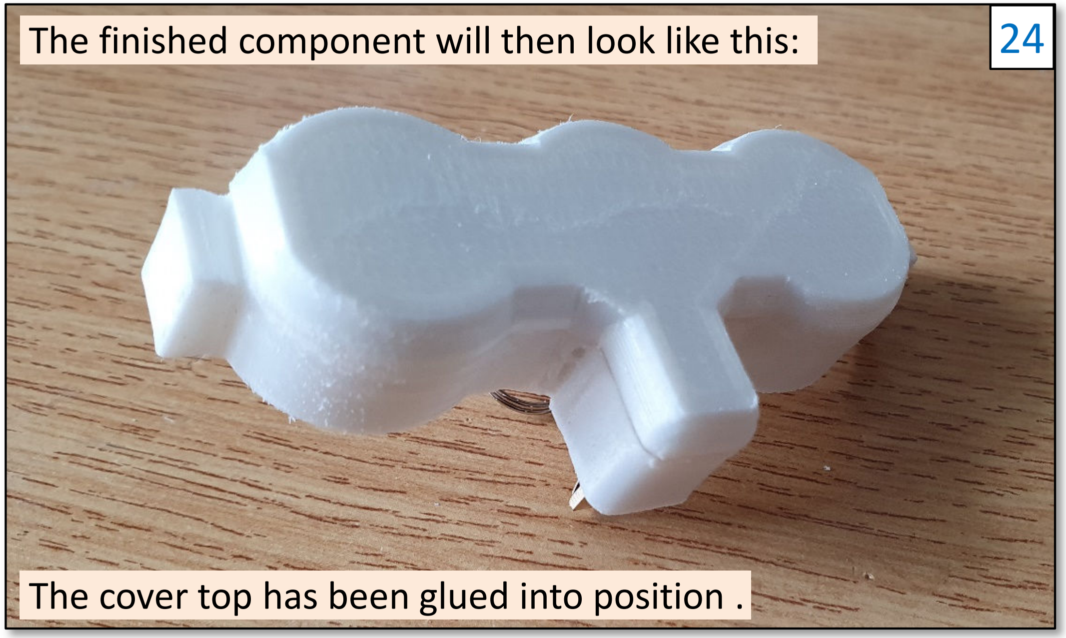
This appears to make the amplifier board more stable

Build Images









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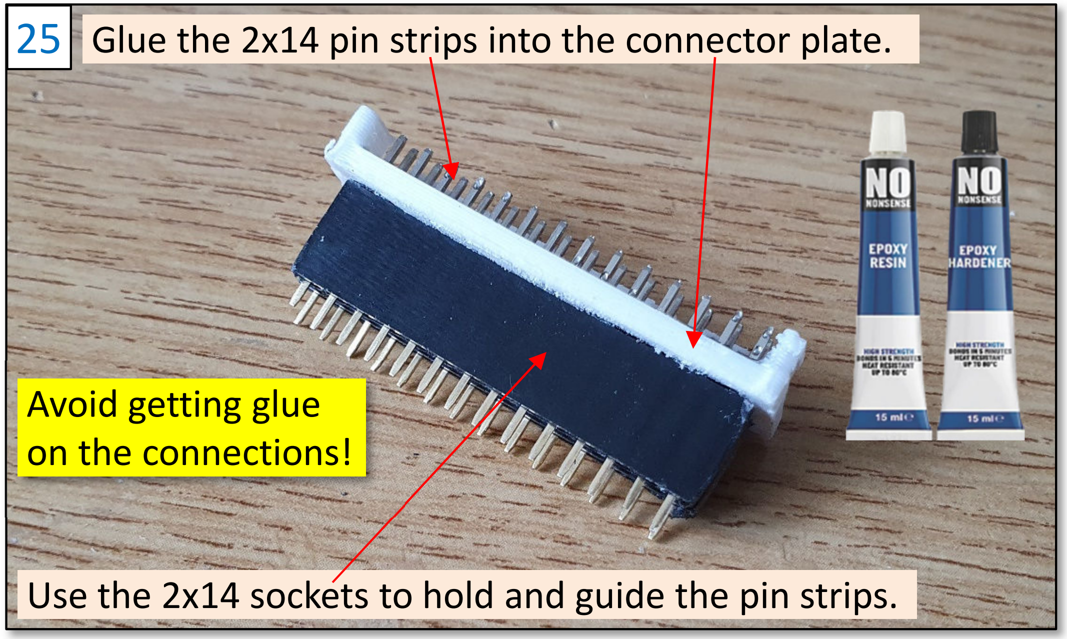
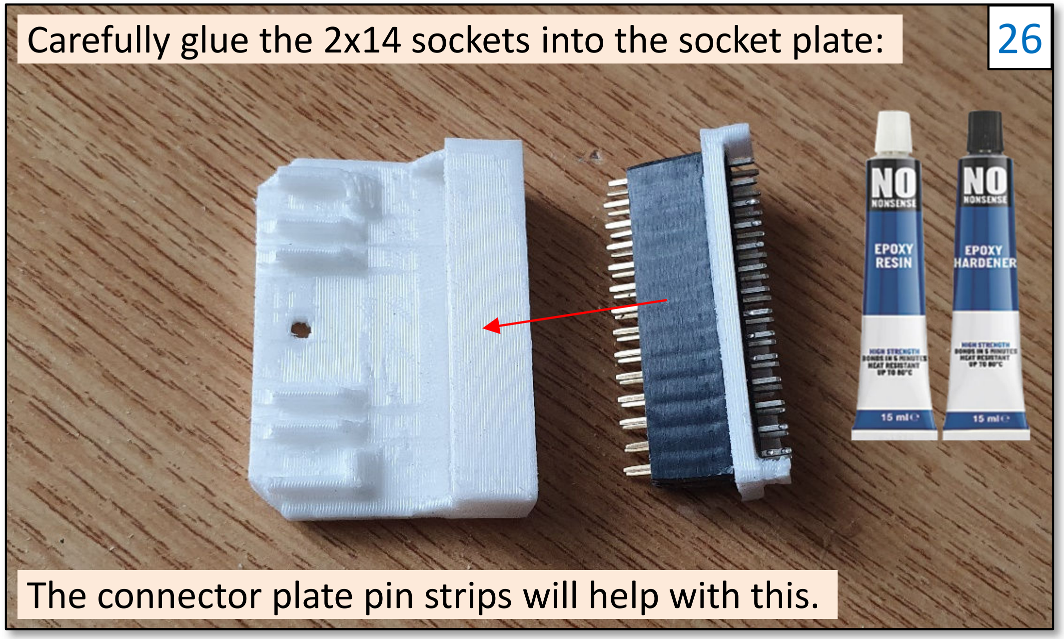


25 Glue the 2x14 pin strips into the connector plate.

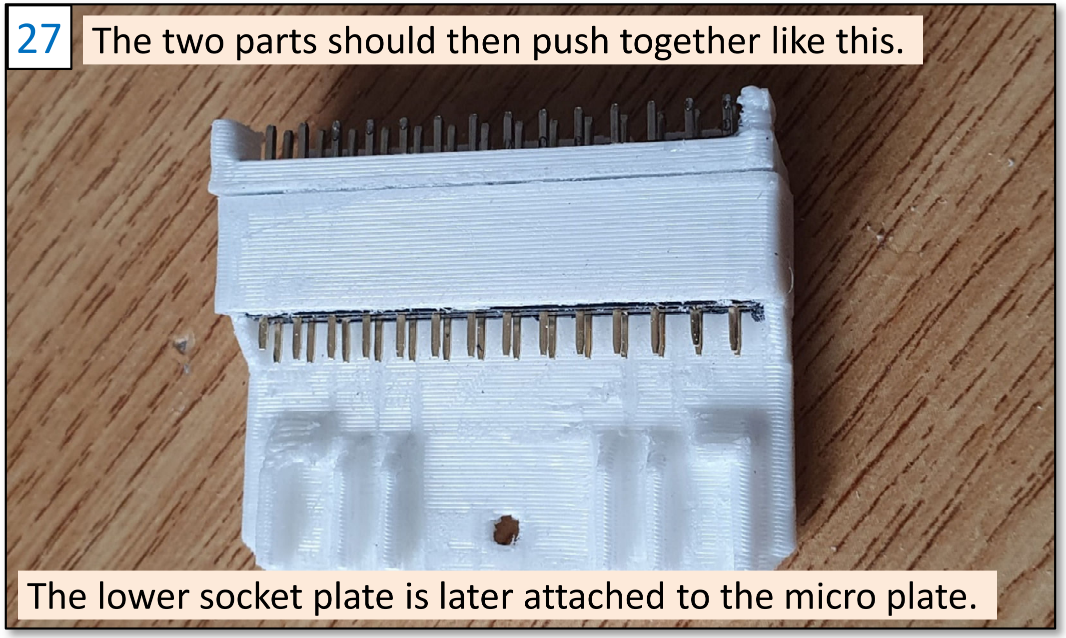
Avoid getting glue on the connections!

Use the 2x14 sockets to hold and guide the pin strips.



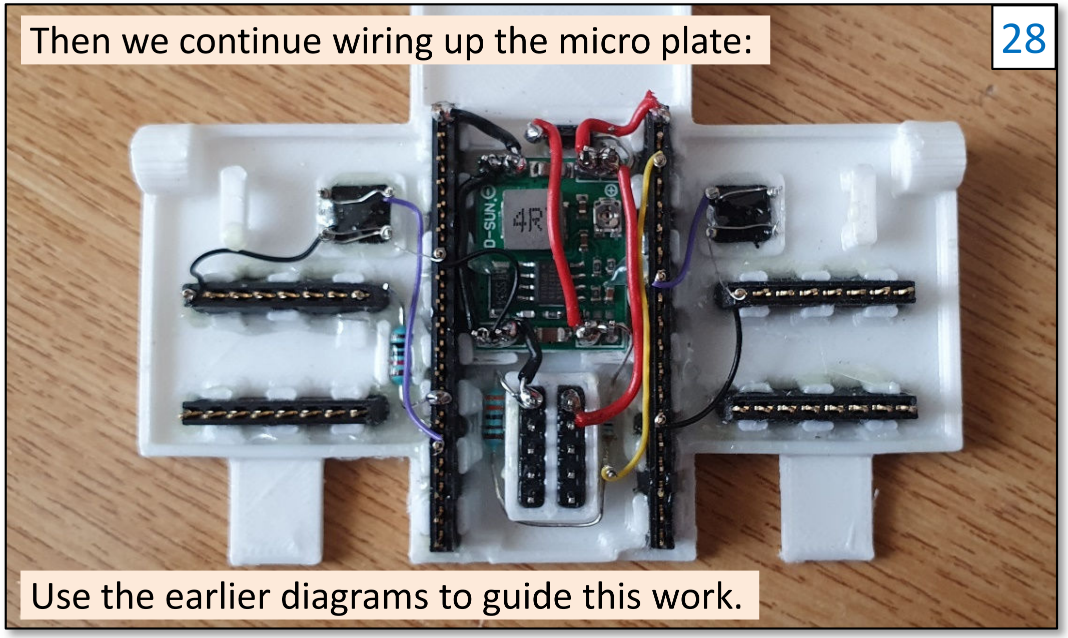
26 Carefully glue the 2x14 sockets into the socket plate:

The connector plate pin strips will help with this.



27 The two parts should then push together like this.

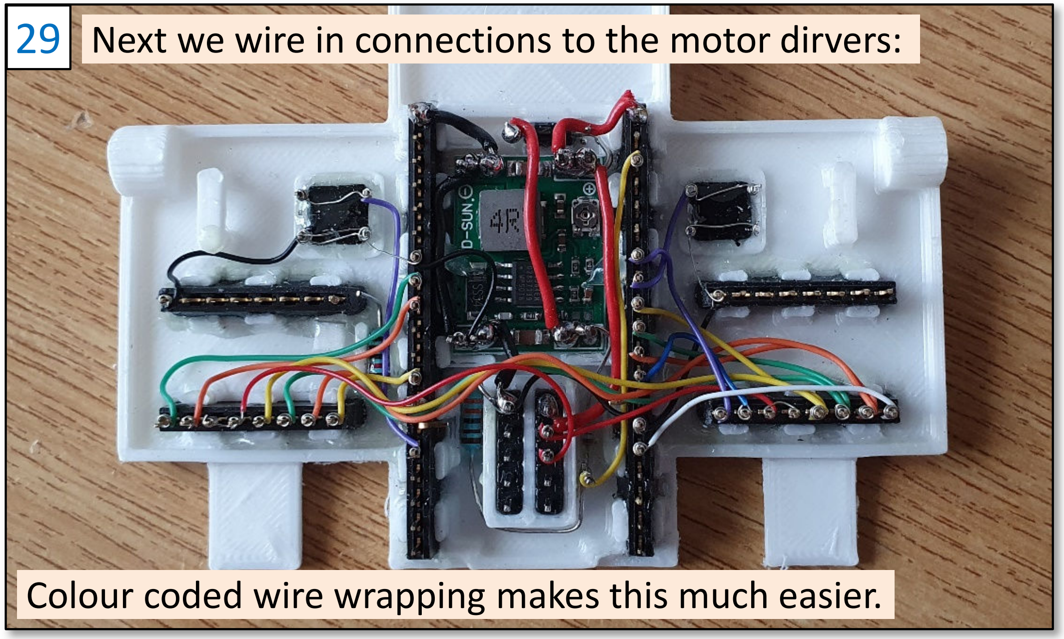
The lower socket plate is later attached to the micro plate.



28 Then we continue wiring up the micro plate:

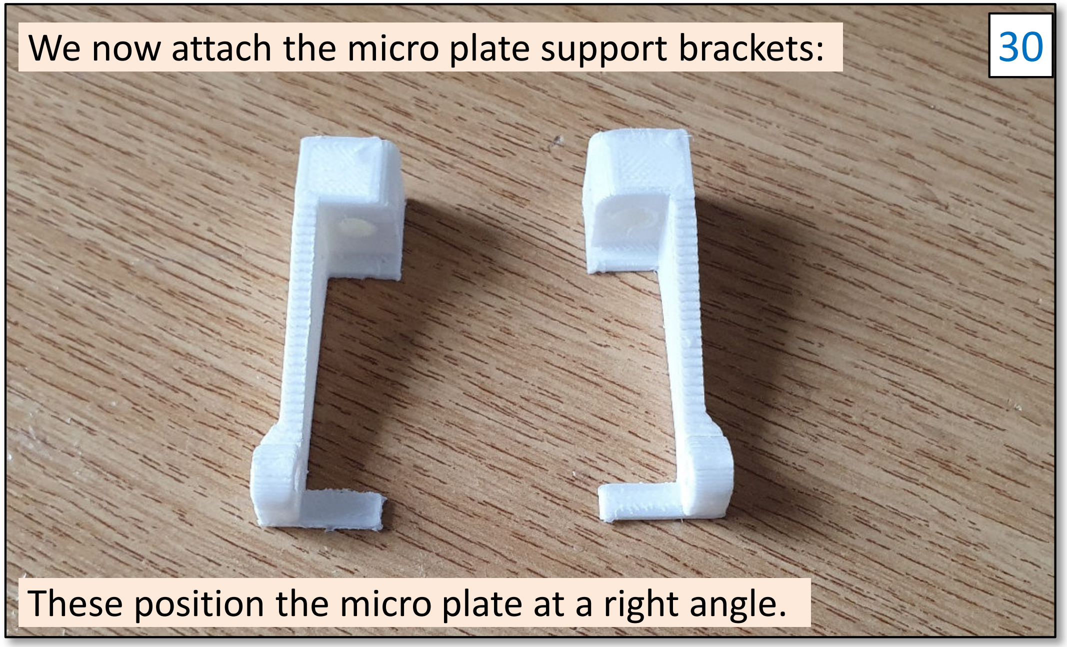
Use the earlier diagrams to guide this work.

Build Images



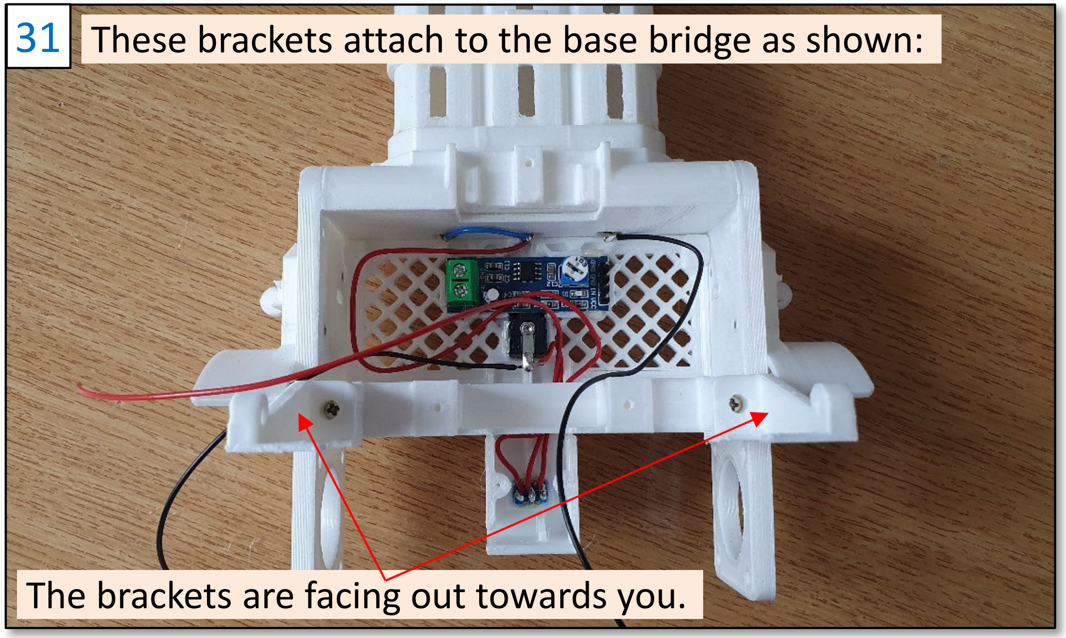
29 Next we wire in connections to the motor dirvers:

Colour coded wire wrapping makes this much easier.



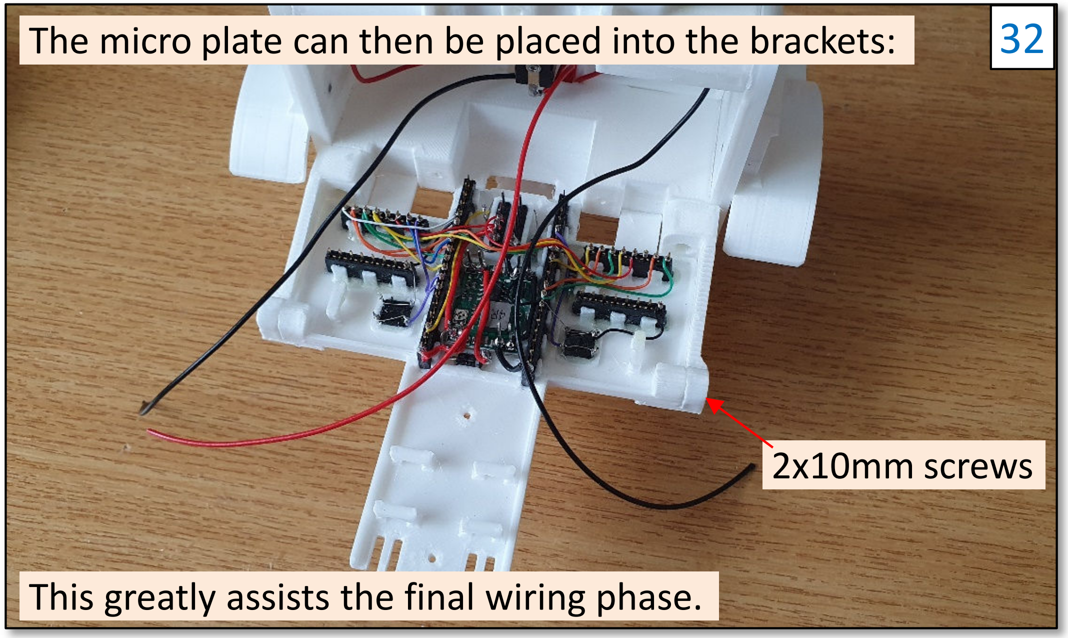
30 We now attach the micro plate support brackets:

These position the micro plate at a right angle.



31 These brackets attach to the base bridge as shown:

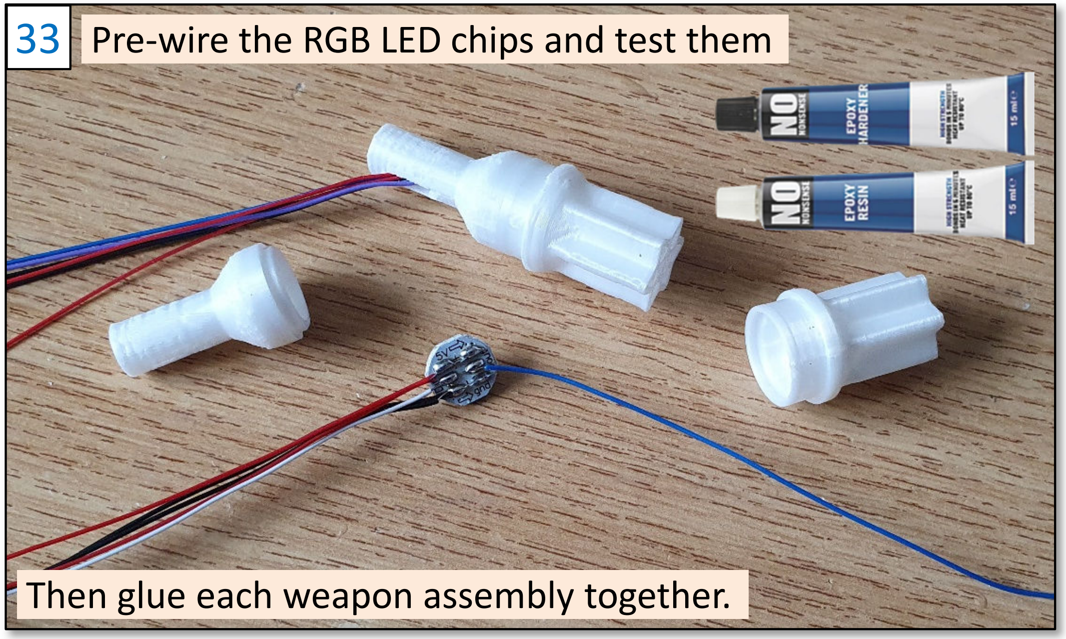
The brackets are facing out towards you.



32 The micro plate can then be placed into the brackets:

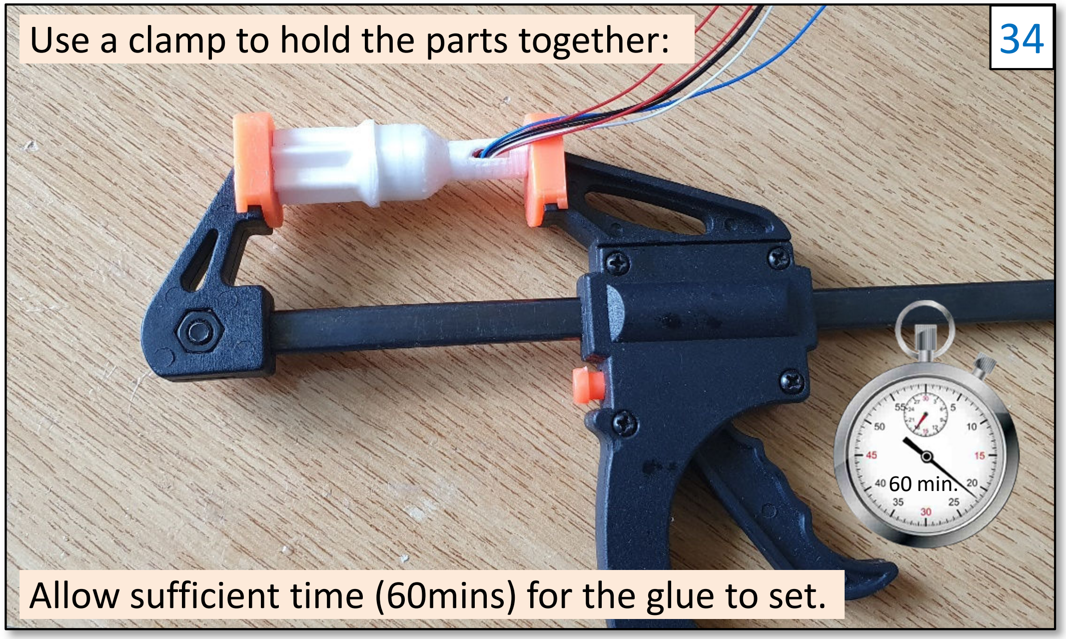
This greatly assists the final wiring phase.

Build Images



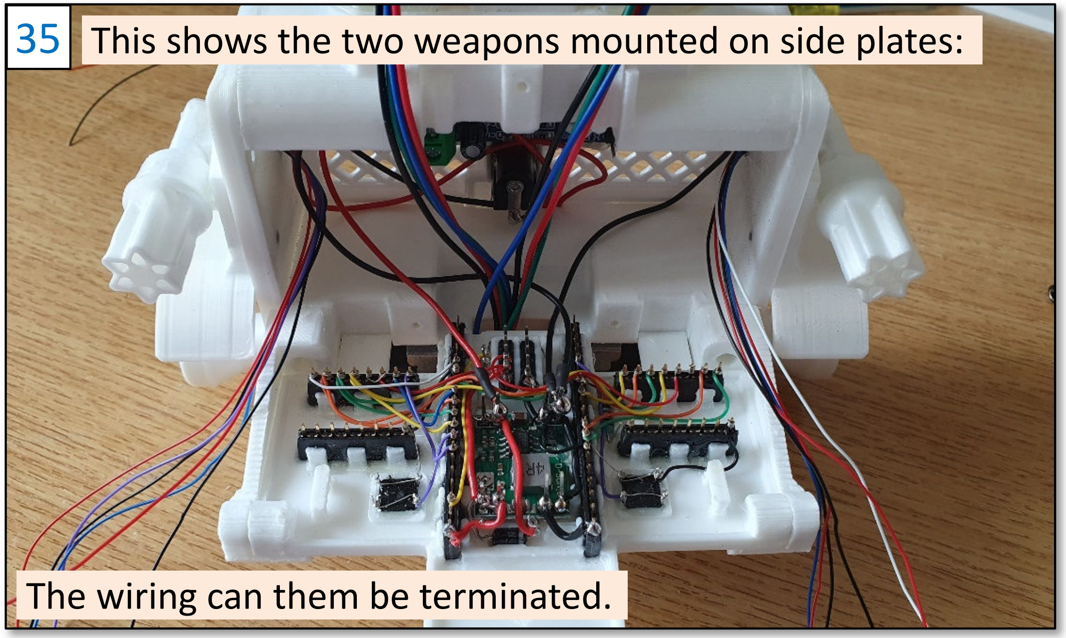
33 Pre-wire the RGB LED chips and test them

Then glue each weapon assembly together.



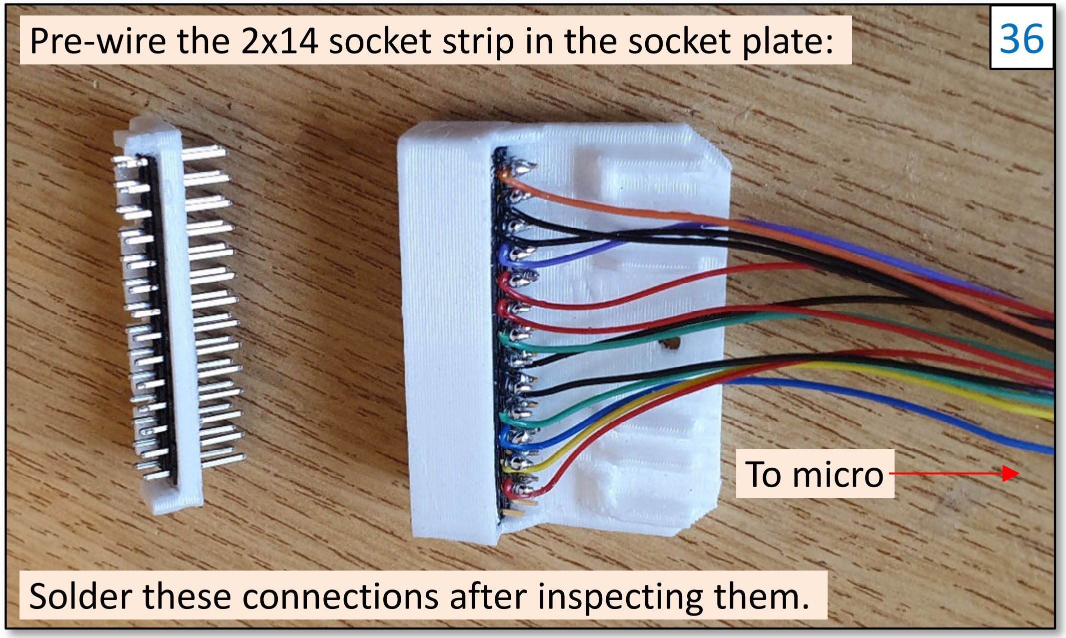
34 Use a clamp to hold the parts together:

Allow sufficient time (60mins) for the glue to set.



35 This shows the two weapons mounted on side plates:

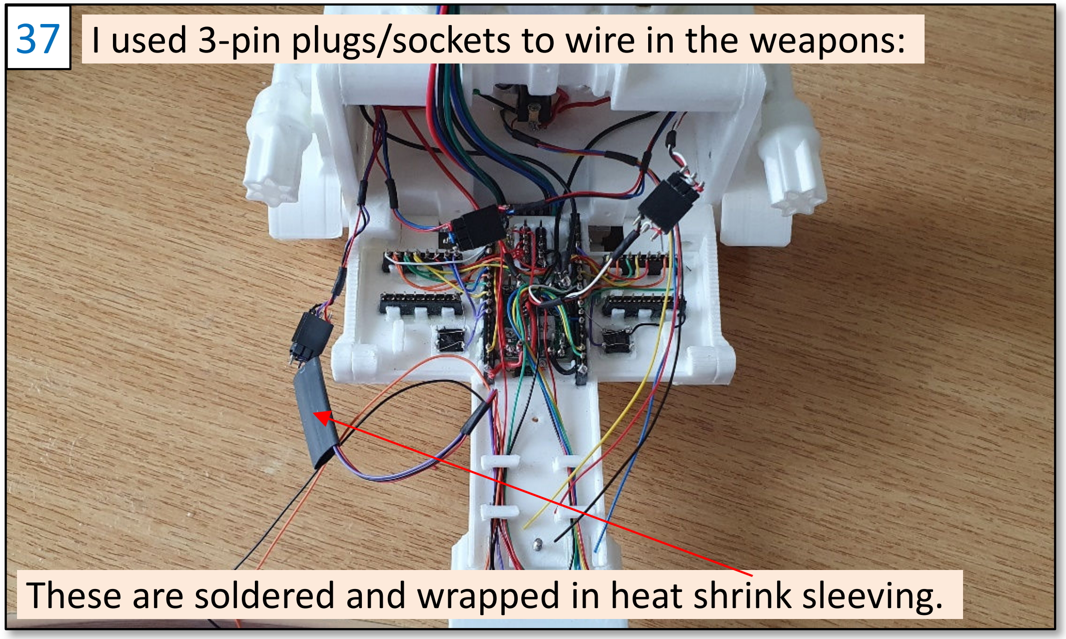
The wiring can them be terminated.



36 Pre-wire the 2x14 socket strip in the socket plate:

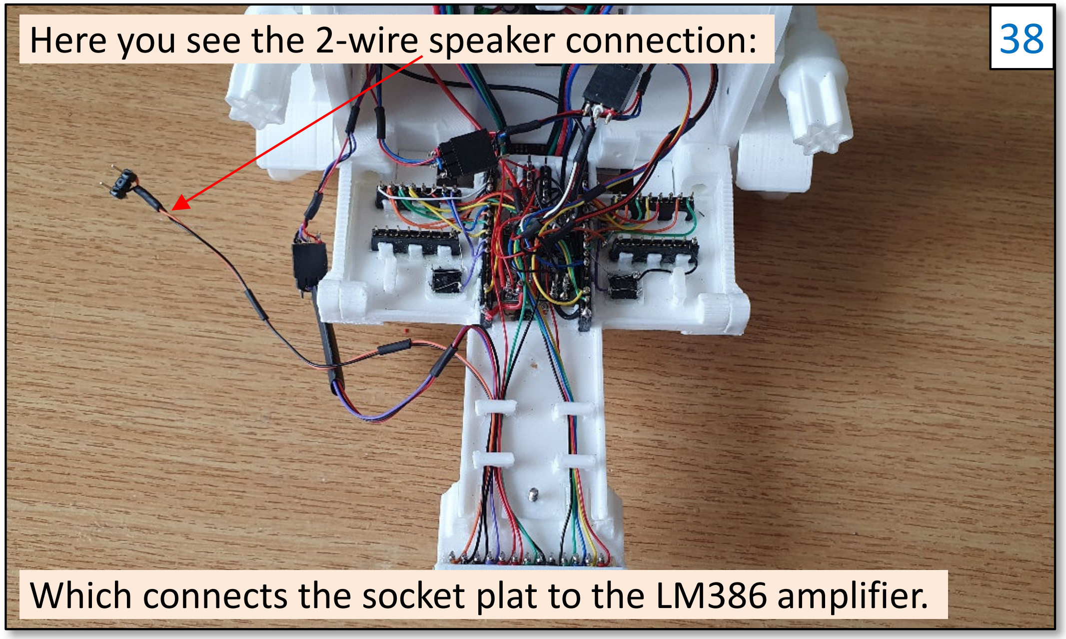
Solder these connections after inspecting them.

Build Images



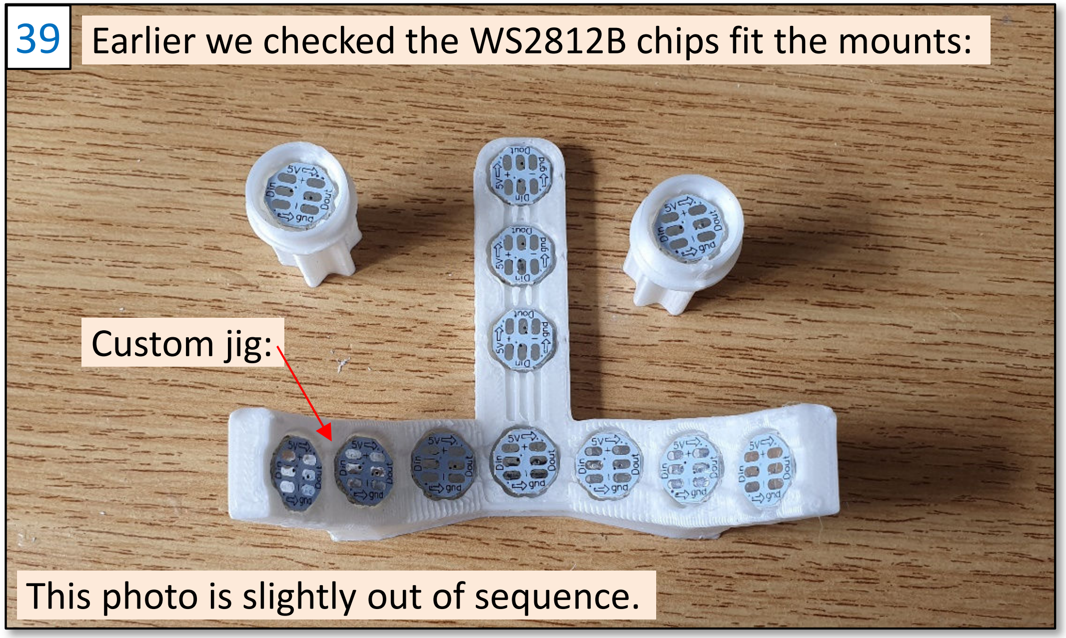
37 I used 3-pin plugs/sockets to wire in the weapons:

These are soldered and wrapped in heat shrink sleeving.



38 Here you see the 2-wire speaker connection:

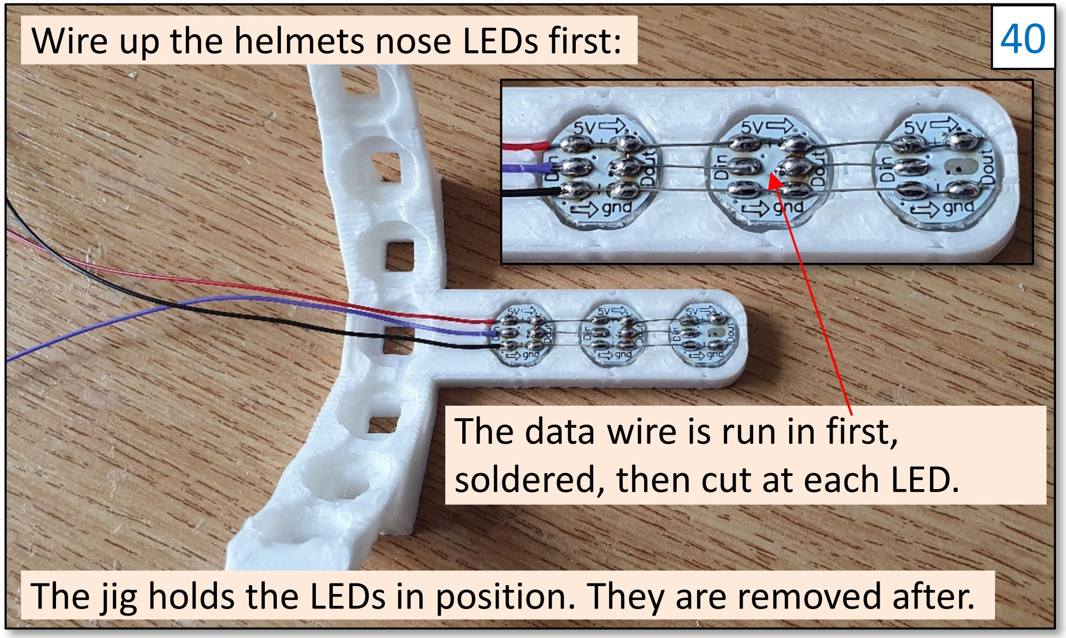
Which connects the socket plat to the LM386 amplifier.



39 Earlier we checked the WS2812B chips fit the mounts:

Custom jig:

This photo is slightly out of sequence.

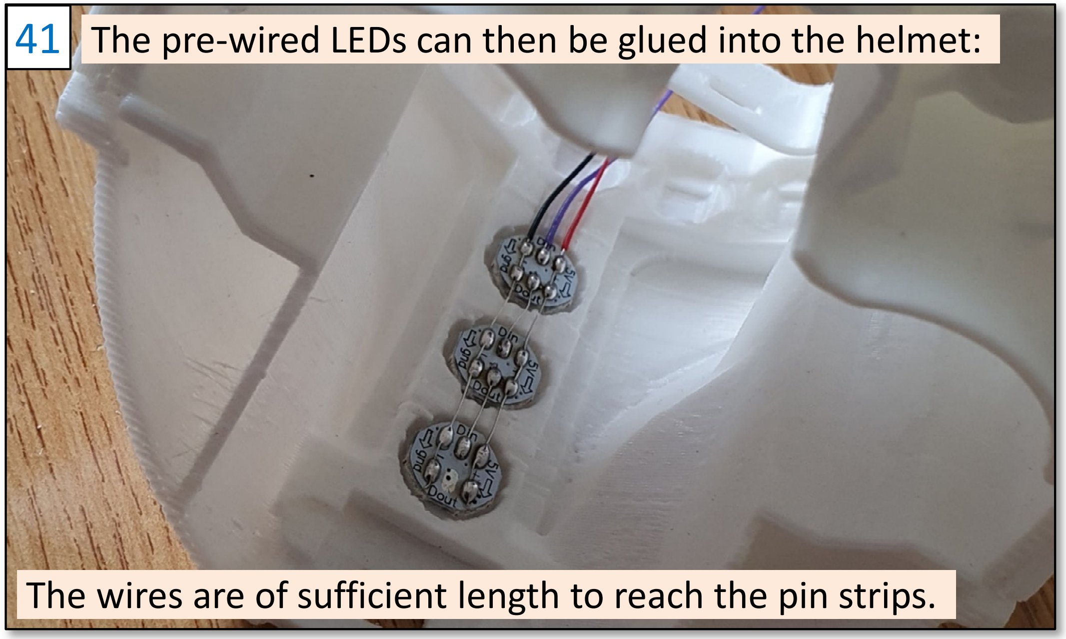


40 Wire up the helmets nose LEDs first:

The data wire is run in first, soldered, then cut at each LED.

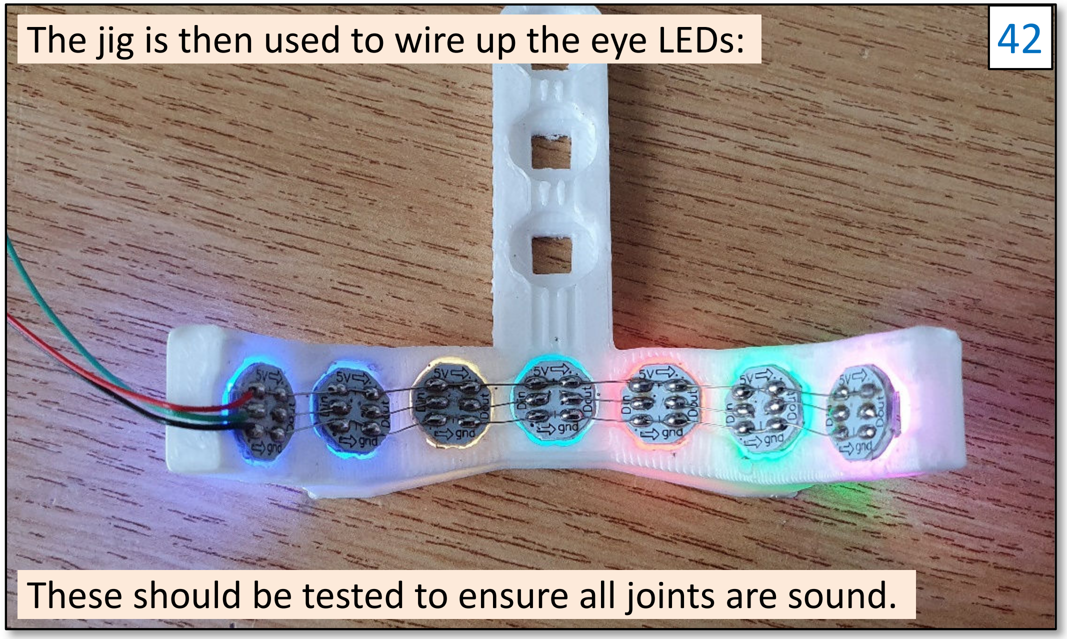
The jig holds the LEDs in position. They are removed after.

Build Images



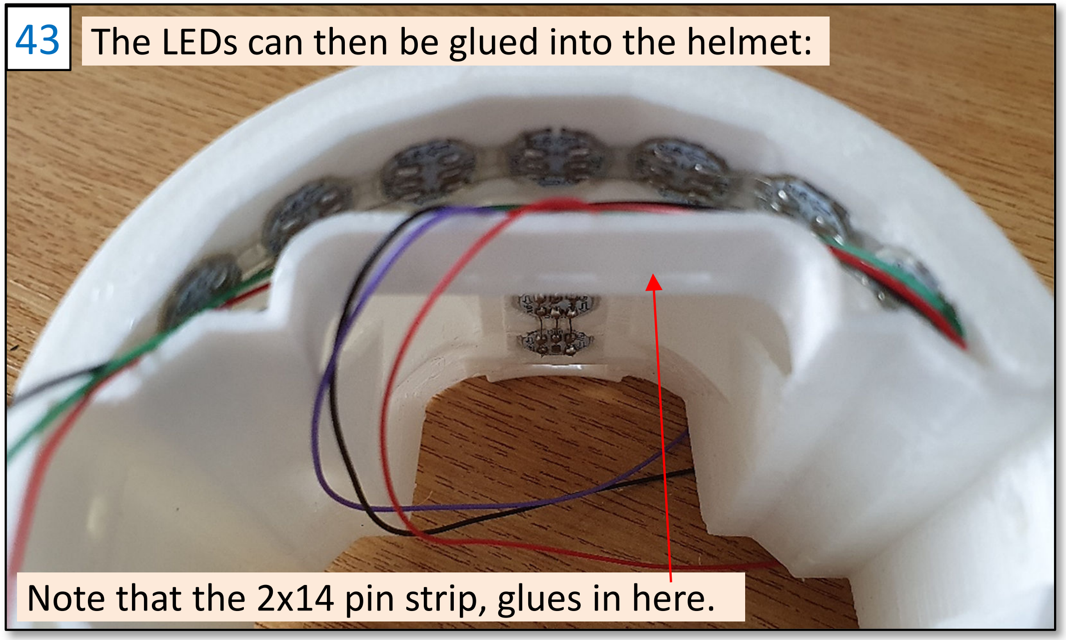
41 The pre-wired LEDs can then be glued into the helmet:

The wires are of sufficient length to reach the pin strips.



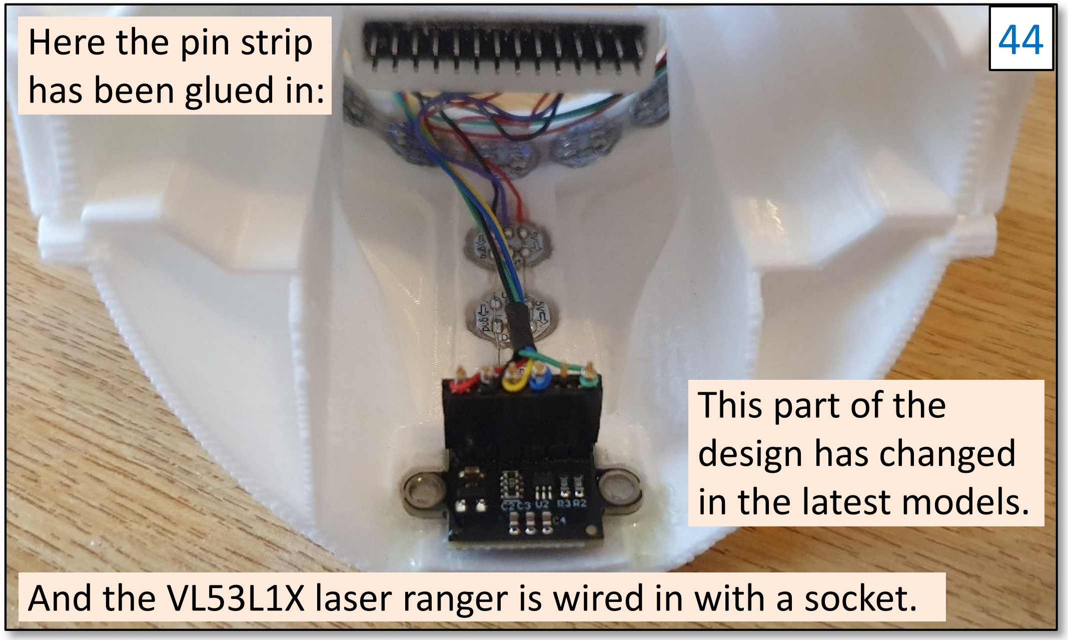
42 The jig is then used to wire up the eye LEDs:

These should be tested to ensure all joints are sound.



43 The LEDs can then be glued into the helmet:

Note that the 2x14 pin strip, glues in here.

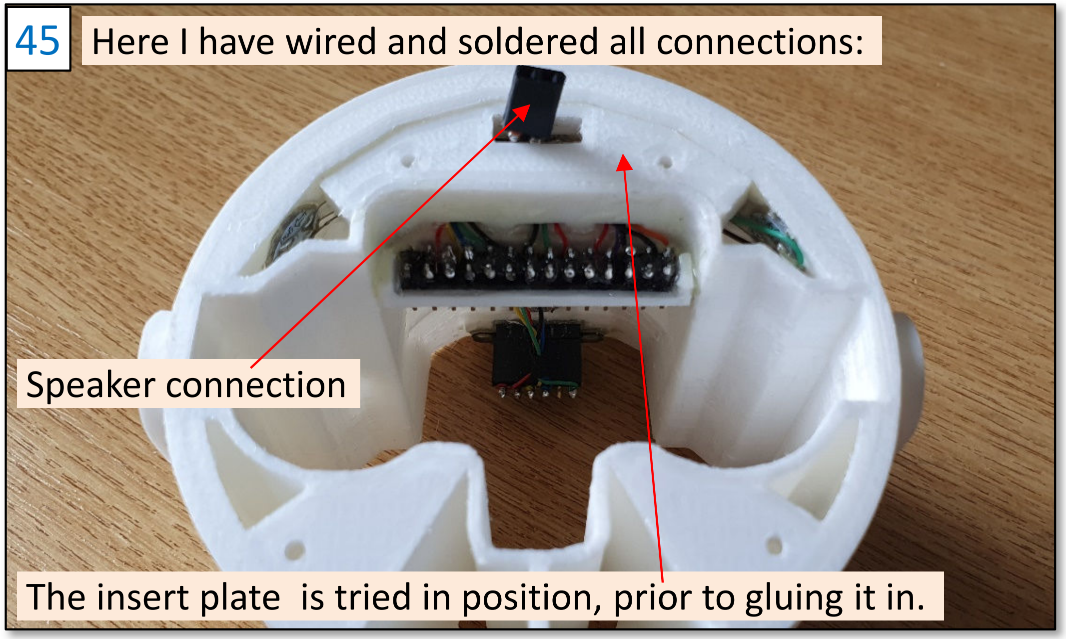


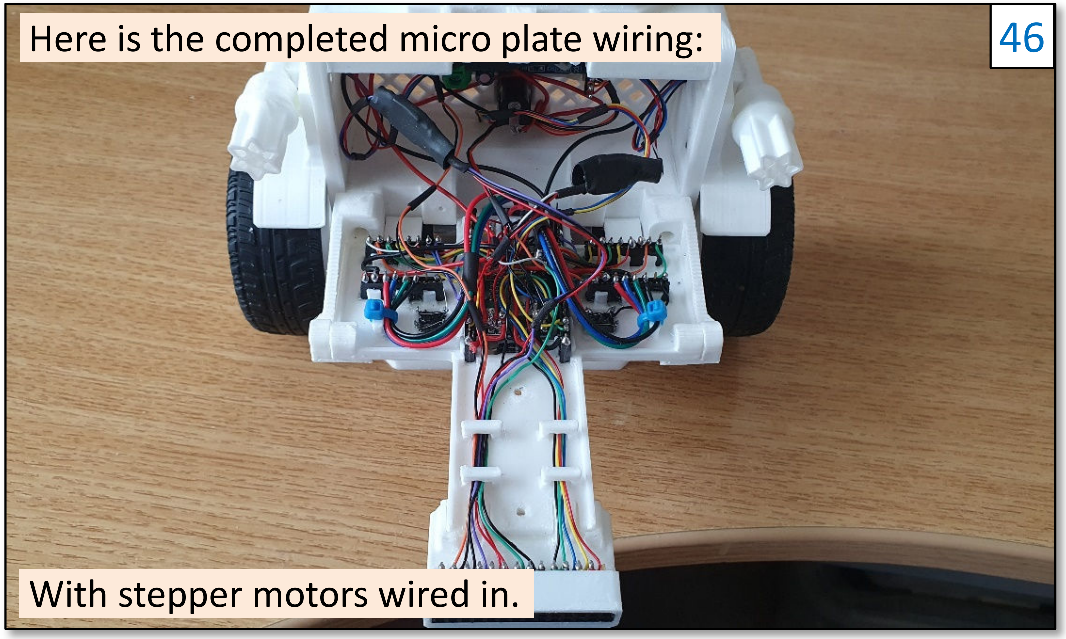
44 Here the pin strip has been glued in:

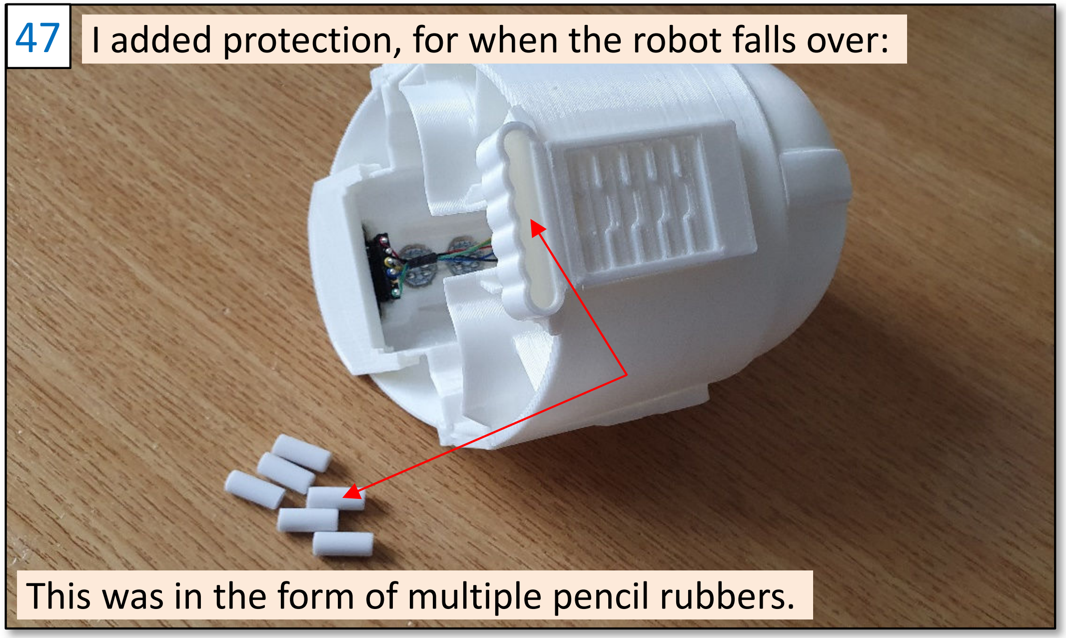
This part of the design has changed in the latest models.

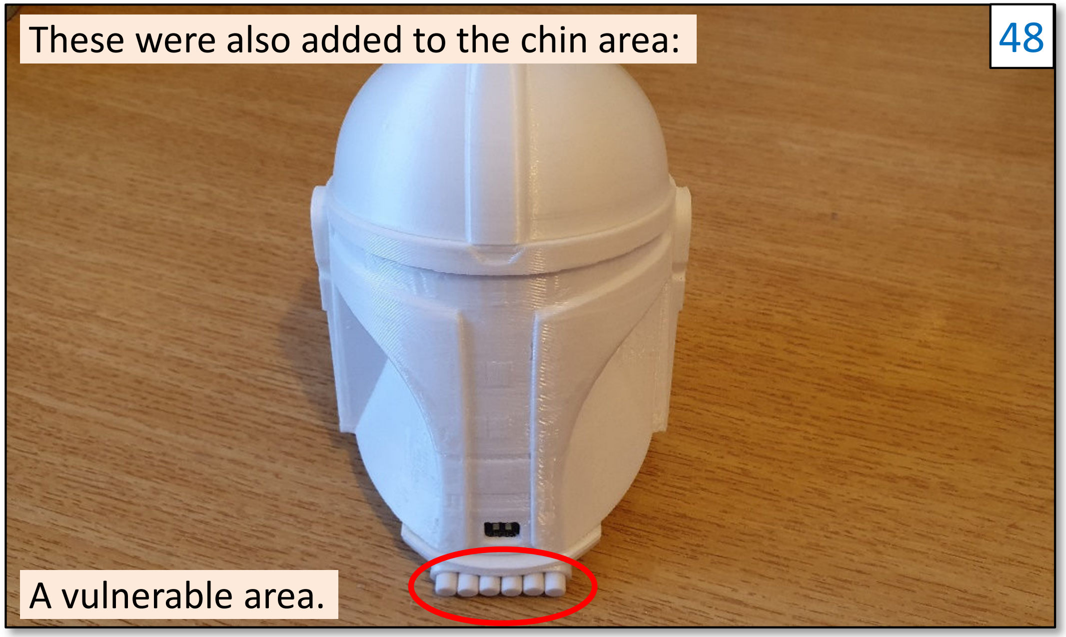
And the VL53L1X laser ranger is wired in with a socket.

Build Images

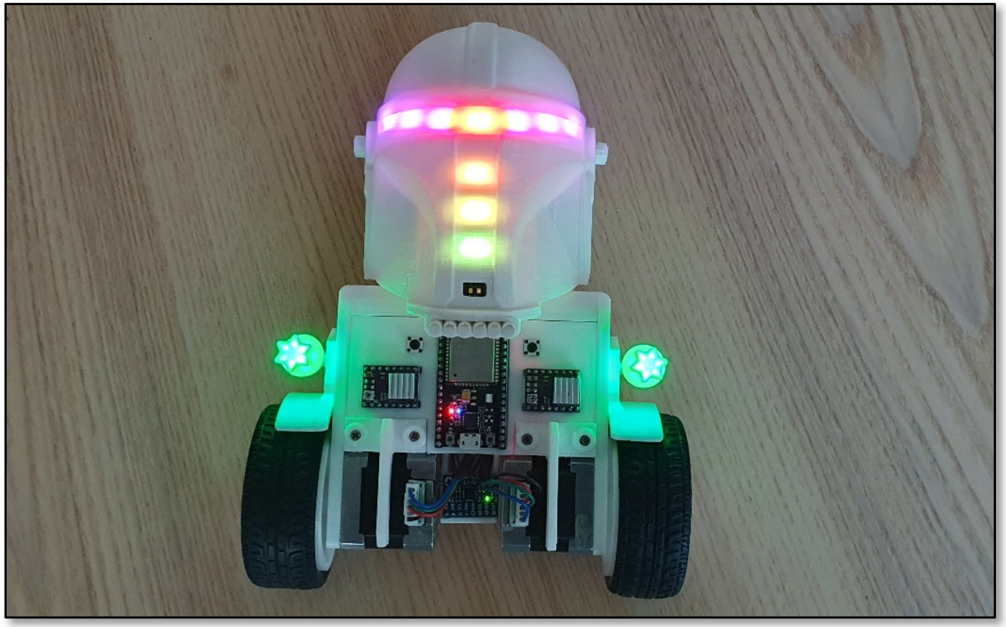


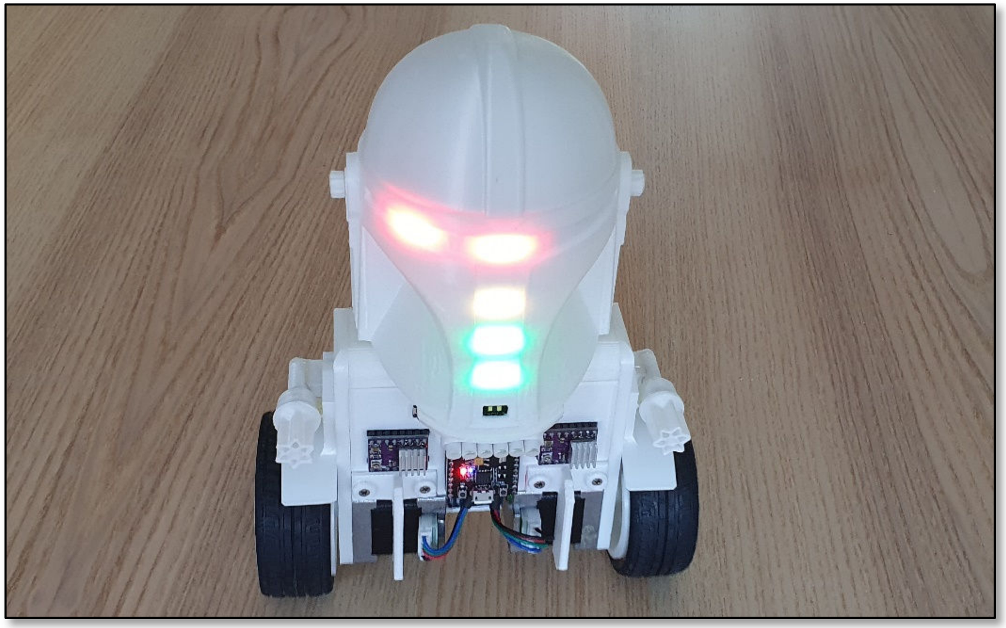


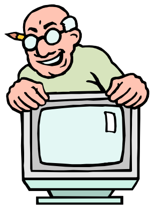




It’s time for testing!







NEMA14 Stepper control

Nema14 stepper motor is 1.8° per step, or 200 steps per revolution.

DRV8825 driver is set to ¼ step(W1-2 phase excitation), giving control resolution of 0.45° per clock pulse.

From DRV8825 datasheet we get the following relationship:

$$f_{step}\,(\mu steps\,/\,second) = \frac{120\left(\frac{rotations}{minute}\right)\times 360\left(\frac{°}{rotation}\right)\times 8\left(\frac{\mu steps}{step}\right)}{60\left(\frac{seconds}{minute}\right)\times 1.8\left(\frac{°}{step}\right)}$$

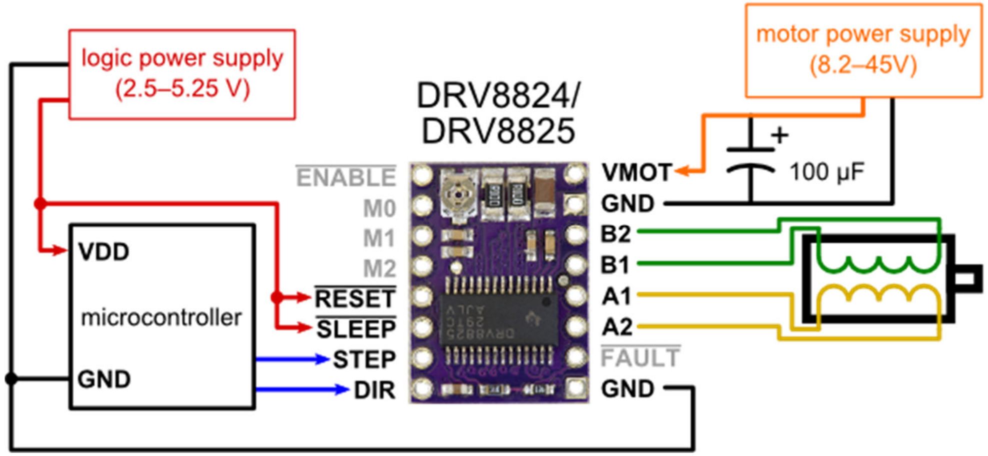
So to run the motor at 3 rev/sec, or 120 rpm, using 1/4 steps, this gives us:

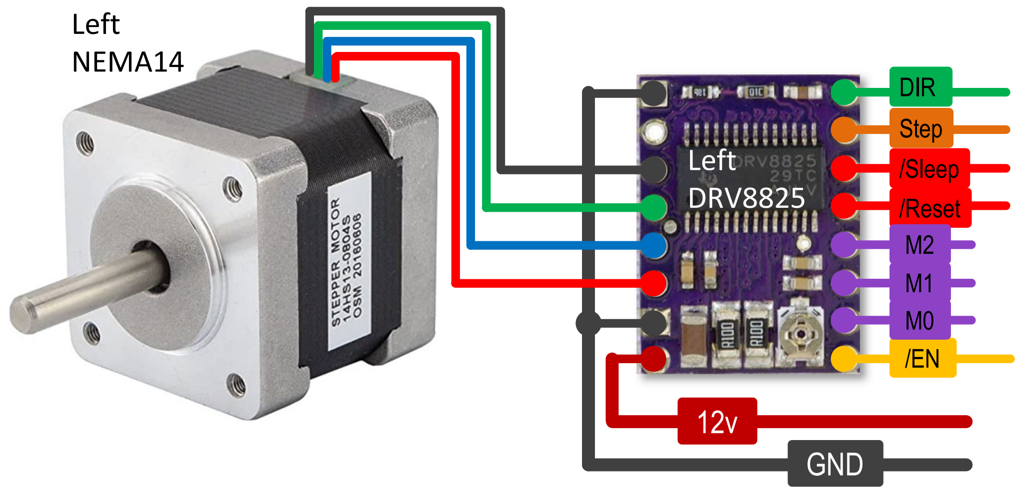
$$F_{step} = 120 * 360 * 4 / 60 \times 1.8 = 1{,}600\ \mu steps/sec\ (1.6kHz)$$

With a step period of 625 µs

In the NANO BalanceBot the ISR gave a minimum step period of 40 µs, which is 25kHz, means it can achieve a max wheel speed of 47 rpm.

This seems quite high, and puts a heavy load on the code, so will run timers off the micros() timer at a max rate of 10 kHz, or 100 µs period.





MODE2	MODE1	MODE0	STEP MODE
0	0	0	Full step (2-phase excitation) with 71% current
0	0	1	1/2 step (1-2 phase excitation)
0	1	0	1/4 step (W1-2 phase excitation)
0	1	1	8 microsteps/step
1	0	0	16 microsteps/step
1	0	1	32 microsteps/step
1	1	0	32 microsteps/step
1	1	1	32 microsteps/step

Battery Voltage Health Monitoring

See Lithium discharge curve obtained from the internet. In this analysis the lipo battery consists of three identical batteries connected in series.
Assume fully charged 11.1v battery max voltage is V_{BM} >= 12.9v max
Set battery warning point at V_B = 10.5v (3 x 3.5v)
Set battery critical point at V_{BC} = 9.9v (3 x3.3v)

The ESP32 is powered via a voltage regulator connected to the 3.3v pin.
V_{ADC} == 4095 on 12-bit converter (4095 max).
If we use a 10k resistor feeding A0 and a 3k3 resistor to GND, we get a conversion factor of 13.3v == 4095, or 3.25mV/bit, or 307.9 bit/v
Using a Multimeter I determined the following V_{ADC} values for corresponding threshold voltages:

MAX: (100%) V_M = 12.3v, gave A0 = 3841 on V_{ADC} (3 x 4.1v)

HIGH: (80%) V_H = 11.4v, gave A0 = 3402 on V_{ADC}

WARNING: (20%) V_B = 10.8v, gives A0 = 3175 on V_{ADC}

CRITICAL: (0%) V_{BC} = 10.0v, gives A0 = 2895 on V_{ADC} (3 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 (1/20) to remove noise. It also detects no battery as USB mode.

In the code I have assumed a discharge curve ranging from 12.3v (100%) to 10.0v (0%) capacity, using the overlay lines shown. The rate of discharge is monitored and used to predict the life 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.