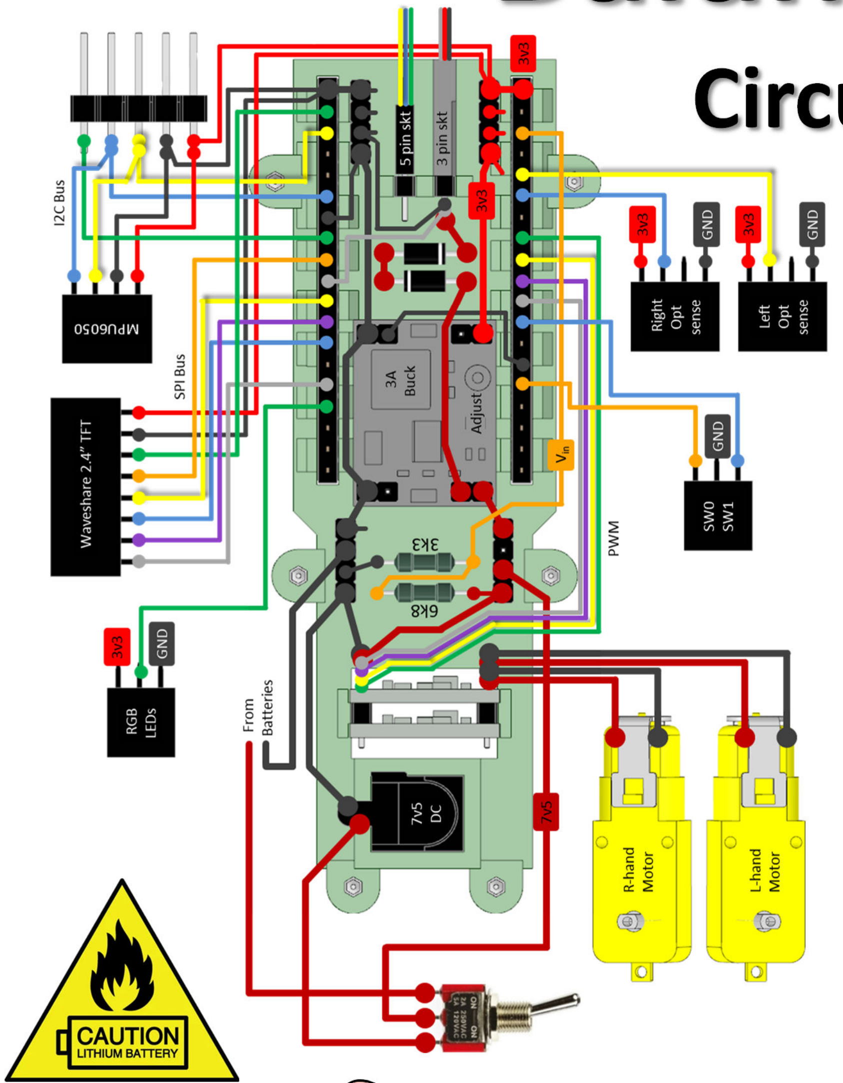
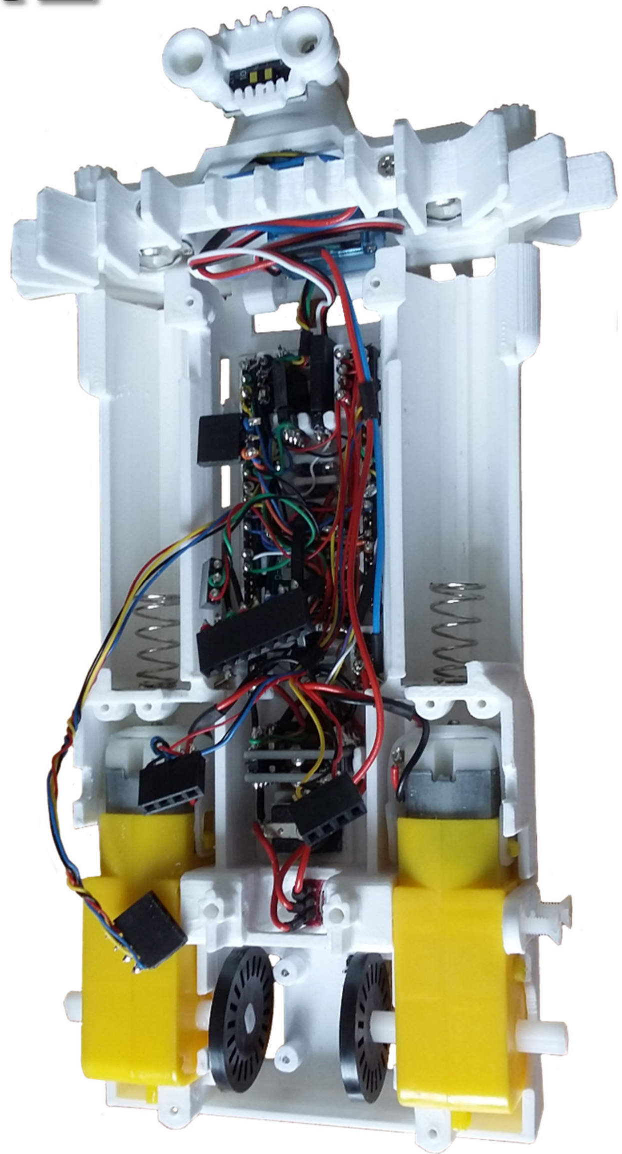
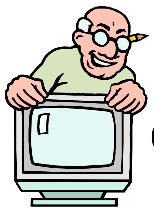
BalanceBot Mk1

Circuits & Wiring



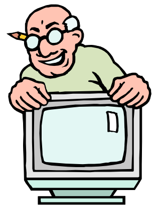




Quite a complex project, please read through this document before starting.

Issue: 1.1 Released: 25/11/2025 TechKnowTone

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 have been 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 needed 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

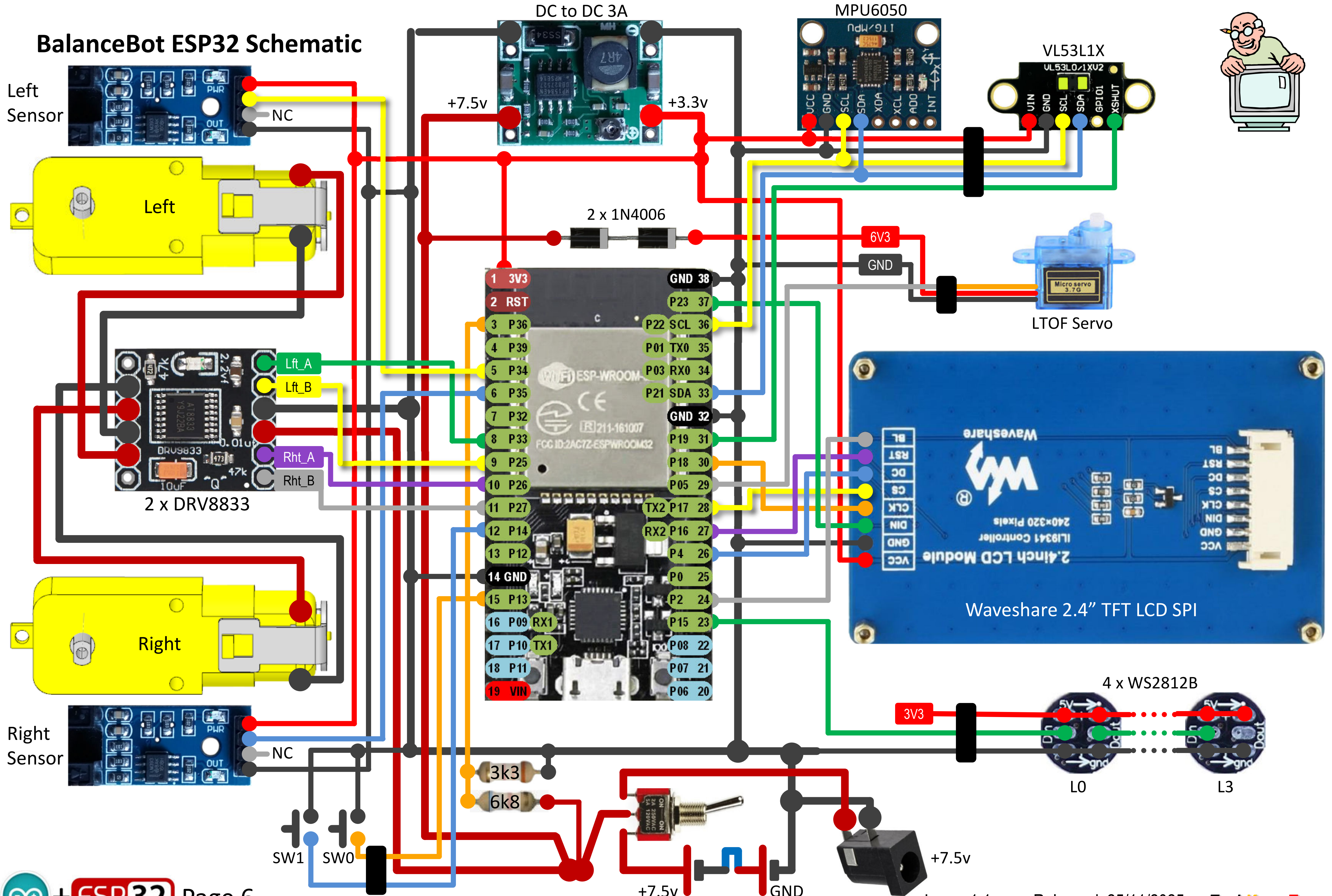
Test Equipment:

You will need a multimeter to set up the 3v3 voltage regulator, and to check wiring continuity.

It is useful to have one which makes a noise when a short circuit is detected, so that you don't need to keep looking at the display.

A servo consistency tester is useful to set the 1500µs position when fitting the head servo lever during assembly. Alternatively you can write some code and use a microcontroller to do this.

BalanceBot ESP32 Schematic



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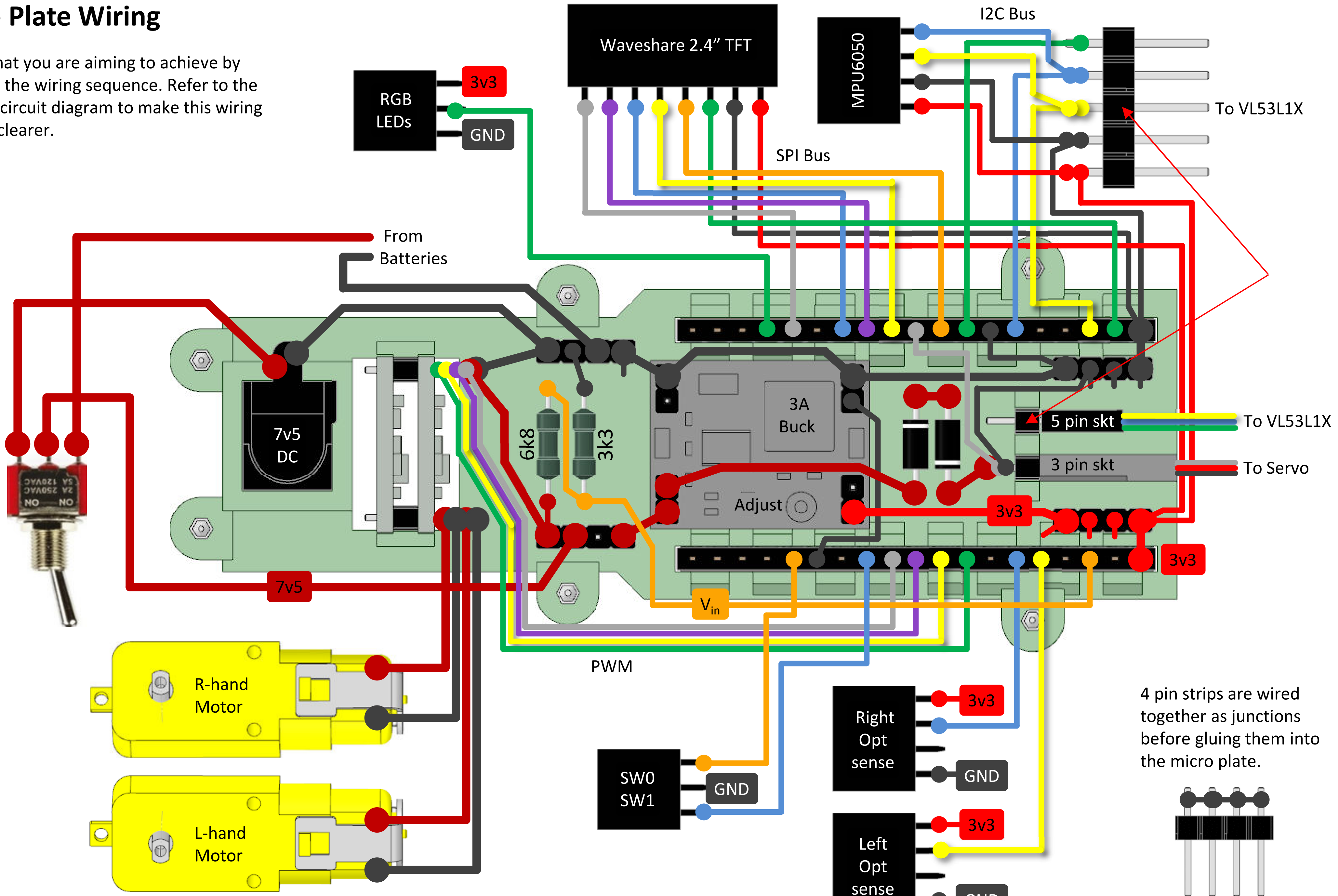
Micro Plate Wiring

This is what you are aiming to achieve by following the wiring sequence. Refer to the previous circuit diagram to make this wiring diagram clearer.



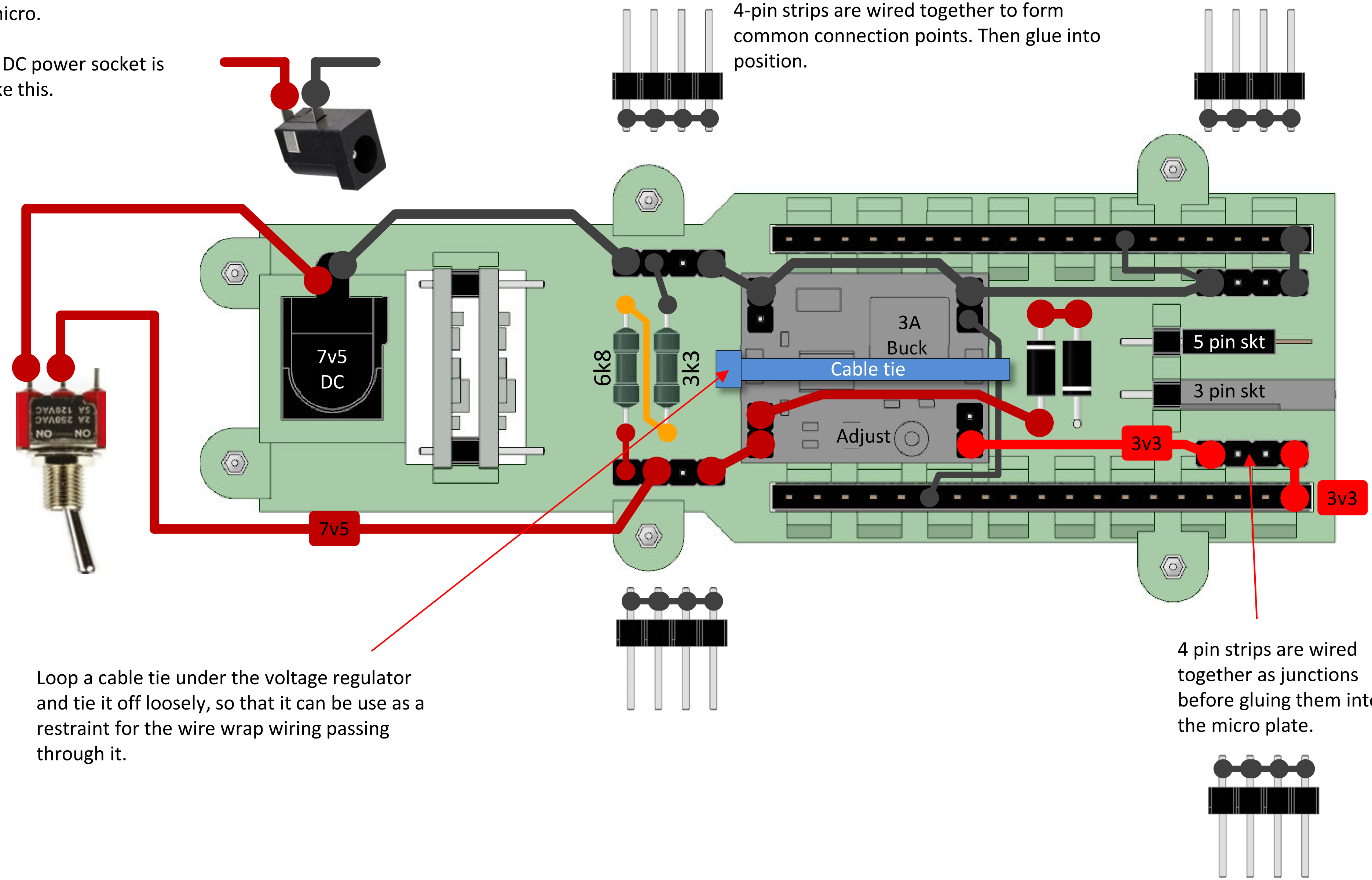
4 pin strips are wired together as junctions before gluing them into the micro plate.

Micro Plate Wiring – Step 1

Refer to the previous circuit diagram to make this wiring diagram clearer. Start by wiring in the toggle switch and power connections to the ESP32 micro.

The 7v5 DC power socket is wired like this.

4-pin strips are wired together to form common connection points. Then glue into position.



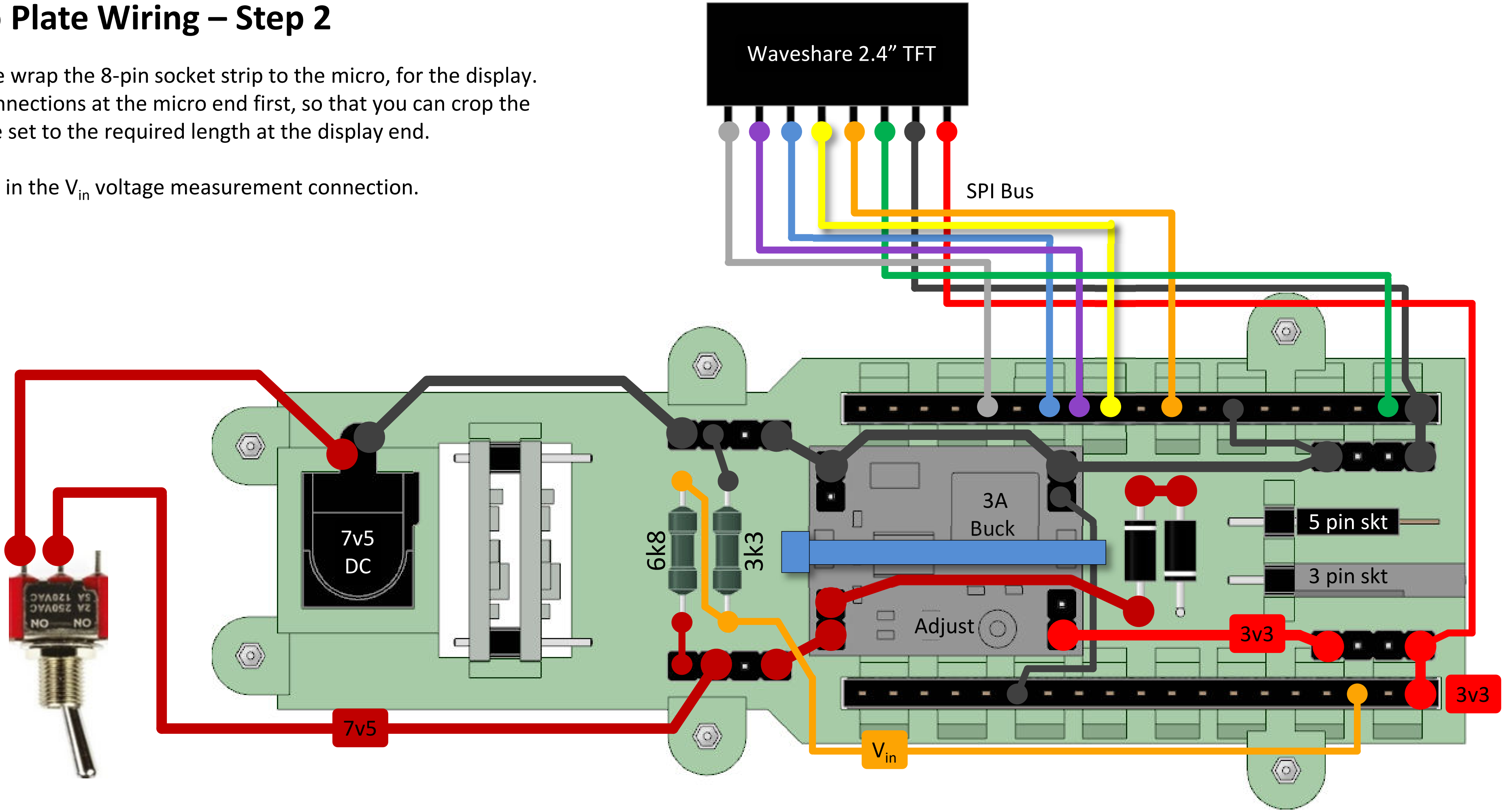
Loop a cable tie under the voltage regulator and tie it off loosely, so that it can be use as a restraint for the wire wrap wiring passing through it.

4 pin strips are wired together as junctions before gluing them into the micro plate.

Micro Plate Wiring – Step 2

Next wire wrap the 8-pin socket strip to the micro, for the display. Make connections at the micro end first, so that you can crop the complete set to the required length at the display end.

Also wire in the V_{in} voltage measurement connection.



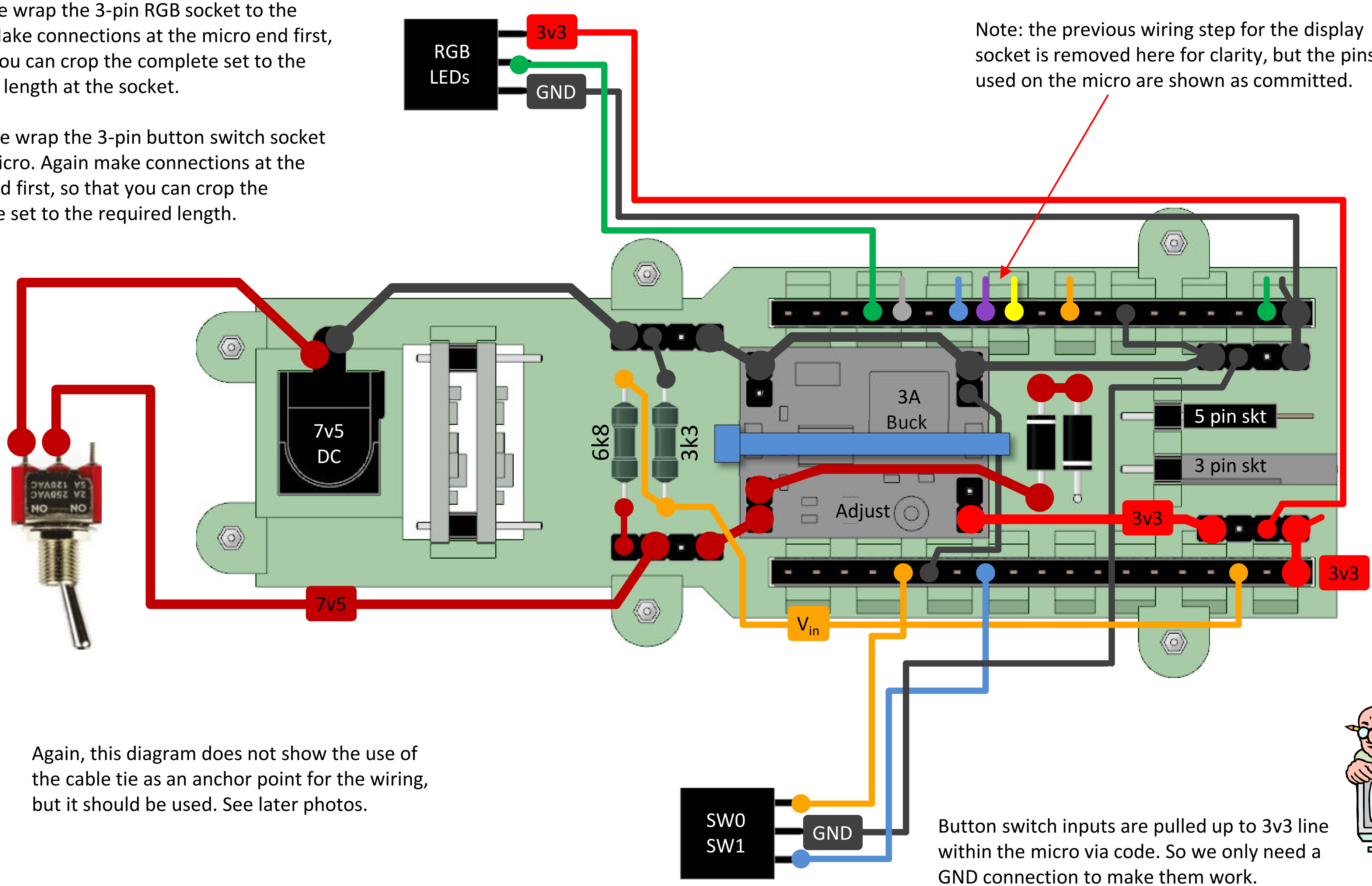
Note this diagram does not show the use of the cable tie as an anchor point for the wiring, but it should be used. See later photos.

Micro Plate Wiring – Step 3

Next wire wrap the 3-pin RGB socket to the micro. Make connections at the micro end first, so that you can crop the complete set to the required length at the socket.

Then wire wrap the 3-pin button switch socket to the micro. Again make connections at the micro end first, so that you can crop the complete set to the required length.

Note: the previous wiring step for the display socket is removed here for clarity, but the pins used on the micro are shown as committed.



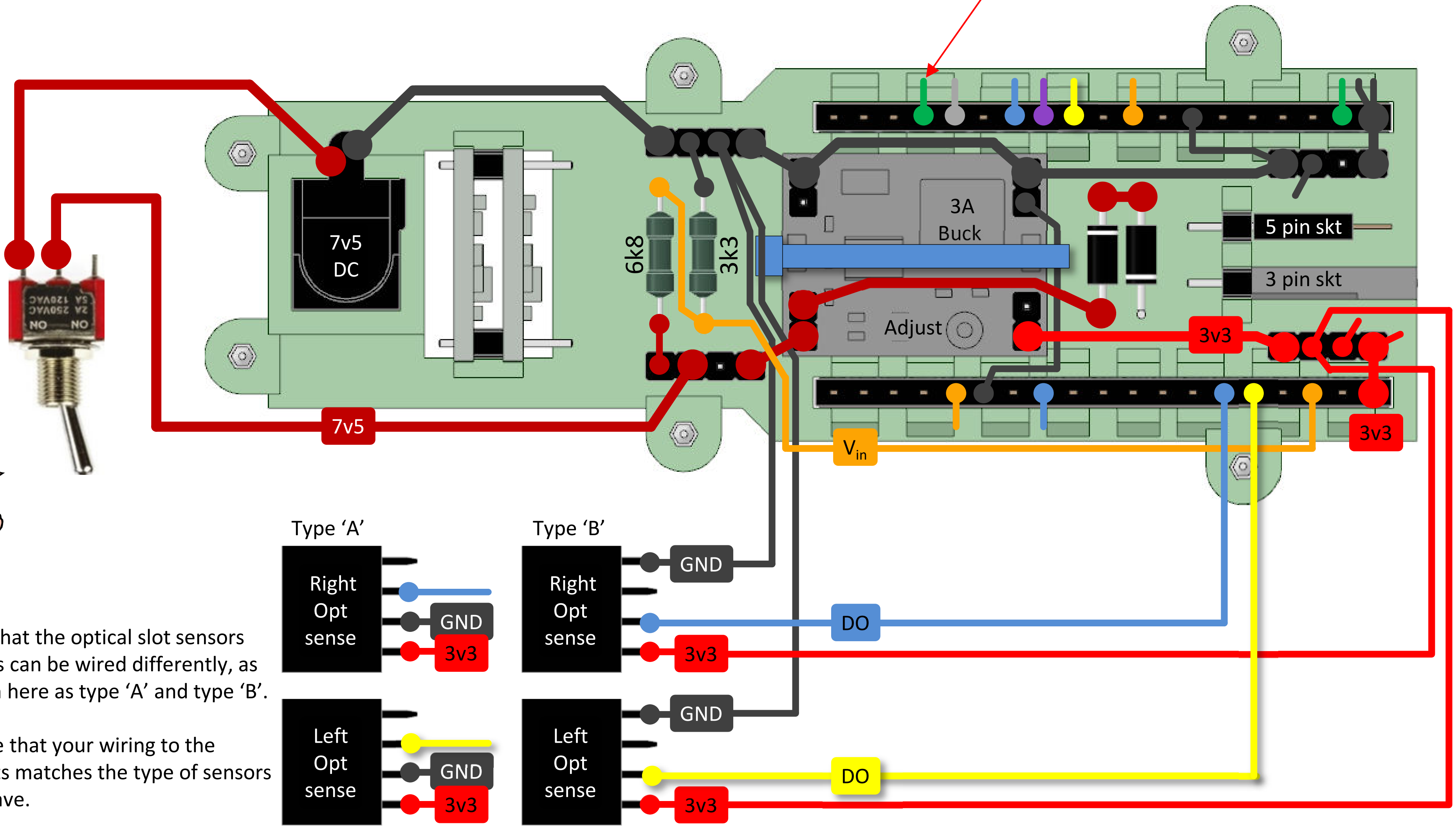
Again, this diagram does not show the use of the cable tie as an anchor point for the wiring, but it should be used. See later photos.

Button switch inputs are pulled up to 3v3 line within the micro via code. So we only need a GND connection to make them work.

Micro Plate Wiring – Step 4

Next wire wrap the two 4-pin optical sensor sockets to the micro. Make connections at the micro end first, so that you can crop the complete set to the required length.

Note: the previous wiring step for the RGB and switch sockets are removed for clarity, but the pins used on the micro are shown as committed.



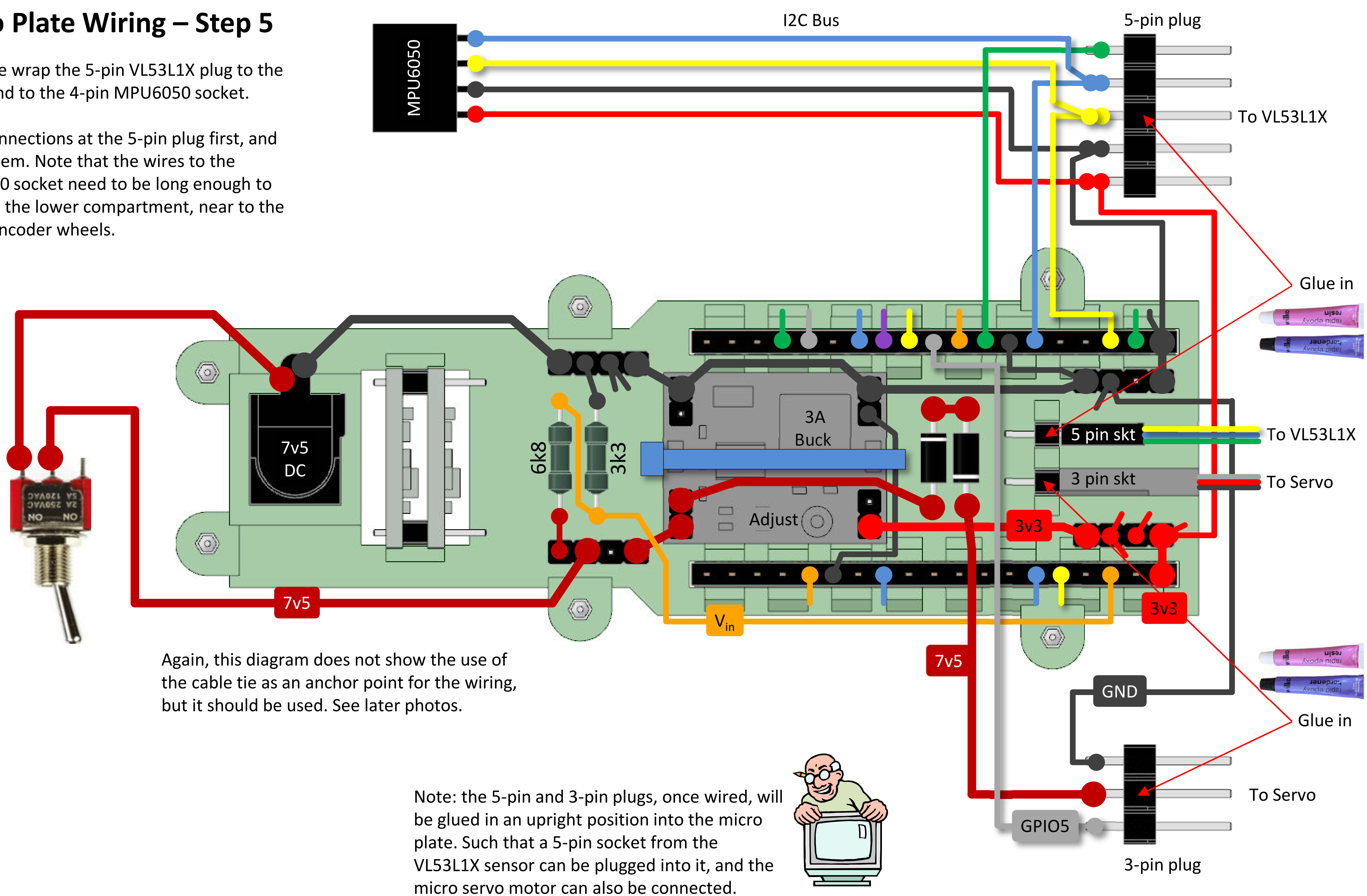
Note that the optical slot sensors boards can be wired differently, as shown here as type 'A' and type 'B'.

Ensure that your wiring to the sockets matches the type of sensors you have.

Micro Plate Wiring – Step 5

Next wire wrap the 5-pin VL53L1X plug to the micro, and to the 4-pin MPU6050 socket.

Make connections at the 5-pin plug first, and solder them. Note that the wires to the MPU6050 socket need to be long enough to reach int the lower compartment, near to the optical encoder wheels.



Again, this diagram does not show the use of the cable tie as an anchor point for the wiring, but it should be used. See later photos.

Note: the 5-pin and 3-pin plugs, once wired, will be glued in an upright position into the micro plate. Such that a 5-pin socket from the VL53L1X sensor can be plugged into it, and the micro servo motor can also be connected.

Dual H-bridge Wiring

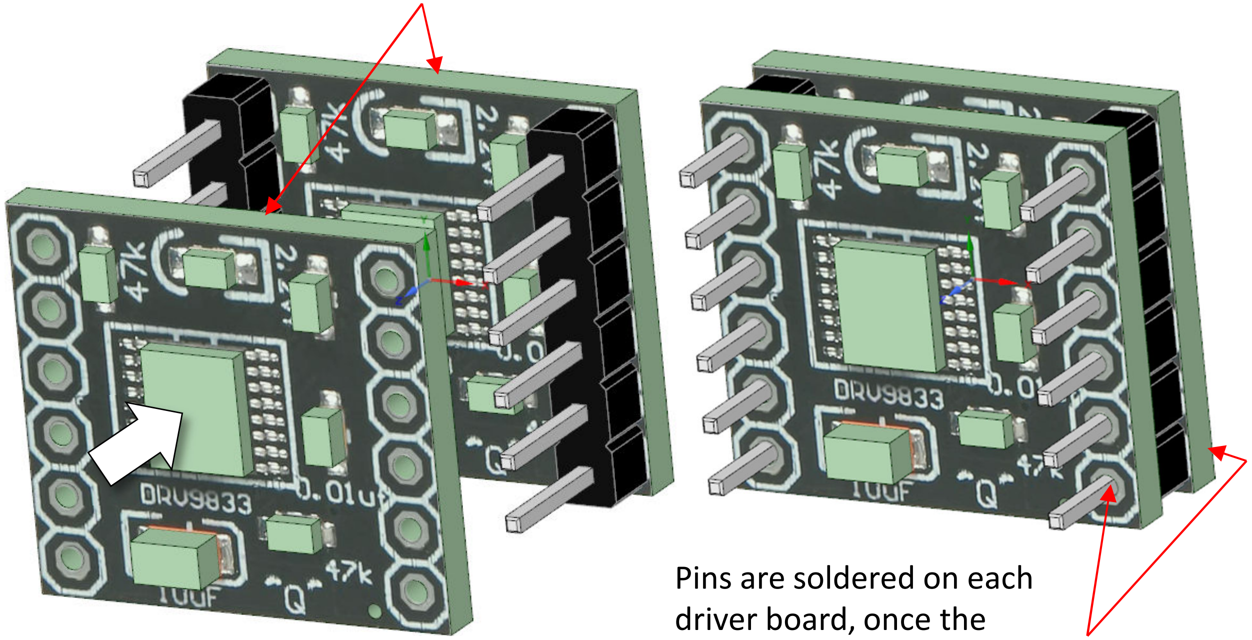
In this design we run two H-bridge controllers in parallel in order to combined their 2A max current capability, and half their MOS-FETs on-channel resistance.

This is achieved by creating a sandwich using two controllers pcb's with 6 pin strips between them. The pins are soldered into each pcb, and the protruding longer pins are used as the connection points.

This sandwich module is mounted in the design such that cooling airflow can circulate over the DRV8833 driver ICs.

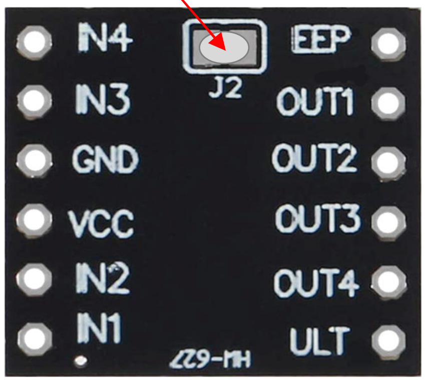
The nSLEEP and nFAULT pins are not connected; however, the nSLEEP pin is pulled HIGH by an on-board 47kΩ resistor when you bridge J2 with a blob of solder, as shown below.

Solder J2

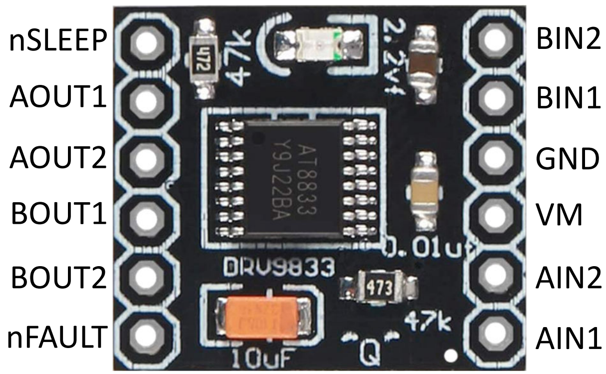


Pins are soldered on each driver board, once the assembly is pushed together. Solder J2 <u>before</u> doing this.

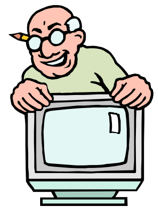
Solder J2

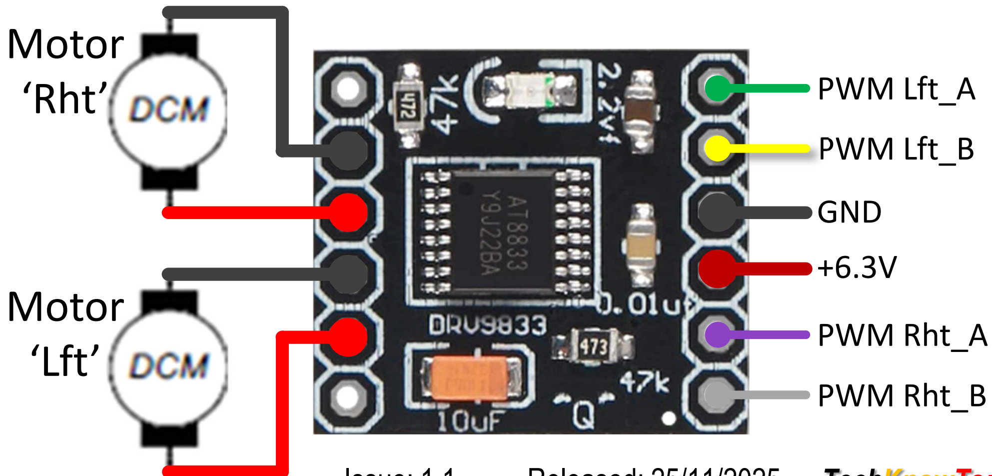


Solder J2 **before** you make the sandwich assembly!



Note that the motor outputs are not opposite their respective inputs.

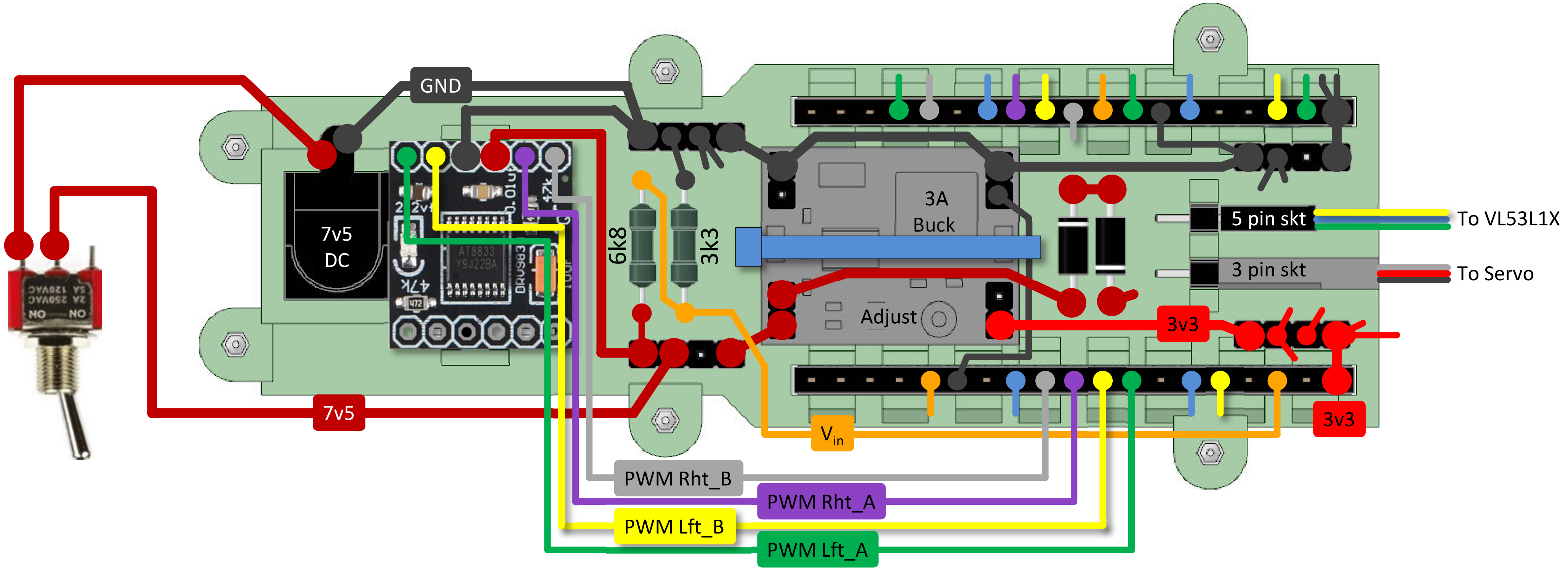




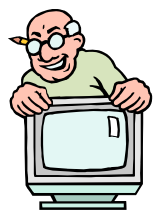
Micro Plate Wiring – Step 6

Next wire wrap the H-bridge controllers to the micro. First connect the +ve and –ve supplies; then the control signals. For each connection start at the H-bridge end and complete the connection at the micro.

The motor connections will be made later.



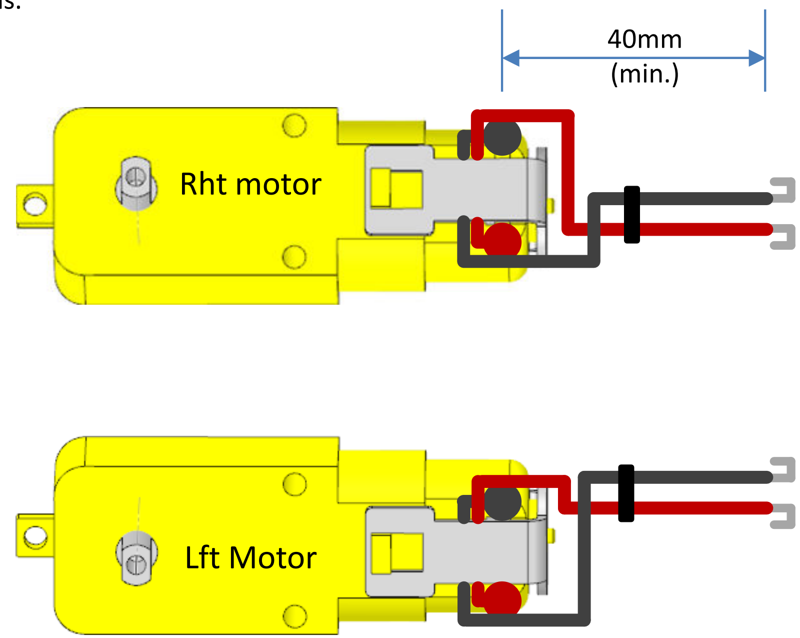
Once the connections to the micro have been made, slot the H-bridge controller into the two vertical mounting posts.

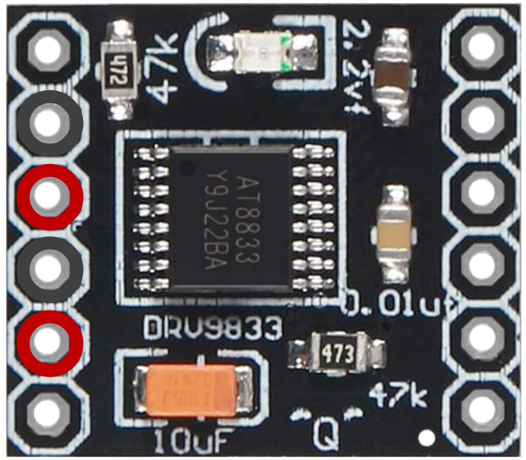


Motor Wiring

Wire the left-hand and right-hand motors as shown, using ?? AWG wire. The wire lengths should be a minimum of ??mm. Strip, twist and tin the ends of the wires, then form them into hooks, ready to be soldered onto the H-bridge controllers.

Mount the motors in the chassis, and mount the micro plate. Lift the H-bridge controller out of its mounting posts to gain access to the motor output pins.





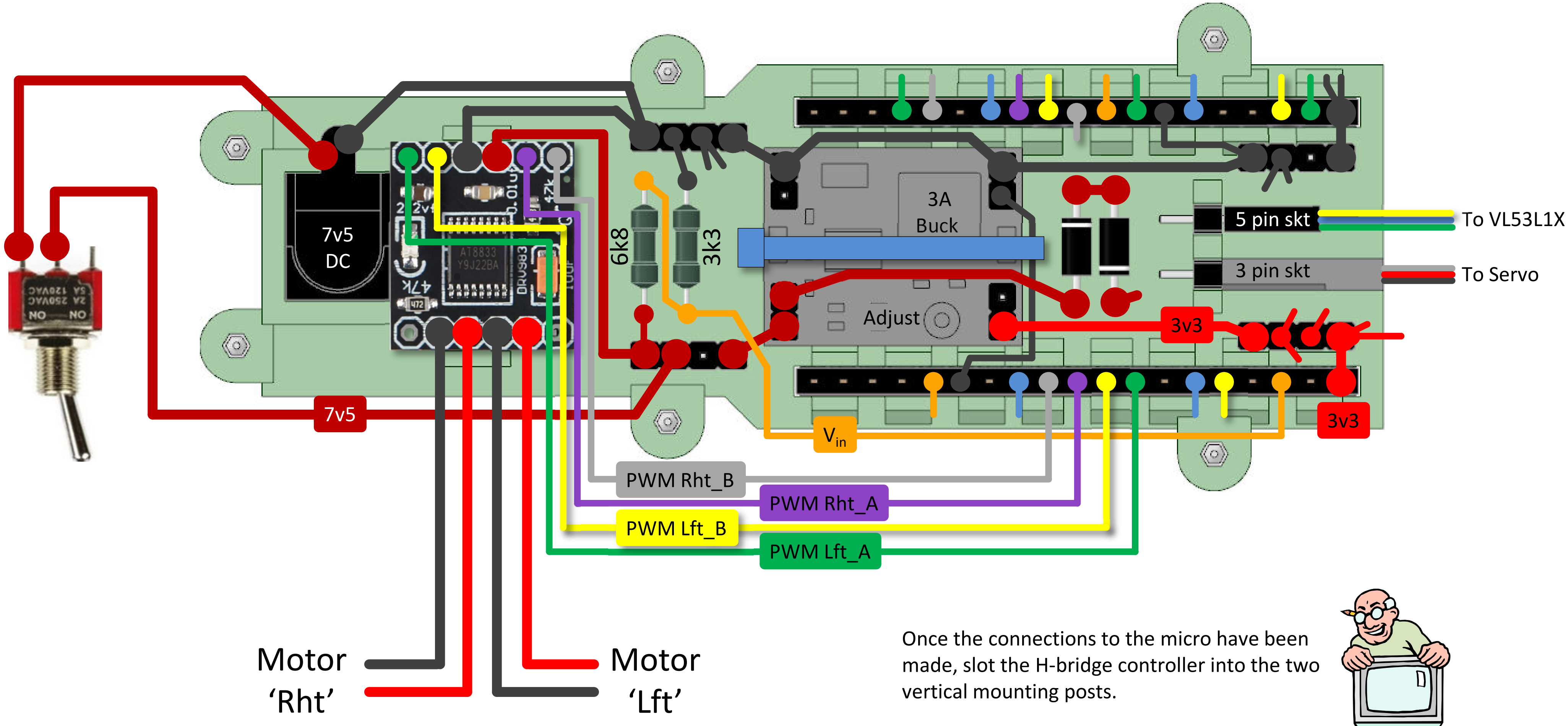
Place the soldered hooks over their respective pins and solder them into position. The open hooks should make a good connection, and also make it easy to unsolder them if needed for maintenance work.

Once the motor wires are connected, place the H-bridge controller back in its mounting posts and apply a small drop of soft melt glue to hold it in position.

Micro Plate Wiring – Step 7

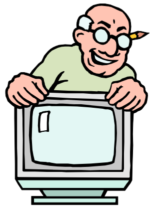
Next wire wrap the H-bridge controllers to the micro. First connect the +ve and –ve supplies; then the control signals. For each connection start at the H-bridge end and complete the connection at the micro.

The motor connections will be made later.



Once the connections to the micro have been made, slot the H-bridge controller into the two vertical mounting posts.

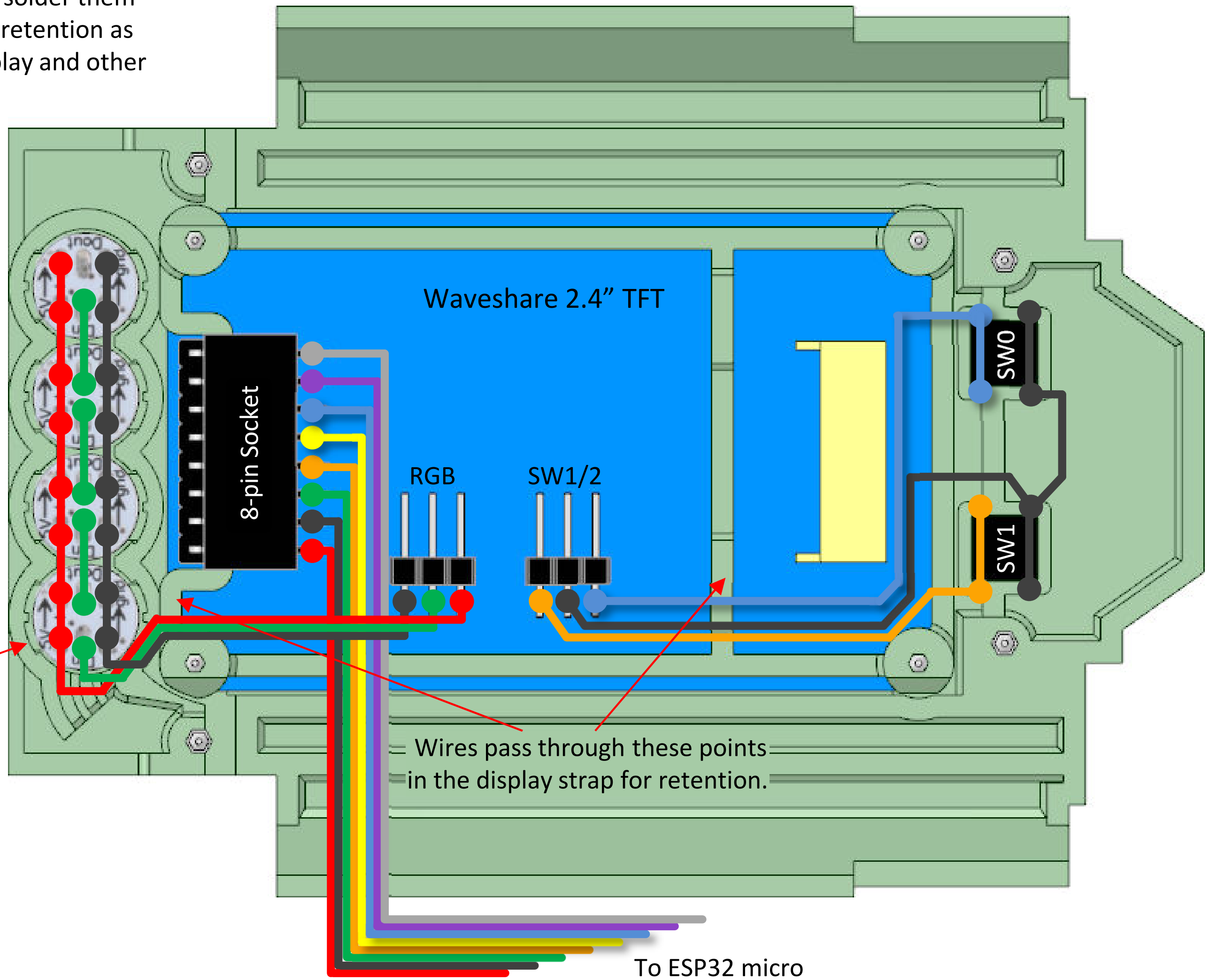
Top Panel Wiring – Step 8



This diagram details the connections to the 2.4" OLED display 8-pin socket, the RGB LED strip 3-pin strip and the switch SW0 & SW1 3-pin strip.

The 8-pin socket is wired with more than enough length to reach pins on the ESP32.

Once the connections are wire wrapped, solder them and then apply hot melt glue to improve retention as well as providing insulation from the display and other connections on the micro plate.



Solder wires onto RGB LED pads, staring from this end.

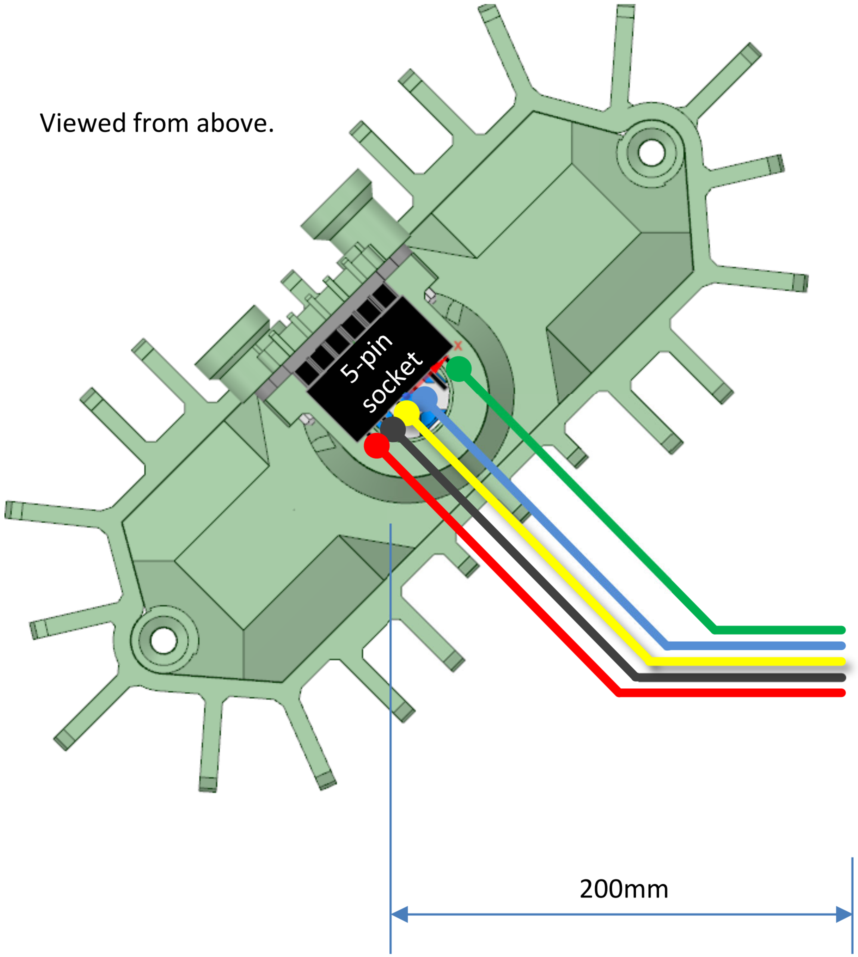
Note that the green data wire is raised up between each soldered pad on the chip, so that they can be cut out once all pads are soldered.

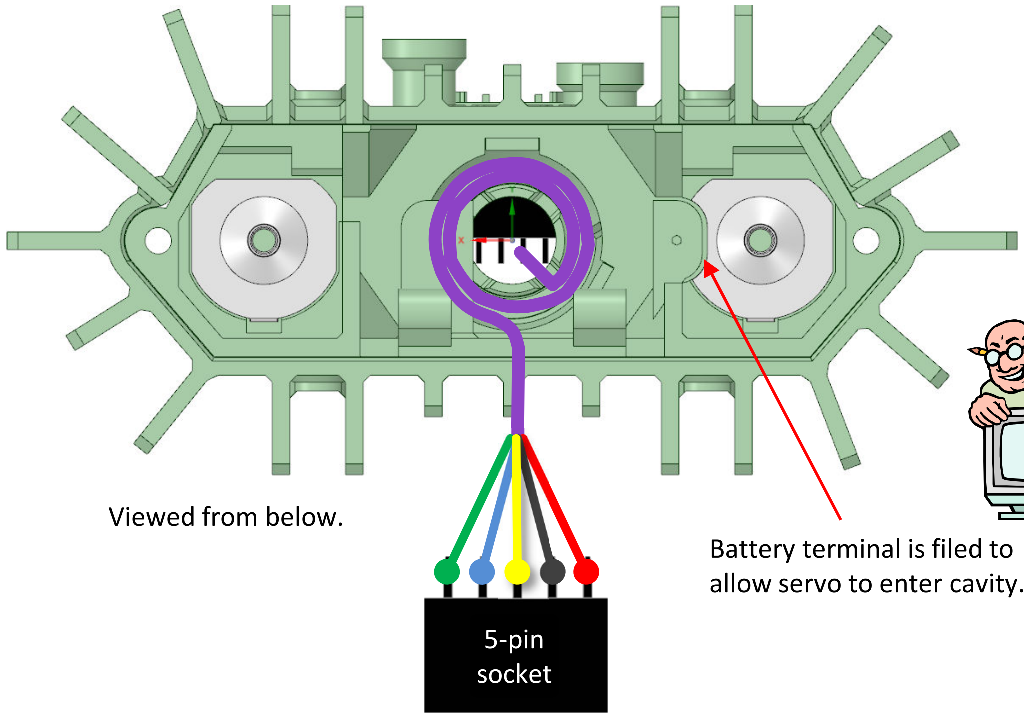
Micro Plate Wiring – Step 8

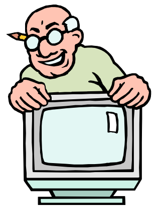
Next wire wrap the 6-pin socket connected to the VL53L1X LTOF range finder. Use the recommended wire length shown below to ensure that you will have sufficient. The wires need to pass through the neck assembly and loop round the throat spindle twice before exiting the unit.

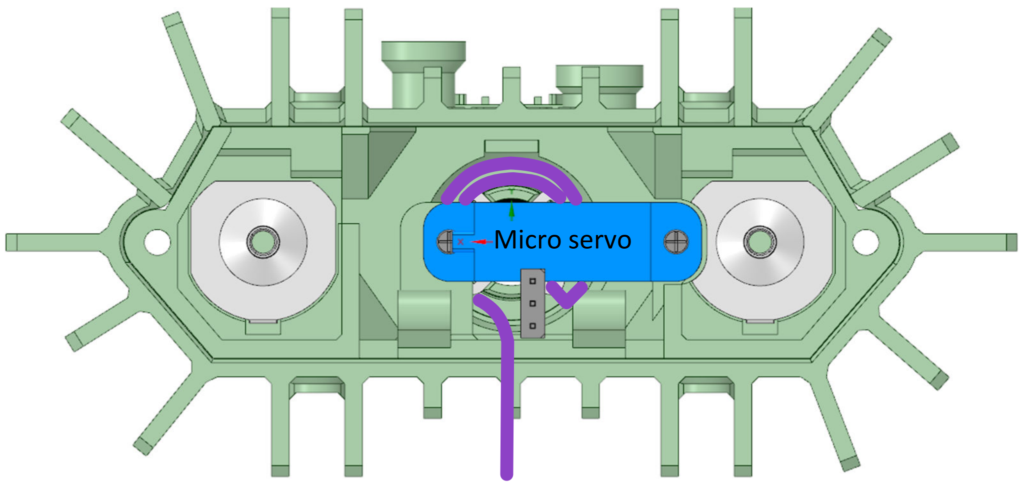
Here I show the looping of the wires, represent by one thick purple strand. When fitted the servo motor will hold the wires in position.

Viewed from above.









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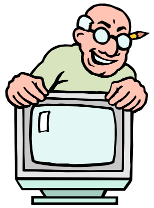
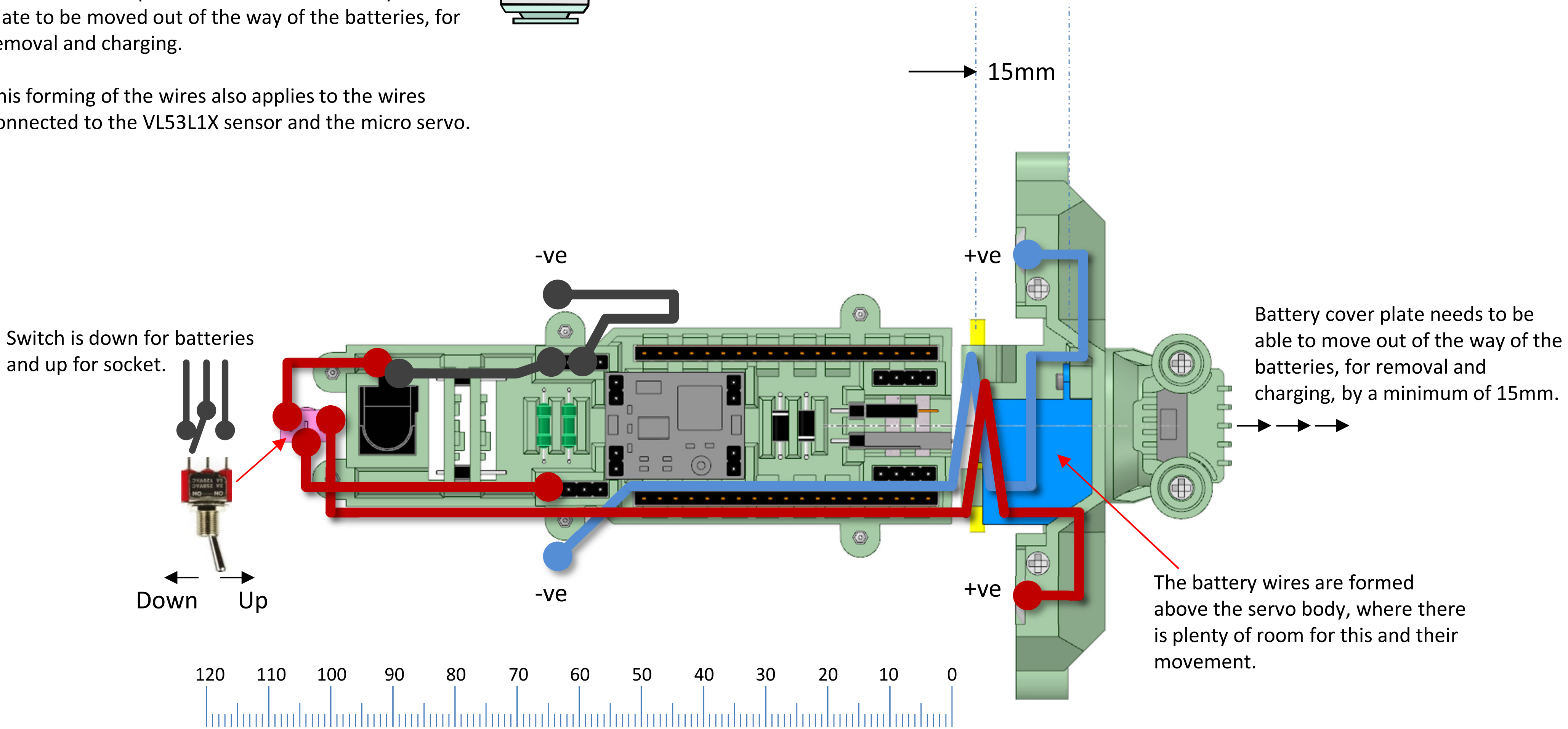
Battery Wiring

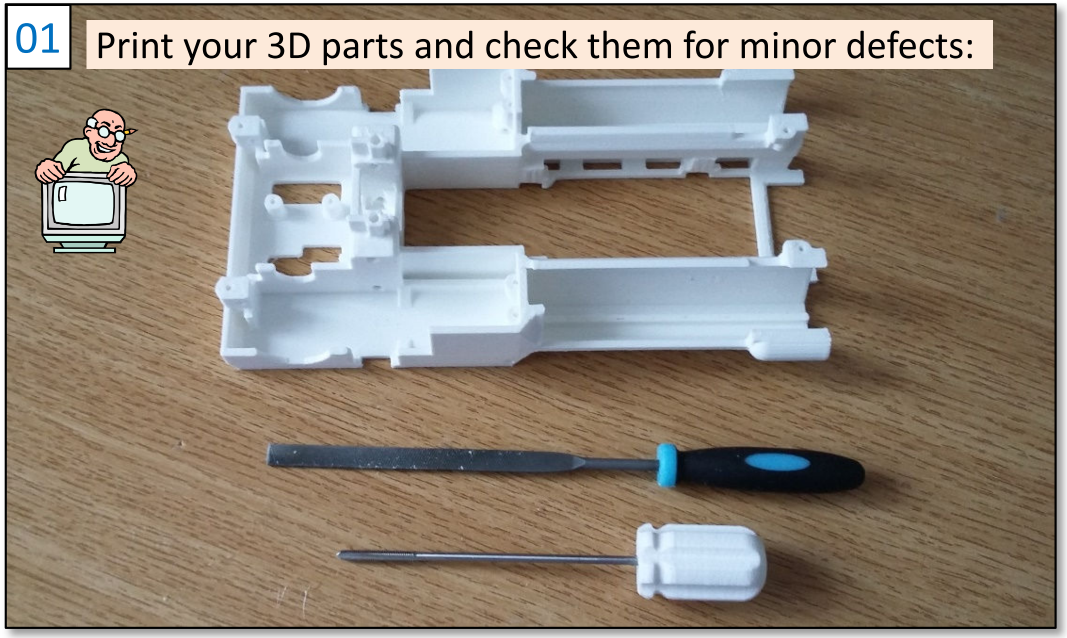
This diagram is to scale if printed at 100%. It shows the routing of the wires, and how they are formed at the end of the micro plate to allow for the battery cover plate to be moved out of the way of the batteries, for removal and charging.

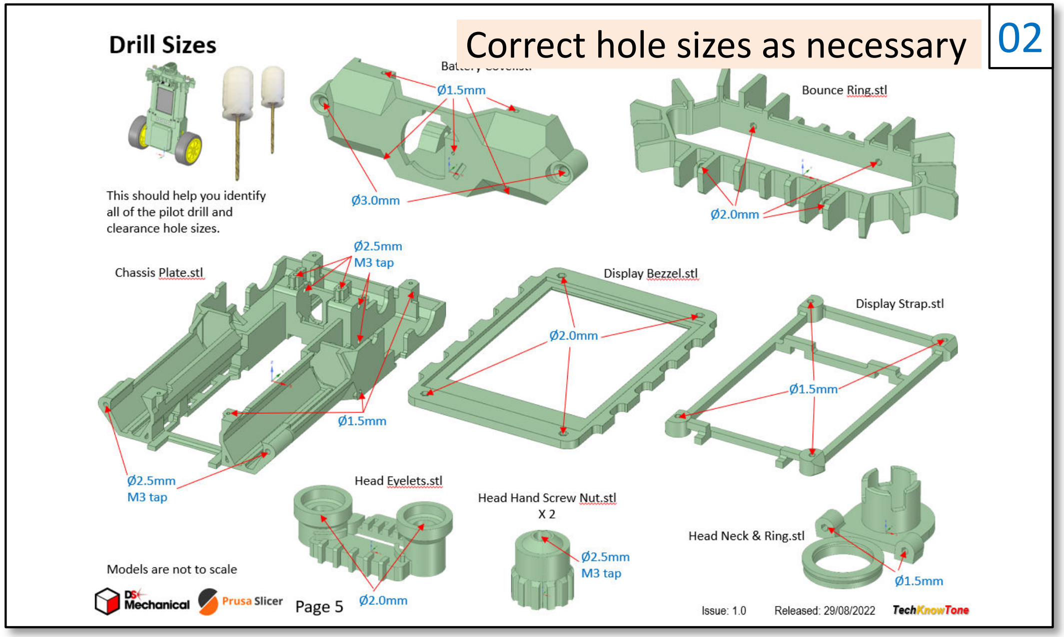


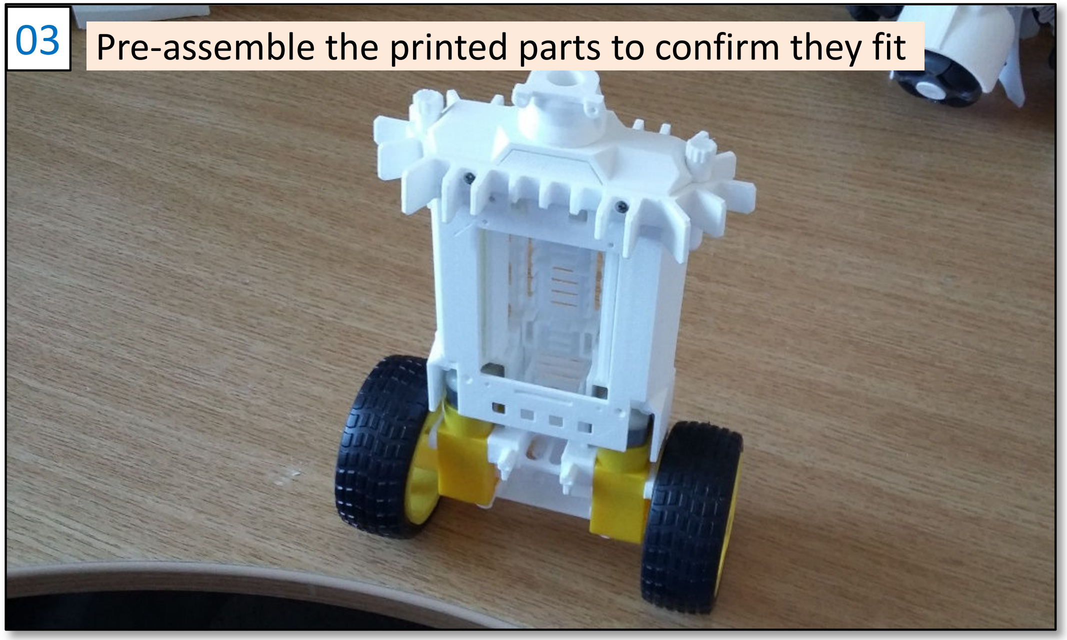
This forming of the wires also applies to the wires connected to the VL53L1X sensor and the micro servo.

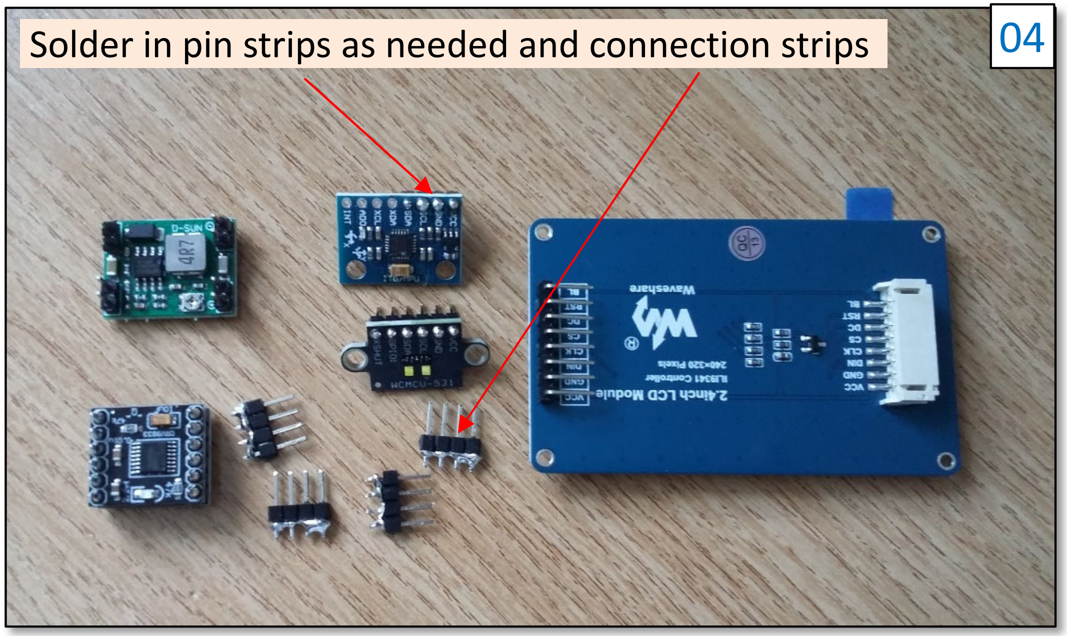


Photos of wiring sequence

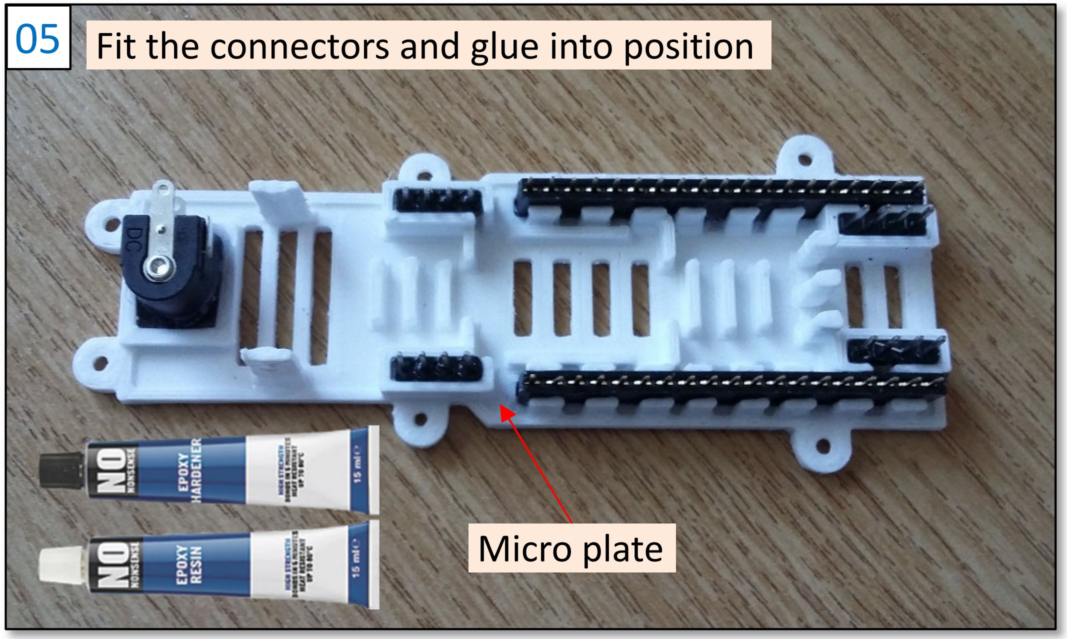


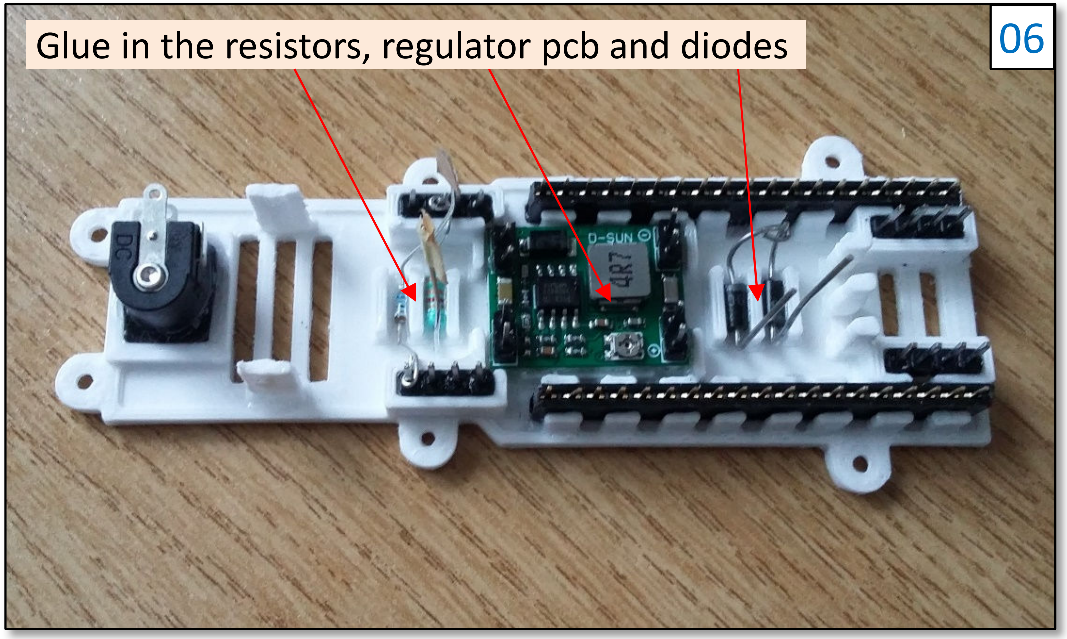


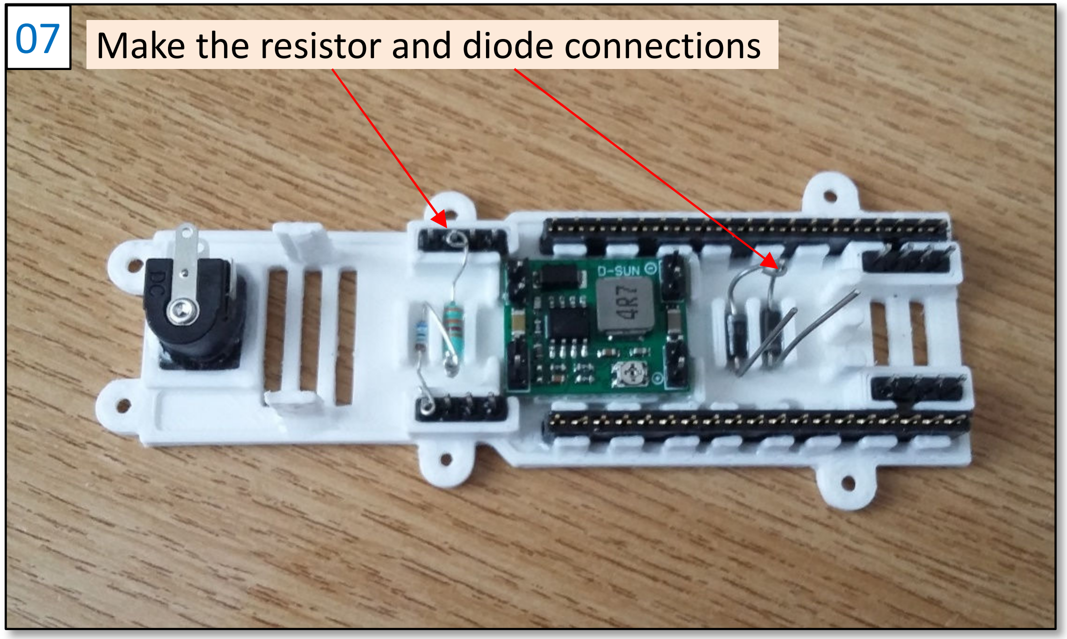


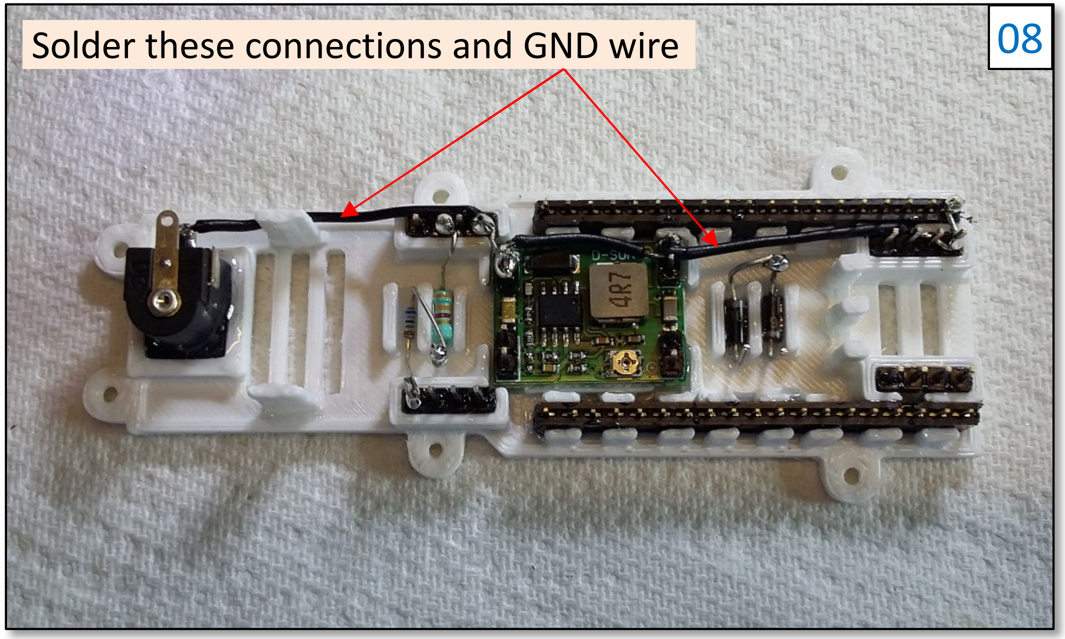


Photos of wiring sequence

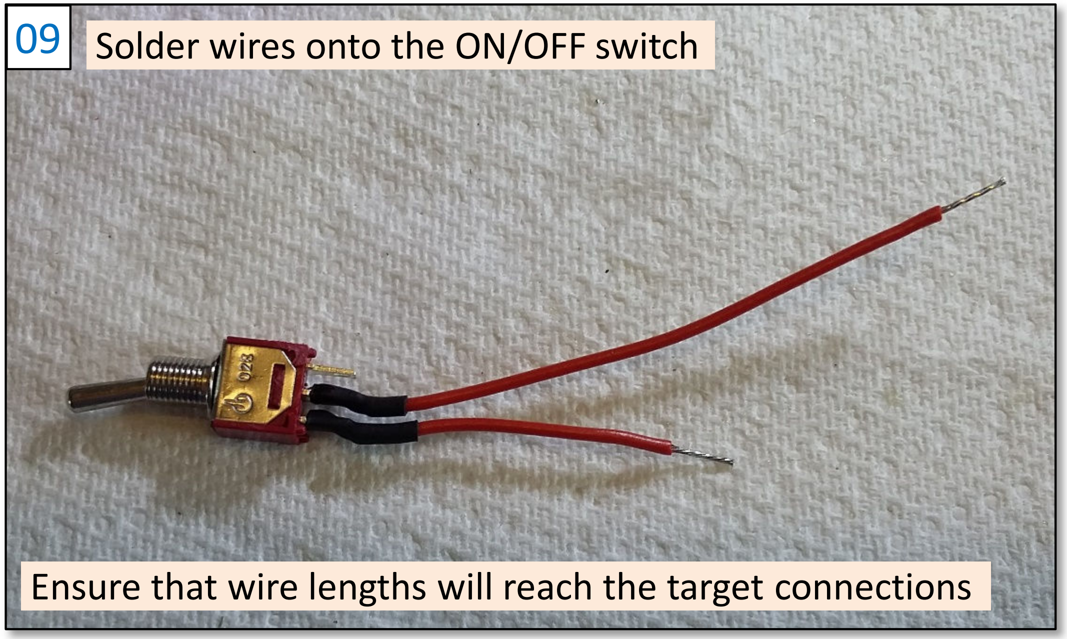






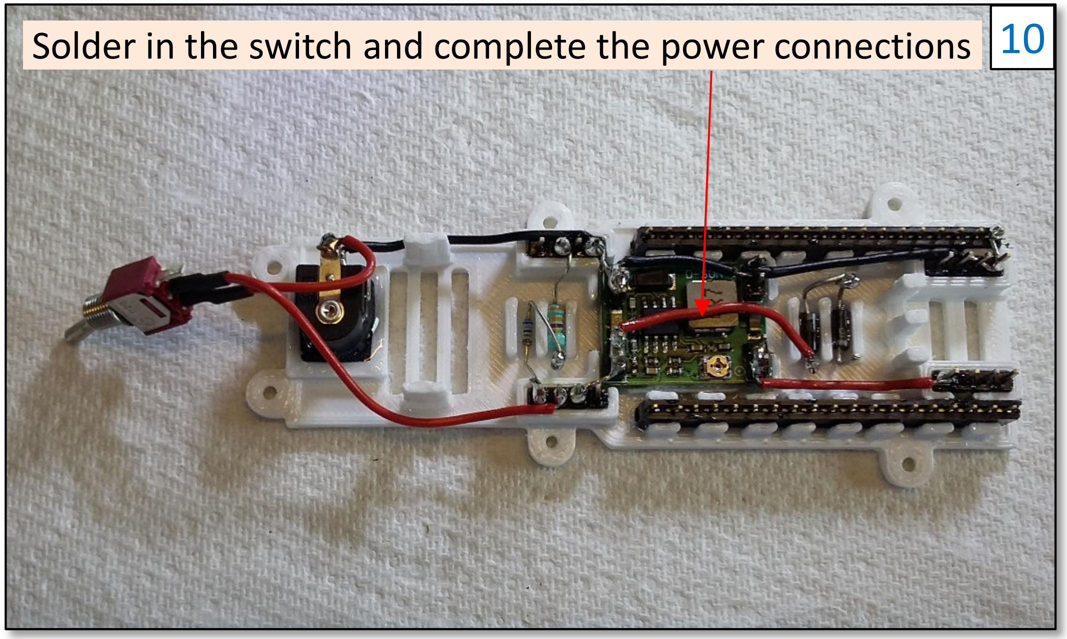


Photos of wiring sequence

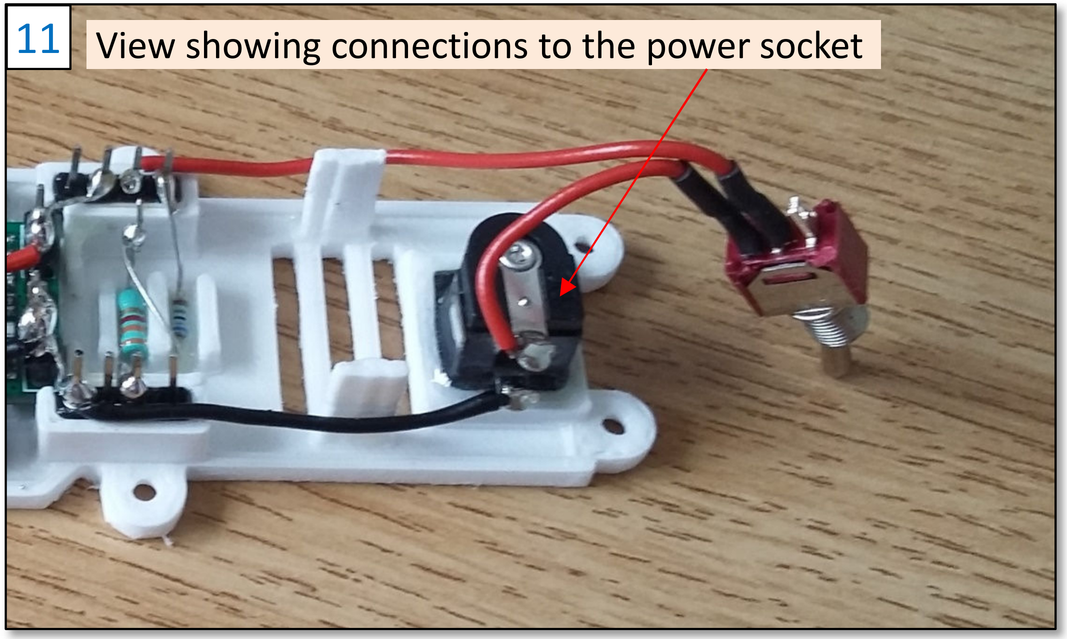


09 Solder wires onto the ON/OFF switch

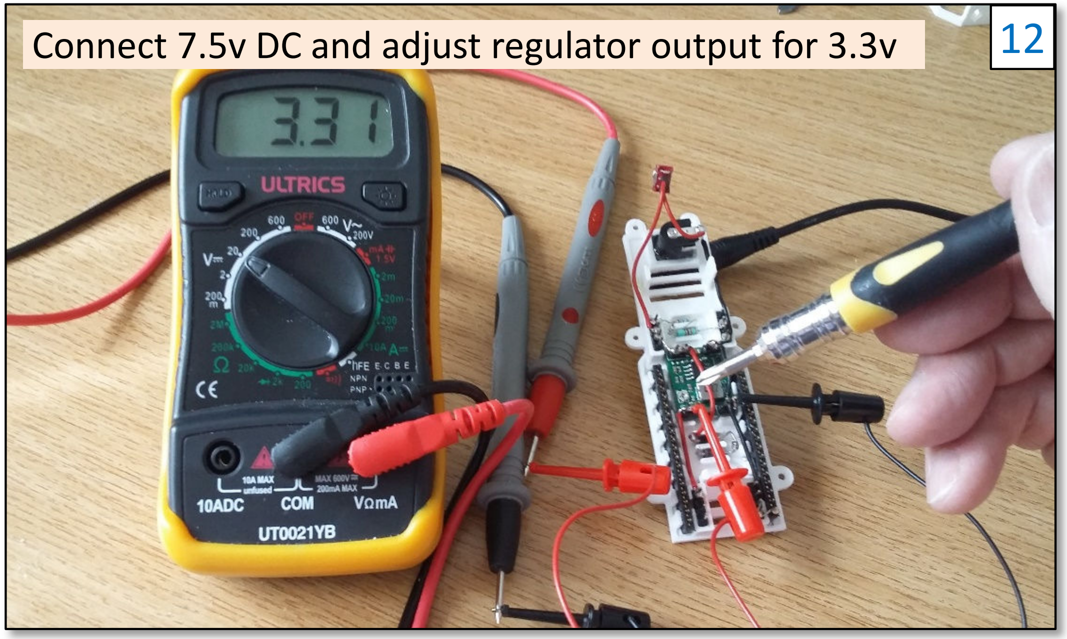
Ensure that wire lengths will reach the target connections



10 Solder in the switch and complete the power connections

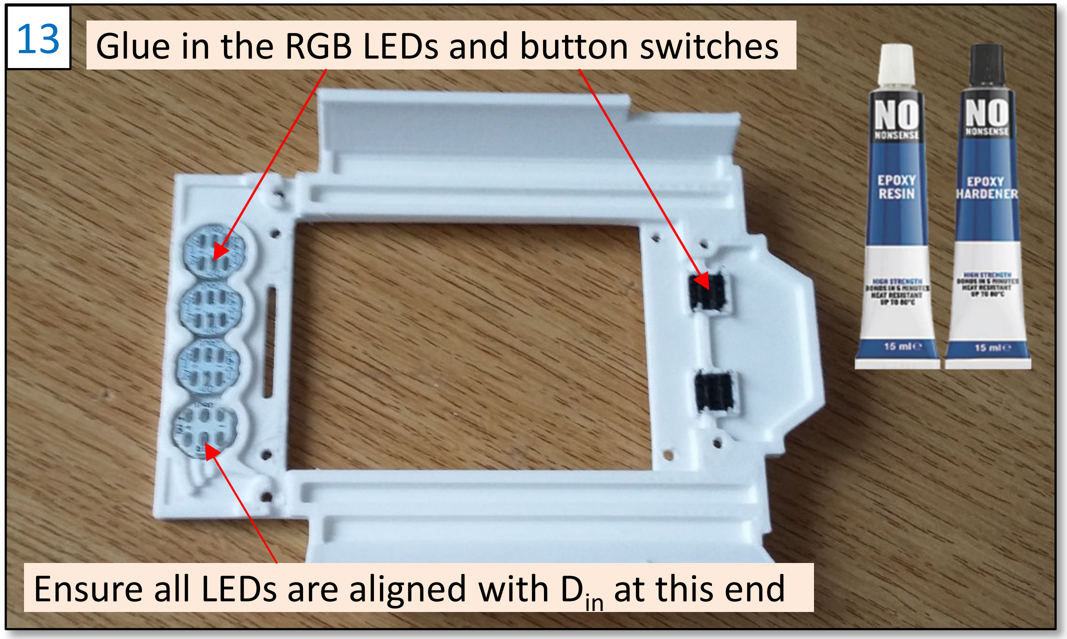


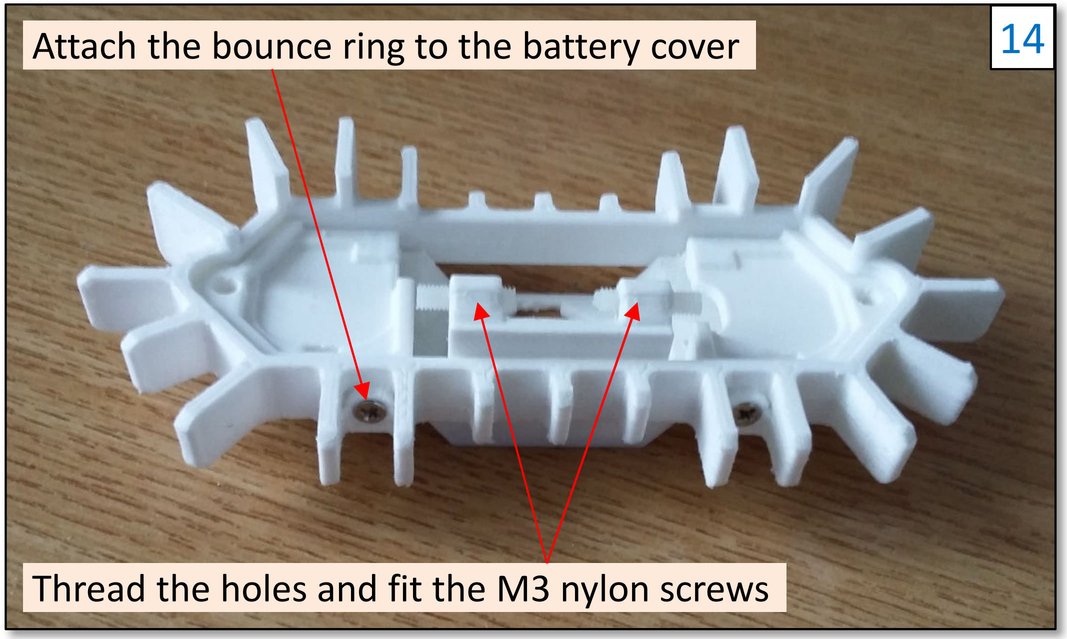
11 View showing connections to the power socket

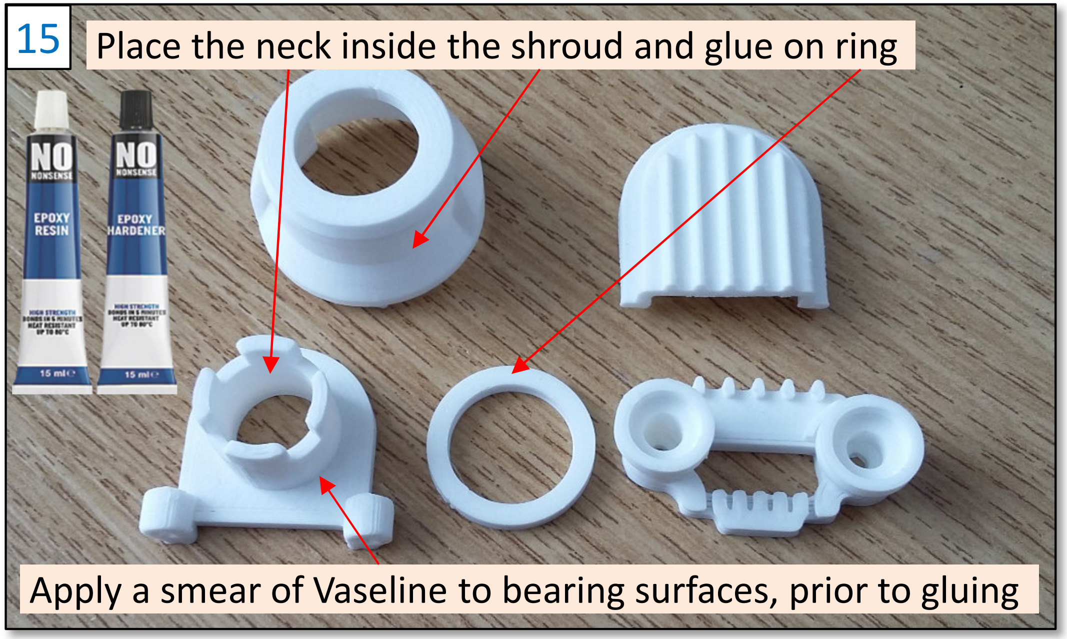


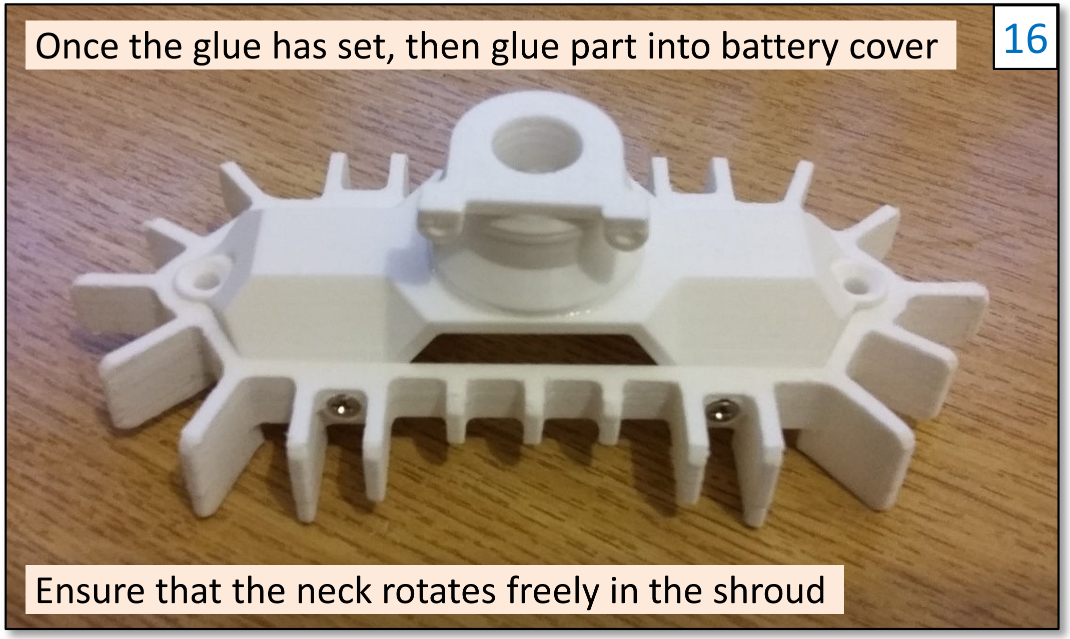
12 Connect 7.5v DC and adjust regulator output for 3.3v

Photos of wiring sequence

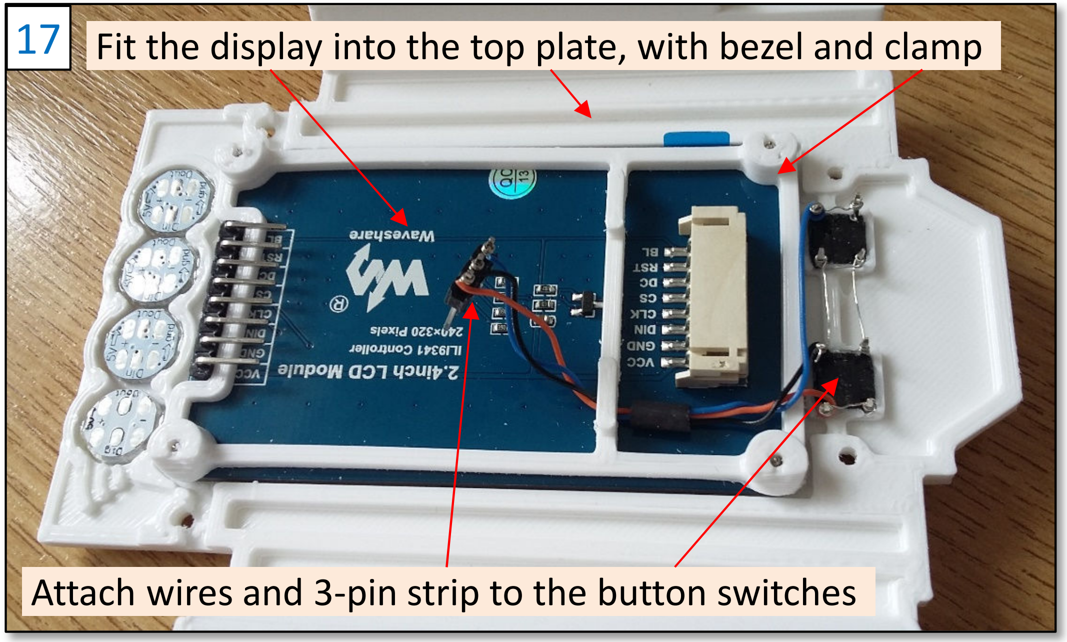


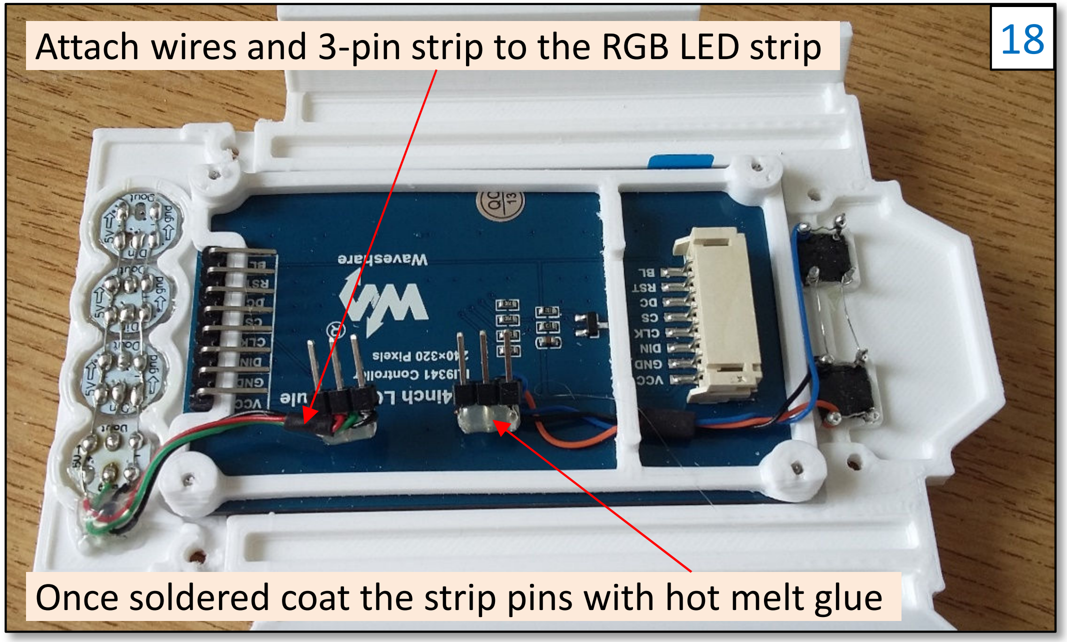


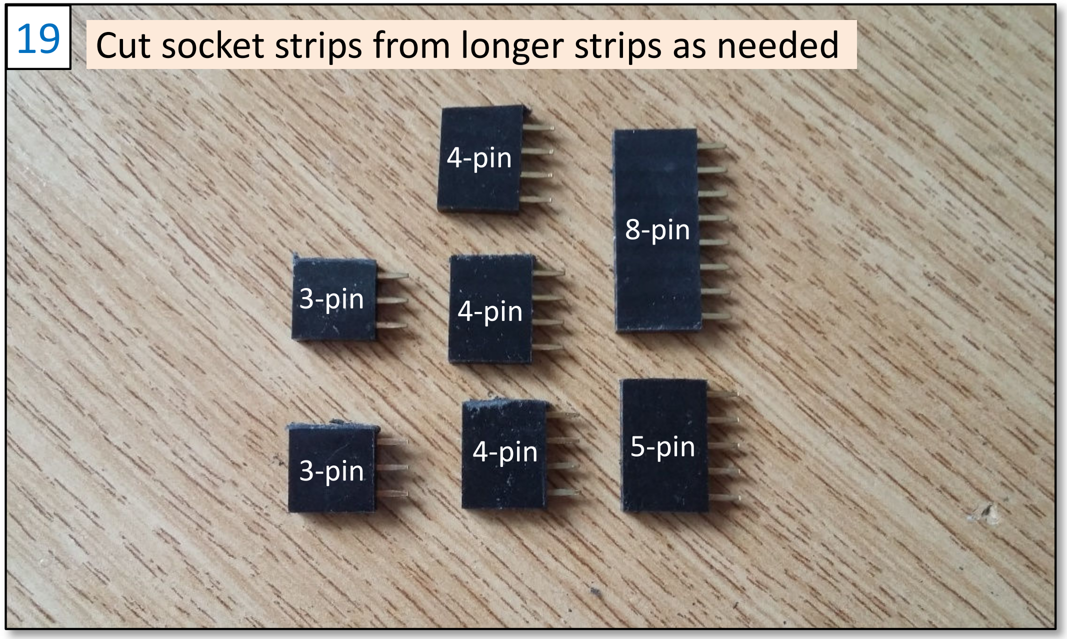


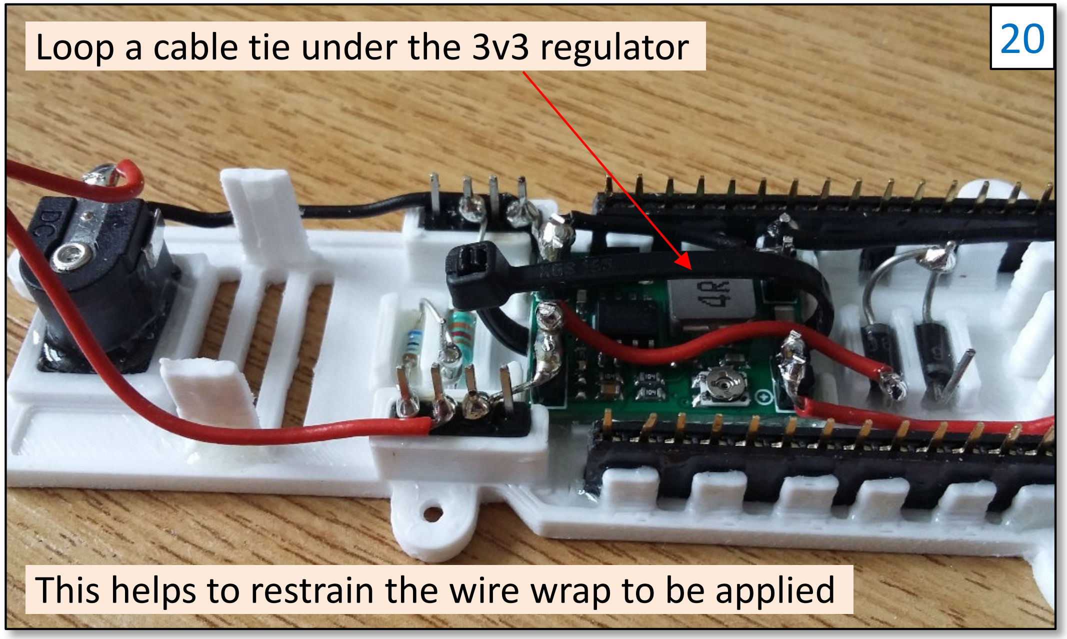


Photos of wiring sequence

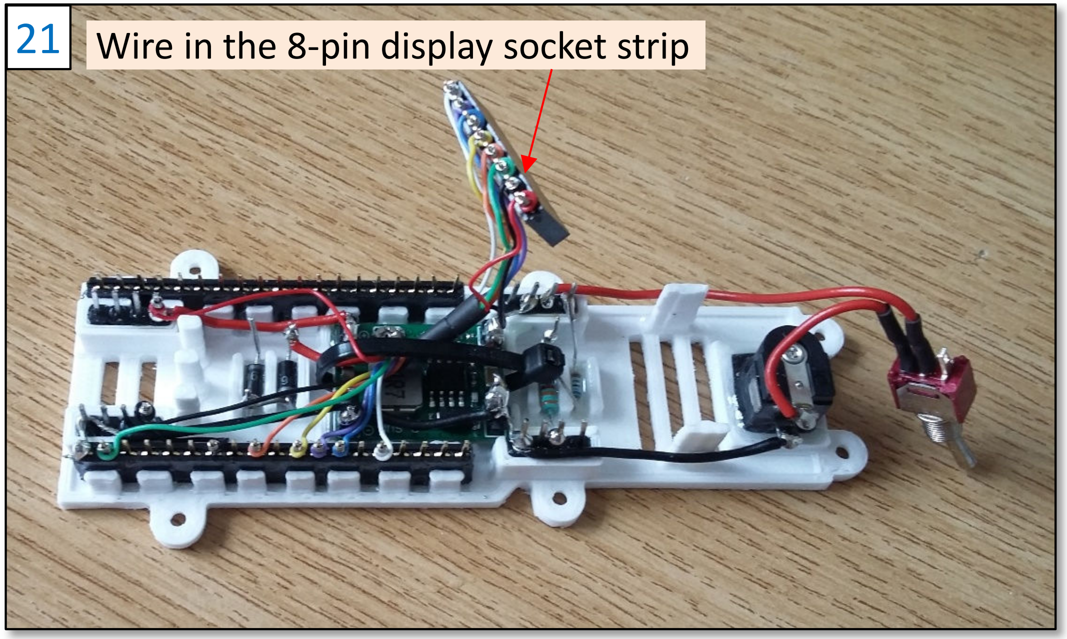


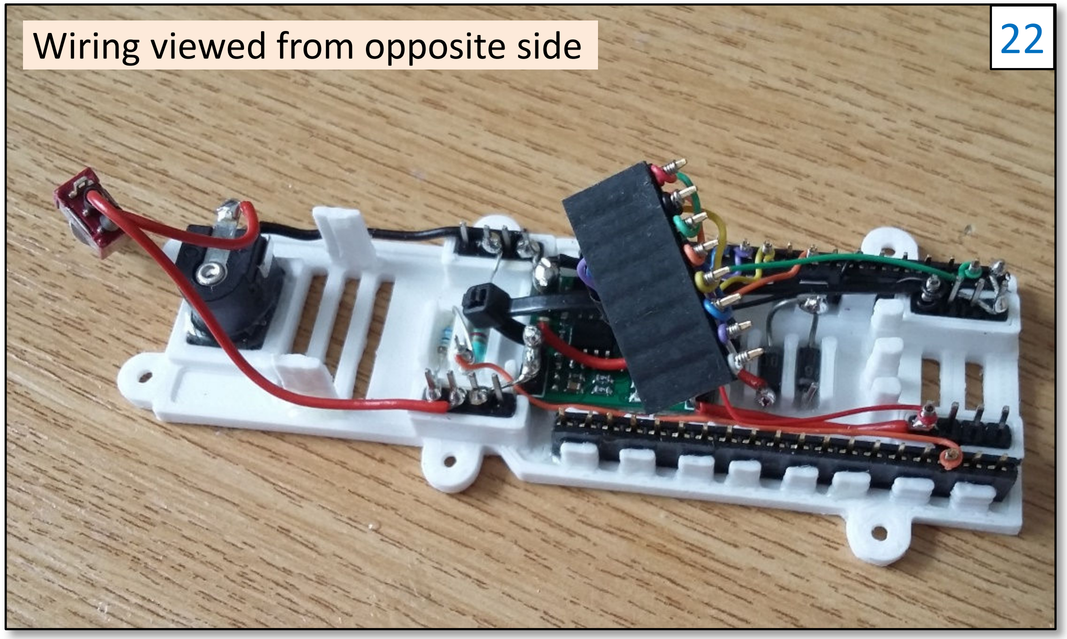


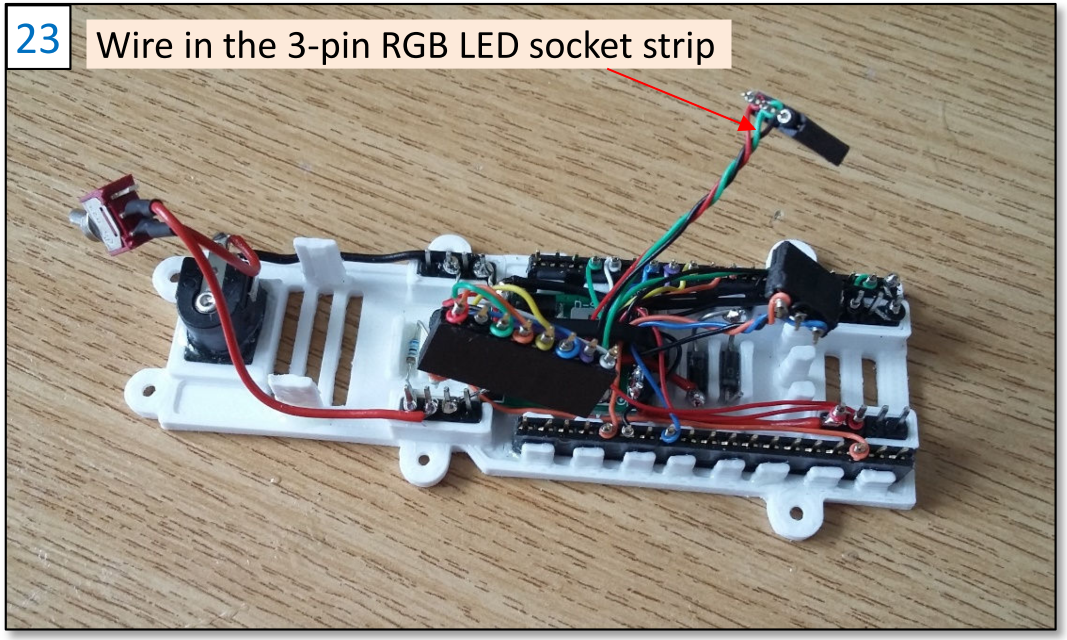


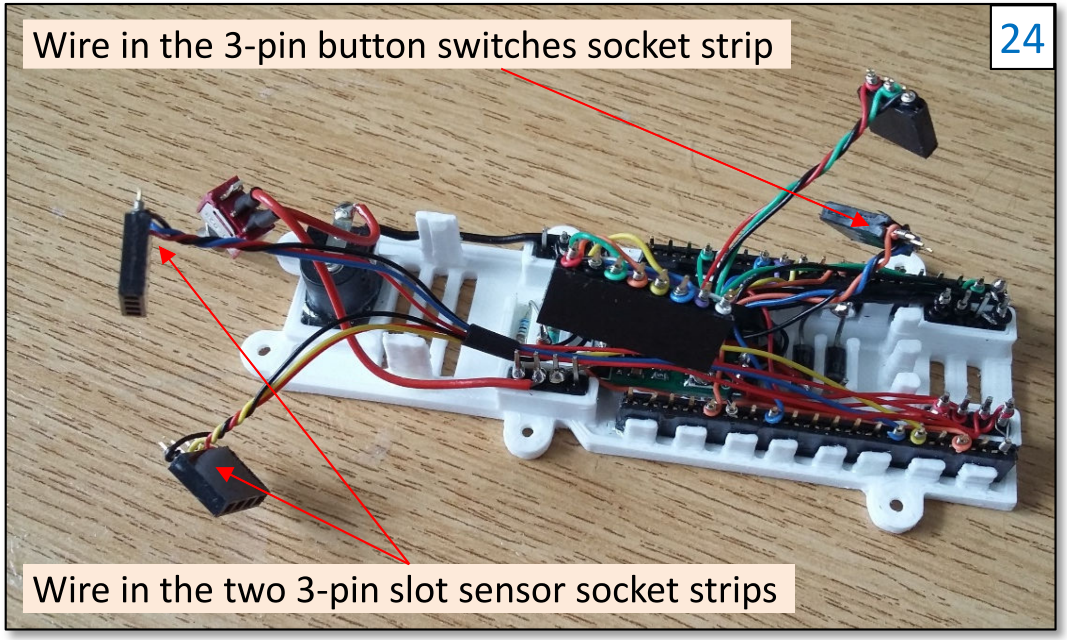


Photos of wiring sequence


21 Wire in the 8-pin display socket strip

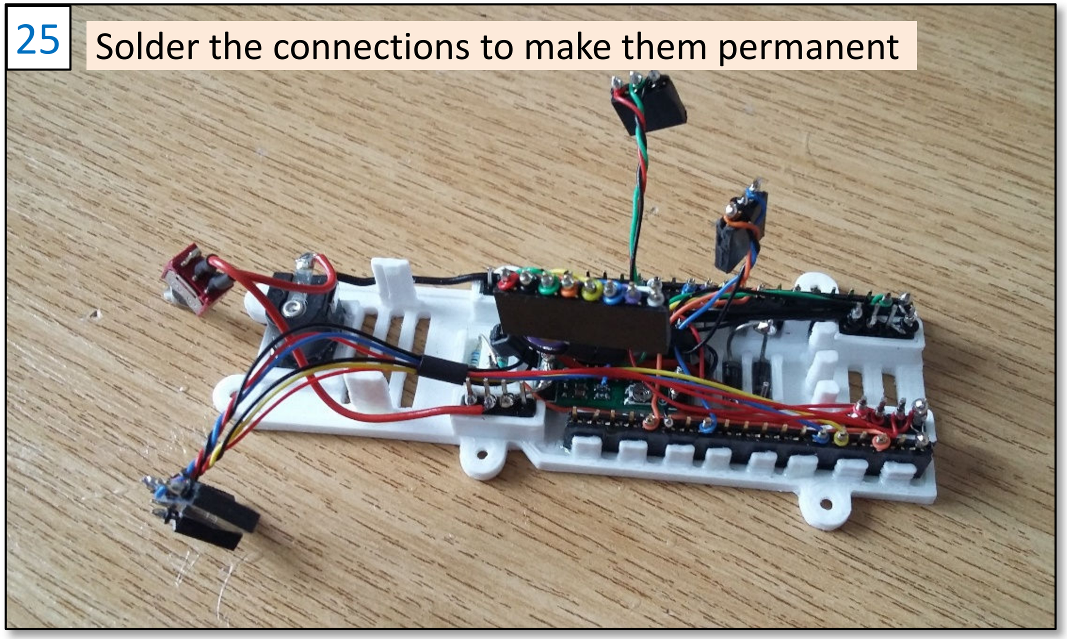

22 Wiring viewed from opposite side

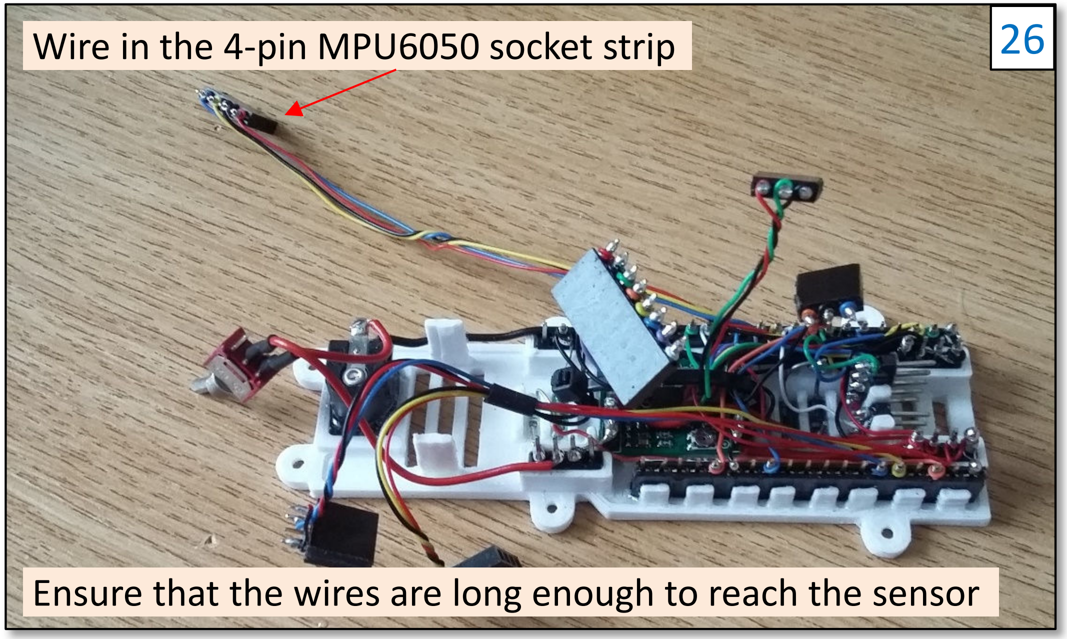

23 Wire in the 3-pin RGB LED socket strip

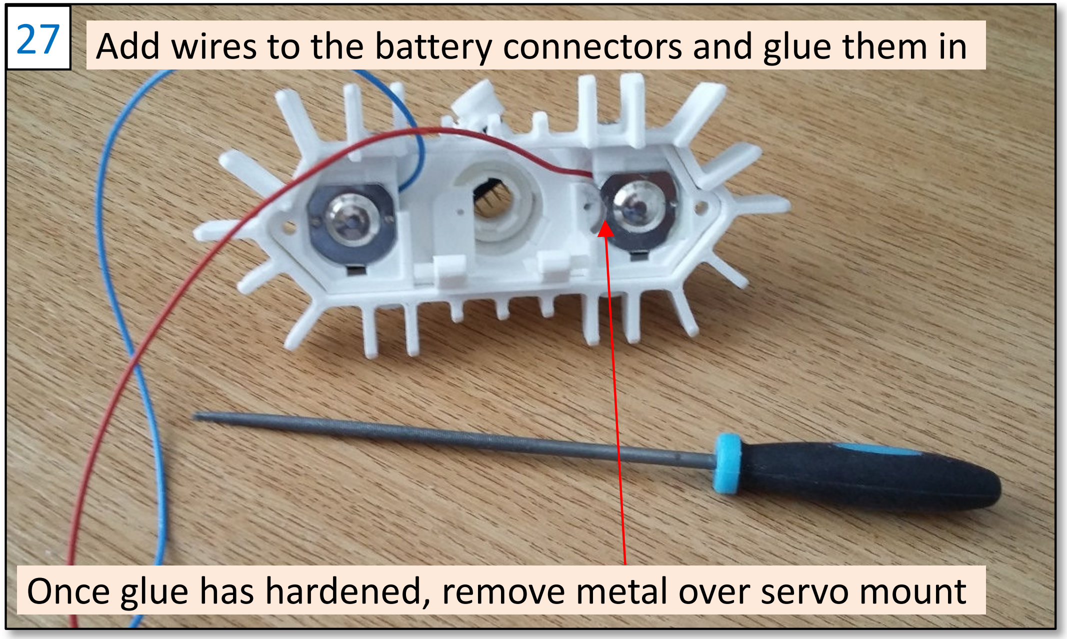

24 Wire in the 3-pin button switches socket strip

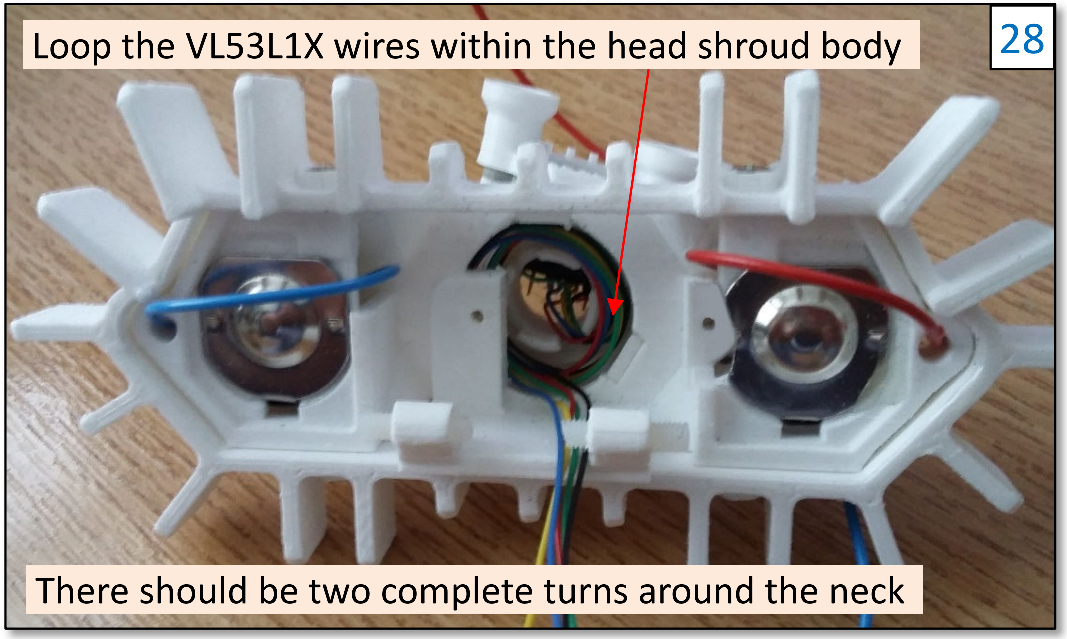
Wire in the two 3-pin slot sensor socket strips

Photos of wiring sequence

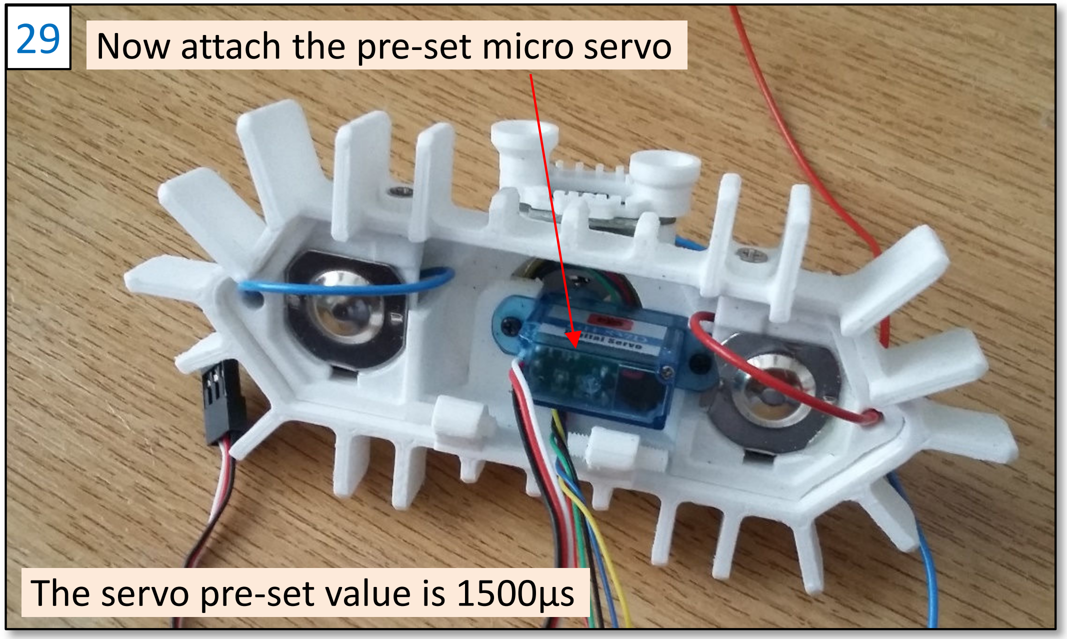




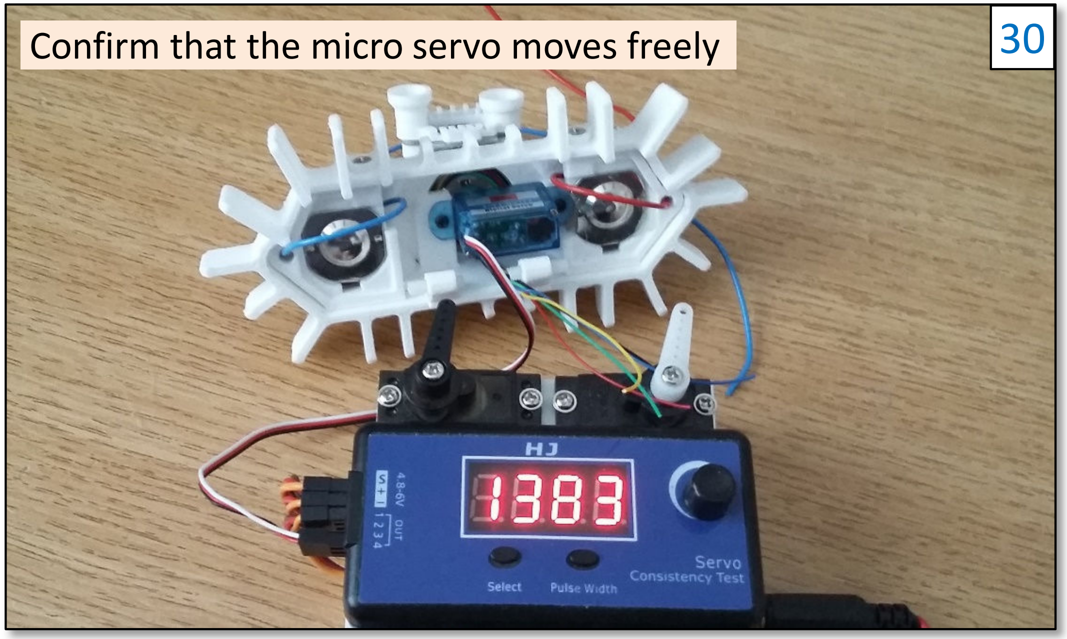




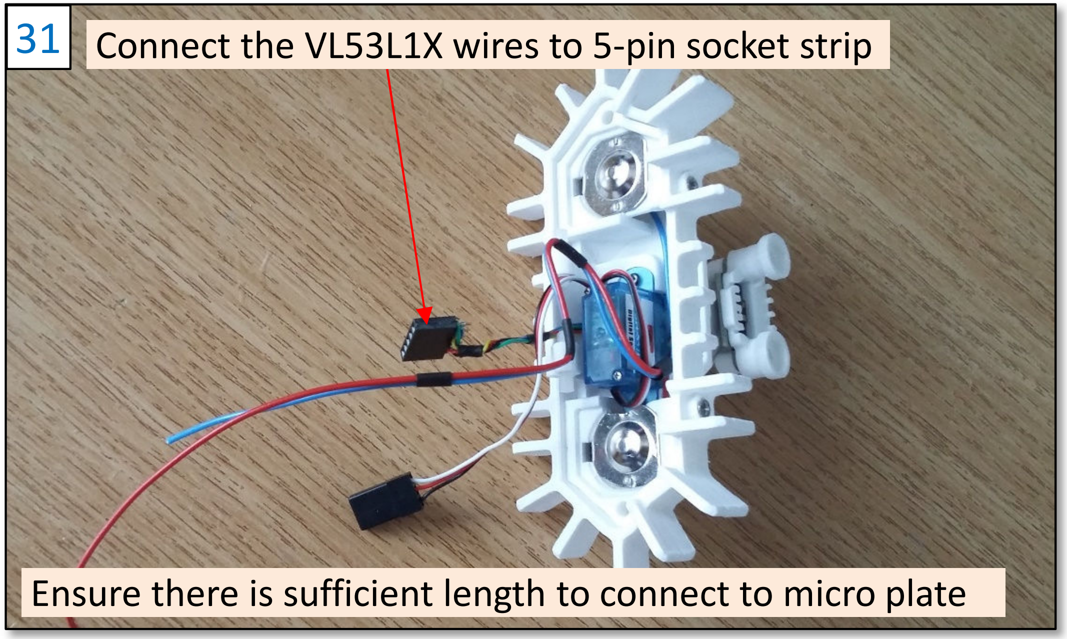
Photos of wiring sequence


29 Now attach the pre-set micro servo

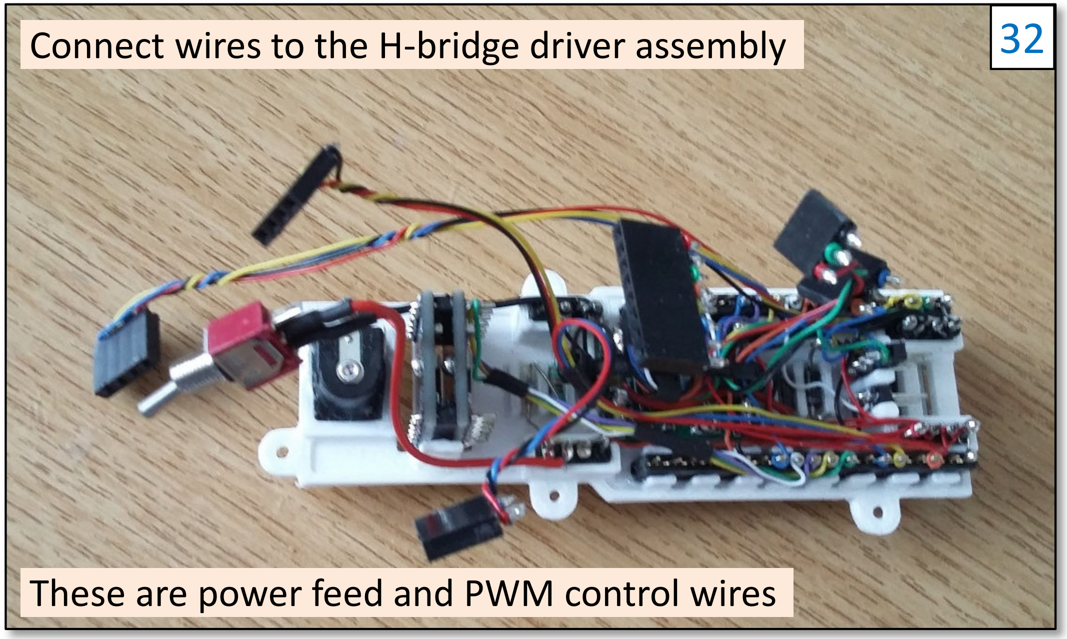
The servo pre-set value is 1500µs



30 Confirm that the micro servo moves freely


31 Connect the VL53L1X wires to 5-pin socket strip

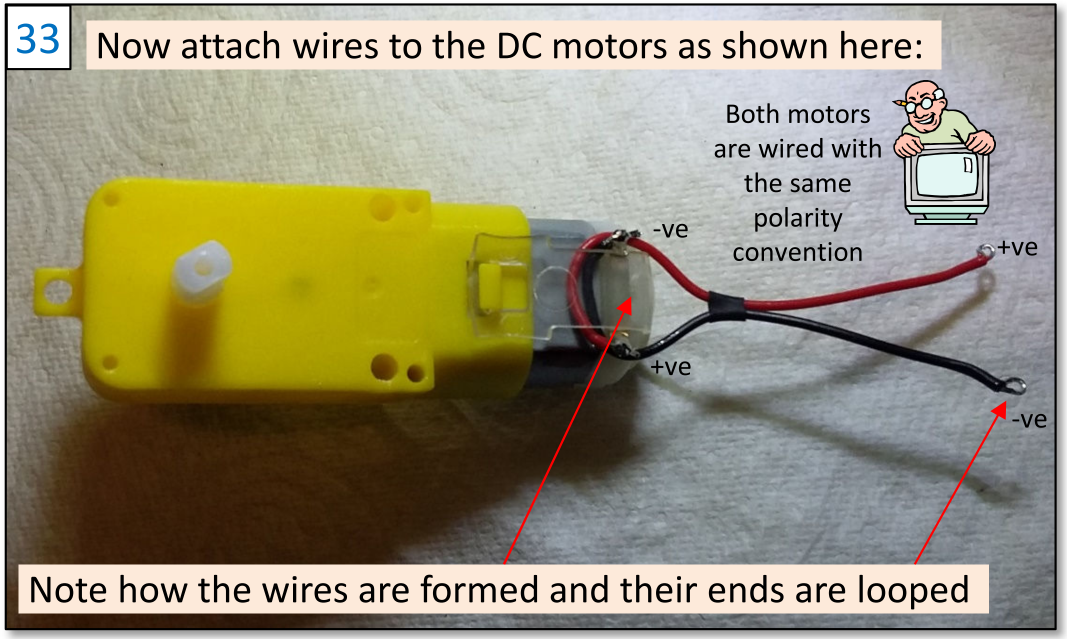
Ensure there is sufficient length to connect to micro plate


32 Connect wires to the H-bridge driver assembly

These are power feed and PWM control wires

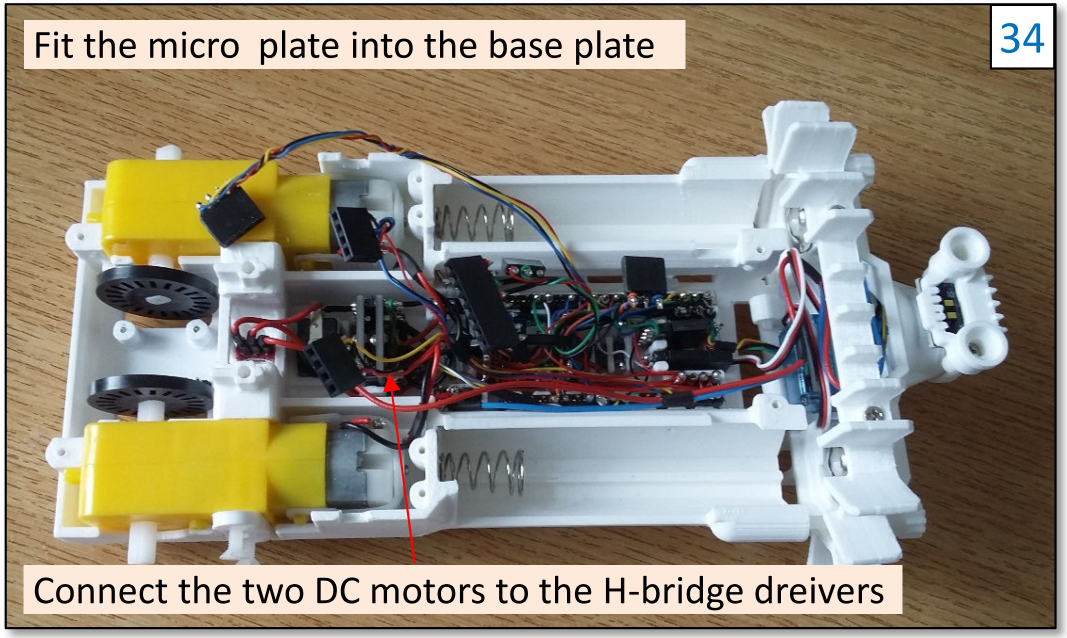
Photos of wiring sequence

33 Now attach wires to the DC motors as shown here:



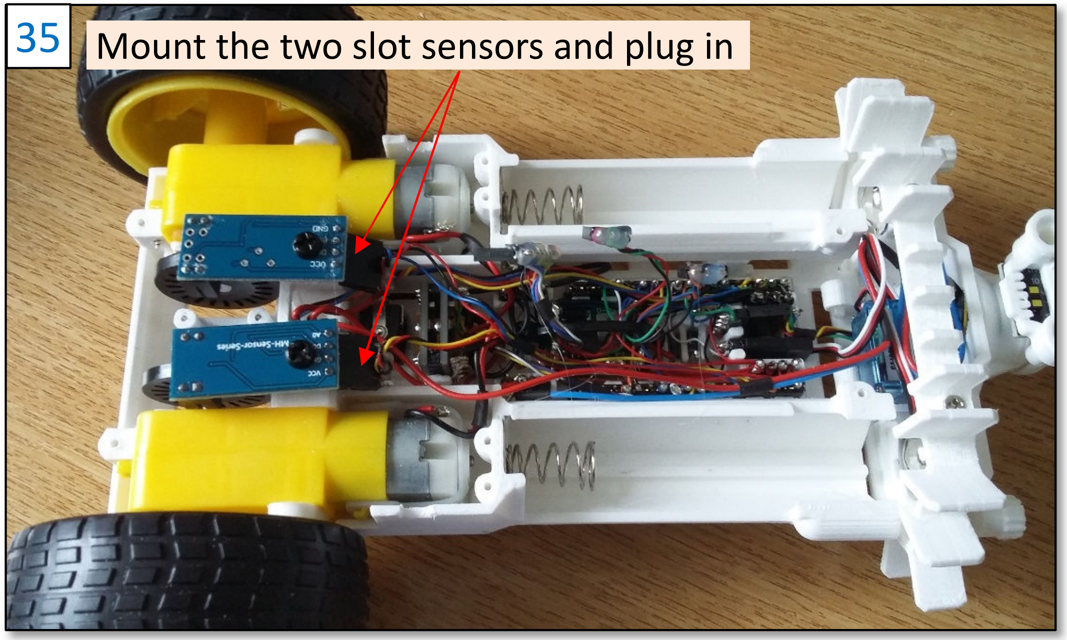
Note how the wires are formed and their ends are looped

34 Fit the micro plate into the base plate

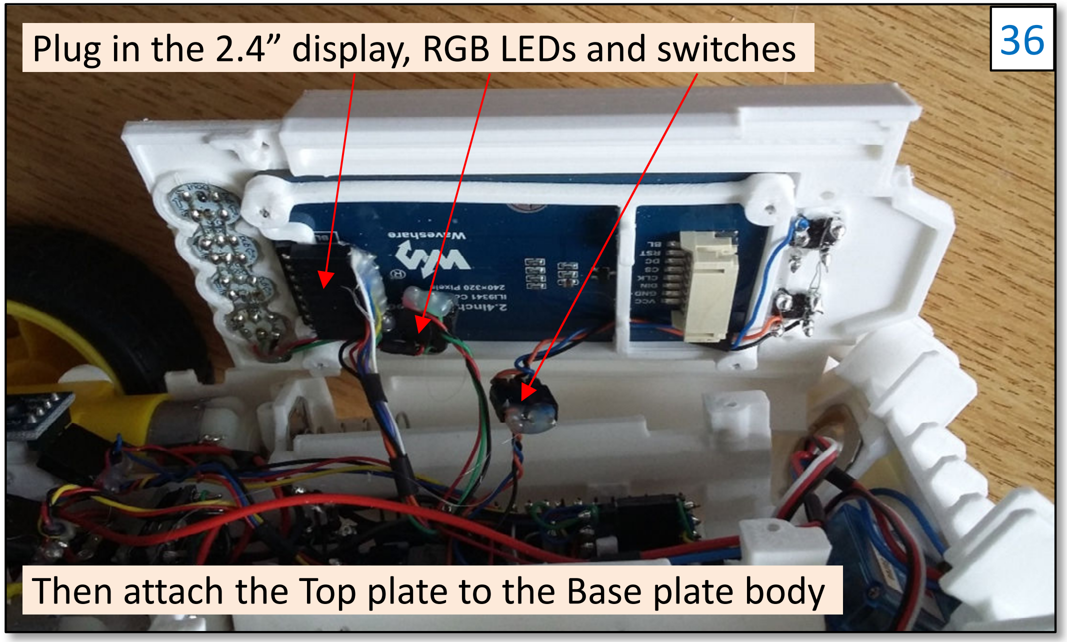


Connect the two DC motors to the H-bridge dreivers

35 Mount the two slot sensors and plug in



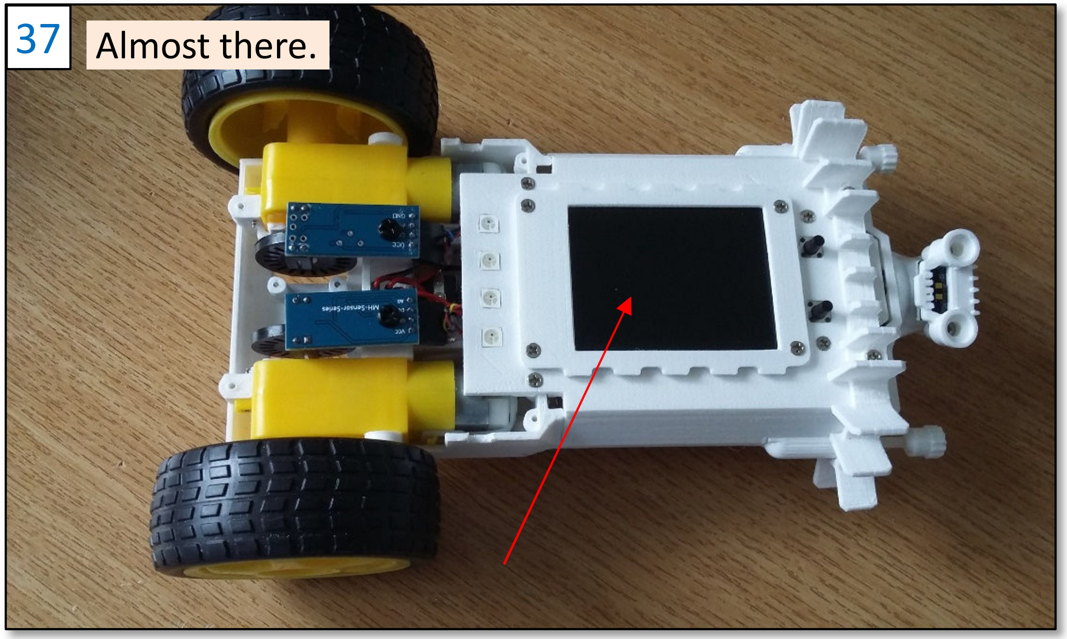
36 Plug in the 2.4” display, RGB LEDs and switches



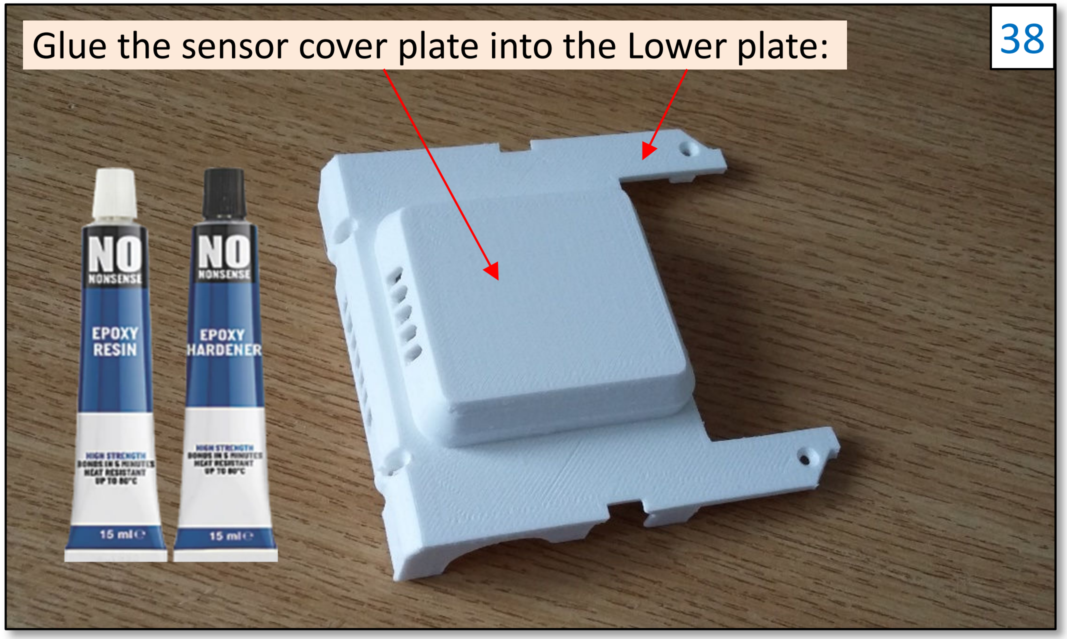
Then attach the Top plate to the Base plate body

Photos of wiring sequence

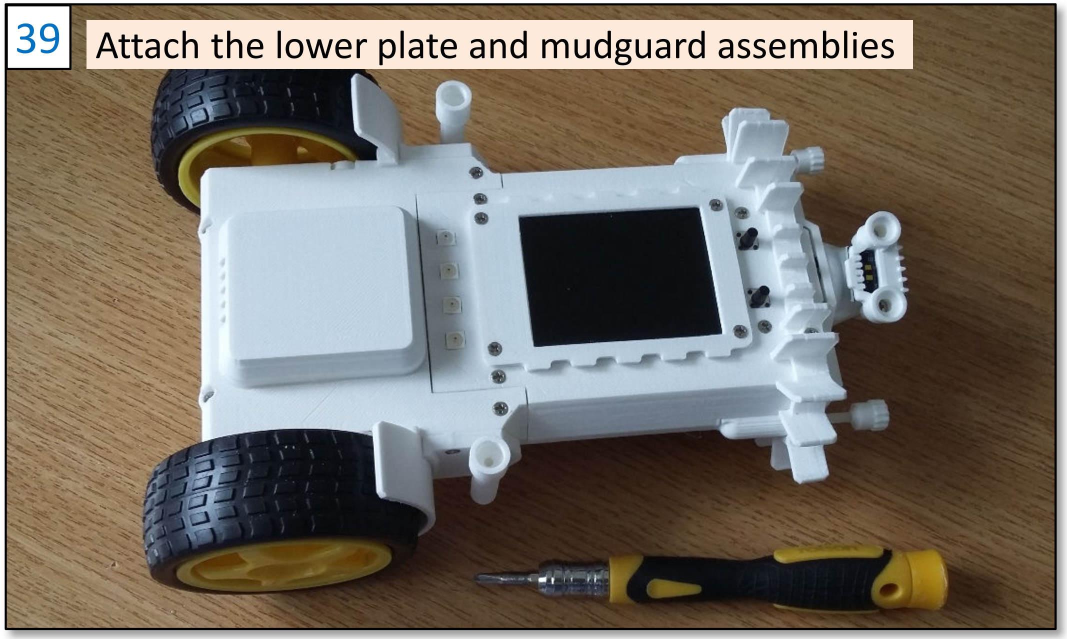
37 Almost there.



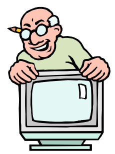
Glue the sensor cover plate into the Lower plate: 38



39 Attach the lower plate and mudguard assemblies



Install the code from the IDE



Start with TEST mode active
and follow the Calibration process.

Build the WiFi transceiver.

Then perform PID tuning over
Wi-Fi to complete the build.

Battery Voltage Health Monitoring

See 18650 discharge curve obtained from the internet. In this analysis both batteries are identical and connected in series,
Assume fully charged batteries max voltage is V_{BM} >= 8.2v max
I measured my rechargeable PP3 at 8.65v when connected and ON.
Set battery warning point at V_B = 7.00v
Set battery critical point at V_{BC} = 6.60v

ESP32 is powered from batteries connected to V_{in}.
3.3v at VADC == 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 404.85
Using a Multimeter I determined the conversion factor needed to be reduced to 383.9 to display voltage correctly.

MAX: V_M = 8.2v, gives A0 = 3148 on ADC (V_M* 383.9)

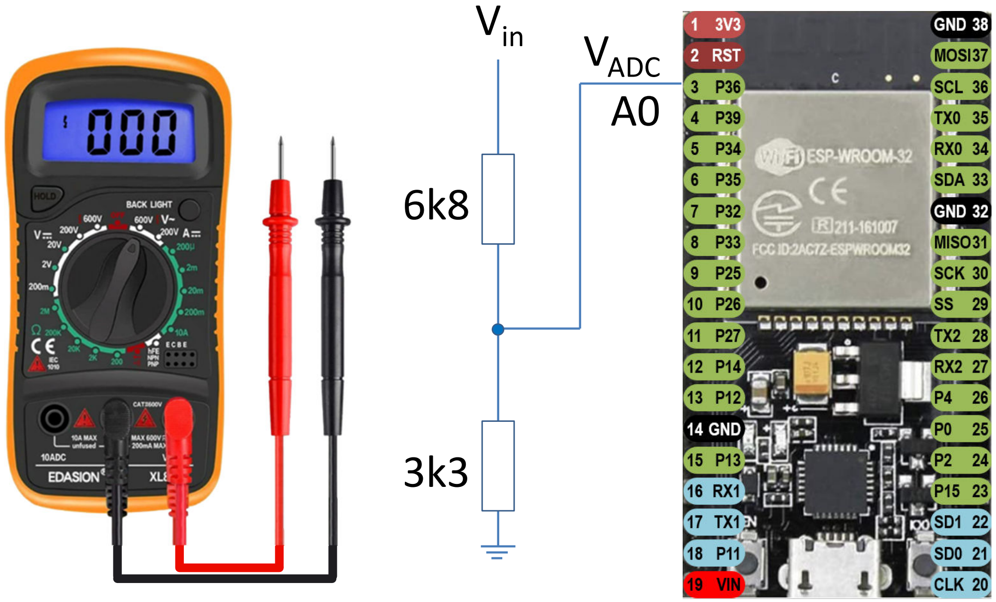
WARNING: V_B = 7.0v, gives A0 = 2687on ADC (V_B* 383.9)

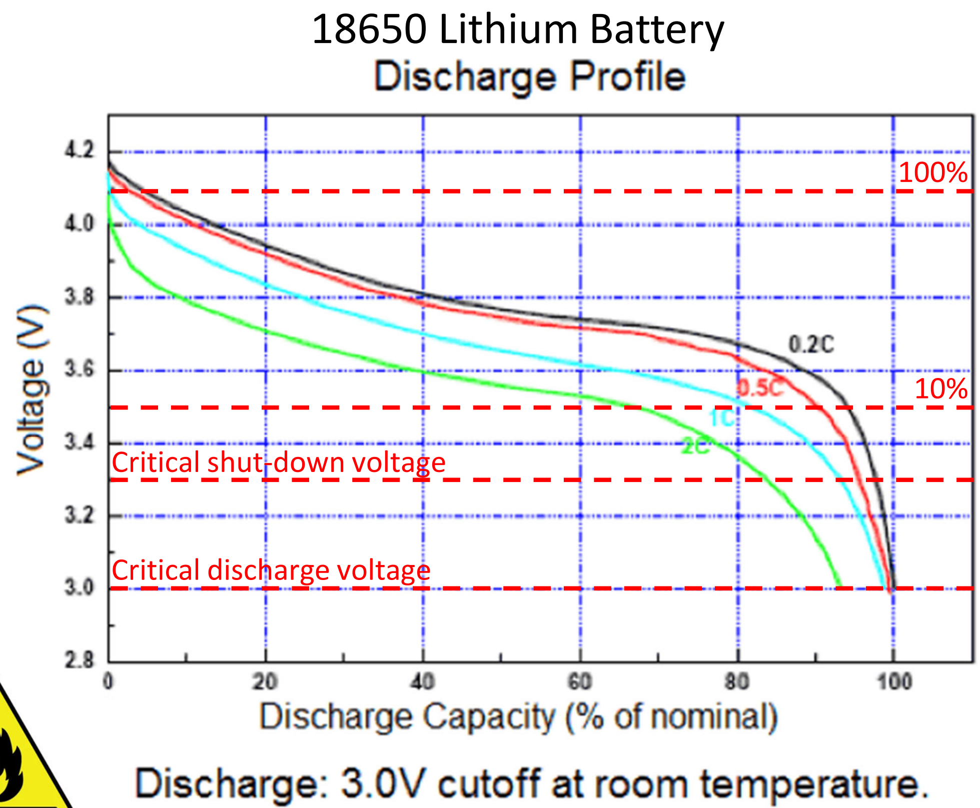
CRITICAL: V_{BC} = 6.6v, gives A0 = 2534 on ADC (V_{BC}* 383.9)

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.

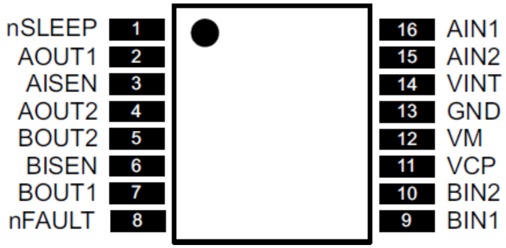
Given the relatively light current drawn I have assumed a linear discharge curve ranging from 8.2v (100%) to 6.6v (0%) capacity. The rate of discharge is monitored and used to actively predict the life of the battery in use.

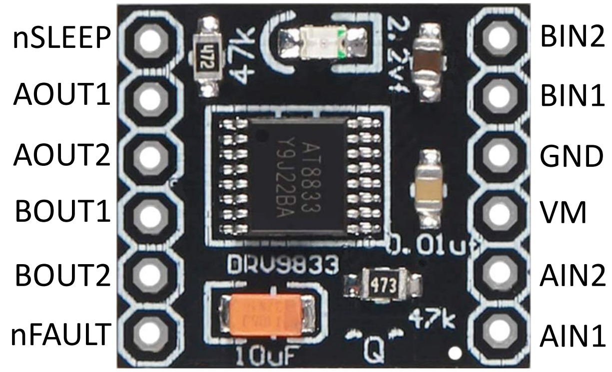
Note: If connected to USB port with internal battery switched OFF the ADC will read a value 5 volts (A0 = 1919) or less. So if the micro starts with such a low reading it knows that it is on USB power.



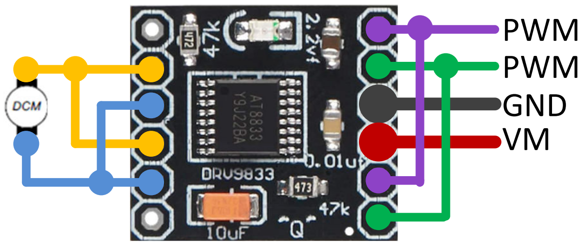


DRV8833 H-bridge Driver

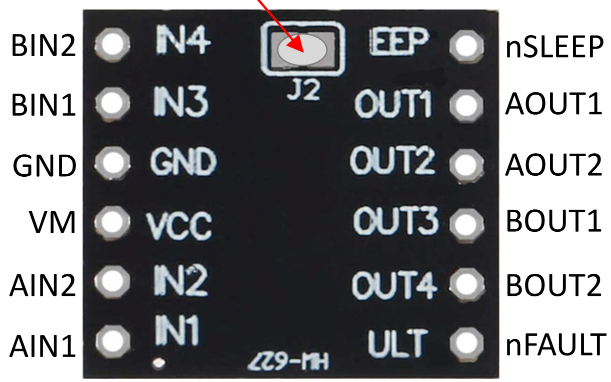


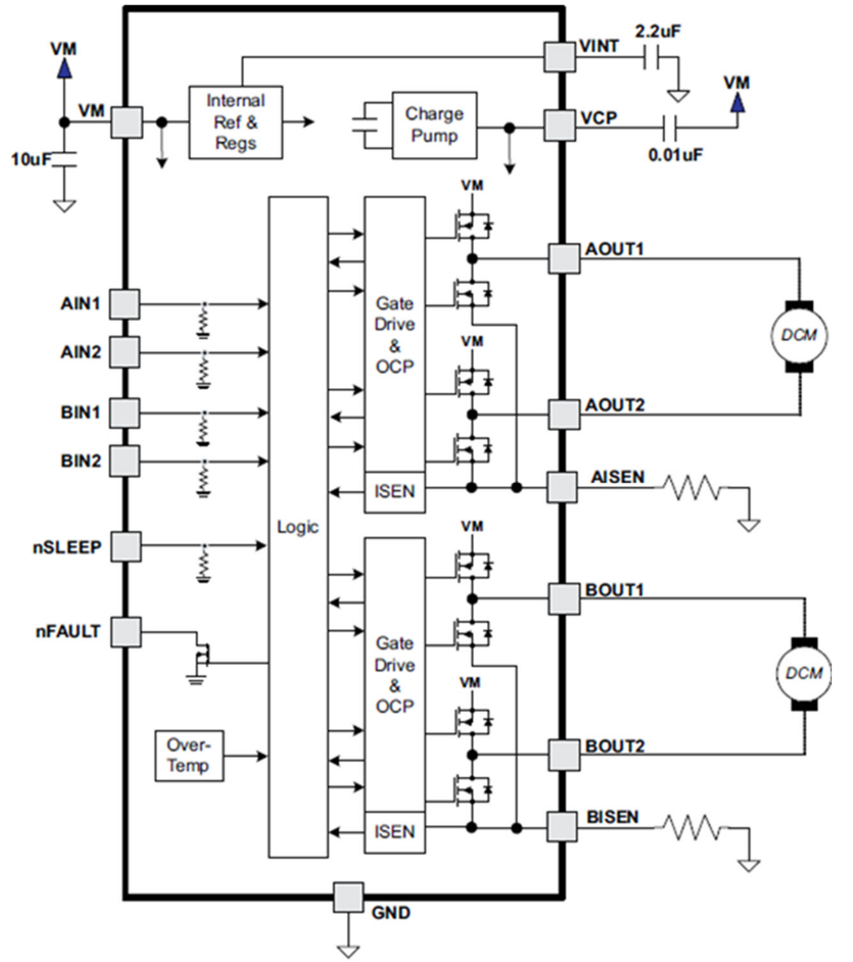


Combined H-bridge.



Solder J2





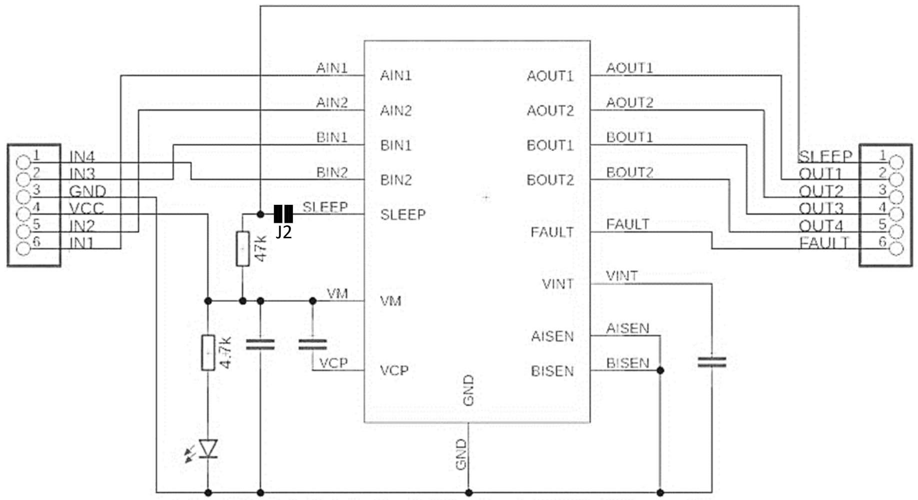


Table 1. H-Bridge Logic

xIN1	xIN2	xOUT1	xOUT2	FUNCTION
0	0	Z	Z	Coast/fast decay
0	1	L	H	Reverse
1	0	H	L	Forward
1	1	L	L	Brake/slow decay

Table 2. PWM Control of Motor Speed

xIN1	xIN2	FUNCTION
PWM	0	Forward PWM, fast decay
1	PWM	Forward PWM, slow decay
0	PWM	Reverse PWM, fast decay
PWM	1	Reverse PWM, slow decay