Arcade Mini

Assembly guide for a one-player arcade whose joystick sensor is 3D printed in conductive TPU.

About 200 × 200 × 320 mm. One stick, one trigger, one Raspberry Pi. All filament from Recreus.

LITecS · C-MAST · Universidade da Beira Interior, with the support of Recreus. Version 1.



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1. How the joystick works

The joystick sensor is not a bought part: it is printed. Conductive TPU is TPU filled with conductive particles. It is not a metal conductor, but it conducts well enough to carry a signal, and its resistance changes when it is stretched. Because it is a TPU, it stretches easily, so even a small movement of the stick gives a clear change in resistance.



Figure 1.1 · The sensor membrane, inside the joystick, under the handle

1.1 The membrane

The membrane carries the whole circuit. It is printed in one go, in two materials: a soft TPU (Filaflex 70A, red) and conductive TPU (black) on top of it. Everything that stands above the red surface is conductive. This is the core of the arcade: the sensors, the resistors that read them and the wiring to the trigger are all part of the same print.

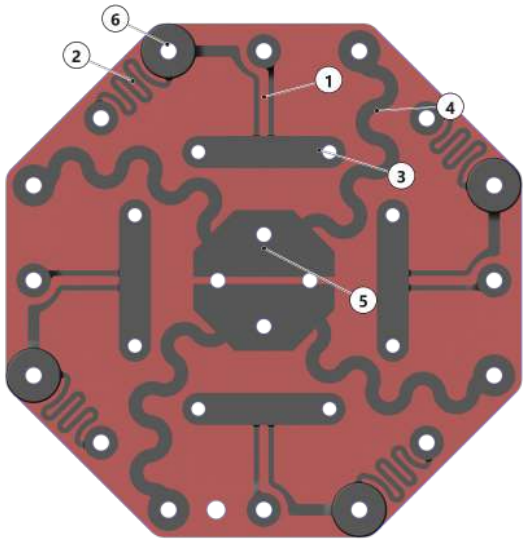


Figure 1.1.1 · The membrane from above. Red: soft TPU. Black: conductive TPU

1. **Sensor**: two thin lines, the variable resistor

2. **Fixed resistor**: the short zigzag on the clamped edge
3. **Stiff block**
4. **Conductor** to the trigger
5. **Trigger pads**, under the handle
6. **Edge contacts**: screw and washer into an insert, wired to the PCB

The pattern repeats four times, once per direction: up, down, left and right.

1.2 The sensor

Each direction has one sensor: two thin conductive lines that run from the clamped edge of the membrane to a stiff block. When you tilt the stick, this stretch of membrane is pushed up and stretched, and the two lines are stretched with it.

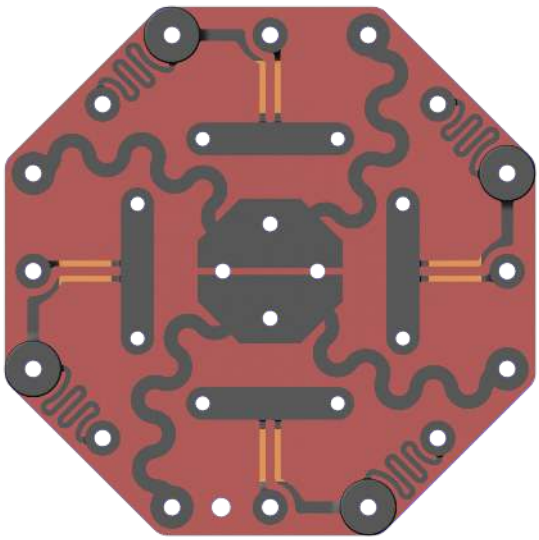


Figure 1.2.1 · The four sensors (orange)

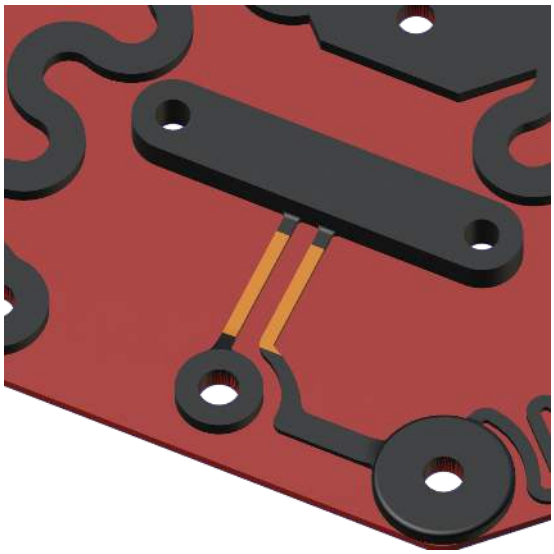


Figure 1.2.2 · One sensor, close up

Why the resistance changes. In conductive TPU, current flows along chains of conductive particles that touch, or nearly touch, inside the soft plastic. When a line is stretched, two things happen. It gets longer and thinner, which alone raises its resistance a little. More importantly, the particles move apart: some chains break and the gaps between the others grow, so current has fewer and harder paths. This is called the *piezoresistive* effect. When you let go, the TPU springs back, the particles close up again and the resistance falls back to its rest value.

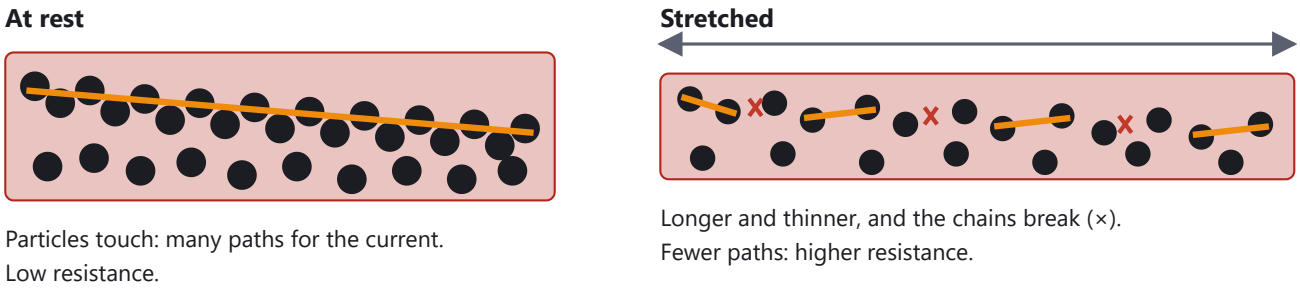


Figure 1.2.3 · What happens inside a conductive line when it is stretched

What stretches it. Under the membrane sits the *presser*, a soft TPU part with four raised arms. It is screwed to the handle through the centre of the membrane, so it tilts with the stick. The whole stick stands on the *pivot*, which is screwed to the bottom of the cup: it does not slide or turn, it bends at its narrow neck. When you tilt the stick one way, the arm on the opposite side rises and pushes the membrane up between the clamped edge and the stiff block. That is exactly where the sensor lines run.

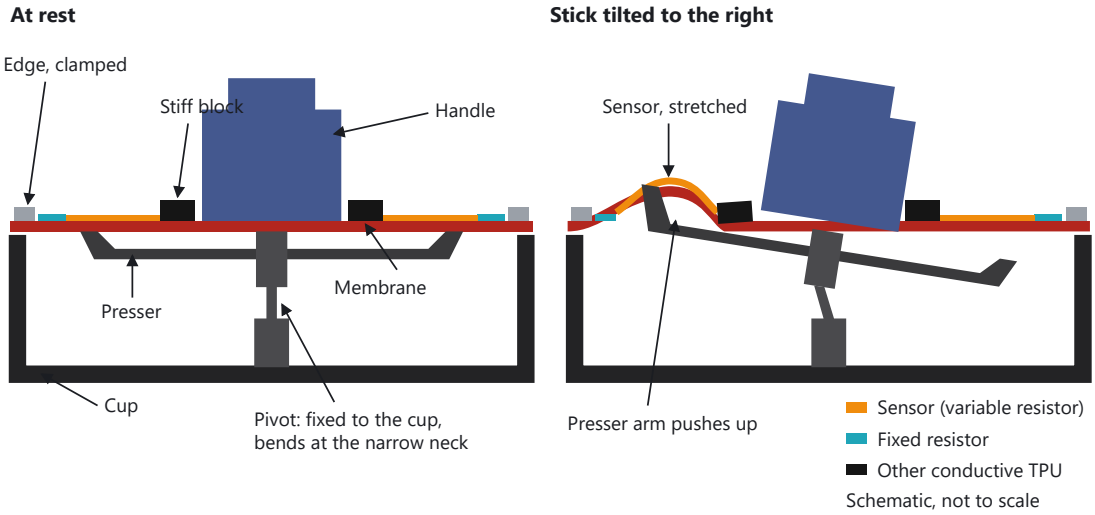


Figure 1.2.4 · Side view of one axis. The pivot is screwed to the cup and bends at its narrow neck. Tilting the stick lifts the presser arm on the other side, which stretches that sensor

1.3 The voltage divider, printed too

A changing resistance has to be turned into a voltage that the ESP32 can read. That is the job of a voltage divider: two resistors in series between 3.3 V and ground, with the reading taken between them. Here the divider is printed as well. The sensor is the variable resistor. The fixed resistor is the short zigzag on the edge of the membrane, which is clamped onto the rigid wall of the cup and so barely deforms.

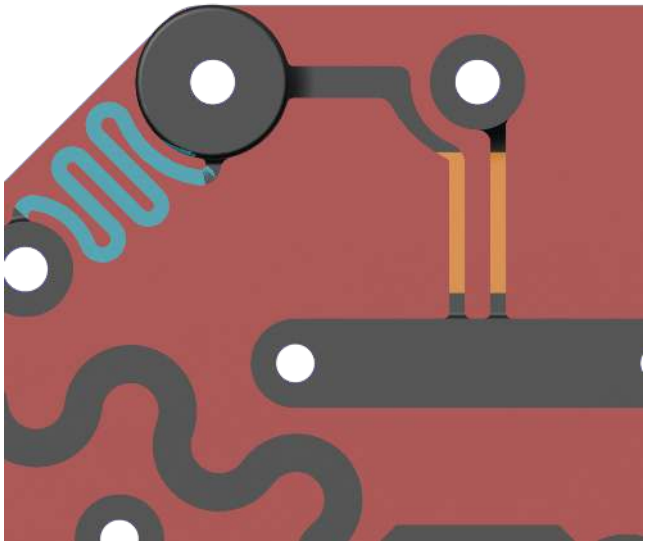


Figure 1.3.1 · One divider: sensor (variable) and fixed resistor

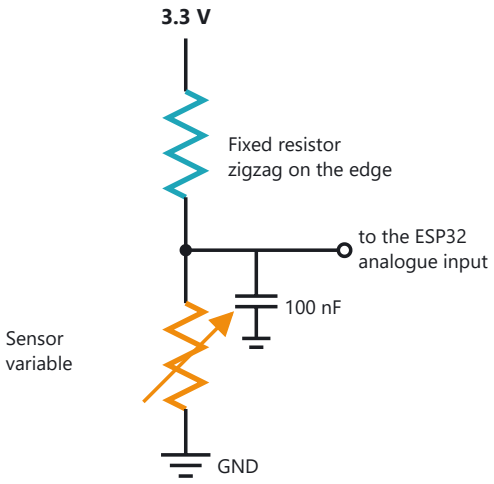


Figure 1.3.2 · The circuit of one direction. There are four, one per direction

Why print the fixed resistor too. Conductive TPU also changes its resistance with temperature and humidity. If the fixed resistor were a normal component, those changes would show up as false

movement. Because both resistors are made of the same material, in the same print, they drift together, and the voltage between them, which depends on their ratio, stays nearly the same. The firmware then also removes whatever drift is common to all four directions.

1.4 Conductors to the trigger

The long wavy lines carry the trigger signal from the pads under the handle to the edge of the membrane, where they are screwed down and wired to the PCB. The waves let them follow the membrane as it moves without being stretched themselves, so their resistance stays almost constant. Each of the two trigger pads has two conductors and two edge contacts: if one contact is poor, the other still carries the signal, which makes the reading steadier.

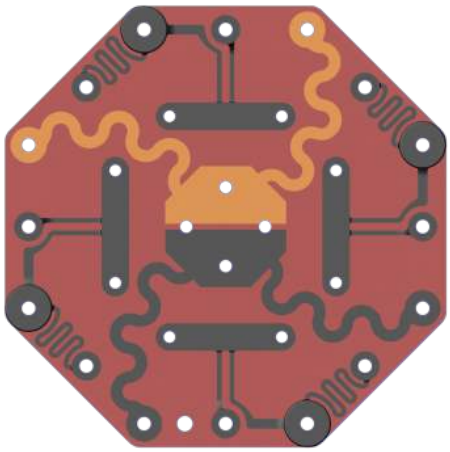


Figure 1.4.1 · One side of the trigger circuit (orange): a pad and its two conductors

1.5 The stiff blocks

The four tall blocks are part of the circuit: each sensor's two lines meet at its block. But they are not there to conduct. They are taller, and therefore stiffer, than the rest of the membrane, and they are screwed down to the cup. They keep the inner end of each sensor still, so the presser stretches the lines instead of just moving them.



Figure 1.5.1 · The stiff blocks (orange)

1.6 The trigger

Two conductive tracks run inside the handle, from the bottom to the trigger. At the bottom of the handle each track ends in a textured contact area that sits on one of the two trigger pads of the membrane. A small ridge under the handle keeps the two pads apart. At the top, the tracks stop just short of each other. The red trigger carries a C-shaped conductive pad at its tip: pressing the trigger pushes it against both track ends and closes the circuit. Closed, it reads about 10 kΩ.

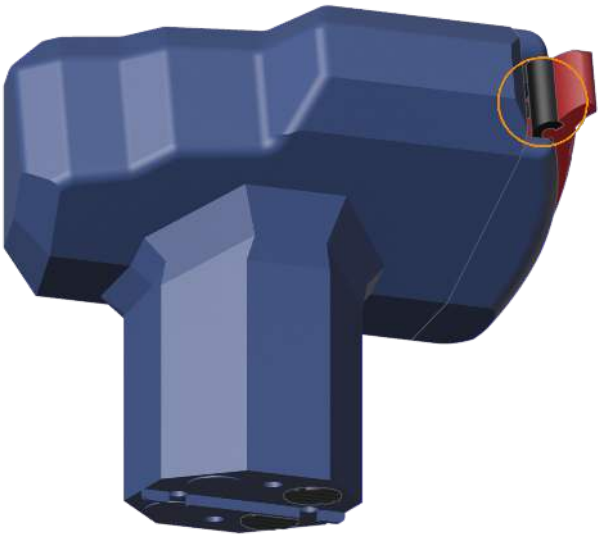


Figure 1.6.1 · The handle and the trigger. The circle marks the contact



Figure 1.6.2 · Closer, with the handle faded: the two tracks inside the handle and the C-shaped pad on the trigger

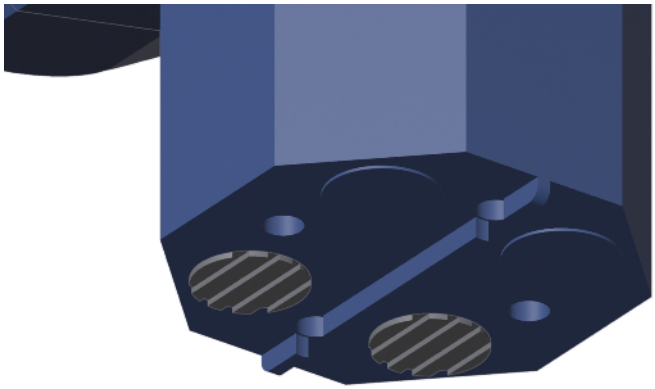


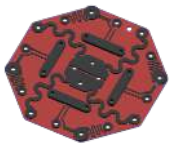
Figure 1.6.3 · The handle from below: the two textured contact areas that sit on the membrane

2. What you need

Printed parts

All filament is from Recreus. Use their print profiles.

	Part	Qty	Material
	Cabinet body	1	PETG Damantium, blue
	Legs	4	PETG, red
	Foot pads, textured	4	Filaflex 60A
	Decorative details: 8 bottom side, 2 top side, 1 middle	11	PETG, red
	QR code plate	1	PETG, white + black
	Joystick plate + rim	1 + 1	PETG, blue + red
	Rear cover	1	PETG, red
	Message sign	1	PETG, blue + white
	Knobs: screen ×4, rear cover ×1, joystick ×1	6	PETG, red

	Screen brackets	4	PETG, red
	Joystick cup	1	PETG, black
	Sensor membrane	1	Filaflex 70A + conductive TPU
	Presser	1	Filaflex 95A
	Pivot	1	Filaflex 95A
	Handle	1	PETG, blue + conductive TPU
	Trigger	1	PETG, red
	Trigger side piece	1	PETG, blue
	Trigger contact	1	Conductive TPU

Screws, washers and inserts

All screws are M3, except the one under the joystick (M4) and the four on the screen (M2.5). Button heads are ISO 7380, countersunk heads are ISO 10642. Inserts are brass heat-set inserts with a flange.

Where	Qty	Screw	Insert
Membrane edge → cup	16	M3 × 12 button + M3 washer	16, from below, with wire
Stiff block → cup	8	M3 × 10 button	8, from above
PCB → cup	4	M3 × 12 button	4, from above

Handle → pivot → presser	4	M3 × 16 countersunk	none: self-tapping into the handle
Trigger and side piece	2	M3 × 10 button	2, in the handle
Joystick plate → body	8	M3 × 16 button	8, in the body
Screen knobs	4	M3 × 12 button	4, in the body
Rear cover knob	1	M3 × 20 button	1, in the body
Message sign	1	M3 × 10 button	1, on top of the body
USB-C panel socket	2	M3 × 8 countersunk	none: the threads are in the socket
Screen brackets → screen	4	M2.5 × 6	-
Joystick → cabinet	1	M4 × 40 socket head	1 × M4, glued into the pivot

Inserts: 46 × M3 and 1 × M4. Washers: 16 × M3, only where a screw carries signal. Two of the cup inserts (at the front, side by side) are for a cable clamp in a future version; they are optional for now.

Electronics and cables

Item	Qty	Description
Raspberry Pi 5	1	With the official Active Cooler (recommended). See below for other models
Power supply	1	USB-C, 5 V 5 A (27 W), such as the official Raspberry Pi 27 W supply. The Pi also powers the screen
Touch screen	1	7", 1024 × 600, HDMI, with an HDMI adapter that plugs straight into the Pi, and mounting brackets
Screen power cable	1	USB-A to micro-USB, 10 cm, right-angle micro-USB plug
Power input	1	Panel-mount USB-C extension, male to female, 30 cm, right-angle plug, female end with two screw holes
Joystick cable	1	USB-A to USB-C **data** cable, Pi to the ESP32
microSD card	1	16 GB or more, with Raspberry Pi OS Desktop
ESP32-S3 SuperMini	1	Soldered to the PCB on pin headers
Joystick PCB parts	1 set	R1 220 kΩ ¼ W; C1–C5 100 nF ceramic; C6 10 µF electrolytic; pin headers; bare copper wire
Contact wires	16	Bare solid copper wire. We stripped the cores out of a network cable

The ones we used: screen (GeeekPi 7" 1024 × 600 IPS capacitive touch screen, HDMI, with an adapter and brackets for the Raspberry Pi 5), micro-USB cable, USB-C panel extension. Sellers come and go: any part that matches the description above will do.

Other Raspberry Pi models. We built and tested the arcade with a Pi 5. A **Pi 4** should also work with the same cables: it has the same USB-C power input and micro-HDMI ports, and its USB ports can supply 1.2 A in total, enough for the screen and the ESP32. It needs its own heatsink or fan, since the Active Cooler only fits the Pi 5, and its USB ports sit in a different place, so the cables run a little differently. A **Pi 3** takes its power through micro-USB and has a full-size HDMI port, so it needs a USB-C to micro-USB panel cable and a different HDMI adapter.

Tools and consumables

Soldering iron (+ heat-set tip, if you have one) | Solder | Super glue (cyanoacrylate) | Hex keys 2 mm and 3 mm | Hand drill (pin vice) with a 1.75 mm bit | Flush cutters | 1.75 mm filament offcuts, for 28 pins | Multimeter | Computer with Arduino IDE

3. Printing

Use the Recreus profiles for your printer and nozzle: they are tuned for each material. Print every part with a **0.16 mm layer height**. Dry every flexible filament first (Recreus: 55 °C for at least 1 hour). We printed with 0.6 mm nozzles on a textured PEI plate.

Part	Printer	What matters
Body, legs, joystick plate	Bambu Lab H2D, 0.6 High Flow	PETG. 2 walls, 15 % grid, tree supports
Details, knobs, cup	Bambu Lab X1 Carbon, 0.6	PETG. 3 walls, 35 % grid
Every TPU part	X1 Carbon, 0.6	**240 °C**, bed 35 °C, 100 % infill, slow (30 mm/s, max. 3.6 mm^3/s)
Handle	H2D, 0.6	PETG + conductive TPU (TPU as above). The two inner fill bodies at 100 % infill

> **TPU at 240 °C.** For the membrane it matters most: the higher temperature improves the bond between the soft TPU and the conductive TPU.

> **Handle.** In the slicer, set the two inner bodies (*Cut-Extrude72[1]* and *[2]*) to 100 % infill. Bambu Studio does not add top and bottom skins where two materials meet inside a part, so without them the conductive tracks would be printed straight onto sparse infill. This avoids printing the whole handle solid.

Supports on the body

The body needs supports in only three places: the flat top edge of the screen opening (front and back; one tree can hold both), the seat for the joystick knob underneath, and the cylindrical cut. The USB-C opening at the bottom may need support too, depending on your printer.

On an H2D the body prints in one piece. Assign its filament to the **right nozzle**: it reaches 325 mm in height, the left one only 320 mm. **On a smaller printer**, cut the body in half through the screen area: the two halves print upside down with no supports at all.



Figure 3.1 · The body as printed, seen from below the front. Orange: faces that point down



Figure 3.2 · The same from below the back

The faces that point down are the ones that need support: the top edge of the screen opening, the knob seat in the middle of the base and the cylindrical cut. Small holes bridge on their own.

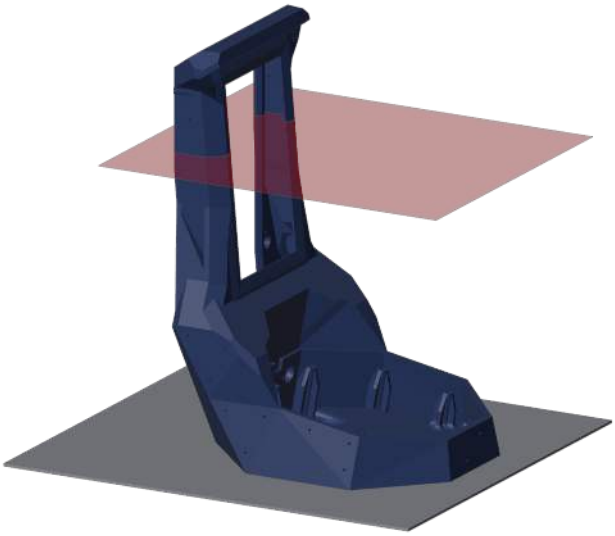


Figure 3.3 · Smaller printers: cut the body through the screen area

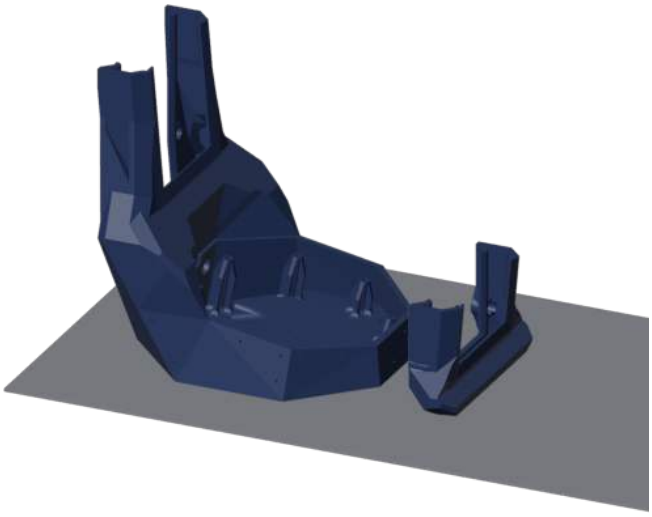


Figure 3.4 · The two halves on the plate, the top one upside down

4. Heat-set inserts

Do all the inserts first, while the parts are still loose. Press each one in with the soldering iron, flange first: the flange stops the insert from pulling out when the screw is tightened. Keep the insert square to the hole.

4.1 Cup, from above: 12 inserts

Eight hold the stiff blocks of the membrane. The four in the middle hold the PCB: they go in from above too, even though the PCB is screwed on from below.

12 × M3 insert

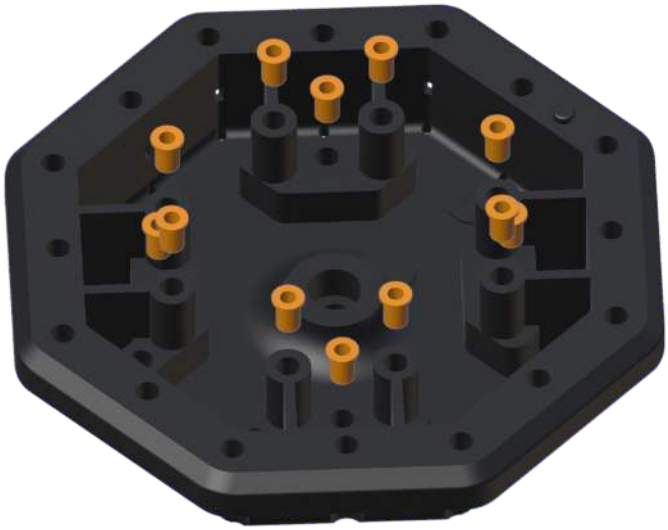


Figure 4.1.1 · The 12 inserts go in from above

4.2 Cup, from below: 16 inserts with wires

Solder a bare copper wire to the flange of each of the 16 edge inserts, then press the insert in from below. The wire runs through the hole next to it and goes straight down to the PCB hole directly underneath, so there is no wiring order to get wrong.

16 × M3 insert + wire

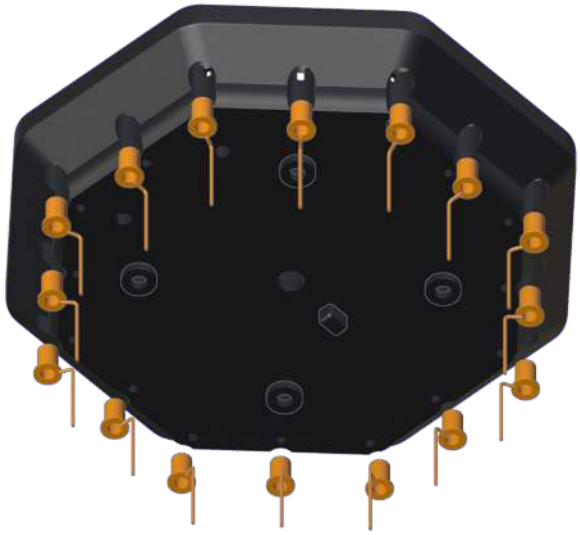


Figure 4.2.1 · The edge inserts with their wires, from below



Figure 4.2.2 · Wire soldered to the flange, before fitting

> Solder the wire before fitting the insert: once the insert is in, the heat would soften the cup.

4.3 Body: 14 inserts

Eight round the joystick opening (for the plate). At the back: four for the screen knobs, one for the rear cover knob and one on top for the message sign.

14 × M3 insert

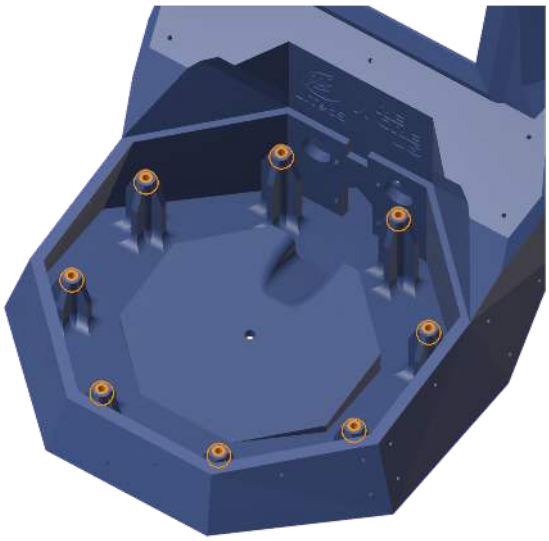


Figure 4.3.1 · The 8 inserts for the joystick plate

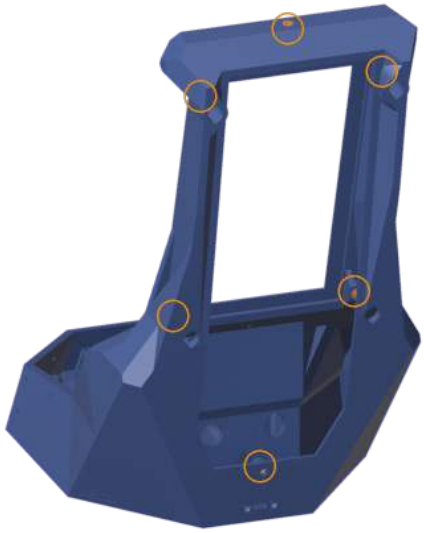


Figure 4.3.2 · Screen knobs, rear cover and message sign

4.4 Handle: 2 inserts

For the trigger and its side piece. The handle comes off the printer in one piece, with the conductive tracks already inside.

2 × M3 insert



Figure 4.4.1 · The handle and its two inserts

5. The joystick handle

5.1 Pivot, presser and M4 insert

Push the pivot down through the presser first. Then glue the M4 insert into the end of the pivot with super glue. The order matters: once the insert is glued in, the pivot no longer fits through the presser. The pivot is flexible TPU, so a heat-set insert would pull out; that is why this one is glued. From here on, pivot, presser and insert are one block.

1 × M4 insert · super glue

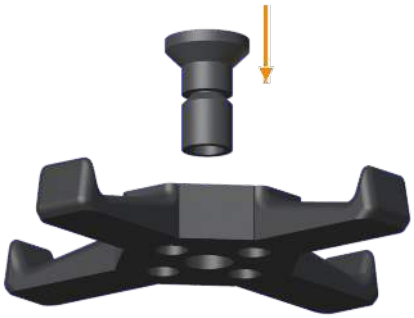


Figure 5.1.1 · 1 · The pivot goes down through the presser



Figure 5.1.2 · 2 · Glue on the outside of the insert, then push it into the pivot



Figure 5.1.3 · 3 · The finished block

5.2 Handle, membrane and the pivot block

Place the handle on the membrane. A small ridge under the handle sits between the two trigger pads: it keeps them apart, so a crumb of something conductive cannot short the trigger. From below, fit the pivot block (from step 5.1) under the membrane and fix the stack with 4 countersunk screws. They cut their own thread in the handle: do not overtighten.

4 × M3 × 16 countersunk



Figure 5.2.1 · From the top: handle, membrane, pivot block, screws

5.3 Contact pad on the trigger

Glue the C-shaped conductive pad onto the tip of the trigger, with super glue.

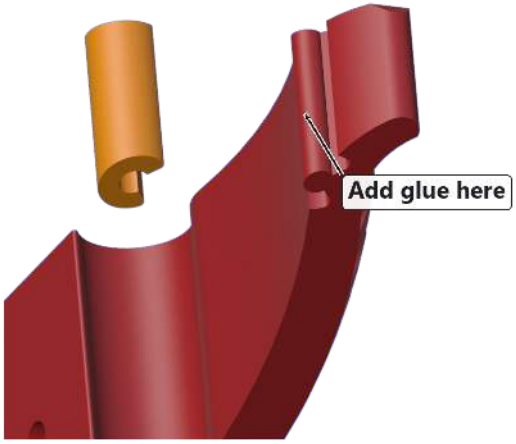


Figure 5.3.1 · Glue on the round tip of the trigger; the C pad slides on from the side

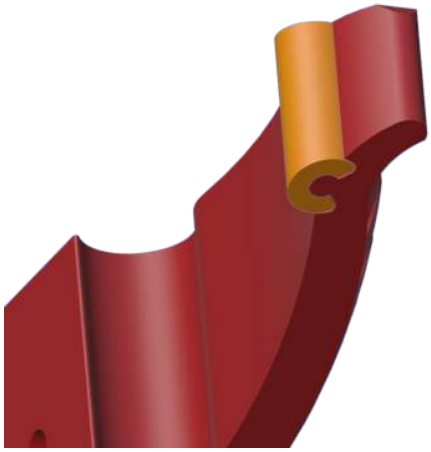


Figure 5.3.2 · The pad glued in place

5.4 Trigger onto the handle

1. Fit the blue side piece to the handle and fix it with the first screw.
2. Fit the red trigger.
3. Fix the trigger and the side piece together with the second screw.

2 × M3 × 10 button

> The cut behind the trigger sets how stiff it feels. Change its size in the CAD to make it softer or firmer.

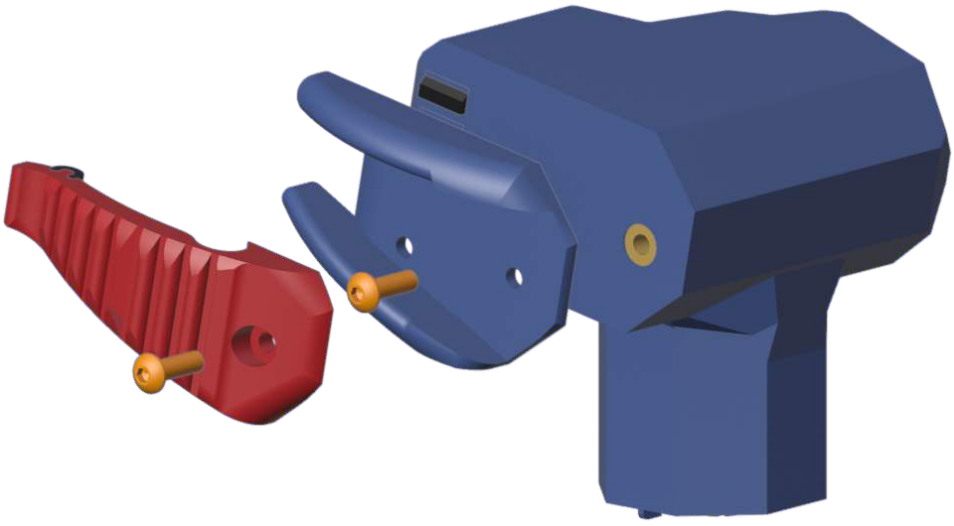


Figure 5.4.1 · From the handle outwards: side piece, first screw, trigger, second screw

6. The circuit board

The board design is in the `PCB_joystick` folder. You can order it from a PCB service, assembled or bare, or make it yourself. If you solder it yourself, follow these steps.

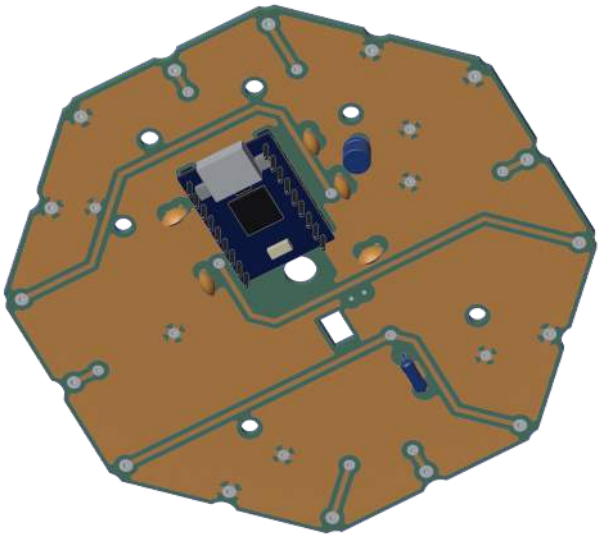


Figure 6.1 · The assembled board, component side

1. **Vias V1–V15**, only on a board without plated holes (for example, one milled at home). Copper wire through the Ø0.8 mm holes, soldered on both sides and trimmed flush. Without solder on both faces a via does not connect.
2. **R1, 220 kΩ, lying flat.** From the front, top centre. No polarity. Solder at the back and trim flush.
3. **C1–C5, 100 nF.** Ceramic, no polarity. From the front, soldered at the back only. **C7 is not fitted.**
4. **C6, 10 µF electrolytic.** It has polarity: the + leg (the long one) goes in the square pad.
5. **ESP32-S3 SuperMini on headers.** On the front, face up, with the USB-C pointing down, towards the two clamp holes. Solder the 18 pins at the back and trim them flush.
6. **Check the back.** This face sits against the cup. The cup's 2 mm spacers leave some room, but keep every solder joint low and trim all leads flush.

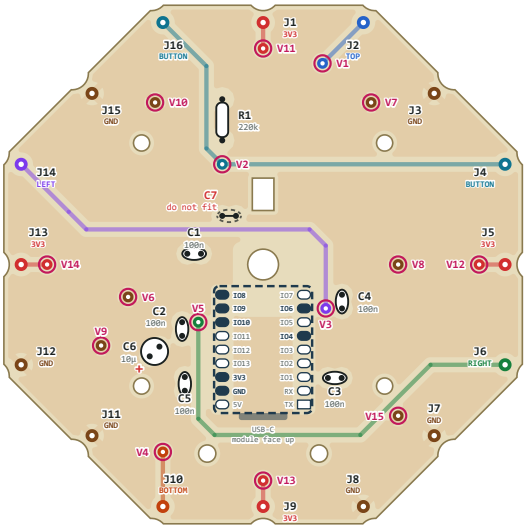


Figure 6.2 · A · Front: where the components go

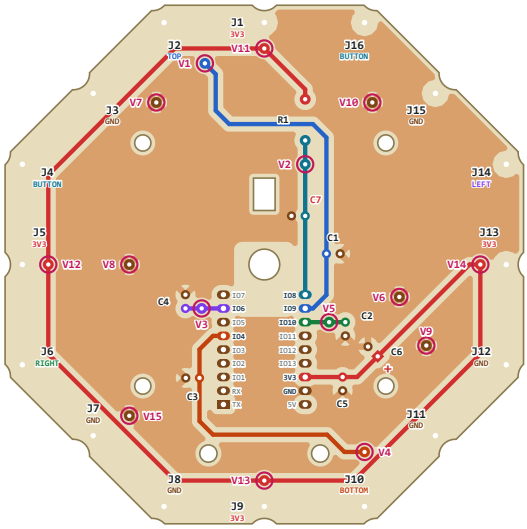


Figure 6.3 · B · Back, seen with the board flipped: where you solder

Tests before plugging in USB

Measure on the front pads of the contacts.

- 3V3 ↔ GND (J1 ↔ J3): no short. The reading climbs slowly while C6 charges; that is normal.
- J1, J5, J9, J13 and the module's 3V3 pin are connected to each other.
- J3, J7, J8, J11, J12, J15 and the module's GND pin are connected to each other.
- J4 ↔ J16 are connected (the two trigger contacts).
- J2 → IO9, J6 → IO10, J10 → IO4, J14 → IO6, J16 → IO8: each contact reaches its own pin and nothing else.

7. The joystick cup

7.1 Membrane onto the cup

Line up the alignment hole in the membrane with the peg on the cup: it only fits one way. Screw the edge down with 16 screws and washers, and the stiff blocks with 8 screws.

Each edge screw is part of the circuit: wire → insert → screw → conductive pad on the membrane. That is why these 16 take a washer. The 8 on the stiff blocks only hold them in place, so they need none.

16 × M3 × 12 button + washer

8 × M3 × 10 button

> **Tighten until the screw seats firmly, then stop.** If you crush the conductive TPU, it stops conducting.



Figure 7.1.1 · The joystick module onto the cup, then washers and screws

7.2 PCB under the cup

Each wire leaves its insert, passes through the cup and comes out straight underneath. The square hole in the PCB fits the square peg on the cup, so the board only goes on one way: each wire then lands in the contact hole (J1–J16) directly beneath it. Solder the wires on the front of the PCB, trim them flush at the back, and fix the board with 4 screws. The cup's own spacers keep it 2 mm away.

4 × M3 × 12 button

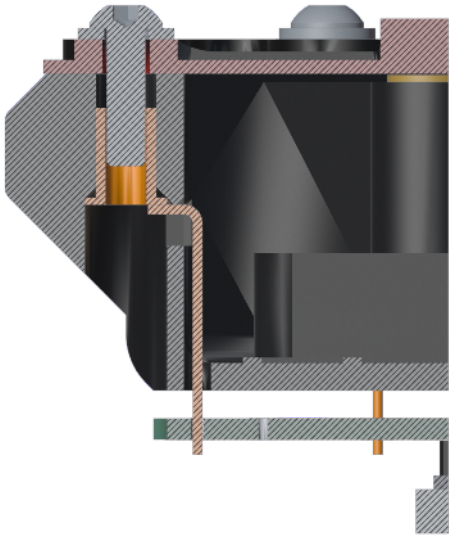


Figure 7.2.1 · Cut through one edge screw (hatched: cut faces). Screw and washer on the membrane, insert with its wire, wire down to the PCB

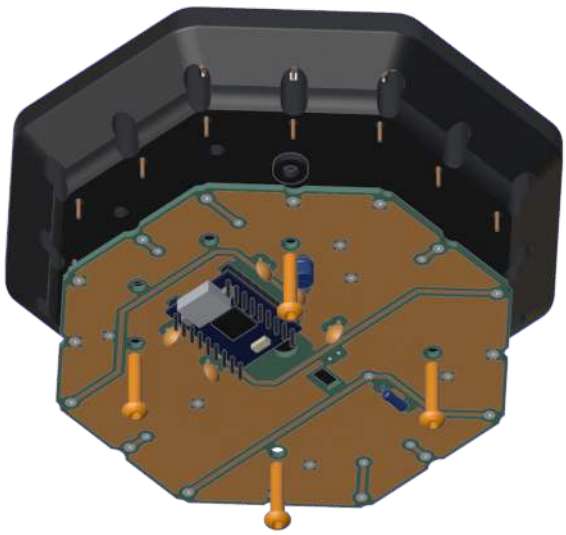


Figure 7.2.2 · The PCB and its 4 screws, from below

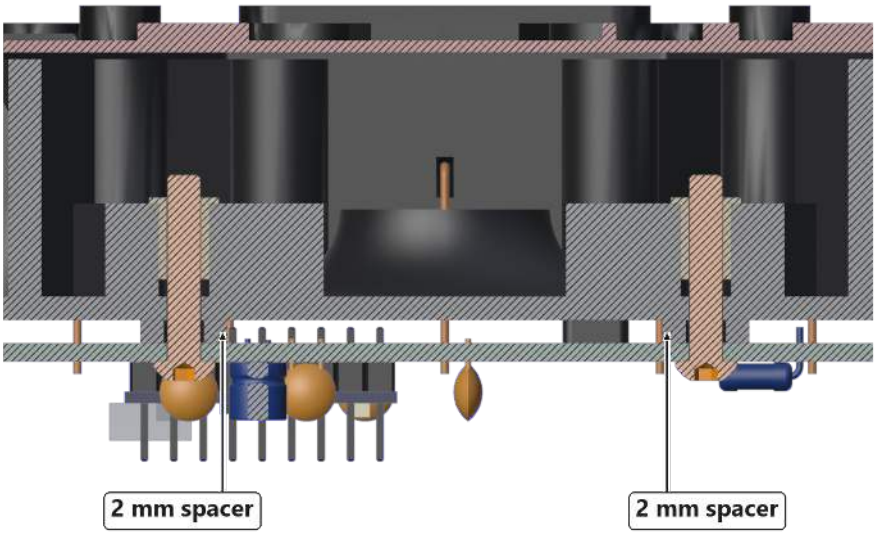


Figure 7.2.3 · Cut through two PCB screws (hatched): the cup's 2 mm spacers keep the board off the cup

8. The cabinet

8.1 Feet onto the legs

Remove the supports from the legs. Glue a textured TPU 60A foot pad under each leg.

4 × leg | 4 × foot pad | super glue



Figure 8.1.1 · A foot pad under each leg

8.2 Legs onto the body

Glue the four legs under the body.

super glue



Figure 8.2.1 · The legs, with their feet, under the body

8.3 Details

Every detail has matching holes in the body for 1.75 mm filament. Cut pins of about 6.5 mm. If a pin does not go into a hole, open the hole with a 1.75 mm bit in a hand drill. Put a drop of super glue in the detail's hole, push the pin in, then press the detail onto the body. The pins keep it aligned and it only goes on one way. A drop of glue between the detail and the body is optional.

8 × bottom side · 2 × top side · 1 × middle · 1 × QR code · 28 × filament pin



Figure 8.3.1 · 1 · Pins into the detail, from the back: glue in the hole, then the pin. Left: a pin in place. Right: a pin going in, and one still to go



Figure 8.3.2 · 2 · Then the details, with their pins, onto the body

8.4 Joystick plate

Glue the rim onto the plate. The plate is printed apart from the body so that the body needs no supports here.

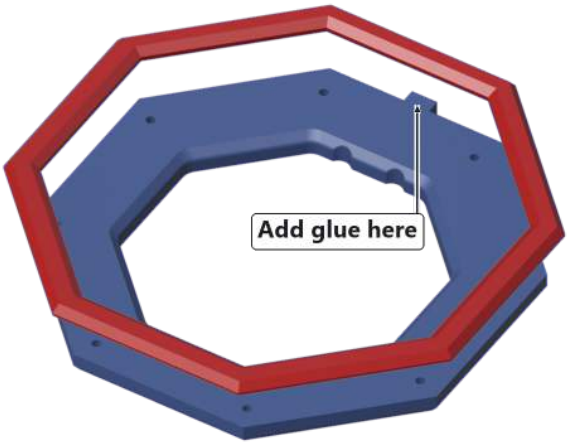


Figure 8.4.1 · The rim goes on top of the plate

8.5 Thumbscrews

Each knob with its screw glued in makes a thumbscrew, which you can turn by hand. Glue a screw into each knob: four M3 × 12 for the screen, one M3 × 20 for the rear cover and the M4 × 40 for the joystick, underneath. Put a drop of super glue **on the screw head**, not in the knob. Then pass the screw through the knob from the grip side, tip first, until the head sits in the knob. Glue put in the knob would be pushed onto the thread.

6 × knob · super glue

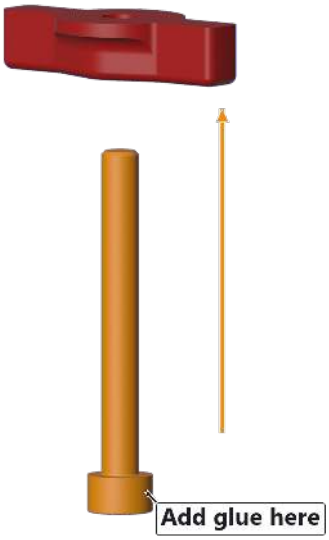


Figure 8.5.1 · The joystick thumbscrew: the M4 × 40 goes in from the grip side

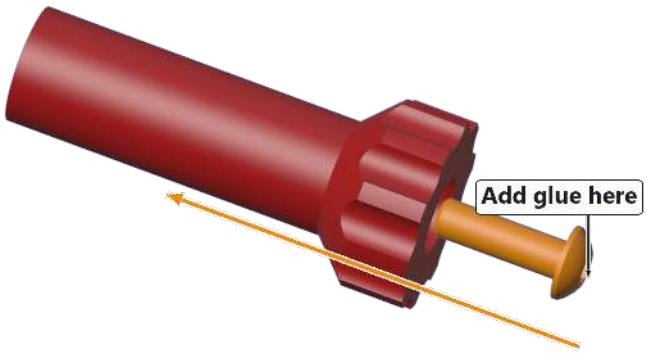


Figure 8.5.2 · A screen thumbscrew: the same, with an M3 × 12



Figure 8.5.3 · Where the six thumbscrews go: four on the screen, one on the rear cover and the joystick one underneath (cabinet shown faded)

9. Joystick into the cabinet

First fix the plate, with its rim, to the body with 8 screws, into the inserts from step 4.3. Then set the cup on the plate: its keying only lets it face forwards. From underneath, screw the joystick thumbscrew into the insert in the pivot. That one screw holds the whole joystick, so to take the joystick out you only undo the thumbscrew.

8 × M3 × 16 button

1 × joystick thumbscrew (M4 × 40)

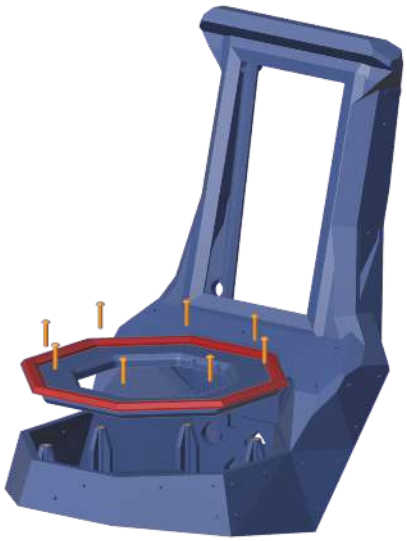


Figure 9.1 · 1 · The plate and its 8 screws



Figure 9.2 · 2 · The joystick from above, the thumbscrew from below

> **Switch the Raspberry Pi off and unplug its power** before you take the cup out and before you put it back: the M4 screw passes close to the PCB and could short it. Lift the cup out carefully: the USB cable is still plugged into the ESP32.

10. Screen, Raspberry Pi and cables

10.1 Screen

Screw the 4 brackets to the screen. They hold the screen slightly off the body so the 4 knobs can clamp it from the back; the knobs stay visible from outside. The screen is not symmetric: it only fits one way round. Upside down, its borders do not line up with the opening.

4 × M2.5 × 6

4 × knob with M3 × 12



Figure 10.1.1 · Screen, brackets and knobs, from the back

10.2 Raspberry Pi and cables

Fit the Active Cooler to the Pi and plug the screen's HDMI adapter into it. Mount the USB-C panel socket at the back of the body and plug its other end into the Pi. Connect the Pi to the screen (micro-USB, power) and to the ESP32 (USB-C). The joystick cable passes through the openings between the screen area and the joystick area.

2 × M3 × 8 countersunk

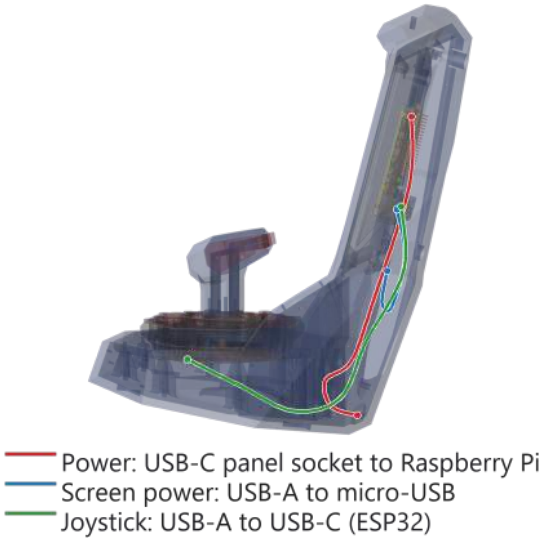


Figure 10.2.1 · Cable routing, seen from the side through the body

10.3 Rear cover

The top of the cover hooks into a slot in the body. Hold the cover low behind the body, push it in (1), then slide it up (2) until the top edge sits in the slot. Then tighten the knob at the bottom.

1 × knob with M3 × 20

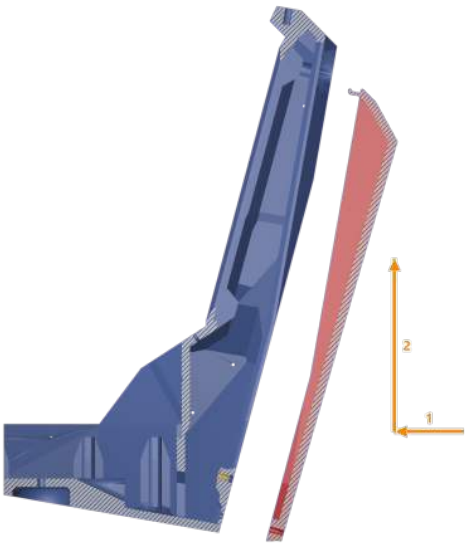


Figure 10.3.1 · Cut through the middle (hatched): in, then up, so the top edge enters the slot

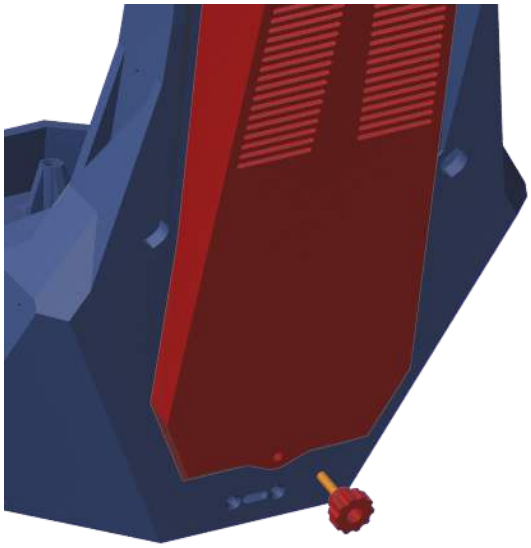


Figure 10.3.2 · Then the knob at the bottom

10.4 Message sign

Screw the sign onto the insert on top. It is separate from the body on purpose, so you can change the message for each event and audience.

1 × M3 × 10 button

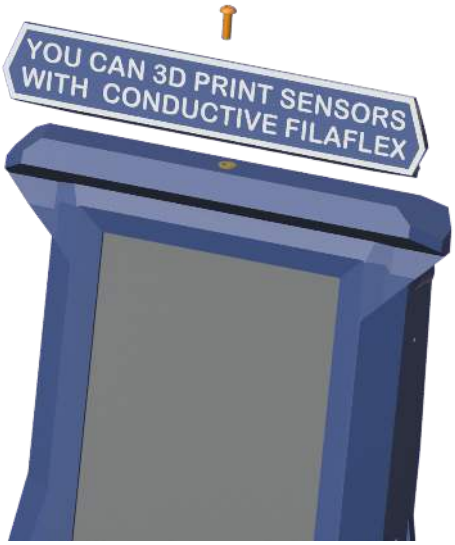


Figure 10.4.1 · The sign and its screw, on top of the cabinet

11. Software and calibration

Firmware (ESP32-S3)

1. Install the Arduino IDE (version 2) on your computer.
2. In *Tools → Board → Boards Manager*, search for **esp32** and install *esp32 by Espressif Systems*.
3. Open `Analog_Orbit_Controller_S3/Analog_Orbit_Controller_S3.ino`. Keep the file inside the folder with the same name.
4. In the *Tools* menu, set:

Option	Value
Board	ESP32S3 Dev Module
USB CDC On Boot	**Enabled**
USB Mode	Hardware CDC and JTAG
Upload Mode	UART0 / Hardware CDC
Flash Size	4MB (32Mb)
Partition Scheme	Default 4MB with spiffs
PSRAM	Disabled

   The sketch refuses to compile if USB CDC On Boot or USB Mode are wrong.
5. Plug the ESP32 into the computer with a **data** USB-C cable, choose its port in *Tools → Port* and click *Upload*.
6. If no port shows up: hold BOOT, press and release RESET, then release BOOT. Choose the port again and upload. After the upload, press RESET; the port may change.
7. Check it works: open the Serial Monitor at 115200 baud. You should see lines of text starting with `{"app":"analog-orbit"`. Close the Serial Monitor before you start the game: the port can only be used by one program at a time.

Game (Raspberry Pi)

1. Write **Raspberry Pi OS (Desktop)** to the microSD card with Raspberry Pi Imager, put it in the Pi and start it. You need a keyboard and mouse for the setup.
2. Turn the screen to portrait: *Preferences → Screen Configuration*, set the rotation, then apply.
3. Copy the `Analog_Orbit_Mini` folder to the Pi, for example from a USB stick to the home folder.
4. Open a terminal in that folder and run `bash SETUP_RPI.sh` once. It installs what the game needs and gives your user access to the USB port. Restart the Pi.
5. Plug in the joystick and run `bash START_RPI.sh --fullscreen`. The game finds the joystick by itself; if not, choose it in *Joystick & calibration*.

6. To start the game automatically with the desktop, run `bash ENABLE_AUTOSTART_RPI.sh` (without sudo). `DISABLE_AUTOSTART_RPI.sh` undoes it.
7. Esc goes back to the menu, F11 switches full screen on and off.

To try the game on a computer without a joystick: `python game.py --demo` (WASD to move, space to fire). On Windows, use `START_WINDOWS.bat`.

Calibration

Main menu → Joystick & calibration → Quick calibration: centre, up, down, left, right, centre again. For each point, hold the stick there, then press and release the trigger. The calibration is stored on the ESP32 and survives a power cycle. Calibrate again whenever you reassemble the joystick. The touch screen always works in the main menu, so you can still get around if the joystick fails.

12. Checks and troubleshooting

Symptom	Check
One direction does not respond	Edge screws of that arm seated? Wire soldered to the insert and to the PCB?
One direction is weak or dead after reassembly	A screw may have been overtightened and crushed the conductive TPU
Trigger does not register	C pad still glued? With the trigger pressed, about 10 kΩ between the two contacts
Stick drifts	Recalibrate. If it keeps drifting, check the 8 screws on the stiff blocks
Game does not find the joystick	Close the Arduino Serial Monitor. Use a data cable, not a charge-only one