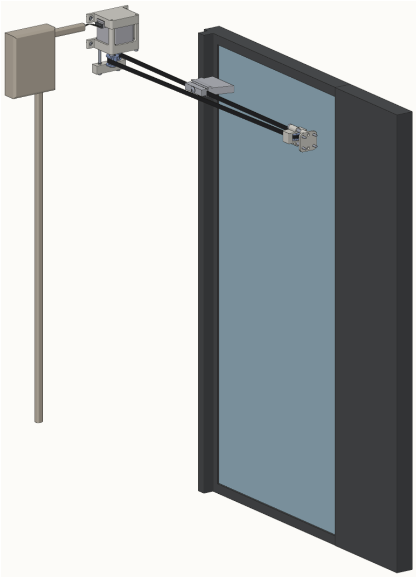
Sliding Window Opener

A belt-driven retrofit that motorises a top-hung sliding glass panel, built around an ESP32 running ESPHome and exposed to Home Assistant as a cover entity.



Drive	NEMA17 + 20T GT2 pulley, 6 mm carbon-reinforced belt
Control	ESP32 + TMC2209, ESPHome, Home Assistant cover entity
Travel	1050 mm measured, auto-calibrated on boot
Cost	about 900 THB / USD 30
Licence	MIT (firmware) / CC BY 4.0 (hardware + docs)
Author	Pawin Jirasuntornsiri

Everything in this guide is generated from the project's own CAD and firmware. Renders are the actual STEP geometry, not illustrations.

1. What this is

A motorised retrofit for a top-hung sliding glass panel. The panel slides horizontally, hangs entirely from a sealed ceiling track with no access to the carriage inside, and has no bottom track or guide. A GT2 belt is clamped to the panel's vertical stile and driven from one end; the far end runs over a tensioning idler.

The design constraint that shapes everything else is that the track is sealed. Nothing can be added inside it, so all the hardware hangs off the jambs at either end and the panel is pulled, not pushed.

Retrofit, not a replacement

Nothing structural changes. The sealed track stays sealed, the panel is never removed or modified, the glass is not touched, and no part of the window is cut, drilled or replaced. The entire intervention is two brackets on the jambs and a clamp on the panel's stile - and both brackets can be bonded with VHB tape rather than screwed, if you would rather not drill at all.

It also stays a normal window. The driver is left disabled when idle, so the panel still slides by hand with the same effort as before; assist mode picks up the nudge and takes over. Nothing is captive, nothing is geared, and there is no clutch to disengage. Take it all off again and you are left with an ordinary sliding window, which is rather the point - this is a weekend addition to a window you already have, not a renovation.

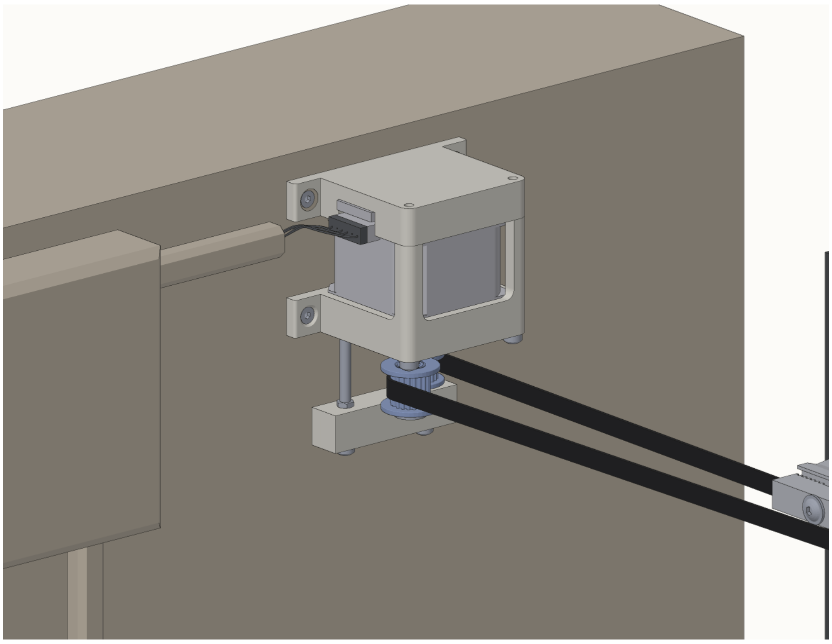
Physical specification

Property	Value
Panel width	about 1.5 m, glass, top-hung
Measured travel	1050 mm
Breakaway force	under 3 kgf (measured)
Drive force available	about 62 N, roughly 2x margin
Belt	GT2 6 mm carbon-reinforced, about 2.5x window width
Pulley	20T GT2 = 40 mm travel per revolution
Duty cycle	about 5 min/day, so thermals are a non-issue
Environment	indoor, no rain / UV / humidity exposure

How the drive works

The motor mounts vertically to one jamb with its shaft pointing down. The 20T drive pulley sits under the housing, and a 16T guide idler plus a 20T tensioning idler set the belt path. The belt is a single open length: both ends terminate in the aluminium clamp bolted to the panel stile, so the clamp both joins the belt and is the thing that gets dragged.

Because the belt is a loop in a horizontal plane with its 6 mm width vertical, the whole mechanism sits in a shallow band just above the panel and needs very little depth.


The motor end. Shaft points down, drive pulley below the housing, tensioning idler on the M3 screw in the block beneath.

2. Bill of materials

Electronics

Item	Detail	Qty
MCU	ESP32 DevKit, 30-pin (Node32s), micro-USB	1
Stepper driver	BIGTREETECH TMC2209 v1.3 (110 mOhm RSENSE)	1
Motor	NEMA17 42BYGH40	1
PSU	24 V 2 A, 48 W	1
Buck converter	LM2596 adjustable, set to 5.0 V	1
Bulk capacitor	2200 uF 35 V, across driver VS/GND	1
Limit switches	MC-38 reed sensors, enclosed type	2
Magnet	MC-38 companion magnet, on the stile	1
Perfboard	7 x 9 cm, point-to-point soldered	1

Mechanical

Item	Detail	Qty
Drive pulley	GT2 20T, 5 mm bore, for the motor shaft	1
Guide idler	GT2 16T W6, 3 mm bore, with bearings	1
Tensioning idler	GT2 20T, 3 mm bore, with bearings (belt tension only)	1
Far-end idler	GT2 20T W6, 3 mm bore, with bearings	1
Belt	GT2 6 mm, carbon-reinforced, open length	about 2.5x width
Belt clamp	GT2 aluminium timing belt clamp (printable, but aluminium is preferred)	1
Tensioner screw	M3, through the 3 mm bore bearing	1
Idler axle	M2.5 x 16	1
Machine screws	M3, assorted lengths, plus nuts and washers	about 14
Heat-set inserts	M3	3
Wall fixings	suit your wall; 4 per bracket	8

> **Note on fastener sizes.** The STEP files were exported with placeholder fasteners from the CAD library, so they read as 6-32, 10-24, M2.5 and M5 in the geometry. Everything is actually **M3**, except the M2.5 far-end idler axle screw. The tensioning idler is an M3 screw through a 3 mm bore bearing, not an M5.

3. Printed parts

Part	Envelope	Notes
Motor housing, main body	45 x 68 x 37 mm	carries the motor and both idlers
Motor housing, cover	45 x 68 x 12 mm	closes the top
VHB standoff block	11 x 48 x 12 mm	flat face for VHB mounting
Idler carrier	16 x 30 x 27 mm	slides to tension the belt
Idler base plate	14 x 29 x 29 mm	2x M3 heat-set inserts

Ready-to-slice STL files for all five parts, plus the printable version of the belt clamp, are in **hardware/stl/**. They are exported in CAD orientation - orient them for the bed in your slicer.

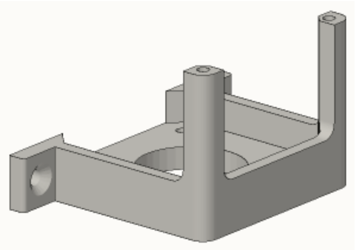
Material and settings

PA6 if you are screwing the brackets to the wall - it was printed at a 70 C chamber temperature with no warping. **ABS or PETG** is fine if you are mounting with VHB tape instead, since the load path is then adhesive rather than a screw pulling through the part.

The VHB standoff block exists specifically so tape has a flat, properly sized face to bond to. Without it, screws are sufficient but VHB is not.

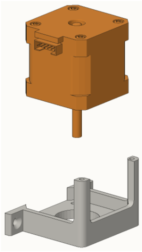
4. Assembly: motor unit

Ten steps. The new part in each frame is highlighted and offset along the direction it goes in.



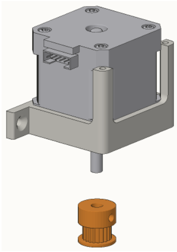
1. Housing main body

Print this first. Everything hangs off it.



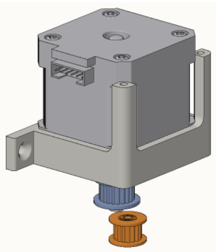
2. NEMA17 motor, in from above

Shaft points down, through the bore. Fit it before anything blocks the opening.



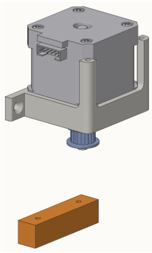
3. 20T drive pulley on the shaft

Slide on from below and tighten the grub screws on the shaft flat. Do this now - there is no access once the housing is closed.



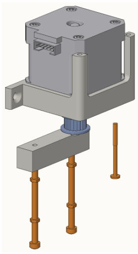
4. 16T guide idler

Sets the belt path together with the tensioning idler.



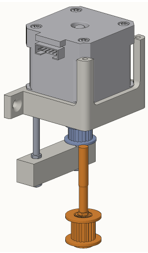
5. VHB standoff block

Only needed if you are mounting with VHB tape. Skip it if you are using screws.



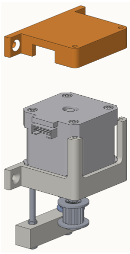
6. 3x M3 screws and nuts

Up through the block and the motor flange. All heads sit underneath.



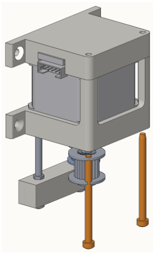
7. Tensioning idler - FIT LAST

Do not fit this yet. It is purely a tension adjustment and it is the very last thing that goes on, during final installation once the belt is routed. Shown here only so you know where it lands. M3 screw through a 3 mm bore bearing.



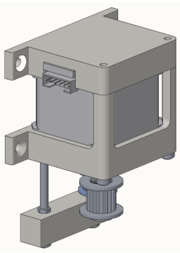
8. Housing cover, on from above

Closes the housing.



9. 2x M3 screws clamping the halves

These pull the two halves together. They pass right through into the cover.



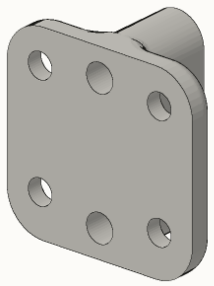
10. Motor unit complete

> **Order matters here.** The drive pulley has to go on the shaft before the cover, and the grub screws have to be tightened before the housing closes. Get this wrong and it comes apart again.

> **Step 7 is deliberately out of sequence.** The tensioning idler is not part of building the motor unit - it exists only to tension the belt, so it goes on at the very end of the final assembly, after the belt is routed and clamped. Build steps 1-6 and 8-9 now, and come back to 7 in section 7.

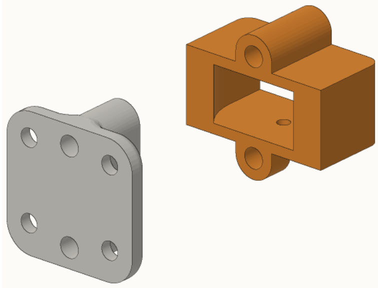
5. Assembly: idler bracket

This is the far end of the run and the main tensioning adjustment.



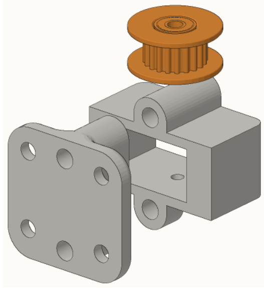
1. Wall base plate

Fit 2x M3 heat-set inserts into the two holes on the inner face.



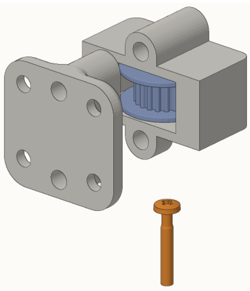
2. Sliding carrier

This is the part that slides to tension the belt.



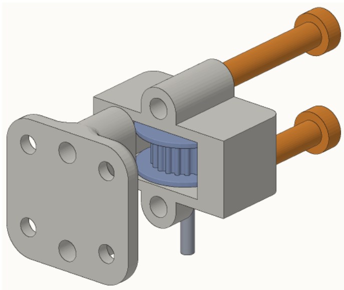
3. 20T idler and bearings

Bearings into the pulley, pulley into the carrier.



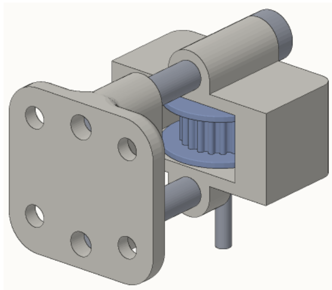
4. M2.5 axle screw, from below

Goes in from underneath, through the carrier and the pulley.



5. 2x M3 adjuster screws

Through the carrier into the base inserts. These also set belt tension - backing them out pushes the carrier away and tightens the belt.

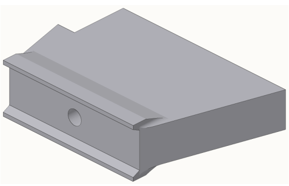


6. Idler bracket complete

> **The axle screw goes in from below.** The published STEP file currently has it modelled head-up, which is wrong. Fit it head-down.

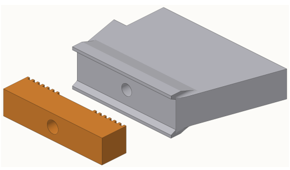
6. Assembly: belt clamp

Both ends of the belt terminate here, and this is what bolts to the panel.



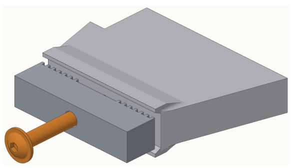
1. Clamp body

Aluminium is strongly preferred, but it prints if you have to.



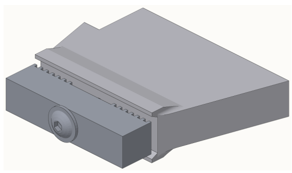
2. Toothed grip bar

The teeth mesh with the belt so it cannot creep under load.



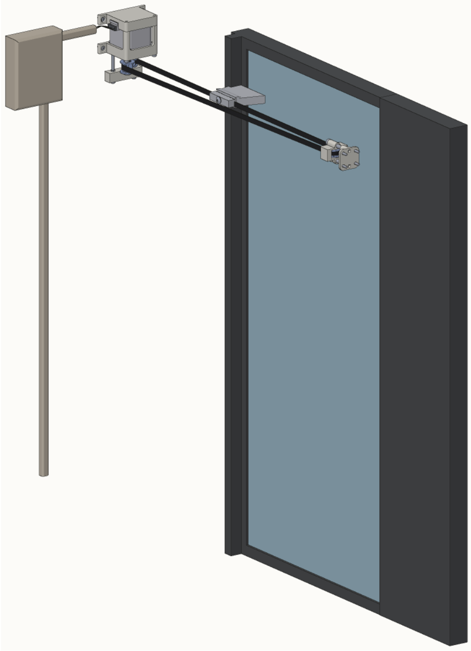
3. M3 screw

Use a washer under the head.



4. Belt clamp complete

7. Installation



The complete installation. Motor unit on the left jamb, idler bracket on the right, belt clamp on the panel's leading stile.

Mounting

Both ends screw to the jambs with 4x M3 countersunk screws each, or bond with VHB using the standoff block. Fix the motor end first, then stretch the belt across and position the idler bracket so the carrier still has adjustment left in both directions.

Belt routing and length

Cut roughly 2.5x the window width. The belt leaves the drive pulley, runs the length of the opening, wraps the far idler, and comes back. Both cut ends go into the aluminium clamp, teeth meshed, and the clamp bolts to the panel stile.

Tensioning

Target 20-30 N. In practice: plucked, the belt should give a dull thud rather than a ring, and mid-span it should deflect 5-10 mm under light finger pressure. Adjust with the two M3 screws on the idler carrier. If that is not enough range, fit the tensioning idler at the motor end (motor unit step 7) and take up the rest there - M3 screw through a 3 mm bore bearing, with washers so the pulley clears the screw head.

> **Re-check tension after the first few full cycles.** A new belt beds in and drops tension, and low tension is the main cause of skipped teeth.

Limit switches

Two MC-38 enclosed reed switches, tape-mounted, one near each end of travel. A single magnet on the stile triggers both.

Position these by testing, not by measurement. Tape them on loosely, slide the panel by hand and watch the binary sensors in Home Assistant until each one trips reliably a little before its hard stop. Then run a calibration and confirm the panel stops clean at both ends. Tape is deliberate here - it means you can move them a centimetre and try again, which is faster than getting it right on paper.

> Whatever offset you land on, the magnet must fully release the switch within the firmware's backoff distance (**backoff_steps**, currently 1200) or the slow confirming pass never re-triggers and homing stalls.

8. Wiring

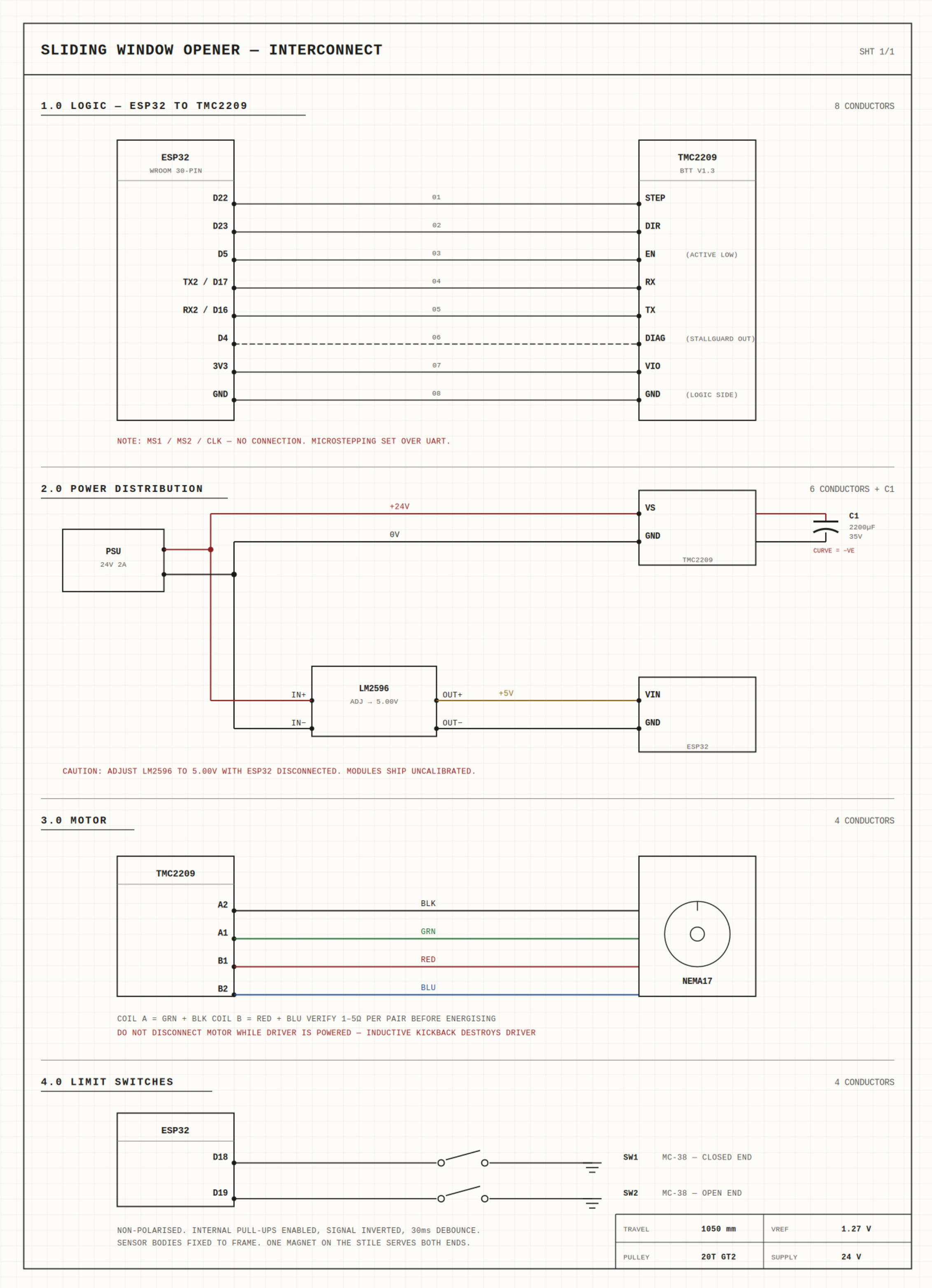
From	To
ESP32 TX2 (GPIO17)	TMC2209 RX
ESP32 RX2 (GPIO16)	TMC2209 TX
ESP32 D22 (GPIO22)	TMC2209 STEP
ESP32 D23 (GPIO23)	TMC2209 DIR
ESP32 D5 (GPIO5)	TMC2209 EN (active LOW)
ESP32 D4 (GPIO4)	TMC2209 DIAG (StallGuard)
ESP32 3V3 / GND	TMC2209 VIO / GND (the one beside VIO)
ESP32 D18 (GPIO18)	MC-38 #1, closed end
ESP32 D19 (GPIO19)	MC-38 #2, open end
PSU +24 V / -	TMC2209 VS / GND (the one beside VS)
2200 uF cap	across VS / GND
Buck OUT+ / OUT-	ESP32 VIN / GND
Motor	green A1, black A2, red B1, blue B2

MS1, MS2 and CLK are deliberately left unconnected. On the v1.3 board RX and TX are broken out separately, so no external 1 kOhm resistor is needed. All connections are hardwired.

Driver current

The BTT TMC2209 v1.3 uses 110 mOhm RSENSE. Vref is currently set to **1.27 V, about 1.4 A RMS**. Turning the pot clockwise reduces current.

Interconnect diagram



9. Firmware

ESPHome on the ESP-IDF framework. The whole configuration is a single file, **window-opener.yaml**.

Auto-calibration

Total travel is not hardcoded. On boot the device seeks the closed limit, backs off until the switch releases, creeps back on slowly and zeroes there, then repeats the same two-stage approach at the open end while counting steps. That count becomes the measured travel.

This sidesteps the microstepping question entirely - whatever mode the driver comes up in, the measured count is correct in those units.

Why homing is two-stage

A single fast approach bounces off the end stop. Splitting it into a fast pass, a backoff, then a slow creep at 200 steps/s fixes that: the panel is barely moving at contact, so it stops on the switch instead of overshooting. It also makes the trigger point repeatable, because it no longer depends on arrival momentum.

Drift correction

On every normal arrival at the open limit, actual position is compared with the stored travel. Under 10 percent difference, the stored value is silently updated; over 10 percent, it logs a warning and leaves it alone. Belt skips therefore heal themselves on the next full traverse.

Tuning values

Parameter	Value	Notes
run_speed	2500	exposed as a Home Assistant slider
home_speed	1000	fast homing pass
creep_speed	200	slow confirming pass
backoff_steps	1200	must exceed magnet/sensor hysteresis
accel / decel	1500	exposed as a slider

Home Assistant entities

cover.window with open, close, stop and position. Sliders for run speed and acceleration. Switches for obstruction stop, assist mode and direction reversal. Buttons to recalibrate and re-home. Diagnostics for position, measured travel and WiFi signal.

10. Commissioning

Set the buck converter output to 5.0 V **before** connecting the ESP32. LM2596 modules ship at arbitrary voltages, frequently well above 5 V.

Set Vref on the driver, flash the firmware, then power up. The device homes and calibrates itself, so the commissioning order beyond that does not matter much. If it runs the wrong way, flip the **Reverse direction** switch in Home Assistant - it inverts the sign used throughout and triggers a recalibration, so nothing downstream needs changing.

> **Never unplug the motor while the driver is powered.** Inductive kickback destroys TMC drivers, and this is the single most common way they die.

11. Gotchas

A 3 MOhm reading between coil pairs is open, not a short. That is leakage through the driver chip when you probe at its pins.

The bulk capacitor makes VS-GND beep on a continuity test while it charges. Wait for it to settle before calling it a short.

ESPHome rejects initial_value and restore_value together on a template number - the compile fails. Values reset on reboot as a result; once settled, promote them into substitutions.

The driver must stay disabled when idle (EN high) or the panel resists being pushed by hand, which defeats assist mode.

12. Known issues and open work

StallGuard is not configured. DIAG is wired to GPIO4 and read as a plain binary sensor, and the handler stops the motor when it asserts - but SGTHRS has never been written, so it will not fire meaningfully. A UART block exists and is currently unused; it was added for exactly this. TCOOLTHRS needs to bracket the actual run speed, since StallGuard is unreliable at very low and very high speeds. Until this works there is no mid-travel obstruction protection at all, and the panel is heavy glass.

Belt skipping at higher speed. Partly tension, and acceleration is suspected too - torque demand peaks at breakaway, which is the start of every move. Both are sliders for live tuning.

Microstepping mode is unknown. The motor ran about 40 rpm at 750 steps/s, implying roughly 1/8. Auto-calibration makes this moot for correctness, but it matters if absolute millimetres are ever needed.

Nudge-to-assist is limited. It only fires near the closed end. The proper fix is polling the TMC2209's MSCNT register over UART, which tracks shaft rotation even when the driver is disabled.

Buck converter whine. The LM2596 pulse-skips under light load. Output is a clean 5.0 V. Expected to be inaudible once enclosed; if not, add a small load resistor or more output capacitance.

13. Licence