Design Verification Report

Document 12 | Rev C | 17 November 2026 | Status: design package. Nothing has been built or bench-tested; numbers are design targets, calculations or simulations.

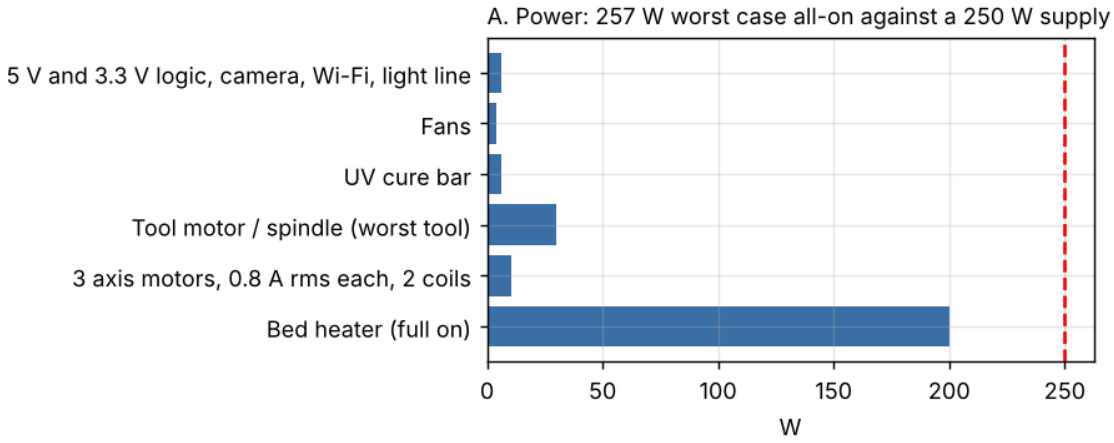
Every check that could be made without hardware, with its result. The scripts are in `07_Verification/1_Simulation`, raw results in `2_Results_data`, plots in `3_Plots`. Circuit simulations use ngspice with generic device models; board checks use KiCad 7's own design rule check; the firmware is cross-compiled for the microcontroller.

Summary

Item	Result	Verdict
A. Power budget	256.8 W all-on against 250 W	Exceeds supply; firmware interlock added and tested (finding F1)
B. Light-line supply	Far LED at 4.9506 V in the full-white fault case; limit 4.5 V	Pass
C. Bed warm-up	180 C in 428 s; hold power 65 W	Pass
C. Bed runaway	Model reaches 501 C if stuck on	Relies on the 260 C fuse (finding F2)
D. Motion	Jerk 375000 mm/s3 against 375000 expected; step margin 1.25	Pass
E. Accuracy	0.072 mm combined against 0.1 mm	Pass on estimates
F. Probe tool	11 of 12 nets judged; see noise plot	Pass with stated limit
G. Bridge	Sag 6.5 um	Pass
H. Board rule checks	4 boards: 0 shorts, 0 clearance, 0 open	Pass (own checker)
I. Firmware tests	113 checks, 0 failed	Pass
I. Software self-tests	inspection: PASS, add-on planners: PASS, line coupons and tag: PASS	Pass
Firmware limits match CAD	True	Pass after fix F4
J. KiCad design rule check	4 boards: 0 clearance, 0 unconnected, 0 shorts after fixes; SC-100 has 12 warnings to review	Pass (KiCad 7.0.11)
K. ARM build	14 modules, 23348 bytes of code, 4.5 % of flash, 0 undefined symbols	Pass as a build check
S1. Light-line rail (SPICE)	4.9506 V; nodal calculation 4.9506 V	Pass; methods agree
S2. Pump switch (SPICE)	Drain peaks at 24.4 V with the diode, 1324 V without	Pass, but 30 V FET has little margin (finding F8)
S3. Heater switch (SPICE)	8.3 A, 0.71 W lost in a 10 milliohm FET	Pass
S4. Input protection (SPICE)	Reversed supply: -3.47 V on the rail at 121 A until the fuse opens. 60 V surge clamped to 31.1 V	Works, with a weakness (finding F9)

A. Power

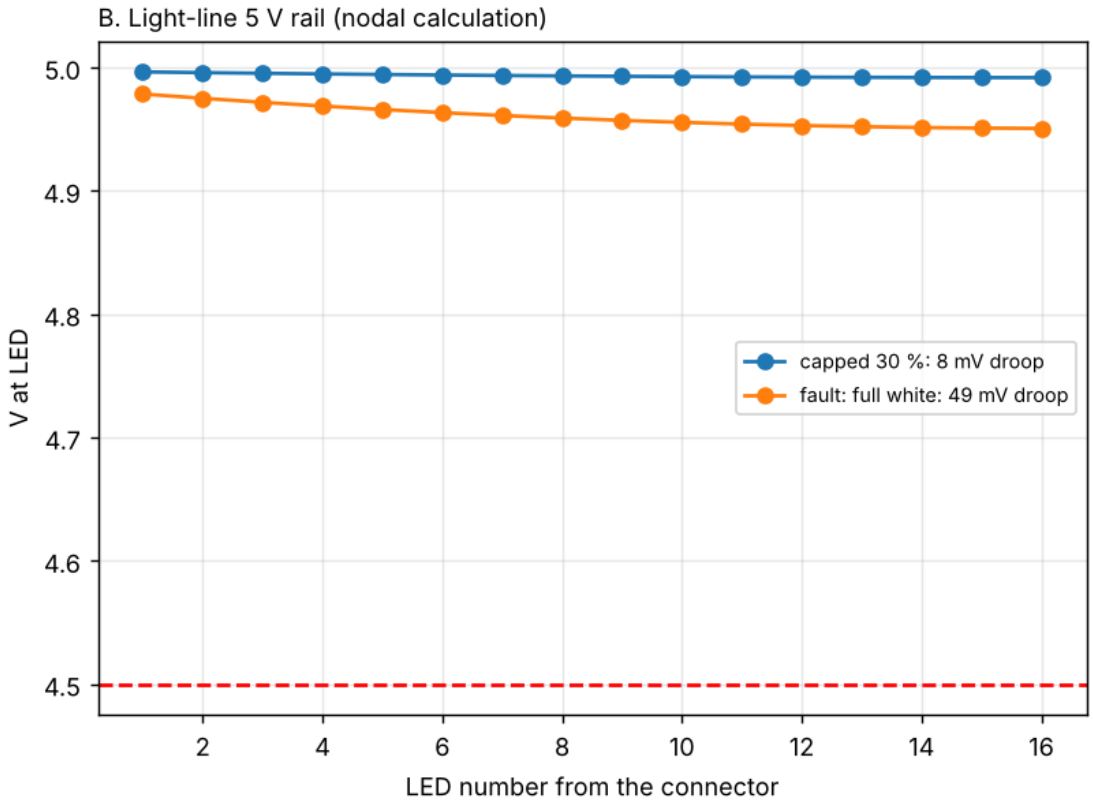
Load	W
Bed heater (full on)	200.0
3 axis motors, 0.8 A rms each, 2 coils	10.8
Tool motor / spindle (worst tool)	30.0
UV cure bar	6.0
Fans	4.0
5 V and 3.3 V logic, camera, Wi-Fi, light line	6.0
Total	**256.8**



Spindle and heater together exceed the supply; firmware must not heat above hold power while milling. Milling recipes do not heat the bed.

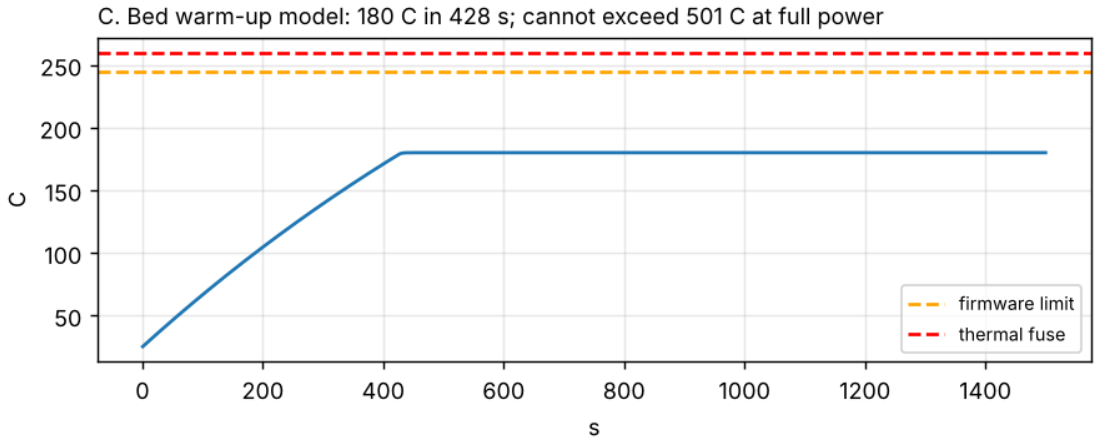
B. Light-line 5 V rail

The rail is a 0.8 mm track with a tap every 10.5 mm (6.45 milliohm per segment). Solved as a resistor ladder with one current sink per LED.



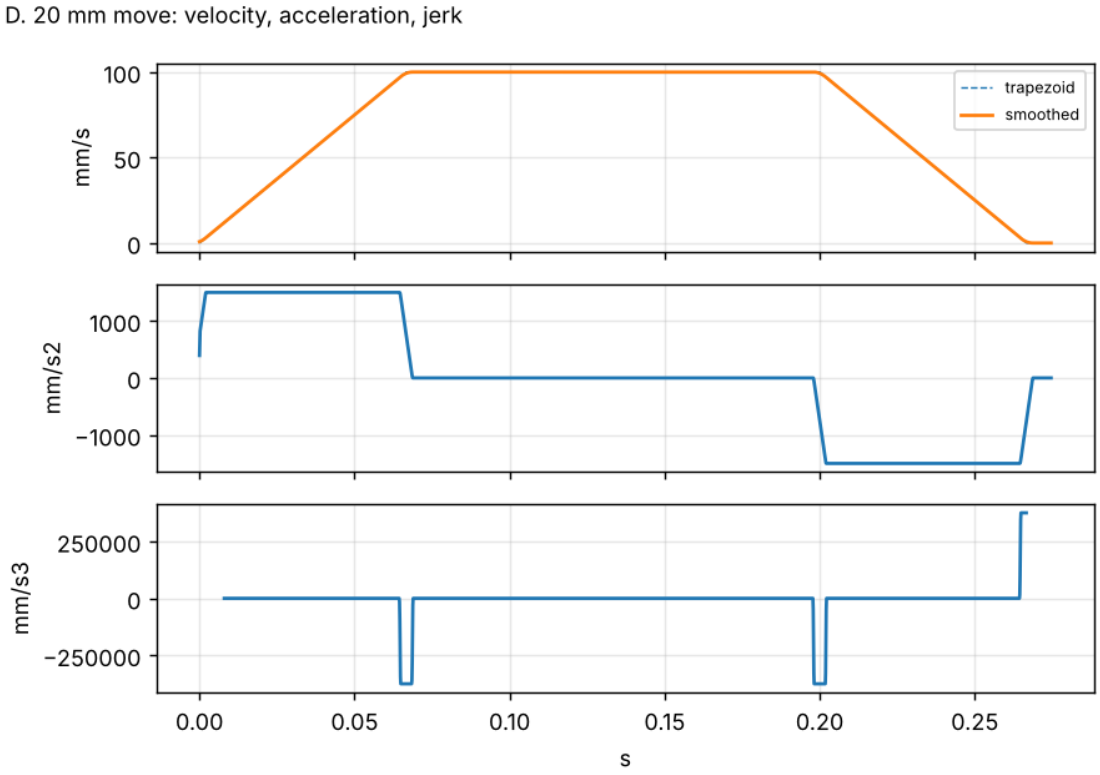
C. Bed thermal

One thermal mass (459 J/K for a 0.408 kg plate plus heater and insulation) losing 0.42 W/K to the room, 200 W heater, proportional control with hold power. The firmware's own model gives 481 s to 180 C; this one gives 428 s. The loss figure is an assumption.

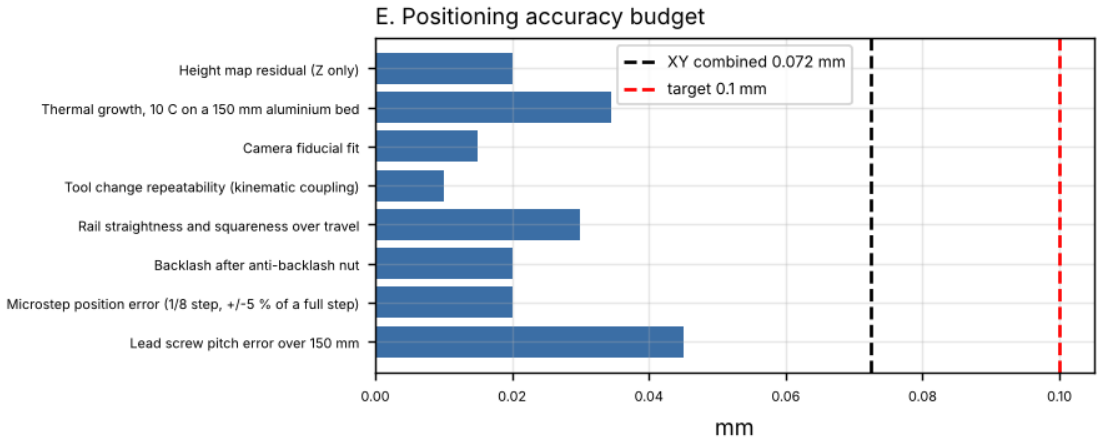


D. Motion

A 20 mm move at full speed and acceleration, with the firmware's 4 ms moving average applied to position.



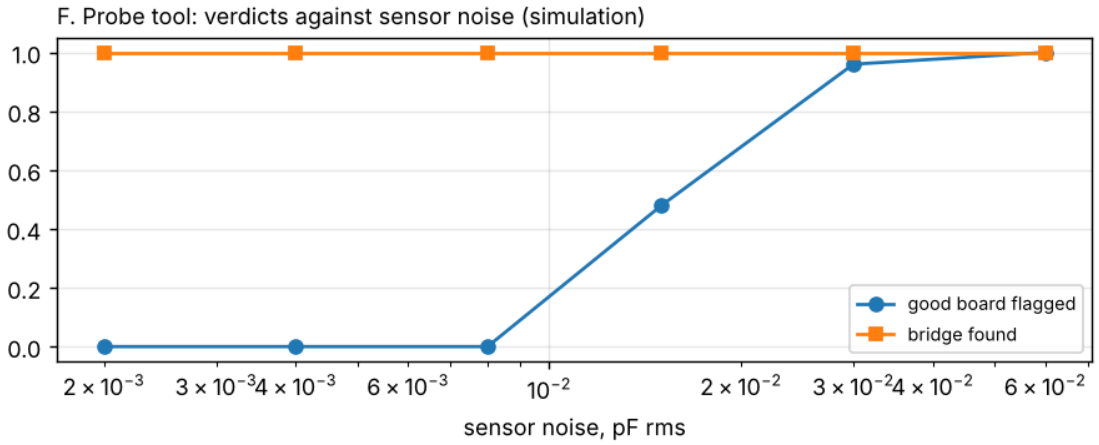
E. Accuracy



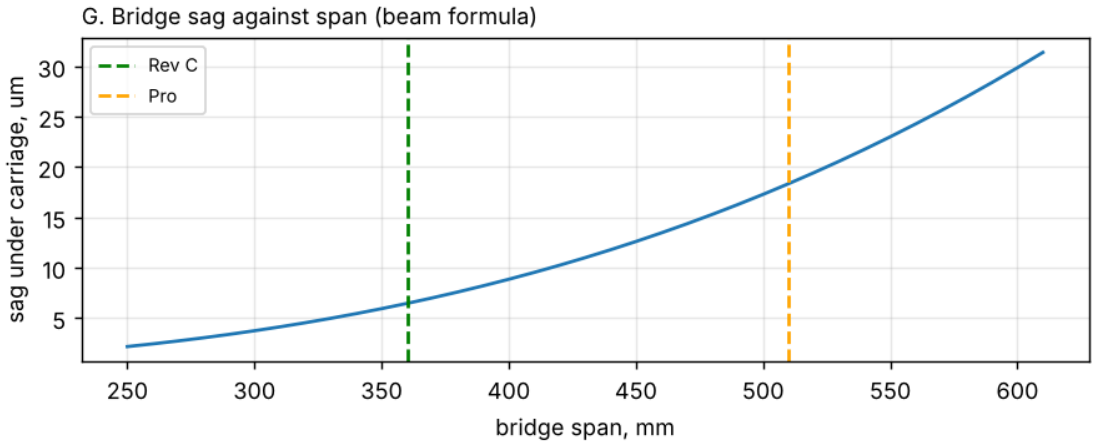
F. Probe tool

Monte Carlo on the sample board: a good board and a board with one injected bridge, against rising sensor noise.

Noise, pF rms	Good board flagged	Bridge found
0.002	0.0	1.0
0.004	0.0	1.0
0.008	0.0	1.0
0.015	0.48	1.0
0.03	0.96	1.0
0.06	1.0	1.0



G. Structure



H. Board rule checks

Board	Size	Layers	Nets	Pads	Tracks	Vias	Shorts	Clearance	Open	Min gap
SC-100	108 x 90	4	156	705	1485	536	0	0	0	0.15
FP-100	210 x 14	2	21	107	120	34	0	0	0	0.3
PT-100	24 x 30	2	13	30	36	6	0	0	0	0.2
PP-100	24 x 30	2	10	34	45	6	0	0	0	0.3

J. KiCad design rule check

KiCad 7.0.11 pcbnew design rule check, run with this design's manufacturing rules.

Board	Errors and warnings	Cosmetic	By type
SC-100	12	524	silk_overlap 199, lib_footprint_issues 199, silk_over_copper 124, via_dangling 8, track_dangling 4, silk_edge_clearance 2
FP-100	0	39	lib_footprint_issues 39
PT-100	0	10	lib_footprint_issues 10
PP-100	0	14	lib_footprint_issues 14

What KiCad found that the package's own checker had missed, all on SC-100 and all now fixed:

- 6 track ends that only grazed their pads (KiCad: unconnected); bridged to the pad centres
- USB power track 0.08 mm from a connector mounting hole; rerouted
- Fiducial 0.25 mm from a 3.3 V track; moved 1.5 mm
- 79 dead-end track stubs removed

Remaining on SC-100: 8 ground vias reported as dangling (they tie to the inner ground plane only) and 4 track-end warnings to review; 524 cosmetic items (silkscreen overlaps, footprint library links).

Not run: KiCad's electrical rule check needs KiCad schematics, and these boards are generated from net lists in code. A net-list sanity check stands in for it. Net-list check on SC-100: 174 nets, 2 with a single pin (CAN_RX, CAN_TX: the unfitted CAN interface).

K. Firmware build for the microcontroller

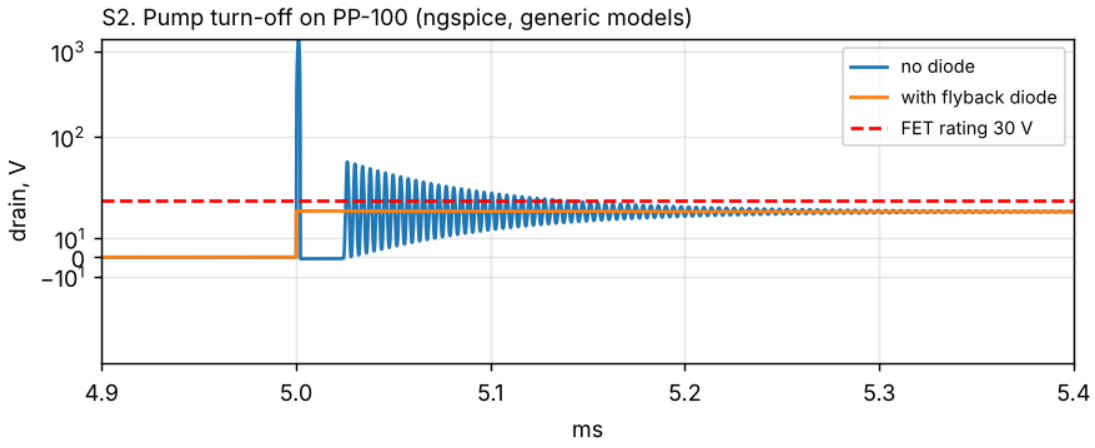
arm-none-eabi-gcc (15:13.2.rel1-2) 13.2.1 20231009, -mcpu=cortex-m0plus -mthumb -Os -Wall -Wextra, target STM32G0B1RET6 (Cortex-M0+). 14 modules compile with 2 warnings; linked size 23348 bytes of code and 80 bytes of data. Link check only: every core module linked with do-nothing hardware stubs and a minimal start-up. It

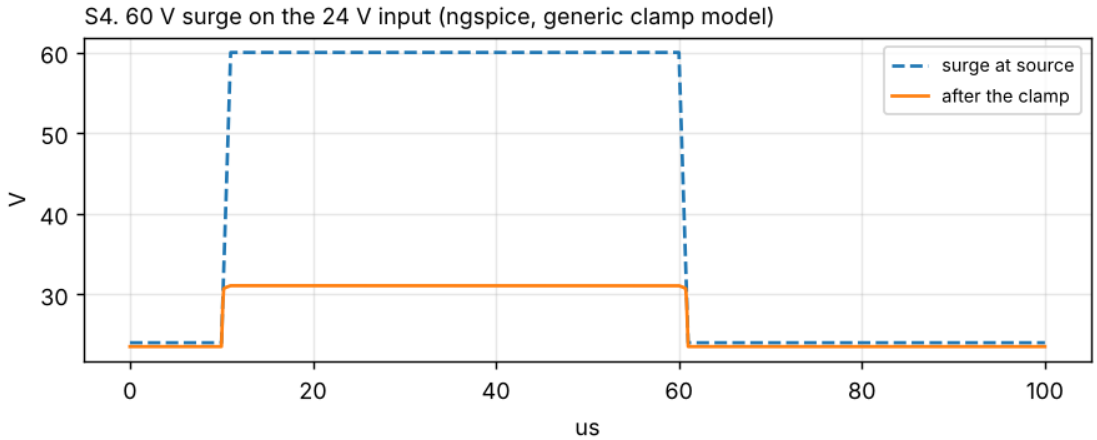
proves the code compiles and links for the target and fits; it is not a working firmware image and must not be flashed expecting motion.

S. Circuit simulations (ngspice)

Generic device models, so the results show behaviour and margins rather than exact values.

Simulation	Result
S1 light-line rail	Far LED 4.9506 V; agrees with the nodal calculation: True
S2 pump switch	Diode is required: without it the model shows a spike far beyond any small FET. With it the drain sits a diode drop above 24 V, under 6 V below the 30 V FET rating: fit a 40 V or 60 V part instead.
S3 heater switch	On current 8.3 A, loss 0.71 W, turn-off peak 24.9 V. Generic FET sized for about 10 milliohm. Loss scales with the real part's on-resistance.
S4 input protection	Reversed supply: the clamp carries about 120 A until the fuse opens, and the rail sits near -3.5 V for that time, more than logic parts tolerate. A series reverse-blocking FET would be safer than a crowbar. A 60 V surge through 2 ohm is clamped near 31 V; parts downstream need a rating above that.





What this report cannot show

- Anything about ink, cure, adhesion, solderability or via reliability.
- Real motion accuracy, vibration, noise, EMC, or laser containment.
- That the firmware runs on the microcontroller.