What causes a thermal runaway error on a 3D printer?

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Abstract. A heater stayed below target too long (Marlin: 4 °C for 40 s). Usual causes: a loose thermistor, heater or wiring fault, fan on the block or untuned PID.

Keywords: error-codes, firmware, hotends

1 What causes a thermal runaway error on a 3D printer?

Thermal runaway means the firmware saw a heater stay below target too long and cut power to prevent fire. The classic cause is a thermistor slipping out of the heater block and reading cooler air. Others are a fan or draft chilling a bare heater block, a failing heater cartridge or wire, and an untuned PID (proportional-integral-derivative) loop.

1.1 The number

Table 1. The number

Firmware or printer	Hotend halts when	Bed halts when
Marlin 2.1.2.5 defaults	It stays more than 4 °C below target for 40 s	It stays more than 2 °C below target for 20 s
Klipper defaults	At temperature, each second adds how far the reading sits beyond a 5 °C band below target to a counter that halts at 120. While heating, it must gain 2 °C every 20 s	Same counter. While heating, it must gain 2 °C every 60 s
Prusa MK2.5 to MK3S+	It drops more than 15 °C for more than 45 s	Not stated separately
Prusa MK3.5 to MK4S and CORE One	It drops 12 °C and has not recovered after 60 s	It drops more than 2 °C for over 60 s

The Marlin values are `THERMAL_PROTECTION_PERIOD` and `THERMAL_PROTECTION_HYSTERESIS` (and their `_BED_` pair) in Configuration_adv.h at release 2.1.2.5. Klipper's are the

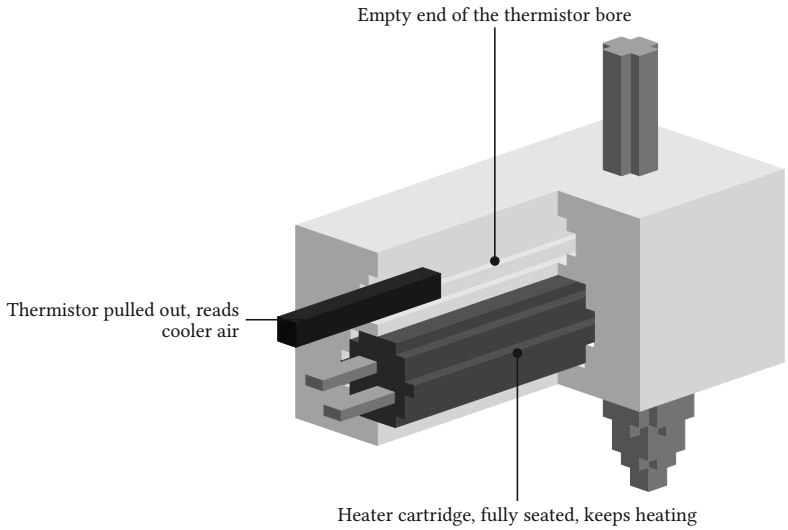


Figure 1. A thermistor that slips out of the block reads cooler air, so the firmware keeps the heater cartridge on while the block gets hotter.

`[verify_heater]` defaults in its configuration reference, and Prusa's come from its thermal runaway articles. In Klipper, a hotend 15 °C under target halts in about 12 s; 7 °C under takes about a minute.

1.2 Why does a thermal runaway error halt the printer?

Because the protection is working. Marlin's documentation describes the failure it was built for: the thermistor works its way out of the block and reads the air. The reading falls, the controller drives the heater harder, and the real block temperature climbs unchecked.

When the window runs out, Marlin 2.1.2.5 turns off every heater and shows `THERMAL RUNAWAY` with the heater's name, then `PRINTER HALTED` and `Please Reset`. The serial log reads `Error:Thermal Runaway, system stopped! Heater_ID: E0` (or `bed`). Klipper shuts down with `Heater extruder not heating at expected rate`. The check also catches a working heater that can't keep up, so a fan or draft can trip it with nothing broken.

1.3 How to fix thermal runaway

Check in this order. The first two are hardware faults; the last two can halt a healthy printer. If it halted a few layers in, as the part-cooling fan switched on, Marlin's docs put the fan first.

1. **Thermistor loose or out of its bore.** Push it fully in and retighten its retaining screw. Prusa's rule is no part of it sticking out of the block.
2. **Heater cartridge or wiring fault.** Reseat the heater and thermistor connectors on the board, then run the cable test in the checklist.
3. **Fan or draft on a bare heater block.** Fit a silicone sock and aim the part-cooling duct at the nozzle tip, not the block (Marlin). Prusa adds a bent or tilted fan shroud, a room below 16 °C (its i3-series figure) and air conditioning or an open window near the bed. See printing in a cold garage.
4. **PID not tuned after a hardware change.** The PID loop holds the temperature, and a new heater, thermistor or block changes how the hotend responds. Marlin's docs call an untuned loop the most common reason a heater drifts out of its allowed band. In Marlin, run `M303 E0 C6 S210 U1` (for 210 °C) and save with `M500` if your firmware stores settings in EEPROM. In Klipper, run `PID_CALIBRATE HEATER=extruder TARGET=<print temperature>`, then `SAVE_CONFIG`.

1.4 How to clear a thermal runaway error safely

Switch the printer off and let it cool. A Marlin thermal error is a kill, not a stop. `M999` won't recover it; only a reset or power cycle will, and the print is lost. In Klipper, send `FIRMWARE_RESTART` once the cause is fixed.

Then heat with nothing printing and watch the temperature graph in your host software: Marlin's docs say a sound hotend sits within a degree or two of target, fan on or off.

Never comment out `THERMAL_PROTECTION_HOTENDS` or raise the period or hysteresis to make the error stop. Marlin's docs call that turning the protection off "in all but name". A loose thermistor would then leave the heater running at full power: a fire risk.

1.5 When does it mean a new thermistor or heater cartridge?

When the checks here are clean and it still trips. Prusa's test: point a hair dryer at the hotend and watch the reading. If it rises, the thermistor works and the heater is the suspect. If it doesn't move, replace the thermistor.

For the heater, Marlin's docs say to measure the cartridge with a multimeter and compare the ohms with its rating. The heating failed page has Prusa's ranges. Replace a thermistor with a damaged cable as a whole part. Prusa advises against splicing or soldering it, because the board reads its resistance.

1.6 How to check it on your own printer

- **Note when it halted.** A halt a few layers in, as the part-cooling fan starts, points to the fan and a missing sock (Marlin).
- **Watch the graph on a test heat.** A sag of more than a couple of degrees when the fan starts means a sock or duct fix (Marlin).
- **Run the cable test.** Move the head through its full travel and flex the cable bundle while watching the temperature. A jumping reading is a cable fault (Prusa).
- **Look at the cold block.** The thermistor should be fully in and its screw tight, with no filament leaking around the block.

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