Mini Filter — User's Guide

How to use FLT-001 between a sensor and your analog input — Rev A production boards.

Document version · revised

1. What it does

The Mini Filter (FLT-001) is a small **active low-pass filter** you place between an **analog sensor output** and whatever reads that signal next — an MCU ADC, a data-acquisition input, an analog comparator, an instrument front-end, or another breadboard circuit.

It removes (attenuates) **fast-changing noise and interference** that rides on top of your measurement — the kind that makes readings jump around even when the quantity you care about changes slowly (temperature, pressure, light level, and similar).

You choose how aggressive the filtering is with a **4-position DIP switch** (six cutoff settings). Factory-tested units are identified by serial number on the back label and in the bag insert — see §6 and §14.

2. What's in the box

Each FLT-001 ships in a **resealable ESD bag**. Inside you should find:

- **Mini Filter PCB** (Rev A) — factory tested, with the shipping DIP setting described in §7. An adhesive serial label on the board back (see §6).
- **One 8-pin breakaway pin header strip** (2.54 mm / 0.1″) — **not soldered**. The board back has **eight through-holes**: `J1` and `J2` are **3-pin** rows (sensor and host); `J3` and `J4` are **single** pins (mechanical only — see §8 Pinout). Break off from the strip the pieces you need (typically two 3-pin sections plus two 1-pin pieces if you use all eight holes), cut to length, and solder — or wire the pads directly if you prefer

jumpers.

- **In-bag reference label** (paper insert) — your part number, DIP switch table with the factory default marked, serial number, QR code, and URL to your unit's factory test data (§14).
- **Resealable ESD bag**

We do not solder headers at the factory — you choose pin length, orientation, and whether to use headers or wires.

3. When it helps — and when it does not

Good fit:

- Noisy bench or wiring environment; readings flicker or scatter on the display.
- The *useful* signal changes slower than the interference you want gone.
- You have a **unipolar analog signal** between 0 V and your supply.

Not a fit:

- Digital buses (I2C, SPI, etc.) — this board is analog only.
- Signals that need the full fast bandwidth the sensor can produce — a lower cutoff will slow the output *on purpose*.
- Negative or bipolar inputs — see §10 Electrical requirements.
- Wrong wiring or supply mistakes — the filter does not replace correct hook-up.

4. Software averaging vs this board

Software (oversampling, moving average, digital filtering) works on samples you already captured. It can smooth random scatter, but it cannot undo what already happened at the analog front-end — fast interference, aliasing, or a comparator tripping on noise spikes.

This board filters in analog, *before* your ADC, comparator, or meter sees the signal. That is the right layer when the problem is too much **high-frequency noise and interference** on the signal — not just "I want more decimal places."

Many projects use **both**: analog filtering here, modest averaging in firmware — they solve different parts of the same symptom.

Step response — it is not instant

After the input jumps, the output creeps toward the new level — it does **not** snap there immediately. A useful rule of thumb is time to settle within about **0.1 %** of the final value after a step; that depends on the cutoff you selected (see table in §11). Example: at the ~1 Hz setting, allow on the order of **one second**; at ~10 Hz, roughly **0.1 s**; at the factory shipping default (~23 kHz), well under a millisecond.

Even when the hardware path is "slow," it is often still **faster than heavy software averaging** for the same calm reading — firmware must wait for many ADC samples spread over time, and those samples still include whatever noise and interference reached the converter first. A long moving average at 10 samples/s can easily add **seconds** of delay; the filter at 1 Hz can settle to 0.1 % in about one second while also cleaning the signal before the ADC.

Filtering strength vs speed — you pick the trade-off

The DIP switch sets an analog **cutoff frequency** on the board. That is separate from how often **you** read the output — your ADC or reader's **sample rate** (e.g. 50 readings per second).

When the priority is to attenuate noise and interference **above your ADC sample rate** (anti-aliasing — clean the wire *before* each conversion), choose a **lower** DIP cutoff. Rule of thumb: cutoff well **below half** your sample rate (below Nyquist), while still passing the real sensor signal. That costs **settling time** after input steps.

When **settling time** matters more than maximum rejection above your sample rate, choose a **higher** DIP cutoff — the output reaches a stable value sooner; less high-frequency energy is removed.

The ~1 Hz DIP row is a **filter** setting (~1 Hz cutoff), not your ADC sample rate. Settling examples in §11 use those filter rows. Start from the factory default if unsure; move **down** for stronger analog cleaning before the ADC, or **up** if the output feels too slow.

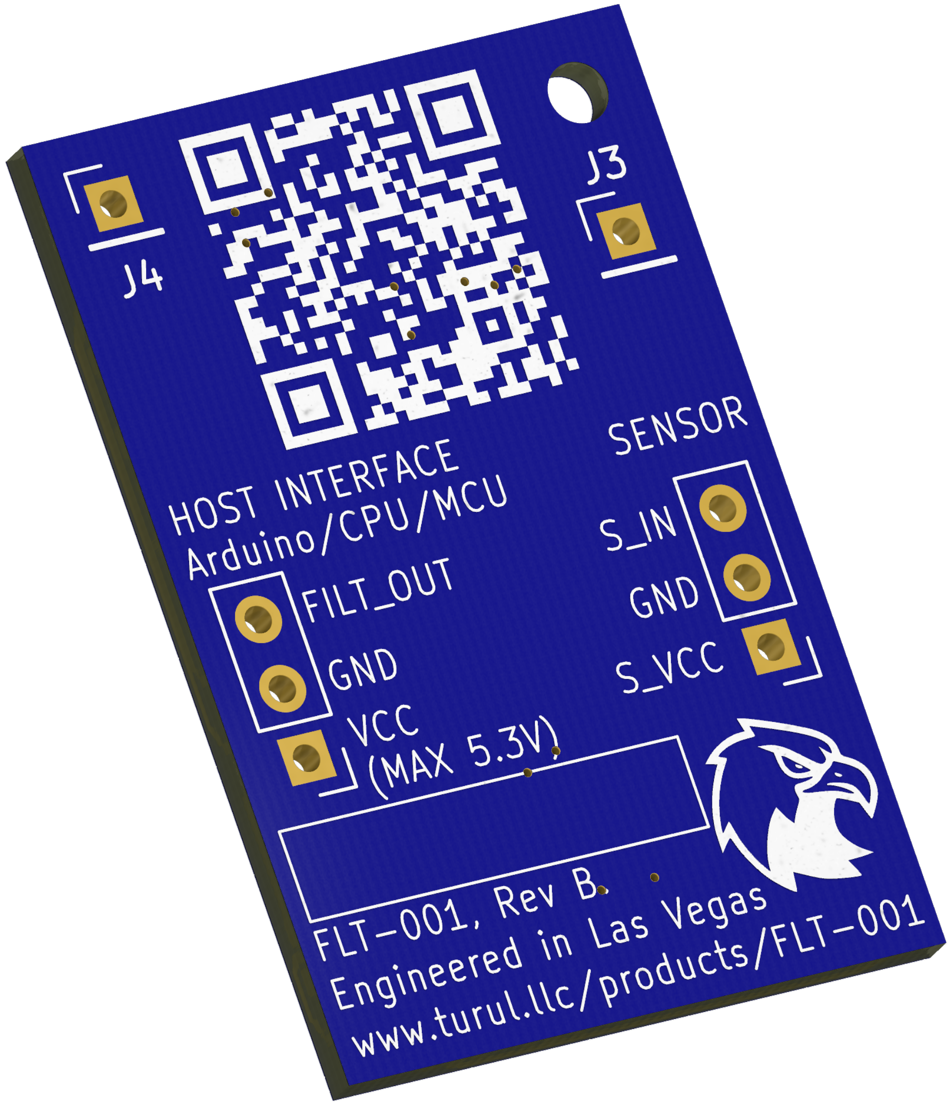
5. Signals & sensors

Any sensor or circuit that presents a **slow-to-moderate analog voltage** on a single-ended output can be a candidate: NTC/RTD dividers, analog pressure or humidity boards, photodiode transimpedance outputs (within voltage limits), pots, and similar hobby/prototype sources.

Connect the sensor to **J1** (`SensorSide` on the back): `S_IN`, `GND`, `S_VCC`. Route the filtered result from **J2** (`HostInterface`): `FILT_OUT`, `GND`, `VCC`.

Pick a DIP cutoff **above** the fastest change you need to track. If you filter too aggressively, the output will lag real steps — that is expected filter behaviour, not a fault.

6. Identification



Back — `SensorSide` / `HostInterface`, silkscreen QR, adhesive label with serial (covers original PCB QR).

Two QR codes on the back: the **silkscreened** QR on the PCB opens the FLT-001 product page — *without* a serial number in the link. The factory prints a QR on the PCB; shipping units get an **adhesive label** on top with a serial-linked QR (human-readable serial and barcode). That label also appears on the paper in the shipping bag — see §14. If the label is removed, use the bag insert or enter the serial on the product page.

- **SKU:** FLT-001
- **Part number:** `FLT-001-{Rev}-{option}` — e.g. `FLT-001-A-61`
- **Serial:** `YYMMDD###` — on the back label and bag insert; scan the **label** QR for your unit page.
- **PCB revision** is printed on the back (e.g. Rev A).
- **Connectors:** `SensorSide` and `HostInterface` on the **board back**; `J1` (sensor) and `J2` (host) labeled on the **top** — see §8. `J3` / `J4` mounting labels are on the back only.

7. Factory DIP setting (shipping default)

> **Your board ships with SW1 pos 1 OFF, pos 2–4 ON** (`0111`) — the **highest cutoff (~23 kHz)**.

> We set it this way so the filter does *not* block a signal you have not chosen to slow down yet. Example: if it arrived on a 1 Hz setting and your sensor changes tens or hundreds of times per second, readings would look “stuck” or wrong — not because the board is broken, but because the cutoff is far below your signal rate.

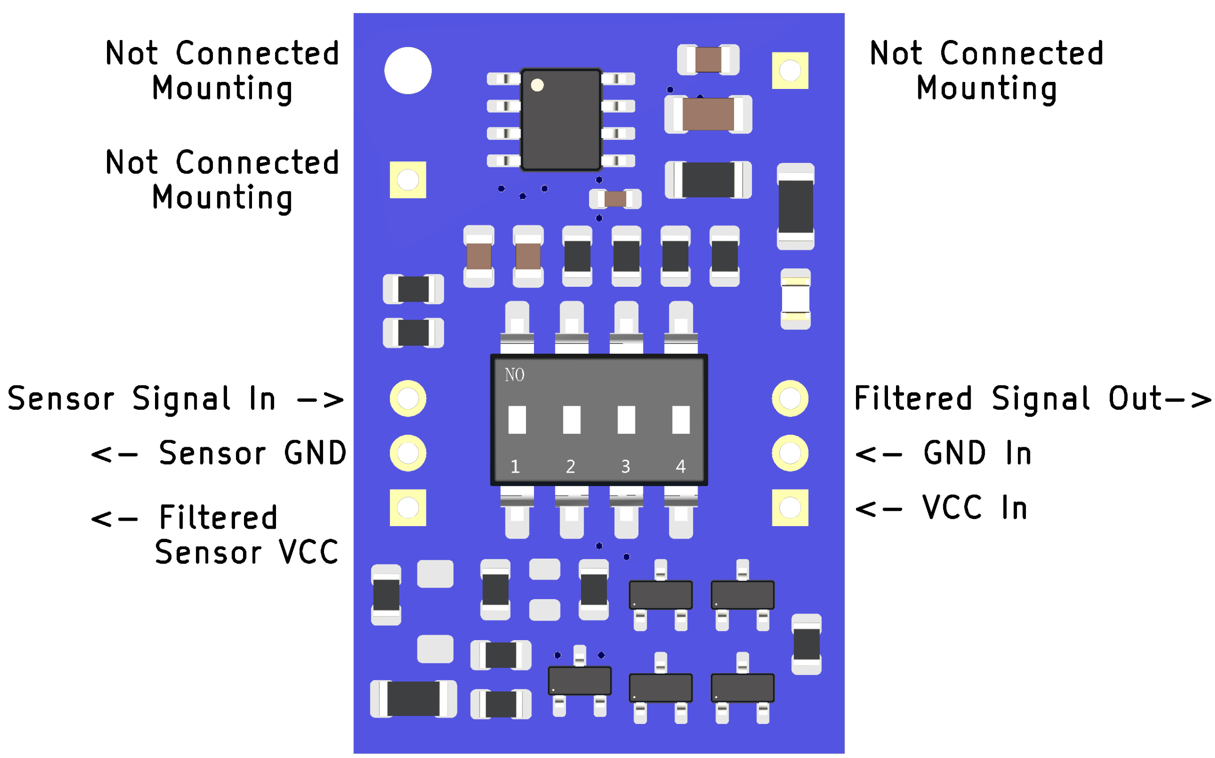
> Change SW1 pos 1 only when you deliberately want a slower cutoff for more noise rejection.

8. Pinout

Two **3-pin signal interfaces** (`J1`, `J2`), two **extra mounting pins** (`J3`, `J4`) for breadboard stability, and one **M2 mounting hole** — see below.

Block	Bottom silk (board back)	Top silk
Sensor side	`SensorSide`	`J1`
Host / reader side	`HostInterface`	`J2`
Extra mounting pins (×2)	`J3`, `J4`	— (not on top — no room; mechanical only)

`J1` and `J2` are labeled on the **top** because those are the signal connectors you wire every day. `J3` and `J4` are **not** routed on the top silk — there was no space, and they are not part of the filter circuit anyway; their `J3` / `J4` labels are on the **board back** only. Signal names on the pinout diagram and on back silk (`S_IN`, `FILT_OUT`, …) refer to `J1` and `J2`.



Pinout (top view) — `J1` sensor, `J2` host. `J3` / `J4` are labeled on the board back only. Arrows show **signal flow**, not pin order.

Diagram label	Back silk	Role

Sensor Signal In →	`S_IN`	Filter input from sensor
← Sensor GND	`GND`	Sensor ground (`J1` / `SensorSide`)
← Filtered Sensor VCC	`S_VCC`	Sensor-side `VCC` (same level as `J2 VCC` in; see below)
Filtered Signal Out →	`FILT_OUT`	To your circuit — ADC, comparator, DAQ, scope, etc.
← GND In	`GND`	Host / reader ground (`J2` / `HostInterface`)
← VCC In	`VCC`	Host supply — **max 5.3 V** (Option B OVP protects the **op-amp path** only; not the sensor side — see §8 VCC & D1)

`VCC` limit & green LED `D1`

The **max 5.3 V** note on `J2 VCC` is there because **Option B** supply protection (when ordered) clamps over-voltage to protect the **op-amp** on the host supply path. It does **not** protect anything on the sensor side (`S_VCC`, `S_IN`, …).

Green LED `D1` sits on the top side, just above `J2`. It is lit when the op-amp supply is **on** — i.e. when protection is *not* actively shutting that rail down. The LED current is chosen for about **5 V** operation, so at lower bench supplies (e.g. 1.8 V or 2 V) it still glows, just **much dimmer**. That is normal.

If supply noise or spikes push `VCC` above about **5.35 V** (Option B units), protection engages **immediately** and removes op-amp power until the voltage falls back — then it restores. Very brief excursions can be too short to notice by eye. The trip level is set with **±0.1%** precision resistors in the protection divider — tighter than the ±1% parts in the filter network — so the clamp stays where it was designed.

How to read the LED:

- **LED off** — a definite problem on the host power path (protection tripped, missing supply, reversed polarity, etc.).
- **LED on** (bright or dim) — the op-amp *may* be powered, but that **does not prove** the supply is clean or stable; short glitches can occur without a visible flicker.

`S_VCC` — sensor-side power (`J1`)

`S_VCC` is at essentially the **same voltage level** as `VCC` on `J2` — not a regulated or boosted rail. The difference is **how** it is wired: host power enters through **two ferrite beads** in series on the supply path.

- The **first ferrite** sits before the op-amp. Its input comes from the incoming supply; its output feeds the op-amp and continues toward the second ferrite.
- The **second ferrite** output is brought out as `S_VCC` for your sensor's power pin.

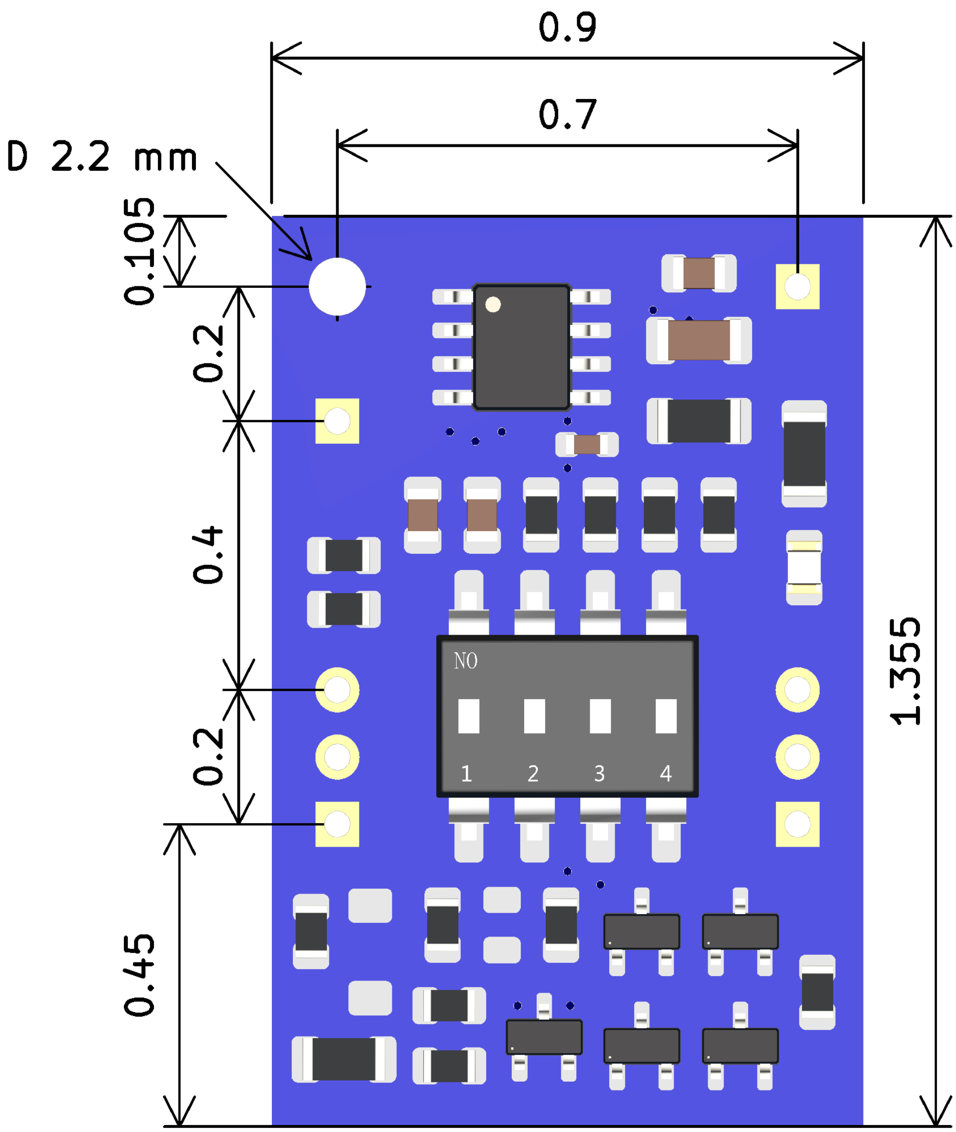
That split is deliberate: the op-amp runs from the first branch (so it sees the same bench supply you apply), while noise or load transients your sensor introduces on `S_VCC` are less likely to disturb the op-amp supply. The ferrites block high-frequency content on the power path, not a separate DC level.

`S_VCC` is **not** meant for heavy loads. The ferrite beads on the supply path are rated **0.5 A** each (about **300 mΩ** DC resistance, **600 Ω at 100 MHz**). Do not power motors or other high-current loads from `S_VCC`; use an external supply with a common ground if needed.

Mechanical fixing (not signals):

- **M2 mounting hole** — labeled **2 mm** on the dimension drawing; **2.2 mm** drill (the only oversized hole on the board). Accepts **metric M2** screws if you panel- or chassis-mount the board.
- **`J3` and `J4`** — two extra pins (same pin size as `J1` / `J2`); `J3` / `J4` labels on the **board back** only. They are **not connected** to the filter circuit — the board does not use them electrically. Solder them into the breadboard (or headers) alongside `J1` and `J2` for a steadier fit. If those breadboard holes happen to carry voltage, that does not affect the filter and does not harm the board. Wire signal, `GND`, and supply on `J1` and `J2` only.

9. Dimensions & breadboard fit



Board dimensions — inches unless marked mm; 0.1″ pin spacing (2.54 mm breadboard pitch).

Callout	Meaning
0.9 × 1.355 in **23 × 35** mm	Overall board outline (short × long edge) — drawing vs measured
1.6 mm (0.063 in)	PCB thickness — 2-layer FR4
6 mm (0.24 in)	Max assembled height (tallest component above board)
3 g (0.11 oz)	Typical unit weight — assembled PCB, no ESD bag
60 × 92 × 6 mm **2.36 × 3.62 × 0.24** in	Factory ESD bag outer size (board + label inside); total **5 g** (0.18 oz) in bag

D 2.2 mm	Mounting hole — 2.2 mm drill (labeled 2 mm on drawing); accepts **metric M2** screws for mechanical fixing
0.1″	Center-to-center between neighboring pins in a row
0.2″	Outer two pins of each 3-pin header (= 2 × 0.1″)
0.7″	Horizontal spacing between mounting hole and top-right pad

Headers are on **2.54 mm (0.1″)** pitch. Span the breadboard center gap with the long edge so `J1` and `J2` sit in opposite columns; plug `J3` and `J4` into nearby breadboard holes for a steadier fit, or use jumpers instead of breadboard insertion.

10. Electrical requirements

- DC-coupled — **do not** apply negative input voltages.
- Keep the input within **0 V … V_{supply}**.

Minimum `VCC` on `J2` depends on the factory op-amp (**Option A** digit in your part number — see §15):

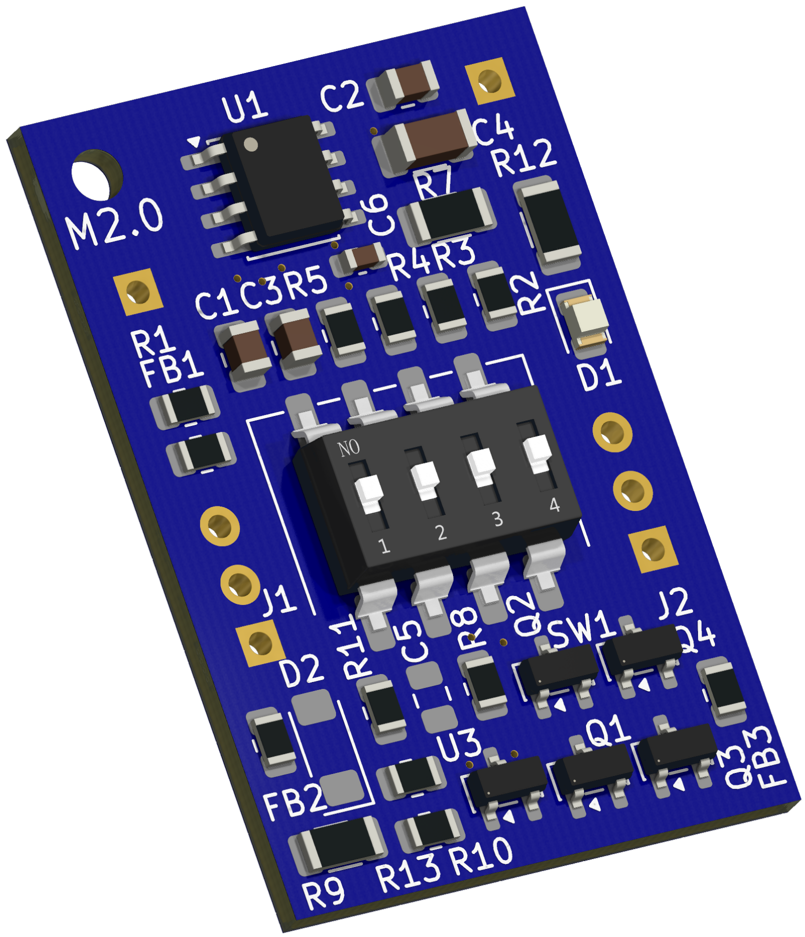
Option A	Op-amp	Min VCC
1	Microchip MCP6022	2.5 V
2	Microchip MCP6V27	2.3 V
3	Microchip MCP6002	1.8 V
4	TI OPA2333	1.8 V
5	TI OPA2350	2.7 V
6	MCP6002 class	1.8 V

- Datasheet minimum supply per populated part — not a recommended operating margin. See `docs/OPAMP_SUPPLY_LIMITS.md` on the project site.

- Align sensor and reader logic levels with your chosen supply.
- With supply protection (Option B = 1), keep `J2 VCC` below ~5.35 V OVP — protects the op-amp path only, not the sensor side; see §8 VCC & D1.
- **Host supply current** (`J2 VCC` at typical 5 V bench use): the board draws **under 10 mA** in normal operation. The exact value depends on which op-amp was populated (**Option A** — quiescent current alone is often on the order of **100 µA**), your supply voltage, and how heavily `FILT_OUT` is loaded. Supply protection may draw slightly more while it is actively engaged above the OVP threshold.
  - Factory test runs the host supply under a **50 mA** current limit for the full protection and filter sequence (not only during reverse-polarity checks).
- `S_VCC` is for modest sensor current only — see §8 (rated **0.5 A** through the ferrite path). If your sensor needs more for any reason, do not draw it from this pin: power the sensor from your bench supply (or

another rail) directly, with a common `GND`, as you would without using `S_VCC` — signal still on `S_IN`.

11. DIP switch — filter cutoff



SW1 — four switches, six cutoff settings. Factory default: `0111`.

SW1 is the 4-position DIP switch on the board (silkscreen name). Its four levers are **SW1 pos 1** … **pos 4** (left to right; the four-digit patterns in the table list pos 1→pos 4, `1` = ON). **SW1** selects one cutoff. The **ON** marking on the switch body shows which side is ON — the small package arrow is pin 1, not the ON direction. On frequency-response plots, filter strength is expressed in **decibels (dB)** — how much the board attenuates each frequency. That describes the *filter*, not your sensor reading in volts or °C.

Cutoff (label)	Measured fc (Rev A)	SW1 pos setting
1 Hz	0.997 Hz	SW1 pos 1 ON, pos 2–4 OFF (`1000`)
10 Hz	10.15 Hz	SW1 pos 1–2 ON, pos 3–4 OFF (`1100`)
100 Hz	102.48 Hz	SW1 pos 1–3 ON, pos 4 OFF (`1110`)
1 kHz	1.04 kHz	SW1 pos 1–4 ON (`1111`)

10 kHz	10.19 kHz	SW1 pos 1–4 OFF (`0000`)
23.4 kHz	23.09 kHz	SW1 pos 1 OFF, pos 2–4 ON (`0111`)

Reference Bode curves (gain in dB vs frequency) and your unit's measured points are on the product page.

How to choose a setting

Two different frequencies are in play: your reader's **ADC sample rate** (how often you convert `FILT_OUT`) and the board's **DIP cutoff** (how aggressively the analog filter rolls off above that frequency). Ask which matters more:

- **Strong analog filtering before each ADC sample** — reject energy **above your sample rate** (and ideally below Nyquist, i.e. below about half your sample rate), so aliasing and unwanted high-frequency content do not reach the converter. Move the DIP switch toward a **lower** cutoff row that still passes your sensor signal — e.g. if you sample at 20 Hz, a ~1 Hz or ~10 Hz board setting may fit; if you sample at 1 kHz, a ~100 Hz or ~1 kHz row may fit. Allow the settling times in the table below.
- **Shortest wait after an input step** — when stable readings quickly matter more than maximum rejection above your sample rate. Move the DIP switch **up** (e.g. 1 kHz … shipping default). Settling shrinks; less attenuation above the cutoff.

Also keep the cutoff **above** the fastest change in the physical quantity you need to track — otherwise the filter lag is intentional, not a fault. If anti-aliasing and settling conflict, stronger filtering before the ADC argues **down**; fast response argues **up**.

Settling after an input step

Lower cutoffs need more time before the output is trustworthy. Approximate time to settle within **0.1 %** of the final value after an input step (Rev A, theoretical, from measured cutoff frequencies):

Cutoff (label)	Typical use	Settle to ~0.1 %
1 Hz	Very slow sensors, max noise rejection	~1.1 s
10 Hz	Slow sensors	~0.11 s
100 Hz	Moderate rates	~11 ms
1 kHz	Faster tracking	~1.1 ms
10 kHz	Wide bandwidth	~47 µs
23.4 kHz ★	Factory shipping default (`0111`)	~0.11 ms

★ Shipping default. Wait at least this long after a large input step before trusting a reading. See §4 for how this compares to software averaging.

12. Output & loading

A **1 kΩ** resistor in series with the output (`FILT_OUT`) protects the op-amp if the output is shorted or overdriven — current is limited (e.g. at 5 V, about 5 mA into a hard short to ground).

In normal use that resistor forms a divider with your load: $V_{out} \approx V_{signal} \times R_{load} / (R_{load} + 1\ k\Omega)$. Example: ~10 kΩ input → the reading is roughly **9 % lower voltage** than at the filter output — often fixable by calibration in software. Prefer a **high input impedance** on the reader (ADC, meter, comparator input with high Z).

Long cables or large input capacitance add extra RC rolloff beyond the filter itself — keep leads short when possible.

Advanced: the series resistor is **R7** — **1 kΩ, ±1%, 1206**. Replacing it voids warranty; see §16 Modifications.

13. Cutoff stability

Expected cutoff frequencies are in the DIP table above and on your factory certificate. Small unit-to-unit spread comes from normal component tolerance.

Resistors in the filter network are specified at **±1% or tighter** (some thin-film parts, e.g. 10 kΩ, are **±0.1%**).

Capacitors that set the DIP-selectable cutoff use **X7R ceramic, ±10%**. At the filter input, **C1** is **680 pF, C0G/NP0 ±5%** (with **10 kΩ** in the input network). X7R is adequate for the switching caps but drifts more with temperature than C0G — use your factory certificate for absolute cutoff at your operating temperature.

For absolute accuracy at a given temperature, use your unit certificate and the reference curves on the product page rather than the nominal labels alone.

14. Factory test certificate

Scan the QR on the **adhesive label** (or the duplicate on the paper in the shipping bag) to open your unit's page on this site. It shows **PASS** and measured response at each reference cutoff for that serial number.

The bag insert lists your **part number**, each **DIP switch setting** with its cutoff frequency, and the **filter gain in dB** measured on your board at each reference point (e.g. –3.01 dB vs –2.86 dB at the standard –**3 dB** cutoff reference — that is how the *low-pass filter* was characterized in test, not a dB value for your sensor's temperature or voltage reading). The **shipping default** DIP row is marked (e.g. with an asterisk on the `0111` / highest-cutoff setting). The insert is not titled "test certificate," but it carries the same traceability data.

On the website, open the reference Bode curves (dB vs frequency) on the product page and compare them to your unit's measured points — useful if you want to see how your board's filter response sits relative to the factory reference.

15. Your part number options

Each board is built to one fixed factory configuration encoded in the part number `FLT-001-{Rev}-{AB}` — not user jumpers on the PCB.

- **Option A** (first digit) — which op-amp is populated on your unit (`0` = none — you install your own op-amp).
- **Option B** (second digit) — supply over-voltage / reverse-polarity protection on `VCC` (`0` = off, `1` = on).

Your exact Option A part is determined by your order code — e.g. `FLT-001-A-61` → Option A = `6` (MCP6002 class, minimum `VCC` 1.8 V — see table in §10). Option A = `3` is the authentic **Microchip MCP6002** when explicitly ordered. Do not swap the op-amp unless you accept warranty loss (§16).

Option B protects the **host power input** to the op-amp — not `S_VCC`, signal pins, or sensor-side abuse. With protection populated, the over-voltage threshold is set using **±0.1%** resistors. Green LED `D1` behaviour: §8 VCC & D1. More detail under Ordering options on the product page.

16. Modifications & warranty

Does not void warranty (normal use):

- Soldering wires or pin headers to **J1** and **J2** (`SensorSide` / `HostInterface`) — required to connect the board.
- Soldering pin headers or wires to **J3** and **J4** for breadboard stability — mechanical only, not connected to the circuit.
- Screws through the **M2 mounting hole** for panel mounting — mechanical only.

Void warranty: replacing or reworking **factory-populated** components (including the op-amp and series output resistor); any other modification that changes the assembled circuit.

Returns (RMA / warranty): When a return or replacement is approved, please ship the board **as it left production** — the bare PCB, without wires, pin headers, or other attachments you added. Removing anything you soldered to `J1`, `J2`, `J3`, `J4`, or the mounting hole before you ship helps us inspect and test the unit the same way we do at the factory.

Boards shipped without a factory op-amp (Option A = 0): If you report a problem with the op-amp **you** installed, please return the board **with that op-amp still soldered in** and include the part number in your message — that lets us test the same configuration you used. Wires and pin headers should still be removed as above; only the op-amp you are asking us to look at needs to stay.

If you report a defect, we may review the board against factory build records, including production photos tied to your serial number.

The series output resistor is **R7** (1 kΩ, ±1%, 1206). The op-amp tier is fixed by Option A in your part number — do not substitute parts without accepting warranty loss and re-characterizing the filter.

17. Support & sales

Order from Tindie or Etsy, or visit turul.llc/products/FLT-001.