

REVERSE-POLARITY AND INRUSH PROTECTION

A backwards battery or a turn-on surge can destroy a board. The series diode, the P-channel MOSFET ideal diode that wastes far less, and how to tame inrush at power-on.

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Two things at the power input can kill a board in an instant: a battery put in backwards, and the surge of current when power first connects. A little protection at the input handles both. This extends the ideal-diode idea from the Fundamentals diode guide into real power design.

THE REVERSE-POLARITY RISK

Connect a supply backwards and current tries to flow the wrong way through parts that tolerate only one direction. Electrolytic capacitors, ICs, and the regulator can be destroyed before you notice. A reverse-polarity guard blocks that backward current so a wrong connection does nothing at all.

THE SERIES DIODE: SIMPLE BUT LOSSY

The oldest guard is a diode in series with the input. It conducts when the supply is the right way round and blocks when it is reversed. It works, but it is not free: the diode drops its forward voltage, around 0.3 V to 0.7 V, all the time, burning that drop times the load current as heat and stealing it from a battery.

$$P_{\text{diode}} = V_f \times I_{\text{load}}$$

THE P-CHANNEL MOSFET IDEAL DIODE

A better guard replaces the diode with a P-channel MOSFET wired to conduct only when the supply is correct. Its on-resistance is milliohms, so the voltage it drops and the heat it makes are tiny, a fraction of the diode's, for the cost of a couple more parts. This ideal diode is why good designs protect the input almost for free (TI, Basics of Ideal Diodes).

$$P_{\text{FET}} = I_{\text{load}}^2 \times R_{\text{ds(on)}}$$

INRUSH AT POWER-ON

When power first connects, every bulk capacitor on the board is empty and gulps a large spike of current as it charges, the inrush surge. It can dip the supply, weld a connector, or trip a protection circuit. Inrush control, a soft-start that ramps the input in over a few milliseconds instead of slamming it on, tames that spike.

A P-FET BLOCKS A REVERSED SUPPLY; AN INRUSH ELEMENT RAMPS THE TURN-ON SURGE.

WHERE EACH GUARD GOES

Both guards sit right at the power input, before anything else. The reverse-polarity device comes first so a backward supply is blocked at the door, then the inrush element so the surge is limited as power reaches the bulk capacitors. Put either one downstream and the parts ahead of it are unprotected.

DEEP DIVE · HOW AN IDEAL-DIODE CONTROLLER BEATS EVEN A PLAIN P-FET

A bare P-FET reverse guard already beats a diode, but a dedicated ideal-diode controller goes further. It actively drives the MOSFET gate, holds the forward drop to a few millivolts, and can switch the FET off within microseconds if the input ever goes backward or a downstream fault tries to push current back toward the source. On boards that share a supply or hot-swap, that fast, controlled turn-off is what keeps one board's fault from feeding back into the rail. Same MOSFET, a smarter driver. (TI, Basics of Ideal Diodes)

- [Texas Instruments. Basics of Ideal Diodes application note \(SLVAE57B\): P-channel MOSFET reverse-polarity protection.](#) ti.com

CHECKPOINT**1. Why prefer a P-channel MOSFET ideal diode over a series diode for reverse protection?**

- It drops a larger voltage than the diode does
- It wastes far less power and heat than the diode's forward drop**
- It raises the output voltage

ANSWER · B

The MOSFET's milliohm on-resistance drops almost nothing, unlike the diode's steady forward-voltage loss.

2. What causes an inrush surge at power-on?

- The empty bulk capacitors gulping current as they charge**
- The regulator reaching its output voltage
- The reverse-polarity MOSFET switching on

ANSWER · A

Discharged capacitors look like a near-short for an instant and pull a large charging spike.

3. Where should the reverse-polarity and inrush guards sit?

- Anywhere convenient downstream
- Only on the output rail
- Right at the power input, before everything else**

ANSWER · C

Guards at the door protect the whole board; downstream, the parts ahead of them are exposed.

- Prerequisite: diodes and LEDs
- Next: power sequencing and soft-start