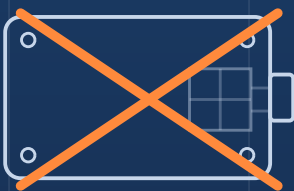


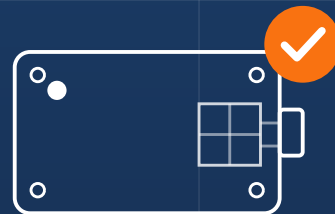
PRODUCTION - GRADE

PROTECTION CIRCUITS CHECKLIST

Seven circuit protections that stand between your product and dead boards, one-star reviews, and real fires. Plus the exact part to use for every one, starting at a few cents.



UNPROTECTED BOARD
FAILS IN THE FIELD



PROTECTED BOARD
SURVIVES THE FIELD

PREPARED BY
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DOC NO.
PRT-07

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Production-Grade Protection Checklist

Seven protections you should never ship a product without

There is a big jump between a prototype that survives you and a product that survives thousands of strangers. You always use the right power adapter, and you would never unplug your prototype in the middle of a firmware update. Your customers will not be that gentle. They will plug in whatever adapter fits, zap your product with static, and cut the power at the worst possible moment.

Most of the product designs my engineering team reviews are missing at least one of the protections in this checklist, and odds are yours is too. Two of them are all that stands between your product and an actual fire, and one of them is completely free and probably already in your design, but almost certainly turned off. Work through all seven before you commit to production.

THE SEVEN PROTECTIONS AT A GLANCE

#	PROTECTION	WHAT IT BLOCKS
#7	Reverse polarity protection	Wrong adapters and backward batteries
#6	ESD protection	Static discharge through every exposed port
#5	Overcurrent protection	Short circuits, smoke, and fire
#4	Overvoltage and transient protection	Wrong adapters, spikes, and surges
#3	Inductive kickback protection	High-voltage spikes from coils and motors
#2	Battery protection	Lithium swelling, venting, and fire
#1	Watchdog and brownout protection	Lockups and corrupted firmware

HOW TO USE THIS CHECKLIST

The entries run in countdown order from #7 to #1, the same order as the video. For every protection you will find why products die without it, the exact part to add, and where to place it.

#7

Reverse Polarity Protection

POWER INPUT

WHY PRODUCTS DIE WITHOUT IT

- A customer plugs in the wrong barrel jack adapter or inserts the batteries backward, and one second later the board is dead.
- You would never make that mistake, but put a few thousand units into the market and someone absolutely will.
- The typical prototype fix is a series diode, and it works, but it drops 0.3 to 0.7 V, which wastes power and adds heat in a production product.

ADD THIS PROTECTION

WHAT TO ADD	HOW TO USE IT
P-channel MOSFET	Wire it on the high side of the power input. The built-in body diode conducts under normal polarity, and once that diode forward biases it turns the MOSFET fully on, so instead of a diode drop you get almost no voltage drop at all. Total cost is just a few cents.
Ideal diode controller	Use one for higher-current designs, because it does the same job even more efficiently.

A KEYED CONNECTOR IS NOT PROTECTION

Customers defeat mechanical safeguards all the time. Treat connector keying as a convenience and put a real reverse polarity circuit behind it.

#6

ESD Protection

EVERY EXPOSED PORT

WHY PRODUCTS DIE WITHOUT IT

- Your product survives all of your testing, then dies in a carpeted office in dry winter air, because a simple carpet-to-doorknob shock can hit anywhere from 8 to 15 kV.
- Every connector, button, and exposed port that a person can touch is an entry point, including USB ports, headphone jacks, SD card slots, charging connectors, and exposed screw terminals.
- The ESD structures built into your MCU pins are designed to survive the assembly line, not your customer's wool sweater in the middle of winter.
- Selling in Europe means passing ESD immunity testing under IEC requirements, and failing at the test lab means a board respin while your launch date slips.

ADD THIS PROTECTION

WHAT TO ADD	HOW TO USE IT
ESD protection diodes	Place one on every externally accessible line, right at the connector, with a short and direct return path to ground. These clamp voltage spikes before they can reach your sensitive components, and each protected line adds just a few cents.
Low-capacitance versions	Use these on USB and other high-speed data lines so you do not degrade signal integrity.

A REAL FAILURE FROM THE HARDWARE ACADEMY

One member had a product working perfectly for a year, then a unit came back with the charger IC physically blown. His USB shield was grounded, but he had no ESD diode on the USB power pin, and one static discharge through the port killed the charger IC. Protect the power pins, not just the data lines.

#5

Overcurrent Protection

EVERY POWER RAIL

WHY PRODUCTS DIE WITHOUT IT

- A damaged cable, a shorted component, or a curious customer poking something where they should not can create a short circuit on your board.
- Without overcurrent protection, that short becomes smoke, melted PCB traces, and a safety incident with your company's name attached to it.
- This is where product risk turns into legal risk, because safety standards and major retailers expect overcurrent protection, and fire liability has ended small companies.

ADD THIS PROTECTION

WHAT TO ADD	HOW TO USE IT
Resettable PTC fuse	This is the simplest answer for most consumer products, and it only costs a few cents. It sharply increases its resistance when too much current flows, trips like a breaker, and resets itself once the fault clears and it cools back down. The catch is that PTCs are relatively slow, so they will not catch very fast transients.
eFuse IC	Use one when you need faster and more precise current limiting. It handles overvoltage lockout in the same part and typically runs about a dollar.
One-time fuse	Put a traditional fuse on safety-critical power rails as your last line of defense, because it blows permanently, which is exactly what you want when the alternative is a fire.

A LESSON FROM MY TIME AT TEXAS INSTRUMENTS

When I designed power management chips at TI, we built current limiting into every chip just to protect the silicon itself. Your board needs that same kind of protection at the system level, because without it one short takes out everything.

#4

Overvoltage and Transient Protection

POWER INPUT AND USB-C

WHY PRODUCTS DIE WITHOUT IT

- You ship your product with a 5 V adapter, and two years later the customer grabs a 12 V adapter from the junk drawer that fits the same barrel jack connector. Everything downstream sees more voltage than it can handle.
- A wrong adapter is not the only source. Voltage spikes from hot-plugging cables under load, line transients from noisy power sources, and load-dump surges near vehicle electrical systems all cause the same kind of damage.

ADD THIS PROTECTION

WHAT TO ADD	HOW TO USE IT
TVS diode	Put one on the power input for short spikes and transients. Size it so the standoff voltage sits above your maximum normal operating voltage and the clamping voltage stays below the damage threshold of your downstream parts.
eFuse or OVP IC	A TVS can only absorb short bursts of energy, so it cannot protect you from a wrong adapter feeding your board 12 V all day long. Sustained overvoltage needs a part that shuts the input off entirely, so the wrong adapter gets ignored instead of killing your board. All of this protection adds well under a dollar.

THE USB-C TRAP

USB Power Delivery can negotiate voltages up to 48 V on the same cable. A misbehaving charger or a bug in your PD negotiation can push dangerous voltage right into a 5 V input rail without warning.

#3

Inductive Kickback Protection

RELAYS AND MOTORS

WHY PRODUCTS DIE WITHOUT IT

- Anything with a coil in your product fights back when you cut the current. Relays, motors, and solenoids all store energy in a magnetic field while current flows.
- The moment you switch that current off, the collapsing field fires a high-voltage spike backward into your driver circuits and MCU pins.
- The sneaky part is that this usually survives short bench tests just fine, so the problem stays hidden until units are in the field.

ADD THIS PROTECTION

WHAT TO ADD	HOW TO USE IT
Flyback diode	Place one across every DC relay coil, every solenoid coil, and every simple DC motor to give the stored energy a safe path to dissipate. Put it as close as possible to the coil itself, not back at the driver, because the shorter that path is, the less chance the spike has to cause damage along the way.

WHY IT LOOKS LIKE RANDOM BAD LUCK

The damage is cumulative, so units start failing in the field one at a time, weeks or even months apart. It looks like random bad luck until you finally figure out the pattern.

#2

Battery Protection

LITHIUM CELLS

WHY PRODUCTS DIE WITHOUT IT

- If your product has lithium batteries and no dedicated protection circuitry, you are setting yourself up for a recall.
- Over-discharging a cell drops its voltage below the point of safe recovery and gradually kills the pack, sometimes without any visible sign until the battery will not take a charge at all.
- Overcharging and short circuits cause swelling, venting, and fire, which makes this the second item on this list that can literally burn a house down.

ADD THIS PROTECTION

WHAT TO ADD	HOW TO USE IT
Protected cells	Start with cells that already have the safety circuit built in. That gives you overvoltage, undervoltage, overcurrent, and short-circuit protection right at the cell, it reduces your liability, and it keeps you safer during development when your own charging circuit might not be fully working yet.
Dedicated charger IC	Add one on your board with correct charge termination, so cells are never charged below freezing or above their rated limit.

BEFORE YOU CAN LEGALLY SHIP

You need UN38.3 testing just to legally ship lithium cells, plus additional safety certifications depending on your market, and most large retailers stack their own requirements on top of that.

#1

Watchdog and Brownout Protection

COMPLETELY FREE

WHY PRODUCTS DIE WITHOUT IT

- The first six protections on this list protect your product from the physical world. This one protects it from itself, and it is the only one that costs nothing.
- Your product locks up in a customer's home, and all they can do is file a support ticket and leave a one-star review.
- The worst case is even scarier. The power dips during a flash write, your firmware corrupts itself permanently, and now your product is an expensive paperweight.
- The fix is already inside the microcontroller you are using right now, but most development teams disable the watchdog timer during debugging and never turn it back on for production firmware.

ADD THIS PROTECTION

WHAT TO ADD	HOW TO USE IT
Independent watchdog	Enable it for production firmware and feed it from your main loop, only after your critical tasks check out, and never from an interrupt that fires no matter what.
Brownout detector	Set it above the minimum voltage required for reliable flash writes, so the processor resets cleanly instead of corrupting firmware during a power dip.

BUT DOES A WATCHDOG JUST MASK BUGS?

Some engineers argue that a watchdog just masks bugs, and I get where that comes from. But in the field, a product that recovers itself beats one that stays locked up, every single time.

Run This Checklist Before You Ship

Seven boxes to tick before your design goes to production

- ☐ **Reverse polarity:** A P-channel MOSFET or an ideal diode controller protects the power input, and a keyed connector is not doing that job alone.
- ☐ **ESD:** Every externally accessible line has an ESD diode placed right at the connector, including the power pins, with low-capacitance parts on high-speed data lines.
- ☐ **Overcurrent:** The board has a PTC fuse or an eFuse in the power path, and safety-critical rails carry a one-time fuse as the last line of defense.
- ☐ **Overvoltage:** The power input has a TVS diode sized for your rails, plus an eFuse or overvoltage protection IC for sustained faults like a wrong adapter.
- ☐ **Inductive kickback:** Every DC relay coil, solenoid coil, and simple DC motor has a flyback diode placed as close to the coil as possible.
- ☐ **Battery:** Lithium cells are protected cells, the charger IC enforces correct charge termination, and UN38.3 testing is planned before shipping.
- ☐ **Watchdog and brownout:** The independent watchdog is enabled in production firmware and fed from the main loop, and the brownout detector is set above the minimum voltage for reliable flash writes.

Get Experienced Engineers On Your Design

If you want experienced engineers reviewing your circuit protection and the rest of your design before it ships, that is exactly what my team and I do inside the Hardware Academy.

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