
Navigating Thermal Analysis for Electronic Enclosures

**Deciding When to Use Steady-State, Transient, and
CFD in SOLIDWORKS Simulation**

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Executive Summary

In the design of modern electronic assemblies, thermal management is too often treated as an afterthought, leading to increased costs and development delays. Compounding this issue is the industry's consistent push toward smaller footprints and higher power outputs, resulting in increasingly dense thermal profiles. Implementing predictive engineering methodologies early in the development cycle is critical to overcoming these challenges, delivering high-performance products, and preventing costly field failures.

Predictive engineering allows designers to simulate key thermal factors and map out major design drivers before physical components are ever built. While early-stage simulations may not perfectly mirror final empirical testing, carefully refining study parameters provides highly accurate insights. This proactive approach prevents common developmental stumbling blocks, such as over-engineering—which adds unnecessary weight, size, and expense—or under-engineering, which risks premature failure or yielding a product that is dead on arrival.

This white paper examines a recurring challenge in electronic assembly design: managing thermal dissipation to protect critical components like integrated circuits (ICs), which directly dictates a product's lifespan. However, not every thermal problem requires the same level of computational complexity. This paper defines three primary thermal calculation methodologies in SOLIDWORKS—Steady State, Transient, and Computational Fluid Dynamics (CFD)—and provides a strategic framework for when to apply each to optimize both design time and accuracy.

By leveraging the appropriate level of thermal analysis, engineering teams can identify and implement effective cooling solutions early in the development process, transitioning away from slow, expensive "build-and-test" iterations in favor of streamlined, data-driven design.

1. Steady State Thermal Analysis: The Equilibrium Baseline

Definition

Steady state analysis assumes the system has reached thermal equilibrium. It calculates the "final" temperature distribution after an infinite amount of time, assuming all loads and environmental conditions remain constant.

Mathematical Basis:

$$\frac{\delta T}{\delta t}=0 \text{ (The change of temperature with respect to time is zero)}$$

When to Use It

- **Constant Loads:** For devices that stay "on" for long durations (e.g., servers, LED arrays).
- **Worst-Case Validation:** To determine the absolute maximum temperature a component will reach under peak load.
- **Computational Efficiency:** When the "journey" to the final temperature doesn't matter, only the "destination."

Practical Example: Sealed Industrial Sensor

- **Scenario:** A 10W PCB housed in a completely sealed NEMA 4X aluminum enclosure.
- **SOLIDWORKS Context:** A standard Thermal Study is used. Because there are no vents or fans, heat is moved via conduction through the enclosure walls.
- **Benefit:** Quickly validates if the surface area of the enclosure is sufficient to radiate heat to the ambient air without exceeding the internal chip's T-junction limit.

2. Transient Thermal Analysis: Capturing the Time-Domain

Definition

Transient analysis tracks how temperature changes over a specific duration of time. Unlike steady state, this method accounts for the "thermal mass" of the materials—how much energy they can store before they get hot.

Key Requirement: Requires Density (ρ) and Specific Heat (C_p) inputs.

When to Use It

- **Duty Cycles:** For devices that pulse on and off (e.g., power tools, camera flashes).
- **Safety Limits:** To see how long it takes for a touch-surface to become too hot for a user.
- **Thermal Shock:** To analyze the stress caused by rapid temperature fluctuations.

Practical Example: Handheld Medical Diagnostic Tool

- **Scenario:** A handheld device that performs a high-power scan for 300 seconds and then sits idle.
- **SOLIDWORKS Context:** A Thermal Study with "Transient" enabled in the study properties.
- **Benefit:** A Steady State study might suggest the device reaches a dangerous 101.3°C. However, a Transient study shows that during the 300-second use-cycle, it only reaches 97.5°C, proving the design remains safely below the 100°C operating limit for the component.

3. Computational Fluid Dynamics (CFD): Modeling Airflow

Definition

CFD goes beyond conduction to simulate the actual movement of fluids (air or liquid). It solves the Navier-Stokes equations to determine how air swirls, stalls, or accelerates around components.

When to Use It

- **Active Cooling:** When fans or blowers are present in the system.
- **Complex Internal Geometry:** When components are crowded, creating "dead zones" of stagnant air.
- **Calculated Convection:** When you don't know the convection coefficient (h) and need the software to calculate it dynamically based on fluid velocity.

Practical Example: Vented High-Speed Network Switch

- **Scenario:** A multi-port switch with a high-RPM intake fan and vented faceplates.
Context: SOLIDWORKS Flow Simulation.
 - **Benefit:** Standard FEA thermal studies require you to "guess" the convection coefficient. CFD calculates it. It can reveal critical fluid behaviors, such as a large capacitor "shadowing" a voltage regulator and preventing it from receiving cool air—a crucial detail that standard conduction-based FEA would miss.
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4. Comparative Summary for Decision Making

Feature	Steady State Thermal	Transient Thermal	CFD (Flow Simulation)
Time Factor	Equilibrium $\frac{\delta T}{\delta t}=0$	Time-Dependent	Both (Steady or Transient)
Primary Variable	Final Temperature	Temperature vs. Time	Fluid Velocity & Pressure
Convection	User-Input (Manual)	User-Input (Manual)	Calculated by Solver
Complexity	Low	Moderate	High
Best Phase	Early Concept	Usage Validation	Detailed Troubleshooting

5. Conclusion

The goal of thermal analysis is not simply to generate visually appealing color plots, but to provide actionable engineering data. By selecting the appropriate calculation type in SOLIDWORKS, engineers can significantly reduce physical prototyping costs while ensuring long-term product reliability and user safety.

- **Start with Steady State** to establish worst-case baselines and size your heatsinks.
- **Apply Transient analysis** if your device has a limited run-time, complex duty cycles, or strict "time-to-fail" thermal constraints.
- **Utilize CFD (Flow Simulation)** for any design where forced or natural airflow is the primary cooling mechanism.

Engineering Pro-Tip for Documenting Results

When exporting screenshots from your SOLIDWORKS Simulation results for reports and design reviews, ensure the imagery matches the methodology:

- **Steady State:** Show a fringe plot of the "Max Temperature" mapped onto the most critical internal components.
- **Transient:** Include a "Design Insight" 2D graph demonstrating the temperature curve over the specific time domain (e.g., a 300-second duty cycle).
- **CFD:** Utilize "Flow Trajectories" (ribbons or arrows) to clearly visualize the path air takes from the intake fans, across the heat-generating components, to the exhaust vents.

6. Case Study: High-Power Vented Electronic Enclosure

Scenario: 20W Internal Architecture A compact, commercially viable electronic enclosure houses a high-power PCBA **Figure 1**. The primary thermal driver is a localized integrated circuit (IC) generating a continuous 20W volumetric heat load. Both the silicon junction and the surrounding FR4 PCB substrate possess a strict structural safety ceiling of 150°C. Exceeding this limit will trigger transistor breakdown or catastrophic board delamination.

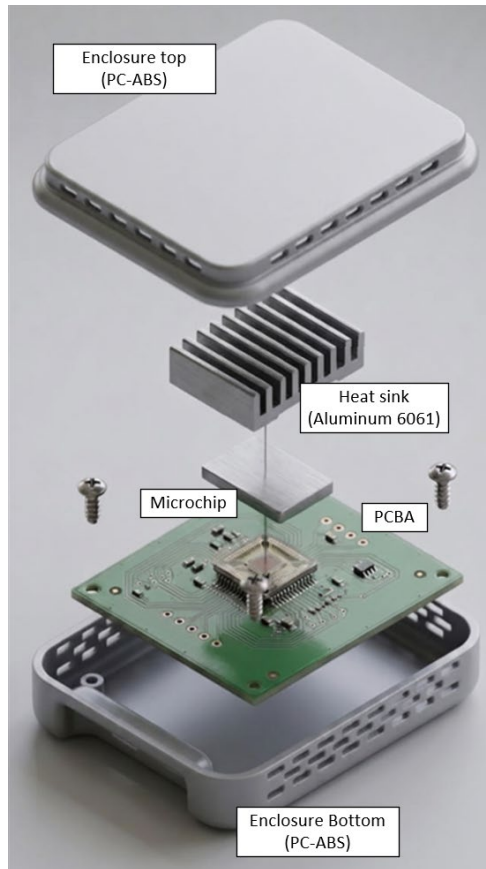
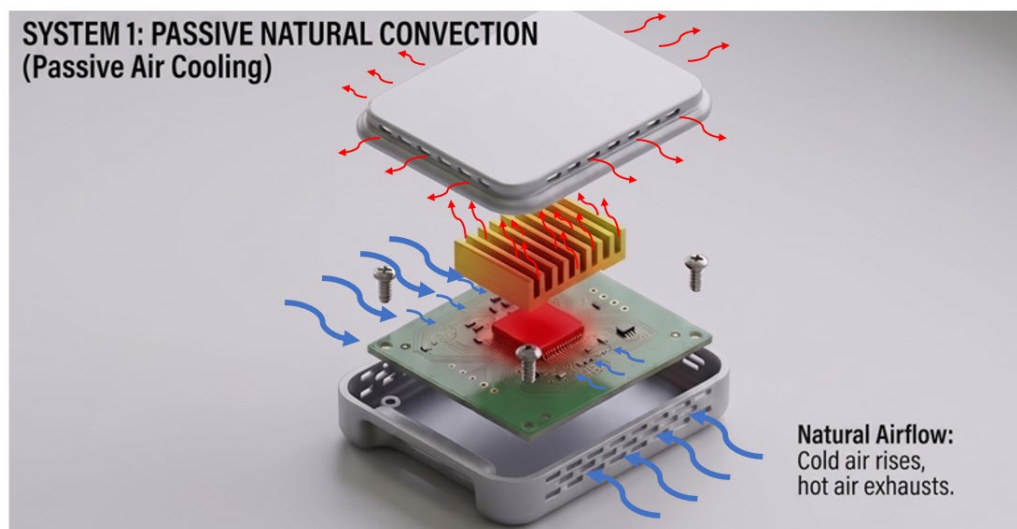
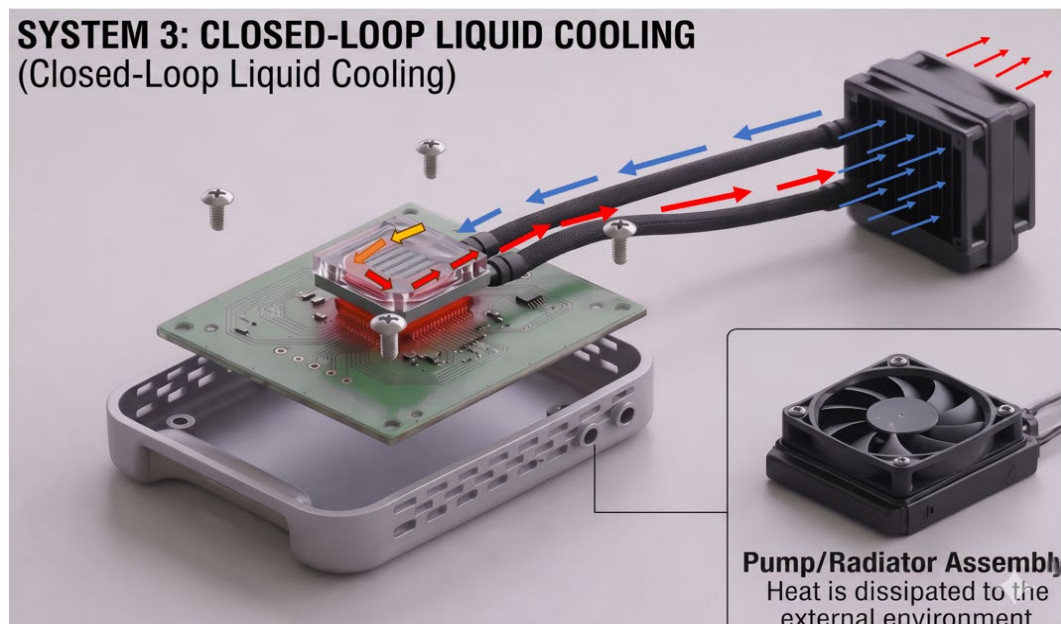
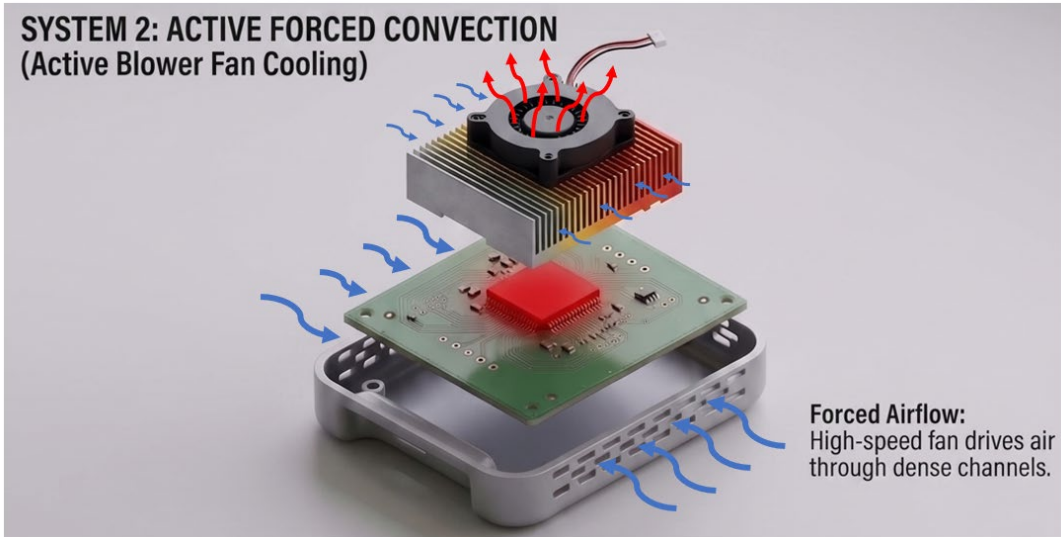


Figure 1: electronic enclosure housing a high-power PCBA

Modern PCBA components are continually pushed to perform with greater power densities, generating higher thermal losses. To manage this heat, the industry generally relies on three primary cooling tiers:





With the use of simulation, this case study utilizes FEA to evaluate and solve the thermal challenge before physical prototypes are built. The overarching goal is to achieve thermal safety with Minimum Complexity. Therefore, the simulation strategy intentionally begins with simpler solutions, such as natural convection. Only if the initial analysis dictates a need for additional cooling would the design progress to more complex, maintenance-prone active systems (such as forced-air blowers or liquid-loop plumbing). To that end, the initial design prioritizes the following optimized passive architectural features:

- In-Plane Copper Thermal Vias: Plated through-hole (PTH) thermal via arrays are integrated directly under the chip footprint, breaking through the insulating FR4 plastic substrate to conduct heat horizontally across the copper board layers.

- **Optimized Heatsink Geometry:** A custom-extruded aluminum fin array is pocketed directly over the chip's top face, establishing a low-resistance vertical conduction path (0.2 K/W) see **figure 2**.
- **Thermal Chimney Venting:** The PC-ABS plastic housing features an optimized alignment of slotted vents on both the lower chassis pan and upper lid to promote natural, buoyant fluid circulation see **figure 2**.

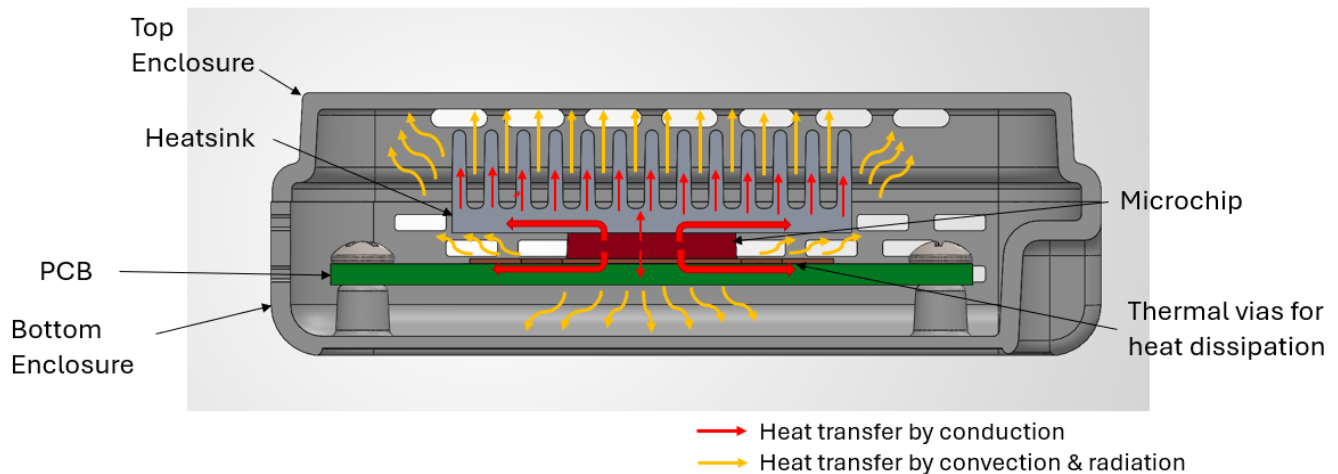


Figure 2: Heat flow diagram

SOLIDWORKS Context: Steady State vs. Transient Validation To evaluate the efficacy of these passive design modifications, the assembly was subjected to both a standard SOLIDWORKS Thermal Study (Steady State) and a Transient Thermal Study (simulating a 300-second timeline).

- **Steady State Results (The Infinite Timeline Destination):** The system achieves thermal equilibrium at an absolute maximum peak temperature of 101.3°C. Because this stabilizes indefinitely below the 150°C threshold, it mathematically validates the passive geometry. It proves the system has an adequate heat rejection path to the environment without risking localized heat pooling over long durations.
- **Transient Results (The Time-Domain Journey):** Captured at the 300-second (5-minute) mark, the transient model clocks a maximum localized temperature of 97.5°C.

Benefit: Unlocking the Practical Solution Comparing the 300-second transient saturation (97.5°C) to the infinite-timeline ceiling (101.3°C) proves that the system achieves 96.2% of its maximum thermal saturation within just five minutes. The asymptotic behavior of the transient curve confirms that the thermal mass of the aluminum heatsink and the copper spreading wings successfully dampens the initial heat surge.

Practically, this cross-study validation proves the device can operate continuously and safely without any duty-cycle restrictions. By optimizing the PCBA layout and enclosure venting early in the CAD phase, the design clears a massive 48.7°C safety margin below the catastrophic failure point. Ultimately, this approach achieves full thermal safety utilizing the lowest possible upfront BOM cost and zero long-term active maintenance overhead.

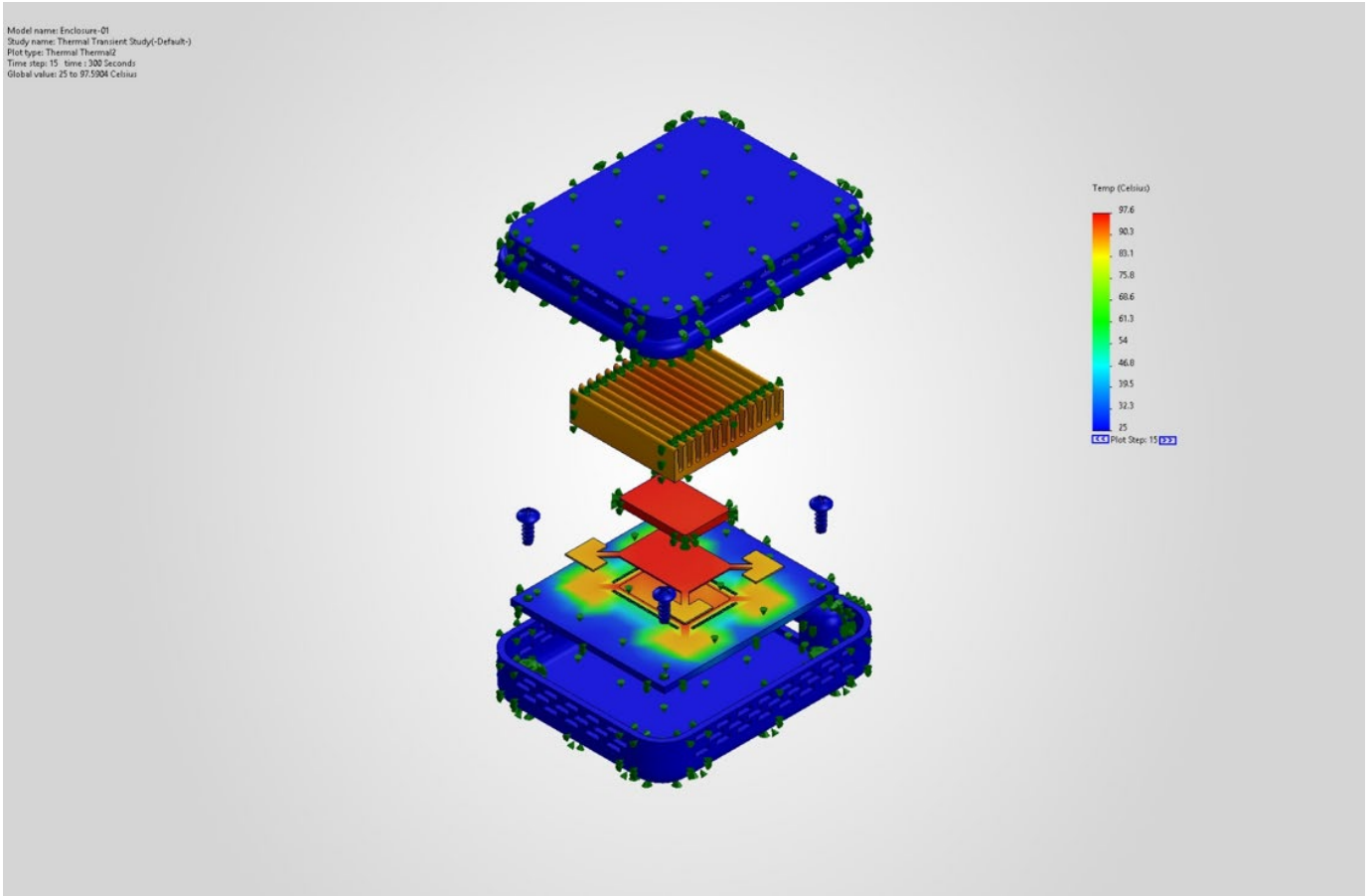


Figure 3: SOLIDWORKS Transient Thermal Analysis results plot. Full report links available at the end of the document.

Benefit: Unlocking the Practical Solution

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Practically, this cross-study validation proves the device can operate **continuously and safely without a duty-cycle restriction**. By optimizing the PCBA layout and enclosure venting early in the CAD phase, the design clears a massive 48.7°C safety margin below the "fry" point. This achieves full thermal safety using the lowest possible upfront BOM cost and zero long-term active maintenance overhead.

Full report SOLIDWORKS Thermal Analysis link:

https://vantage-pd.com/wp-content/uploads/2026/06/VantagePD_Whitepaper_Report_PDF.pdf