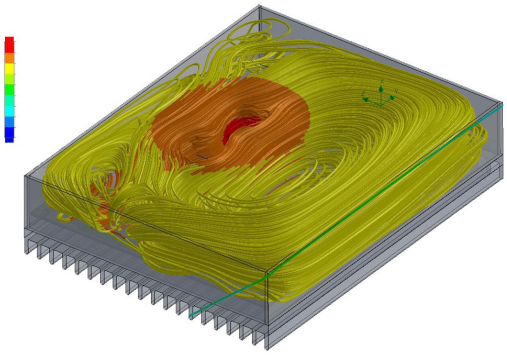
Heating Up: Solving Thermal Management Challenges

Introduction



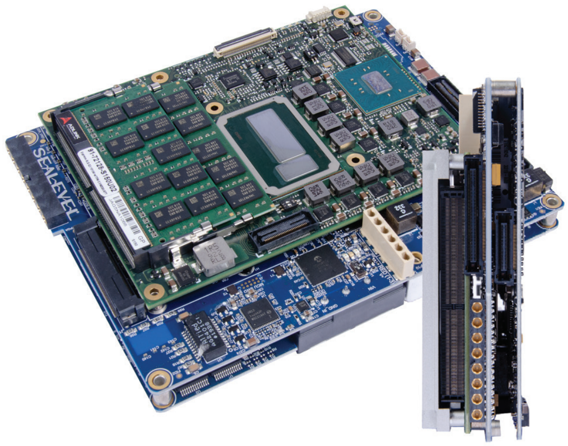
For industrial computers, processing power and performance are not the only success indicators. As these devices are frequently subject to environmental extremes, reliable operation can be complicated by intense temperatures. In environments where external heat cannot be controlled, engineers design devices with minimal heat production and the ability to dissipate heat for continuous, reliable performance. The following white paper reviews the considerations specific to high heat environments and thermal management solutions engineers can employ during the design process.

Key Considerations

Engineers must first evaluate the specific temperature extremes, as well as the duration and/or cycles, that the device may be subject to in the operating environment. In lieu of a site visit, thermal engineering teams often rely on client-provided intel regarding ambient temperatures, airflow rates and space constraints. Understanding temperature fluctuations is also vital as this will affect the design process. For example, the desert can get very hot during the day and very cold at night, so a full range of capability is required. Solar loading is also something to examine. Solar loading occurs when the application site is subject to sun exposure – thereby adding another layer of thermal impact.

Component Selection, Placement and System Evaluation

Once the required operating temperature is defined, each individual component must also meet that temperature range requirement. Evaluating the material specifications and thermal characteristics of each component better ensures the end-goals of durability and reliability. Any component inconsistencies – including integrated circuits and inductors – should be considered as they have the potential to impact the overall design.



Component conduction can be optimized through the use of fine surface finishes to encourage more efficient connections, reducing thermal energy. One tool is TIM or a thermal interface material: a flexible solution that helps promote heat flow by using known thermal conduction characteristics.

For circuit placement and design, reduce the proximity between heat-producing components to avoid “hot spots” and magnify heat dissipation. The use of simulation software and other prototyping tools can help guide and direct these efforts for optimal placement.

Looking at other equipment that will be part of the overall system is also vital as this equipment can not only produce additional heat but reduce airflow. For example, power supplies can be one of the greater heat-producing elements. As such, careful consideration and selection of the power supply should lead to a stable, low-heat connection that will not erratically radiate heat.

Heatsinking High Power Components

Within the constraints of the specifications, heat spreading solutions, as well as techniques to remove heat from the system, are an integral part of the system design.

While fans are a common solution to mitigate heat and improve airflow, they increase cost and complexity and introduce another opportunity for failure. Designs that rely on conventional cooling through fans will eventually fail (faster at higher temperatures).

In industrial, mission-critical operations, fanless and solid-state designs are preferred to ensure reliable performance. For example, heat sinks work by absorbing heat from the central processing unit or the graphics processing unit. As these components are heat-producers, it is vital to keep them cool and mitigate heat as the risk of failure increases with more heat generation.

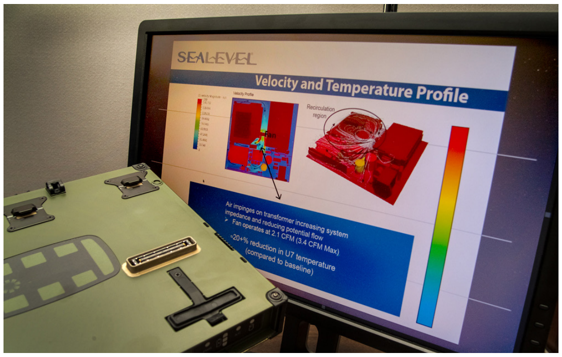
Enclosure Design

When designing for temperature extremes, especially high heat, the exterior body should be assembled with the fewest parts possible. Minimizing the locking points of the enclosure reduces thermal resistance which allows energy to escape the system and ultimately improve heat conduction. One technique is to use a ram extrusion process to create the top and bottom pieces of the enclosure from a solid block of the chosen material. Anodized aluminum alloy is often selected as it encourages heat radiation, allowing heat to dissipate into the external environment. It is also shock and vibration tolerant, furthering its success in extreme environments.

Machining processes allow for creative designs that are used to further draw heat away from the system components. For example, a series of fins can be arranged along the device or rods can be extended from the enclosure. These design elements may vary in placement based on component location. For example, if the bottom of the device includes more of the heat-producing elements, any protrusions for that side may need to be longer.

Simulation is a valuable technique for enclosure design as it allows for experimentation with varying conditions and air flow.

Thermal Simulation



To assist with identifying the thermal properties of conceptual components, materials and product shape, rugged technology design starts in simulation.

Once a prototype is designed, it is tested against fluctuating extremes and temperatures.

To minimize product failure, extreme temperature resistance testing is conducted by placing the device in a thermal chamber. In the thermal chamber, the devices will cycle through high or low temperatures according to their anticipated operational conditions. Similarly, humidity and condensation resistance is tested by spraying the device with water, setting the test chamber to freeze for an hour and then leaving the device to naturally return to its set temperature.

Ideally, prototype testing and thermal simulation takes place as the manufacturing site to expedite the process and reduce overall costs. Design refinements can then be made in-house to improve performance prior to sending the device off for official testing and certification.

Summary

There are a variety of techniques that can be applied depending on a device's intended application and environment. Independent of the design, the initial step of understanding the deployment, along with any constraints, and the final steps of thermal simulation and refinement are vital to engineering and manufacturing a successful solution. At Sealevel, we're excited about the opportunity to combine over 35 years of experience in designing and manufacturing rugged I/O and computing solutions with new opportunities at the edge. Our team is uniquely qualified to design, build and test edge computers that not only meet rigorous thermal requirements — they exceed them.

Sources

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