Key Thermal Design Ingredients for Industrial-grade Computers

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One of the greatest challenges for industrial computing manufacturers is to deliver products that meet industrial standards and operate in harsh environments. This challenge is made even greater due to the fact that industrial users prefer the reliability of devices that do not use fans and cables. This makes matters more difficult and imposes additional hardware layout and component selection restrictions, leading to a higher production cost. Intelligent thermal design makes it possible to overcome these limitations and ensure industrial-grade quality and standards. With a solid thermal design, an industrial computer will dissipate heat more efficiently and demonstrate a wider operating temperature in rigorous chamber tests. This white paper explores the major ingredients that contribute to an intelligent, efficient thermal design in industrial-grade computers.

What Is Thermal Design?

Electronic components generate heat as some of the electrical energy in the components is converted into heat energy. Thermal design refers to the technology and mechanisms used to conduct heat and control system temperature.
What Drives the Development of Thermal Design?

Industrial computing providers continually strive to improve their thermal designs because of the following business drivers:

1. Industrial operations are often space-limited. A smaller form factor increases the number of potential applications and field sites where that computer can be used. An efficient thermal design makes it possible to shrink the computer’s form factor.

2. Industrial systems increasingly demand more performance from their computing devices, but computer performance is often constrained by heat generation. Improved thermal design can ensure reliable system operations and high performance, even without cables and fans.

3. Industrial computers often need to operate continuously and reliably in harsh environments with extreme temperatures.

4. Industrial users expect a longer lifetime from their devices.

Effective thermal design balances high performance with stability and reliability.
Basic Considerations of Thermal Design

**Form Factor:** Thermal design and form factor are interrelated subjects. A larger space translates into lower energy density (and consequently faster cooling), while a smaller space translates into higher energy density. Engineers need to apply efficient thermal design in order to create a computer that is both small and fast-cooling.

![Efficient thermal design allows devices to be both small and fast-cooling](image)

**Component Level:** Thermal design occurs on two different levels: the component level and the system level. On the component level, engineers need select components that can endure heat or dissipate heat easily. In addition, engineers must design mechanisms that efficiently dissipate heat and lower thermal resistance, such as heat sinks, heat pipes, coolers, and fans. Unfortunately, fans are often off-limits for industrial computers because they are fragile components that add moving parts to the system and affect reliability.

A successful component-level thermal design must include a sophisticated analysis of each individual component’s thermal characteristics to determine the parameters and requirements of the heat sink.

**System Level:** Engineers also need to strategically organize the system components in order to achieve optimum
system-wide thermal characteristics. Components should not simply be put wherever they fit on the motherboard. Ideally, each heat source and heat spot will be placed on the motherboard as part of a broader overall thermal design strategy that dissipates heat via a specific transfer route.

Components should be placed on the motherboard as part of a broader system-wide thermal design strategy

Staying Cool in High Temperatures

An industrial-grade computer is expected to operate in temperatures up to 75°C. This is a high bar to reach, but the following strategies make this level of performance possible:

Quality Components: Some components are simply better at high temperature operations than others. For example, low Equivalent Series Resistance (ESR) solid capacitors and high current inductors have no trouble operating in temperatures that handicap capacitors and inductors of lesser quality. Hardware and layout designers should know which components available on the market meet high temperature requirements; today, engineers commonly create and use databases that track the temperature specifications of components.

Applying Thermal Modules: Unfortunately, not all components are able to shrug off high temperatures so easily. This is where heat-dissipating thermal modules come into play.
These are particularly important in industrial computers which do not use fans to contribute to heat dissipation. Generally speaking, the thermal modules can be divided into two categories:

1. **Heat Sinks**: Heat sinks are a common heat transfer solution, and are often made of copper or aluminum. For heat sinks, aluminum’s advantages are that it is light, possesses good heat conductivity, can be easily shaped for mass production, and is strong enough to pull double duty as a rugged, hardened exterior. Heat sinks may directly cover the component to absorb heat and transfer it out of the computer. They can serve as the cooler for the CPU, the main heat spot, or the entire computer. Heat sinks commonly come in an H-type or L-type fin-shaped design to maximize surface area and speed up heat transfer. These heat sinks effectively cool down the entire unit’s internal temperature and can increase heat dissipation efficiency up to 50%.

2. **Heat Pipes**: Since heat sinks may not be the right tool for all scenarios, a copper heat pipe is another way to direct heat out of a computer, via the thermal cycle. This is a particularly effective strategy for devices that contain CPUs and chipsets as the primary heat sources because thermal pads and heat absorbers can be placed directly above these components. One or more copper heat pipes can then conduct this heat away towards a location where it is easier to dissipate, such as a plate on the front of the computer. These hollow heat pipes are lined with a wick containing a working fluid, such as water, to absorb heat. In addition, the heat pipes take part in the thermal cycle and transfer heat from one side of the computer to the other.

**Staying Warm in Low Temperatures**

Most of the attention in thermal design is directed at how to lower system temperature in high temperature environments. However, many industrial applications are located in cold
environments, and the computers used must stay warm somehow. This poses an additional challenge that often creates trade-offs with high temperature operations. Generally speaking, the more effective a computer is at dissipating heat in high temperature environments, the less effective it is at operating in low temperatures. Therefore, manufacturers must balance high temperature strategies and low temperature strategies. Fortunately, there are additional tools that can be used to improve reliability at low temperatures:

**Quality Components:** Just as with high temperature, there are components that excel in low temperatures. Choosing components that are verified to work well in lower temperatures increases the overall reliability of the system in cold environments. Engineers now include low temperature specifications in their databases so they have a convenient source of information.

**Auto Temperature Gain Control System (ATGCS):** With a well-made heater and sophisticated BIOS technology, it is possible to manipulate the internal temperature of the computer. An advanced BIOS can trigger a heater when the temperature drops below a certain point, such as -20°C. This variable power system can keep the internal temperature above a certain level even in extremely cold environments.

**Verifying Thermal Performance**

Design is only half of the thermal picture: the device ultimately must also be tested in order to verify its performance. However, not all tests are equal: test parameters and conditions directly effect how accurately the test simulates real world conditions. There are two types of test chambers used by industrial computing providers:

**Forced Convection Chamber (FCC):** This chamber uses slow airflow to heat the chamber. However, this type of chamber produces less reliable results, as it poorly simulates the actual environmental conditions of industrial applications.
Natural Convection Chamber (NCC): This chamber is a windless environment, and more closely resembles actual industrial application settings. Results from these tests are more reliable because the static airflow is a closer simulation of real-life industrial environments.

The chamber should be set to exceed the temperature range of the expected industrial application. For example, even though 75°C is considered the industrial standard for high temperature operations, the device should be tested in a chamber set 9 to 12°C higher. On the other end of the thermostat, the chamber should also test at temperatures as low as -40°C. This ensures that the testing scenario is even more harsh and rigorous than the actual environment.

Thermal Design in Action: Moxa’s V2101 Computer

Moxa’s V2101 computer is an excellent example of how all of the thermal design strategies outlined in this white paper combine to create a computer with a wide operating temperature.
Moxa’s hardware and layout designers carefully selected components that would meet wide temperature requirements, and carefully arranged the board and chipset layout to optimize heat dissipation. The product was then rigorously tested in a forced-convection thermal chamber that created a cold and snowy environment which closely resembles the actual environmental conditions of industrial applications. Then, it was tested in a natural-convection thermal chamber that simulated a hot, windless environment.

Finally, the V2101 was subjected to harrowing worst-case scenario testing. The product was first heated for eight hours, then subjected to four hours of fluctuating extremely high temperature that sometimes exceeded the target temperature, and then finally exposed to one hour of operation at the target high temperature. This rigorous testing ensures a high level of system reliability.

For more information on Moxa’s V2101 computer and thermal design, or to request a quote, visit the following site: www.moxa.com/Event/Sys/2010/V2101/Index.htm