The Secret Behind Wide Temperature Technology

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Industrial applications are often associated with harsh, demanding environments. Facilities and key computing equipment may be located at remote sites where there is little or no protection from severe weather conditions. Computers that are not designed to tolerate harsh conditions face significant limitations in how they can be used in industrial applications. Typical industrial standards call for an operating temperature range of 0 to 40°C. Although these standards are far more rugged than those for consumer products, industrial computers need higher quality construction to provide protection from the elements for use in harsh environments.

Wide temperature industrial computers are even more rugged and generally have an operating temperature range of -40 to 75°C. The ability to operate under such extremes allows wide temperature industrial computers to be deployed in many more locations such as desert and polar regions. By constructing an industrial computer to be operable under extreme heat and cold, manufacturers can assure reliability and reduce the likelihood of product failure for applications in a variety of harsh environments over extended periods of time.

The Importance of Wide Temperature Computers

Industrial applications are found in various settings, including

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factories, power stations, road-side traffic control boxes, as well as marine, desert, and polar locations. Given the severe and harsh conditions often found in these environments, computers used in these applications must be able to endure extreme temperatures. For example, a computer server may be deployed in a factory where it is likely to be exposed to a great deal of heat. If it is deployed in a remote outdoor location, the computer would need to be able to operate under extreme cold or heat, depending on the climate. A computer without wide temperature design is usually ill-suited for the harsh demands of industrial applications. As a result, wide operating temperature has become an important feature for industrial computers.

The Challenges of Designing Wide Temperature Computers

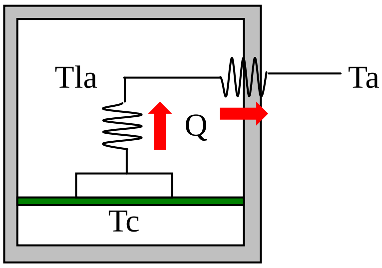
1. Fanless design

Onboard fans are the traditional cooling method for computers but may burn out and cause additional problems. When the fan stops operating, the whole system usually crashes. The fanless design has become standard among industrial computers as it eliminates mechanical problems caused by onboard fans. However, the fanless design presents additional challenges for developers of wide temperature products. Not only do the critical components selected need to meet wide temperature requirements, but the hardware layout design that integrates all peripheral computers must fulfill wide temperature demands as well.

2. High temperature

High temperatures can have crippling effects for the entire computer system. The absence of a well-designed ventilation system may cause the system to crash when exposed to prolonged periods of extreme heat, increasing system recovery effort and maintenance costs. Unfortunately, the components that support the optimal system performance are likely to generate more heat. For example, a high performance CPU produces more system frequency and heat. This challenge is a nightmare for hardware designers, since it takes a great deal of effort and time to choose the optimal components and lay out the hardware to ensure that the computer can endure high temperature conditions. In addition, we also need a better overall thermal solution, which involves placing the components on the PC board in an efficient manner, and choosing materials with high thermal conductivity and an optimal heat sink design. By making intelligent use of standard thermal conductivity theory, we are able to lower the thermal resistance (θ) at each point on the heat transfer route.

[Thermal Resistance]



$Tc:$ IC Case Temperature (°C)

$Tla:$ Local Ambient Temperature (°C)

$Ta:$ Ambient Temperature (°C)

$Q:$ Heat Flux (W)

$\theta_{ca}:$ Thermal Resistance (°C/W)

$$\begin{aligned}\theta_{ca} &= \theta_{c-la} + \theta_{la-a} \\ &= \frac{Tc \cancel{- Tla}}{Q} + \frac{\cancel{Tla} - Ta}{Q} \\ &= \frac{Tc - Ta}{Q}\end{aligned}$$

3. Low temperature

Building an industrial computer that can operate under low temperatures poses another challenge to manufacturers as they usually focus more on addressing the high temperature issue. Computers always generate heat when they run, so it makes sense that manufacturers would be more concerned with developing an optimal cooling system. However, some industrial applications take place in cold climates and computers used in these settings need to be heated in some way. Generally speaking, the better a computer is at dissipating heat for high temperature environments, the less effective it is for low temperature applications. The more effort manufacturers invest in addressing high temperature issues, the more effort they need to invest in addressing low temperature issues as well.

4. Production cost

Costs are among the biggest factors manufacturers consider when designing a new product. Wide temperature design requires higher quality components and more effort in hardware layout and system integration. As a result, it is more costly to develop and produce wide temperature computers, which makes the products less competitive in terms of price. Lowering production costs while enhancing the value for wide temperature products has become a critical concern for industrial computer manufacturers.

How to Overcome These Challenges

1. Optimize the thermal placement of components

Designing a wide temperature industrial computer requires a full understanding of the product's thermal gradient in order to optimize the placement of components. Several factors need to be considered with regards to the thermal placement of components inside the computer.

First of all, hardware engineers need to identify the main heat sources and hot spots so layout designers can optimize the component placement on the motherboard. Basically, the closer a component is to the main heat source, the more durable it needs to be. Designers can also reduce the number of heat sources by using components that generate less heat and arranging the components in the most optimal positions.

The chassis and total system power consumption should also be considered when developing a wide temperature computer. For example, using a larger chassis or reducing the system's power consumption can help dissipate the heat generated by the computer.

It is also crucial for engineers to determine a main direction for heat transmission. This involves a sophisticated understanding of the component placement and a technical arrangement of the components to dispel the heat via a specific transfer route.

Understanding the system's thermal gradient is essential to optimizing the thermal placement of components and designing wide temperature computers.

2. Use natural-convection thermal chambers

Environmental test chambers are an important way to determine if a product can be used in harsh surroundings. Most manufacturers use forced-convection thermal chambers for testing. However, results from these tests are usually unreliable as the environments they replicate are generally inconsistent with actual environmental conditions found in industrial applications. Using a natural-convection thermal chamber allows engineers to establish a windless environment that more closely resembles actual industrial application settings.

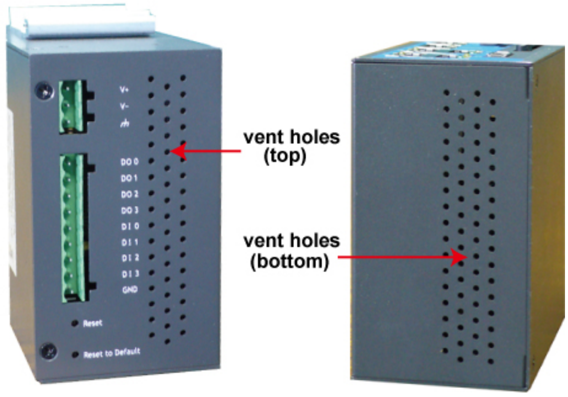
3. Establish a wide temperature component database

Using wide temperature components is the most direct way to produce wide temperature computers. To make is easier to find and deploy wide temperature components, hardware and layout designers should construct a database of components that meet the rugged requirements for use in wide temperature environments. Testing components, materials, and products in a natural-convection thermal chamber first makes it easier to determine which ones are suitable for the wide temperature database. This database is extremely important and helpful should you decide to convert a standard temperature product into a wide temperature one. Designers can easily choose the components from the database and deploy them in the product, which accelerates product development and shortens time-to-market.

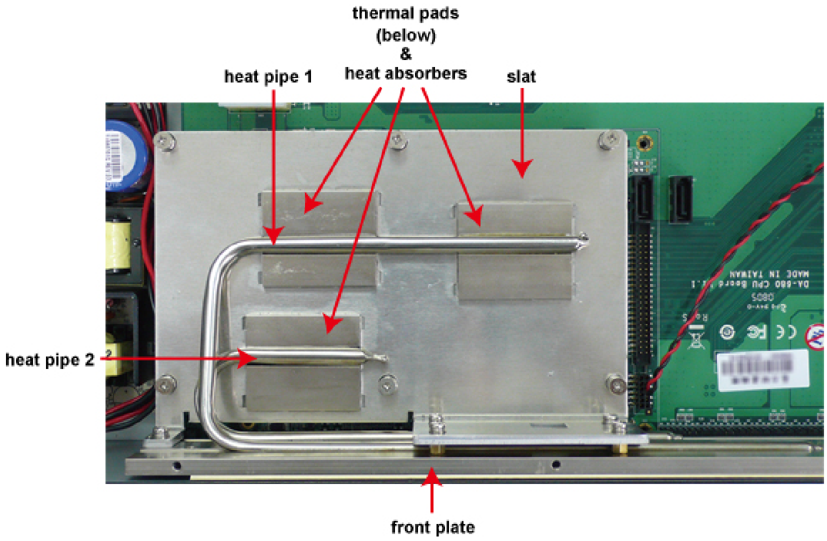
4. Deploy optimal heat transfer methods

Vent holes

The simplest way to transfer heat from the computer is to use vent holes. These holes are usually arranged in pairs and located on both sides of the computer (often vertically) so that hot air can flow through the computer and accelerate the ventilation effect. However, this method is only suitable if the computer does not generate too much heat and there is good airflow at the field site. Unfortunately, this method cannot prevent dust or water from entering the computer.

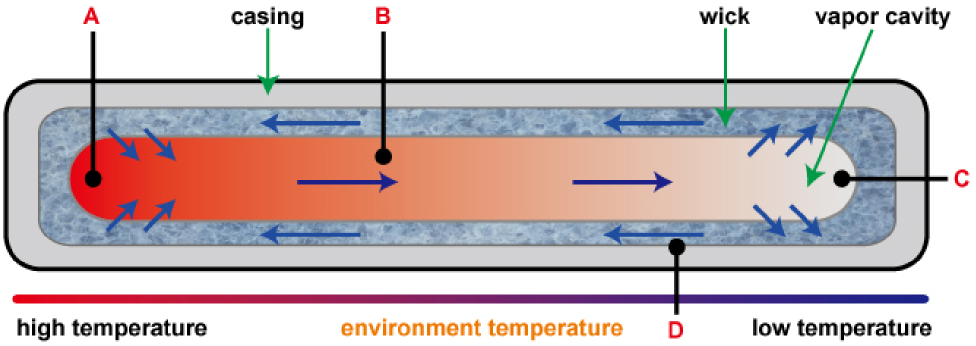


Heat pipes—Another method is to use a heat pipe to direct the heat out of the computer. This solution employs specific materials and instruments to transfer heat via the thermal cycle. It is particularly suitable for board-based products that contain CPUs and chipsets as the primary heat sources.



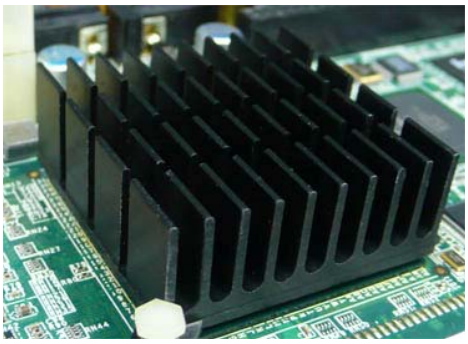
For example, silicon thermal pads can be used to directly cover the onboard CPU and chipsets, which are then covered by aluminum heat absorbers located on the slat where one or more bronze heat pipes are affixed. The heat pipes are hollow but lined with a wick containing a working fluid, such as water, that can absorb the heat from the heat sources. The pipes are often led to a location where it is easy to dissipate the heat, such as a plate at the front of the computer. In addition, the main function of the heat pipes is to transfer heat from one side of the computer to another via the thermal cycle.

How does the thermal cycle work in the heat pipe?

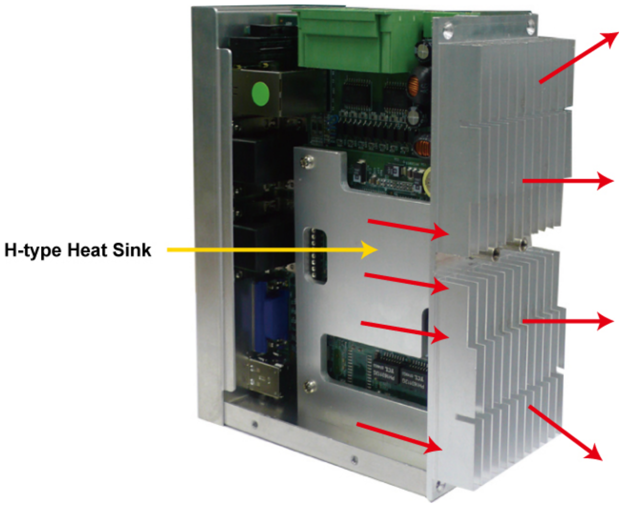


A. Fluid evaporates into vapor to absorb thermal energy
B. Vapor migrates along the cavity to the end at a lower temperature
C. Vapor condenses back to fluid and is absorbed by the wick, releasing thermal energy
D. Fluid flows back to end at a higher temperature

Heat sink—Heat sinks are another solution that can be used for transferring heat. The heat sink is usually made of bronze or aluminum, materials that can easily dispatch heat from one side to another. For example, a heat sink made of aluminum may be used to directly cover the component and absorb the heat to transfer it out of the computer. This method is widely used and can serve as the cooler for the CPU or the entire computer. It usually has a fin-shaped design to maximize the surface area and speed up the heat transfer. When a heat sink is used, the size makes a big difference since the designer needs to optimize the sink to maximize the heat transmission effect.



However, traditional heat sinks can only solve a limited number of challenges as they are externally attached to the unit. It is not guaranteed that all the heat can be directed to the sink and lower the temperature of the computer. To solve this problem, Moxa has introduced a patented "H-type" heat sink design that can essentially cool down the unit's internal temperature. "H-type" heat sinks involve a plate that can be inserted into the inner part of the unit to make direct contact with the main heat sources. This design ensures that most of the heat can be absorbed from the main heat sources and directly transmitted to the external fin-shaped plates. This solution is also more cost-effective compared to the traditional heat sink design.



5. Install a self-warming system

The methods mentioned above are all geared towards heat transmission and only apply to high temperature environments. However, different technology is required to ensure reliable operation for the computers used in cold climates and settings. Balance heaters that automatically start working when the exterior temperature drops too low can be used to warm the interior of the computer. However, this method requires precise and accurate temperature configuration to ensure that the resistors start operating when needed.

Where Wide Temperature Computers Are Used

Wide temperature industrial computers generate less heat and consume less power, making them particularly reliable and less prone to failure over long periods of time. As a result, they are well-suited for the following situations:

- Outdoor applications, such as deserts or mountains, where it is difficult or costly to build a climate-controlled shelter for sensitive electronic equipment.
- Indoor applications, such as a factory floor, where equipment must be placed near machines that generate extreme heat.
- Mobile or mixed applications in harsh environments, such as in the military, where machines must operate reliably in low and high temperatures.

Wide temperature models present a much more reliable and affordable alternative to using regular industrial-grade devices. They are an ideal solution for any application involving harsh industrial environments, such as power substation automation, gas stations, intelligent transportation systems, environmental monitoring, factory automation, and other related systems.

Summary

Wide temperature is an important feature for industrial computers deployed in locations with harsh environmental conditions. In this paper, we explained the key elements of wide temperature industrial computers and the particular challenges manufacturers face when developing them. To overcome these challenges, manufacturers need to pay attention to the following factors:

- Optimize the thermal placement of components.
- Use natural-convection thermal chambers.
- Establish a wide temperature component database.
- Deploy optimal heat transmission methods for high temperature.
- Install a self-warming system for low temperature.

NOTE: Moxa provides a rich selection of wide temperature embedded computers for industrial applications. For details, check our website at www.moxa.com, or send us an e-mail at support@moxa.com.