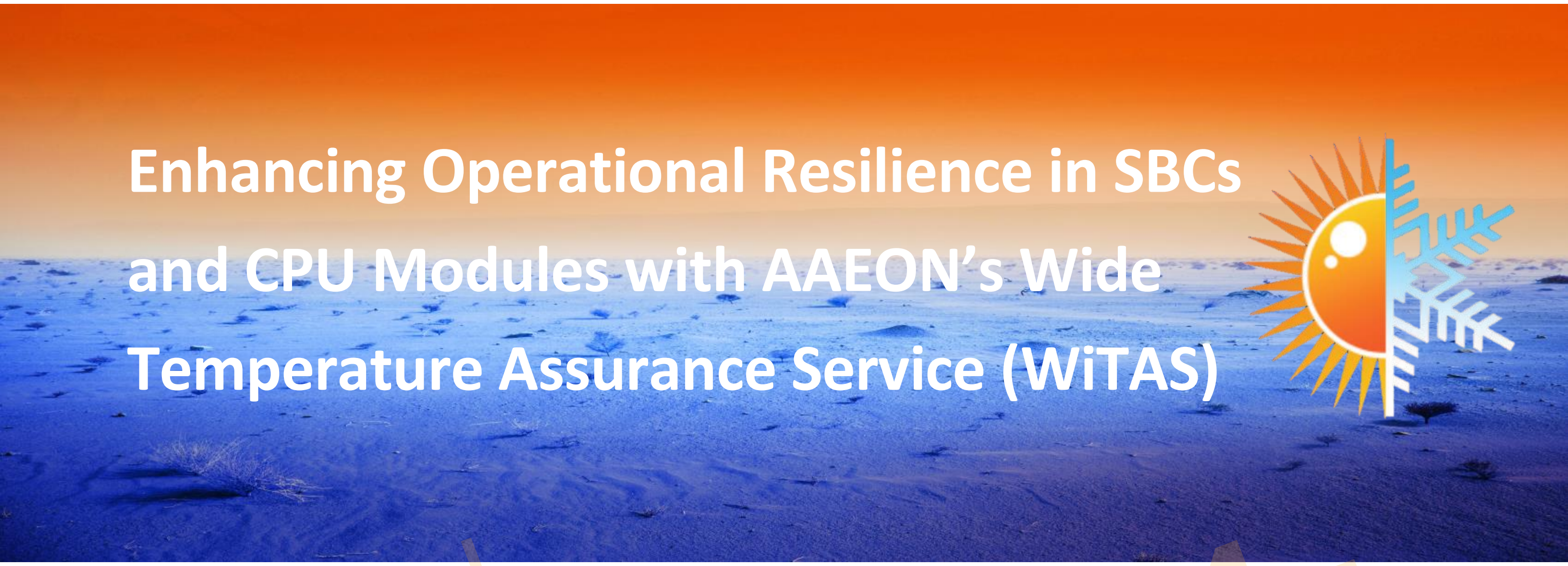
White Paper



Enhancing Operational Resilience in SBCs and CPU Modules with AAEON's Wide Temperature Assurance Service (WiTAS)

Overview

When AAEON first developed its Wide Temperature Assurance Service (WiTAS) over a decade ago, its purpose was to certify the operability of its single-board computers (SBCs) and CPU modules in extended temperature environments, with an emphasis on outdoor deployment.

At the time, a number of specific mission-critical applications such as outdoor digital signage, military, and transportation were pinpointed as being those that most required thermally reliable computing enclosures that are both compact and fast cooling. Consequently, AAEON developed and adopted a rigorous internal testing process as part of its product development cycle, subjecting its boards to extreme temperatures at both ends of the spectrum.

This testing protocol, in conjunction with the use of durable components, allowed AAEON to enhance the longevity of its SBCs and modules. However, since the above criteria were established, there have been enormous changes across all aspects of embedded computing, from increasingly sophisticated chip architecture to the functions that vertical markets demand SBCs and modules fulfil.

The need for SBCs and modules that can operate in areas of extreme temperature variance is no longer confined to a handful of industries, but can instead be a prerequisite for innumerable applications, particularly within the contextual backdrop of edge computing and automation becoming standard facets of many business operations. AAEON has addressed the needs that these changes have brought by reevaluating both the default temperature tolerance of its SBCs and modules and the criteria under which they are tested.

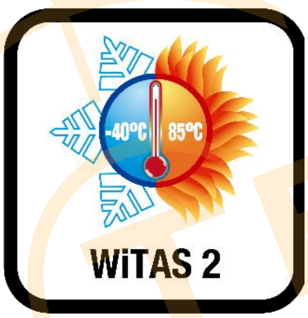
This white paper presents detailed insights into AAEON's testing processes, including the redefinition of temperature tolerance ranges, considerations for wide temperature board design, and the evolution of its rigorous WiTAS testing protocol. It also highlights the significance of thermal design and component selection in achieving optimal performance, durability, and longevity for its SBCs and modules.

Redefining AAEON’s Wide Temperature Assurance Service (WiTAS) Criteria

The default operating temperature range for SBCs and modules remained relatively unchanged for a long time, with 0°C ~ 60°C (32°F ~ 140°F) being the typical range within which most of AAEON’s embedded single-board computers fell into.

Meanwhile, system and server-level products have often been subject to a narrower temperature tolerance range due to a variety of factors, chief among them being these products’ need for greater processing power and their reliance on the integration of expansion modules for storage, graphics, or AI functions.

Consequently, upon the introduction of AAEON’s Wide Temperature Assurance Service (WiTAS) program, SBCs and modules that passed AAEON’s stringent testing criteria were issued with one of two designations.



Boards that passed the thermal tests of being able to operate within -20°C ~ 70°C (-4° F ~ 158°F) were certified as WiTAS 1. Meanwhile, boards that were able to operate within -40°C ~ 85°C (-40°F ~ 185°F) were certified as WiTAS 2, with the standard operating temperature for most boards outside of those issued with a WiTAS classification falling into the 0°C ~ 60°C (32°F ~ 140°F) range.

As the needs of different industries have changed, and AAEON recognized the need for SBCs and modules that are both small and able to host more powerful processors, it has begun the process of revising its definition of what constitutes a ‘standard’ SBC and a ‘wide temperature’ SBC.

As a result, AAEON’s Embedded Computing Business Unit (ECBU) will adopt -20°C ~ 70°C (-4° F ~ 158°F) as the new temperature range expected of its ‘standard’ SBCs and CPU modules powered by Intel® technology, beginning with those featuring the Intel® Processor N-series and extending to the next generation of Intel® Core™ embedded SoC platforms entering mass production from the beginning of Q3, 2024. This means that boards developed by ECBU that previously would have been classed as WiTAS 1 will now be considered standard temperature, while boards and modules with a -40°C ~ 85°C (-40°F ~ 185°F) tolerance will be considered ‘wide temperature’.

This will grant users access to a wider scope of products for projects that may previously have fallen outside of the 0°C ~ 60°C (32°F ~ 140°F) limitation, but did not require the extreme temperature tolerance granted by a WiTAS 2 designation.

Wide Temperature Board Design Considerations

With AAEON’s Embedded Computing Business Unit producing SBCs and CPU modules that incorporate a variety of processor architectures from different chip providers, the limitations of each processor platform must be taken into consideration at the very beginning of the product development process.

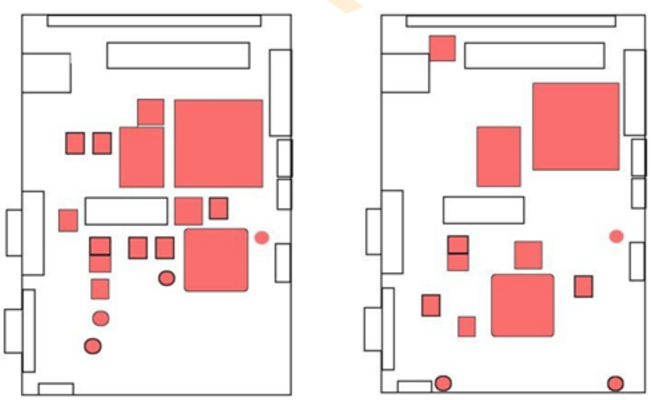
AAEON’s SBC and CPU modules, particularly product lines based on the 2.5”, 3.5”, and 4” form factors and CPU modules, have a history of producing boards with processors based on x86 architecture, such as those included in the Intel® and AMD Ryzen™ roadmaps. While the thermal capacity of these platforms must be considered when developing new generations of SBCs on these form factors, AAEON’s position as a Titanium member of the Intel® Internet of Things Solutions Alliance grants it early access to new Intel® technologies and thus, enables AAEON to modify its PCB design based on the unique specifications of each processor generation.

The same can be said for the attention needed when working with processor lines such as the AMD Ryzen™ Embedded V2000 processor family, which despite also being built on x86 core architecture, boasts AMD's Zen 2, 7nm process technology.

Other product lines must be considered however, given AAEON's investment into developing SBCs and modules based on RISC architecture. Such platforms typically employ multiple different die components into one chip, such as integrated Neural Processing Units (NPUs), secondary cores, and machine learning accelerators, alongside their main CPU platform, as in the case of Arm® platforms.

When developing an SBC or CPU Module, it is crucial to ascertain the anticipated power dissipation in Watts during regular operation, known as Thermal Design Power (TDP). For instance, a board featuring a powerful processor such as a 13th Generation Intel® Core™ CPU can have a TDP of up to 65W, while CPUs that are targeted towards greater efficiency, such as those from the Intel Atom® Processor X Series, may only have a TDP up to 12W. By using this TDP as a reference point for SBC and module design, it ensures that the thermal solution will accommodate all boards within the same product series, operating safely within the designated temperature range.

Moreover, to further optimize the thermal design of solutions to guarantee stable performance within extended temperature ranges, other design elements such as BIOS customization to limit CPU power output and air flow optimization can assist in providing the necessary thermal dissipation for AAEON's new temperature standard.



Poor Thermal Component Design | Ideal Thermal Component Design

Given the continued market demand for boards to be smaller, while also offering expandable storage, AI support, and (in many cases) fanless operation, processors are only one concern of many with respect to wide temperature product development.

Printed Circuit Board (PCB) component selection, both industrial and consumer grade, play a role in the thermal durability of an SBC. The main thermal pathways consist of thermal interface material, a heat spreader, and a heat sink. Meanwhile, the secondary thermal pathway encompasses interconnect layers, I/O pads, and the printed circuit board.

Therefore, design choices such as those that maximize airflow via the sparse placement of heat-generating components on a board also contribute to the efficiency of fanless heat dissipation.

WiTAS Testing Focus

The initial selection of components in-house is succeeded by the meticulous sorting of assembled boards. A comprehensive test plan is then implemented to verify the board's capability to withstand the extreme temperature variations it may encounter in real-world scenarios.

This plan involves subjecting the board to stress tests under controlled conditions to identify any potential design or performance flaws during typical operation. Such procedures enhance confidence in achieving optimal performance levels for boards intended to operate in wide temperature environments, but are particularly important with the expansion of AAEON's 'standard' operating temperature range from 0°C ~ 60°C (32°F ~ 140°F) to -20°C ~ 70°C (-4° F ~ 158°F).

After the electrical design and board assembly are completed, the board is subject to a high-temperature testing process consisting of power on/off, cold start, and burn-in tests for 2.5 days. The test focus for high-temperature testing is to achieve stable operation with 100% loading, along with consistently stable power up cycling.

The temperature testing procedure begins at 70°C, with the board's temperature increasing every hour while the board is cycled on and off until failure occurs. If failure transpires within the standard temperature range of -20°C ~ 70°C (-4°F ~ 158°F) or the WiTAS range of -40°C ~ 85°C (-40°F ~ 185°F), the board undergoes a ‘design re-check.’ In the event the temperature successfully surpasses 90°C, the board is cooled and moved on to low-temperature testing.

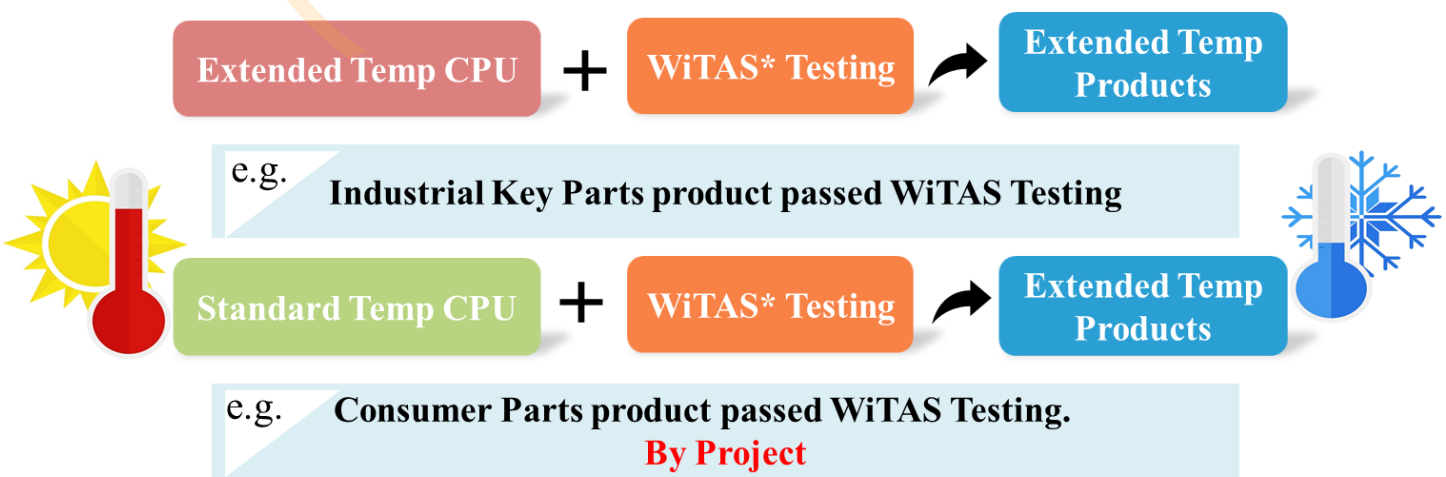
AAEON’s new low-temperature testing procedure consists of 2.5 days of power on/off, hot start, and burn-in testing from -20°C (-4°F) until failure. The test focus for low temperature testing is to achieve stable boot up and stable running with 100% loading with each drop in temperature. The final stage of AAEON’s WiTAS testing protocol is to evaluate a board’s thermal shock tolerance.

This stage is undertaken over a two-day period, and measures a board’s ability to sustain rapid temperature changes. The accumulated time for AAEON’s WiTAS testing is therefore 7 days. Industry standard for such tests typically follow the pattern of high-temperature testing for 1 day, low temperature testing for 1 day, and thermal shock tolerance testing for 2 days, for a total of 4 days.

AAEON exceeds the industry standard and institutes more stringent requirements for performance, instilling confidence in the durability of its final product. Isolating errors at this stage of the Engineering Verification Test (EVT) further refines the final product as issues are addressed.

All extended temperature products will go through the production sorting process to ensure they reliably meet the standards outlined above. Typical testing includes high and low temperature power cycle testing, along with a burn-in test within 8 hours of initial testing. As part of AAEON’s dedication to providing the highest level of service, sorting methods and the timing of each step can be adjusted to meet the specific use scenario or customer project requirements.

In addition to the greater detail and time taken in validating a board’s temperature range, AAEON also addresses the role that PCB components, either industrial or consumer, play in the durability of a board. Consequently, boards designed with extended temperature CPUs and extended temperature components are considered ‘Industrial Key Parts’ products. Conversely, boards utilizing standard temperature CPUs and extended temperature parts are considered to be ‘Consumer Parts’ products.



*WiTAS => Wide Temperature Assurance Service

To safeguard the validity of wide temperature testing, AAEON performs WiTAS testing on both 'Industrial Key Parts' products and 'Consumer Parts' products. As part of the product design process, consumer or commercial parts such as standard temperature CPUs or components are not routinely selected. However, with its reputation for providing ODM and customization services, AAEON applies the same high standards to all of SBCs and modules. Consequently, while 'Consumer Parts' products are assembled on a project basis, they still undergo the rigorous testing criteria outlined.

Scenarios

There are both environmental and industry-specific considerations that affect the demand for boards with wide temperature tolerances. These can be as straightforward as the geographic location in which a solution is deployed, or the board's operational requirements as one part in a larger application ecosystem with more volatile components.

The following non-exhaustive list grants some insight into scenarios in which customers may need stable, reliable board operation in extreme environments:

- **Ultra-Low Temperature Environments** – High altitude countries, smart transportation applications
- **Ultra-High Temperature Environments** – Solar energy farm deployment in the desert, installation within cargo vehicles
- **Environments with Extreme Temperature Variations** – Flight control systems, AMR or AGV solution in factories or warehouses

Markets

While demand cannot be isolated to specific industries, wide temperature SBCs and modules can be particularly useful for some key applications within them, such as:

- **Transportation** – Traffic surveillance, passenger information systems, ADAS
- **Smart City** – Intelligent parking solutions, smart highways, crowd monitoring
- **Industrial Automation** – AMR, AGV, AOI, CNC
- **Military** – Field electronic devices, aerospace system controllers, drone detection
- **Energy** – Wind turbine controller, solar energy controller, power stations
- **Environmental** – Climate, water, pollution and weather monitoring applications
- **Medical** – Pharmaceutical processing, telemedicine, AI-assisted imaging

AAEON's new standard for evaluating the suitability of both its standard and its Wide Temperature Assurance Service (WiTAS) certified products aims to build a robust framework through which its boards and modules will provide greater utility to its customers.

As an industry leader in the embedded computing sphere, AAEON's heightening of their default product's temperature range, more stringent testing criteria, and flexible dynamic approach to PCB design will allow for wider deployment and remove barriers to entry into the use of embedded solutions for a great number of organizations across vertical markets.

About AAEON

Established in 1992, AAEON is one of the leading designers and manufacturers of industrial IoT and AI Edge solutions. With continual innovation as a core value, AAEON provides reliable, high-quality computing platforms including industrial motherboards and systems, rugged tablets, embedded AI Edge systems, uCPE network appliances, and LoRaWAN/WWAN solutions. AAEON also provides industry-leading experience and knowledge to provide OEM/ODM services worldwide. AAEON works closely with premier chip designers to deliver stable, reliable platforms. For an introduction to AAEON's expansive line of products and services, visit www.aaeon.com

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Texim Europe - contact details

Headquarters & Warehouse

Elektrostraat 17
NL-7483 PG Haaksbergen
The Netherlands

T: +31 (0)53 573 33 33
E: info@texim-europe.com
Homepage: www.texim-europe.com

The Netherlands

Elektrostraat 17
NL-7483 PG Haaksbergen

T: +31 (0)53 573 33 33
E: nl@texim-europe.com

Belgium

Zuiderlaan 14, box 10
B-1731 Zellik

T: +32 (0)2 462 01 00
E: belgium@texim-europe.com

UK & Ireland

St Mary's House, Church Lane
Carlton Le Moorland
Lincoln LN5 9HS

T: +44 (0)1522 789 555
E: uk@texim-europe.com

Germany - North

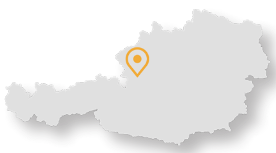
Bahnhofstrasse 92
D-25451 Quickborn

T: +49 (0)4106 627 07-0
E: germany@texim-europe.com

Germany - South

Martin-Kollar-Strasse 9
D-81829 München

T: +49 (0)89 436 086-0
E: muenchen@texim-europe.com



Austria

Warwitzstrasse 9
A-5020 Salzburg

T: +43 (0)662 216 026
E: austria@texim-europe.com

Nordic

Søndre Jagtvej 12
DK-2970 Hørsholm

T: +45 88 20 26 30
E: nordic@texim-europe.com

Italy

Martin-Kollar-Strasse 9
D-81829 München

T: +49 (0)89 436 086-0
E: italy@texim-europe.com