EMBEDDED COMPUTING MYTHBUSTER

Myth: "Extended Temperature" Embedded Computers
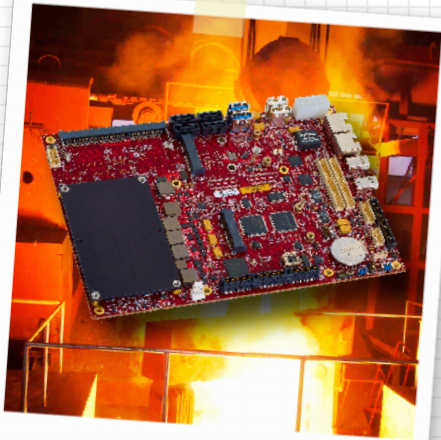
Extended Temperature Range Single Board Computer

FACT

There are **no standards** for how to design, manufacture or test extended temperature range single board computers.

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UP TO 38% DIFFERENCE IN RANGE!

Introduction

Military, aerospace, and outdoor industrial applications are often associated with extremely demanding environments. These systems are frequently deployed in applications exposed to high impact, vibration, and extreme temperatures. When integrating embedded computers, into these systems, manufacturers typically specify an extended temperature range Single Board Computer (SBC) for their computing requirements. The "extended temperature" designation theoretically assures that the SBC will perform reliably in extreme temperature environments. If an SBC supplier labels their product as "extended temperature", then it will be reliable in the field. Right?

Well, that depends. To understand the reliability of a supplier's extended temperature SBC, you first need to answer a few questions.

1. How does the SBC supplier define the "extended temperature" range?

2. Does the supplier use commercial temperature components on their "extended temperature" SBCs?

3. How is the SBC tested to ensure it will perform over the rated temperature range?

Let's take a closer look at these questions and uncover some facts about extended temperature SBCs.

The Definition of Extended Temperature Varies by SBC Supplier

Supplier	Supplier's Definition of Extended Temperature Range
VersaLogic Corporation	-40^0 to 85^0C
Vendor A	-20^0 to 70^0C
Vendor B	-40^0 to 75^0C
Vendor C	-40^0 to 75^0C and -40^0 to 85^0C
Vendor D	-40^0 to 85^0C

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How does the SBC supplier define "extended temperature range"?

In a survey of extended temperature range SBC suppliers, about 1/3 of them specify -20° to 70°C as "extended temperature" range; 14% of the suppliers specify -40° to 70°C. The remaining suppliers, such as General Electric, VersaLogic Corp., and Curtiss-Wright, specify a range of -40° to 85°C.

Many producers of industrial and rugged systems do not appreciate the importance of the full -40° to 85°C temperature range. When designing systems such as communications equipment, in-vehicle computing, surveillance systems, and digital signage, designers may not realize that their products are often exposed to extreme temperatures. A few real world examples help to illustrate how easy it is for a product to encounter these extremes; and the value of an extra 10 or 20°C of operating range.

Take the example of an embedded system being operated in a vehicle. The inside of a parked vehicle on a summer day can reach over 90°C (194°F) in less than 30 minutes. At this temperature, semiconductors are highly susceptible to thermal overstress (heat damage). For example, semiconductors, including CPUs, operating in high temperature environments are susceptible to a condition called thermal runaway. Thermal runaway can occur when a semiconductor device operates beyond its maximum high temperature range. Power dissipation of the semiconductor device increases as a function of the temperature. The increase in power dissipation raises the temperature of the device, which, in a circular fashion, increases the device power dissipation, until destruction of the device results. System failure, electrical explosion and fire are some of the hazards which can result from thermal runaway.

On the other end of the spectrum, temperatures in cities such as Chicago, Toronto, and New York frequently fall below -20°C (-4°C F). When exposed to these conditions, board-level passive components become a major issue in embedded systems. The performance of components such as crystal oscillators and capacitors degrade as they reach the lower limits of their operating range. The result is clock skew, timing errors, change in values … all of which can negatively impact computing reliability.

Mission critical applications deployed in truly extreme temperature environments, such as pilotless drones, armored personnel carriers and battlefield communications equipment, clearly need the full -40° to 85°C range in order to achieve the required level of reliability.

The Bottom Line

For outdoor applications requiring reliable operation and extended life, an SBC with an operating range of -20° to 70°C (or even -40° to 75°C) is not good enough. In many outdoor applications, an extra 10°C of operating range is needed to prevent temperature-related performance issues and field failures.

90°C (194°F)

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Exhibit A.

Extreme temperatures are far from uncommon. On a sunny day, the interior temperature of a vehicle can reach over 90°C in less than 30 minutes!

Thermal Headroom

Having thermal headroom is critical when SBCs are enclosed in a sealed box. Limited air flow and slow transfer of heat to the outside environment, means that the SBC must be able to withstand high temperatures inside of the box, even when the external ambient temperature may be in a more normal range.
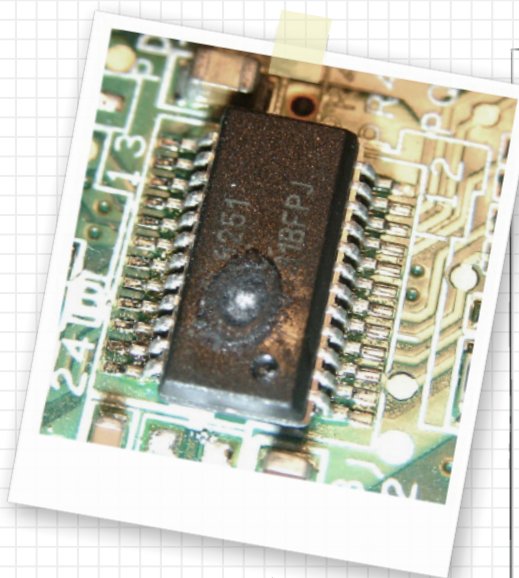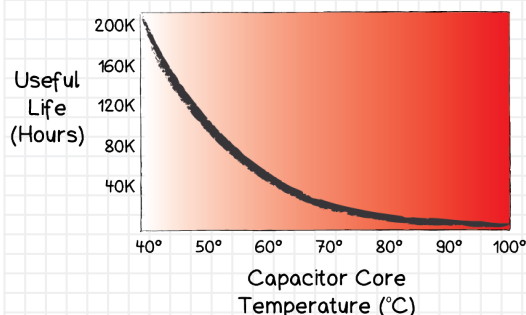
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A failed IC due to overheating. Commercial grade components operating in high temperature environments are more prone to overheating and thermal runaway.

Electrolytic Capacitor Lifetime Decreases with Increasing Temperature

The useful life of electrolytic capacitors rapidly decreases with increasing temperatures. Industrial grade capacitors are essential for extended temperature SBCs.

Does the SBC supplier use commercial grade components on their extended temperature range board?

To lower costs, many embedded computer manufacturers use commercial grade components on their "extended temperature" products. The extreme temperatures encountered in hostile environments are unforgiving to commercial grade electronics. In fact, commercial grade components such as Ethernet magnetics are especially vulnerable to cold temperatures. Commercial grade magnetics often experience failures when temperatures drop below freezing. Unfortunately, such a failure may not manifest itself at the time of deployment. Rather, it could happen over the course of field operation gradually, leading to unexpected downtime and system trouble shooting long after installation.

And it's not just commercial grade magnetics. Commercial grade crystal oscillators, transistors, diodes, relays, inductors, capacitors, resistors, etc. are found on many so called "extended temperature" SBCs. When one of these inexpensive components fails in the field, the cost of service and repairs typically runs into the thousands of dollars! The cost of a single failed component in a deployed system is very high.

The typical single board computer contains large numbers of capacitors, mostly for power supply smoothing and decoupling active components. Some SBC suppliers use low-cost capacitors on their extended temperature products. The characteristics of these gel-like materials can change over time, drying out or failing with extended use at high temperatures. To ensure high reliability, companies such as VersaLogic Corp. use industrial grade capacitors. They also take the additional step of applying a 2X de-rating approach to capacitors. Thus if the design requires a 5 Volt capacitor a more robust 10 Volt capacitor is selected. Using this 2X rule for capacitors ensures long-life operation at temperature extremes.

The Bottom Line

An SBC supplier using commercial grade components on their extended temperature boards may appear to be offering a good value. It's often tempting to select a vendor based on price. However, it pays to investigate the quality of the components used on an SBC. System reliability issues resulting from failing commercial grade components, such as an Ethernet interface, can be extremely difficult to diagnose and repair.
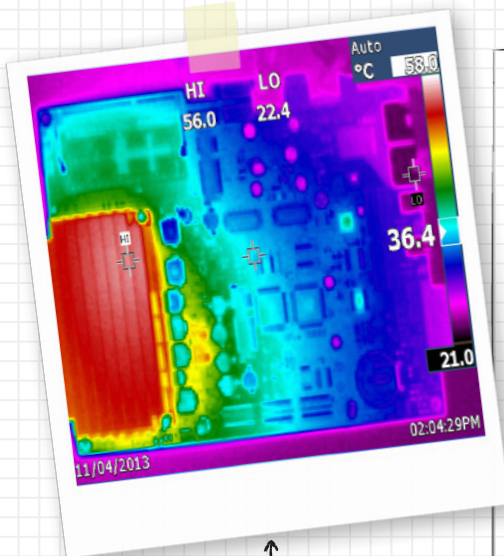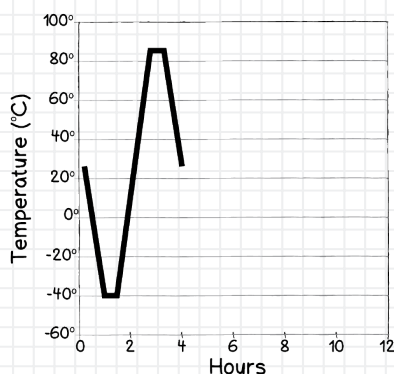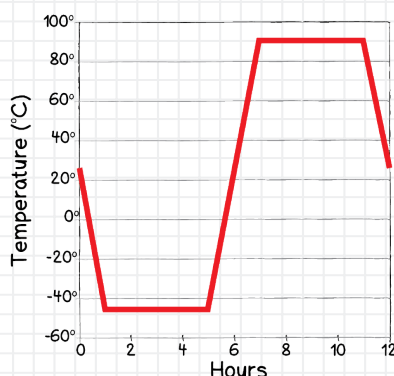
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Exhibit C.

Specifications such as "-40 to +85°C maximum CPU case temperature" mean that a product will not operate at +85°C ambient.

Is the SBC tested to ensure it will perform over the extended temperature range?

Now that we've identified relaxed temperature ranges and commercial grade components as potential concerns, let's take a look at how SBCs are tested. Even the best designs, using the highest grade components require considerable testing to ensure that the product performs as expected at extended temperatures.

Unfortunately, many manufacturers do not thoroughly test their extended temperature boards. For example, boot-up tests are a critical step in the SBC quality process and should be performed numerous times across the full extended temperature range. During product validation, some SBC suppliers perform only a few boot tests and call it good. To achieve best-in-class reliability, companies such as VersaLogic perform hundreds or thousands of boot tests during validation.

Some SBC suppliers design boards that will theoretically operate at extended temperature, but don't actually test them at temperature! Others simply screen standard temperature boards and sell them as extended temperature SBCs if they appear to operate properly. Both of these practices put customers at high risk. In order to operate reliably in extreme temperatures a product must be designed, validated, and tested for extended temperature operation.

Extended temperature specifications for any given product need to be examined closely. Some specifications can be confusing or misleading. Specifications such as "-40 to +85°C maximum CPU case temperature" mean that a product will not operate at +85°C ambient. Since the ambient temperature must be below the maximum case temperature (in order for the CPU to not overheat), a board with this specification might operate reliably to only +70 or +75°C, even with an excellent heat sink.

The Bottom Line

Buying a single board computer that is specified as "extended temperature" doesn't guarantee its ability to operate in an extended temperature system. Some SBC manufactures take short cuts in their design or testing cycle. Before choosing an SBC supplier, you need to examine the test methodologies they employ.

Typical 4-Hour
Extended Temperature SBC
Environmental Test

VersaLogic's 12-Hour
Extended Temperature SBC
Environmental Test

VersaLogic's full temperature cycle takes approximately 12 hours and adds a 5° guardband

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Conclusion

The fact is there are no industry standards for how to design, manufacture or test extended temperature embedded computers. The freedom to define their own quality standards combined with a price sensitive marketplace, offers embedded computer manufacturers a tempting opportunity to cut corners. Many embedded boards are designed with severe cost constraints and with tight design schedules. As a result, the reliability of SBCs can vary greatly from supplier to supplier.

Asking the right questions and performing due-diligence before partnering with an embedded computer supplier is a critical step in procuring reliable extended temperature computers.

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