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Extending the Thermal Solution by Utilizing Excursion Temperatures

Some UltraScale+™ and Versal™ devices offer an excursion temperature, which raises the upper temperature operating limit by 10°C for a limited period. Properly used, this feature can extend the thermal solution of many applications.

ABSTRACT

Maintaining thermal limits in many modern applications is becoming progressively more difficult. This is due to increasing bandwidth and compute requirements exacerbated by shrinking enclosures and resulting higher operating temperatures.

From the IC device perspective, operating at sustained high temperature has a negative impact on device performance, reliability, and lifetime.

To improve operating temperature limits while maintaining a high reliability specification, Xilinx introduced *excursion temperature* operation to certain devices. When properly used, expanded temperature headroom is allowed without sacrificing performance or reliability.

This white paper explains which devices support temperature excursion as well as how to use it for several applications.

Introduction

Temperature excursion is a device-specific allowance to operate at a higher-than-normal temperature for a specified maximum amount of time. For the Xilinx devices that support this feature, users can often set the maximum operating temperature at 10°C higher in situations where sustained operation at maximum ambient and/or maximum power is not expected. Standard Extended grade devices can maintain 0°C to 100°C continuous operation over a ten-year lifetime. Similarly, Industrial grade devices (generally used in outdoor applications) can maintain –40°C to 100°C continuous operation over a ten-year lifetime. Excursion temperatures allow such devices to operate between 100°C and 110°C for short periods of time.

Supported Devices

The devices in Table 1 are tested to meet the timing performance levels indicated by the Vivado® Design Suite, even when operating at up to 110°C. No additional settings or changes are needed within the Vivado tools other than selecting the proper speed grade. These devices have been characterized for operation in these extended temperature ranges for the specified duration of time (or less) and still meet their full lifetime specification of ten years operation.

Table 1: **Xilinx Devices Supporting Excursion Temperature Operation**

Device Family	Speed Grade	Operating Temperature		Excursion Duration
Virtex® UltraScale+™ Kintex® UltraScale+ Zynq® UltraScale+ RFSoC Zynq UltraScale+ MPSoC	-2LE	Continuous	0°C to 100°C	• 1% of lifetime (876 consecutive or accumulative hours)
		Excursion	100°C to 110°C	
Virtex UltraScale+ HBM[(1)]	-2LE	Continuous	0°C to 95°C	• 4.1% of lifetime (3,591 accumulative hours with no more than 96 consecutive hours)
		Excursion	100°C to 105°C	
Zynq UltraScale+ RFSoC	-2LI	Continuous	–40°C to 100°C	• 5% of lifetime (4,380 consecutive or accumulative hours)
		Excursion	100°C to 110°C	
Versal™ ACAP	-2E	Continuous	0°C to 100°C	• 3% of lifetime (2,628 consecutive or accumulative hours)
		Excursion	100°C to 110°C	
	-1I, -2I	Continuous	–40°C to 100°C	
		Excursion	100°C to 110°C	

Notes:

1. Pertains only to the HBM portion of the device. Refer to Virtex UltraScale+ for FPGA excursion specifications.

When to Use Excursion Temperature

There are multiple situations in which using the temperature excursion specification might result in an improved thermal design. Three of these scenarios are explained here.

Outdoor Operation

Applications that are deployed outdoors often experience large ambient temperature swings due to changing external conditions. Seasons usually dictate different daytime high temperatures; during night hours, both temperature and solar loading drop, allowing for cooler operation. Typically, maximum operating ambient temperatures are experienced only during a few hours of a few days each year—i.e., afternoon hours during the hottest summer month(s). Examples of temperature over the year can be obtained from multiple government agency websites. For example, Death Valley, California is one of the hottest places both in the United States and in the world. The yearly temperature data is depicted in Figure 1:

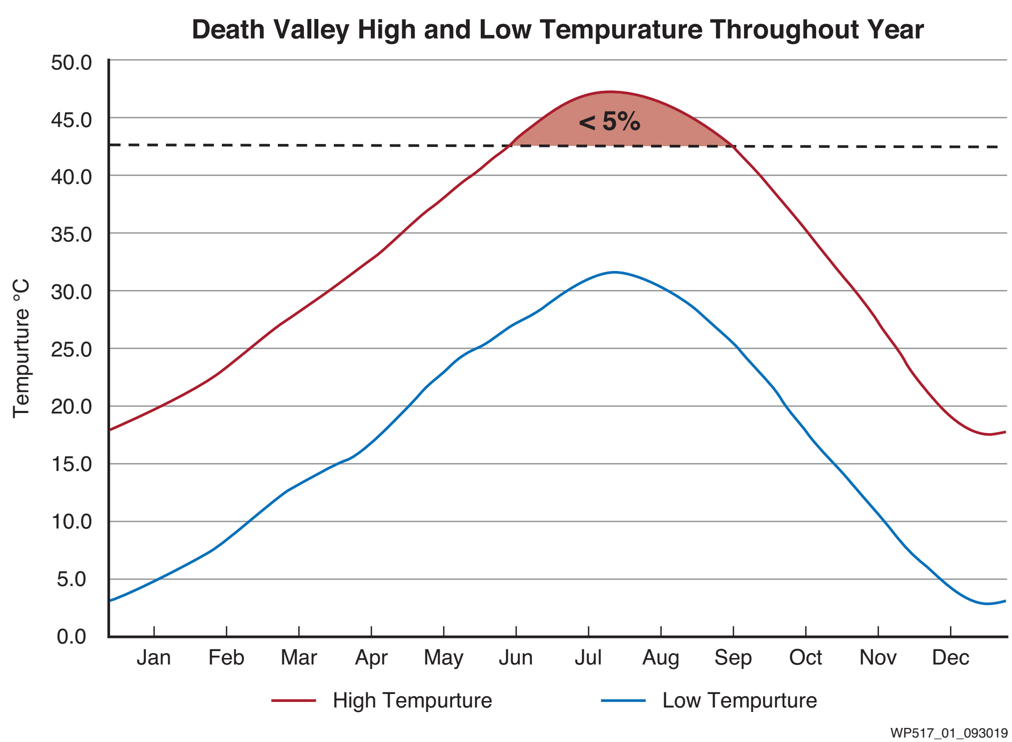

Figure 1: **Average High and Low Temperature throughout the Year in Death Valley, CA.** Temperatures remain above 43°C for less than 5% of the time. *Source: U.S Climate Data*

In Figure 1, the graph shows both a temperature swing of 30°C from summer to winter months, but also a greater than 15°C swing in temperature during the day in even the hottest months. The data shows that the temperature is expected to exceed 43°C less than 5% of the time, while the hottest temperatures are over 47°C. When using a Versal™ Industrial-grade device allowing for up to 110°C for 5% of the lifetime, an application deployed in this environment can be safely designed to an ambient temperature 4.5°C cooler. For environments with even steeper temperature changes, the full 10°C of permitted temperature excursion might be possible.

In the Event of Temporary Equipment Failure

Engineers can be required to design for a temporary equipment inefficiency or cooling fan failure where the local ambient temperature is expected to rise, but not for a sustained time. In this scenario, the temperature excursion can be used to allow continued operation of the device in elevated ambient conditions until the problem can be corrected. Some standards account for this situation, such as the Telecordia NEBs GR-63 standard used for telecom designs:

Table 2: **Telecordia Temperature Excursion Specifiction**

Conditions	Limits
Temperature:	
• Operating (up to 1,829m [6,000 ft]) • Short-term[1] • Short-term with fan failure	5°C to 40°C –5°C to 50°C –5°C to 50°C
Rates of Temperature Change:	
• Operating	30°C per hour
Relative Humidity:	
• Operating • Short-term[1]	5% to 85% 5% to 93%[2]

Notes:

1. Short-term refers to a period of not greater than 96 consecutive hours, and a total of not more than 15 days in 1 year. (This refers to a total of 360 hours in any given year, but not more than 15 occurrences during that 1-year period.)
2. Not to exceed 0.026 kg water per kg of dry air.

Table 2 lists a portion of the Telecordia specification where limited operation at 10°C above typical operating ambient is required. The excursion temperature specification allows the thermal designer to target a 40°C ambient condition or a 110°C junction temperature taking this limited operational specification into account.

Regardless of whether the design must adhere to a limited operation specifications like this, having this excursion temperature allows extra operating margin for unforeseen or rare occurrences like a fan outage.

For Brief Periods of High Compute

Many applications have variable processing and compute needs depending on the amount and type of data traffic presented to the device coupled with the compute needs of that situation. In many of these applications, peak power is only seen for small fractions of the overall operating time; thus, higher temperature resulting from this power dissipation is more rarely seen. For designs where short-term periods of extraordinarily high compute can be foreseen, it is possible to use temperature excursion to ease the thermal design.

Table 3: **Example Analysis: Power Dissipated under Various Operating Conditions**

Driving Scenario	Percentage of Time	Power	Operating Temperature at Max Ambient
 Parking Lot	10%	5.35W	81.4°C
 Street Driving	45%	7.93W	91.7°C
 Highway Driving	25%	8.94W	95.8°C
 Complex Highway	1%	10.52W	102.1°C
 Traffic Jam	17%	8.05W	92.2°C
 Bad Weather	2%	11.35W	105.4°C

Table 3 illustrates operating power varying for different compute conditions as input to a driving analysis application. It also computes the maximum junction temperature based on that operating power condition at maximum ambient temperature.

Most pertinent to this analysis, however, is the computed duration of each driving condition. It is found that the highest compute scenarios are not expected to occur for long periods of time during the lifetime of the application. Using this information, the thermal parameters can be favorably shifted to allow for an easier and potentially lower cost thermal design utilizing this temperature excursion.

These and other situations can also be combined to produce further improvements. For example, in the automotive power analysis scenario, maximum temperature is seen during a snow storm. However, it can be safely assumed that maximum ambient temperature never occurs in that situation. That being the case, even better operating margin could be seen with this next level of analysis. Cars also operate in an outdoor environment where many of these scenarios cannot be sustained at maximum ambient temperatures (i.e., driving at night or in the winter). Often when factoring in both the power dissipation and external operating conditions, it can be found that the expected maximum junction temperature of a device happens under fairly rare circumstances.

How to Use Excursion Temperature

Once it is determined that maximum operating temperatures should only occur within the device temperature excursion limits, then power estimation and thermal design analysis should be adjusted to account for this.

Early power estimation should be performed the same as if temperature excursion is not used—with one exception: The maximum operating temperature should be adjusted to the maximum expected junction temperature. In the case of using the full temperature excursion, that would be 110°C. To do this, in XPE the user simply specifies “User Override” in the Junction Temperature field and specifies the now-adjusted maximum junction temperature:

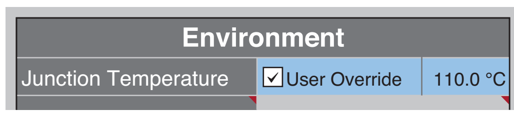

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Figure 2: **User Override Junction Temperature Setting in XPE**

The total power should now be adjusted to this specified junction temperature. The Total Power field in XPE turns yellow since this is out of typical operating range; however, as long as the maximum junction temperature is within the excursion temperature limits, this is considered a valid power estimation.

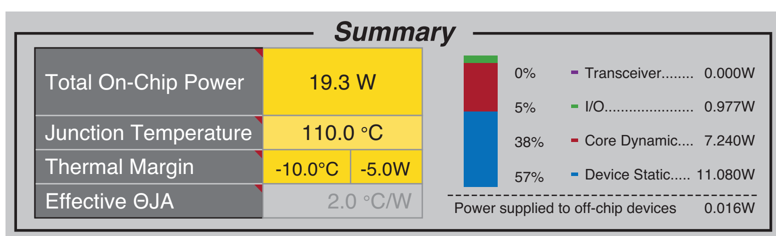

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Figure 3: **Example XPE Result When Using Temperature Excursion**

Once there is a high degree of confidence in the power estimation with the excursion temperature specified, the “Total On-Chip Power” value can be used for thermal simulation in the modeled environment with the Xilinx-supplied thermal model for the device. If an accurate thermal simulation can maintain junction temperature below the maximum anticipated excursion with adequate thermal margin, the thermal design can be considered complete.

Summary

Excursion temperatures can be used by many designs to raise the temperature ceiling of Xilinx devices, allowing for eased thermal design. With some simple design analysis, it can be determined if an excursion temperature can be used, and if so, straightforward adjustments to the power and thermal analysis allows for a reduced burden to maintain device operating temperatures. Even for designs where it cannot be accurately determined that an excursion temperature can be used, this favorable characteristic can be considered additional thermal margin for any design. However, those that can gain the full benefit of temperature excursion could enjoy results in a faster, cheaper, easier thermal design.

Revision History

The following table shows the revision history for this document:

Date	Version	Description of Revisions
10/23/2019	1.0	Initial Xilinx release.

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