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Upgrading the Zynq-7000Q AP SoC to Full Compliance with –55°C MIL /Aero Low-Temperature Specification

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Aerospace/Defense applications are undergoing an increasing demand for higher performance computing and higher bandwidth communication and processing that can operate within a full military temperature range environment (–55°C to +125°C). While embedded processing solutions are often a perfect fit for aerospace and defense performance requirements, not all embedded processors support start-up/operation at the extreme low-temperature end of the military specification.

This white paper introduces a thermal management concept to enable a low-temperature extension to the full specified military operating range for embedded devices.

Introduction

Xilinx leads the industry in providing All Programmable system integration solutions such as the Zynq®-7000 All Programmable SoC. This device family is offered in Commercial, Automotive, and Aerospace/Defense grades. The Automotive and Aerospace/Defense devices are available in both the industrial (I) and expanded (Q) temperature grades. For example, the Aerospace/Defense-grade Zynq-7000Q devices are fully tested and qualified for guaranteed operation across the full expanded temperature range of –40°C to +125°C.

Table 1 summarizes information about temperature grades and ranges offered within each device grade.

Table 1: **Operating Temperature Grades/Ranges for Zynq-7000 AP SoC Family**

Device Grade	Temperature Grade	Specified Operational Junction Temperature (Tj) Range
Commercial grade	C	0°C to +85°C
	I	–40°C to +100°C
Automotive grade	Q	–40°C to +125°C
Aerospace/Defense grade	I	–40°C to +100°C
	Q	–40°C to +125°C

The Zynq-7000 family is based on the Xilinx® All Programmable SoC architecture. These products integrate a feature-rich dual-core ARM® Cortex™-A9 based processing system (PS) and 28 nm Xilinx programmable logic (PL) fabric in a single device. The ARM Cortex-A9 CPU is the heart of the PS, which also includes on-chip memory, external memory interfaces, and a rich set of peripheral and connectivity interfaces.

Ambient and Junction Temperature Considerations

Low-Temperature Specification Differences within the Zynq-7000Q Device

While the Zynq-7000Q PL fabric (as well as all Xilinx 28 nm FPGA devices) is fully characterized across the Aerospace/Military temperatures range of –55°C to +125°C, the ARM Cortex-A9 and processor subsystem are not characterized at junction temperatures below –40°C. Therefore, because the ARM processor controls configuration of the PL, operation at ambient temperatures below –40°C requires the use of a thermal management system to allow start-up when Tj is below –40°C and maintain a junction operating temperature within the specified range for the entire device.To facilitate this requirement, all Zynq-7000 devices (including the Zynq-7000Q family) provide a built-in passive temperature-sensing diode accessible on pins TDP and TDN. These outputs measure the junction temperature of the device prior to, during, and after device power-on and configuration programming, and can thus be used as part of an efficient temperature control solution. An analog temperature control circuit that makes use of the Linear Technology LTC2997/6/5 (contact LTC for –55°C screening options) can be implemented, or a digital solution can be designed with a local temperature sensor such as the Maxim MAX6627/8, a device already characterized to support the full Aerospace/Military temperature range (–55°C to +125°C).

The temperature sensor conditioning method chosen — analog or digital — depends on various factors in the overall system design and, more specifically, whether fully autonomous operation or external digitally controlled operation is most appropriate to fulfill project needs.

A Simple Thermal Management System

A basic thermal management system is demonstrated in Figure 1 through Figure 3. While high-performance systems usually integrate a method for heat extraction and dissipation (typically, a heatsink), this system additionally incorporates an active heater (such as a polyimide), a temperature sensor, and a controller to maintain a minimum operating junction temperature.

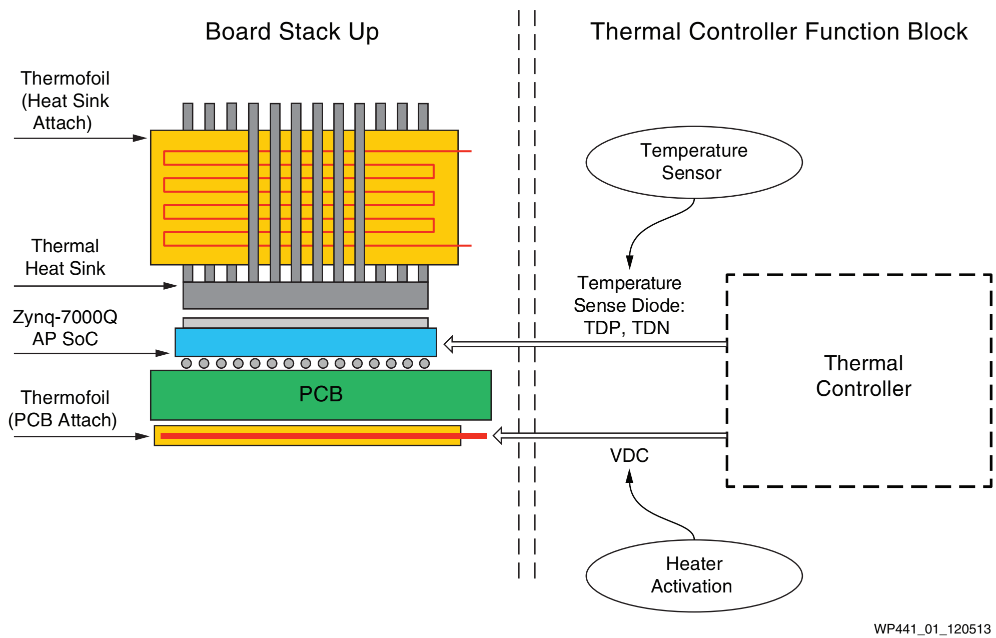

Figure 1: **Thermal Management System**

Either the analog or digital controller (Figure 2 and Figure 3) should facilitate the development of a simple algorithm to determine when to activate the thermofoil via a power MOSFET by comparing the output of the temperature sensor (T_S) to the desired settings (T_L and T_H). This allows maintenance of a minimum operating junction temperature for the Zynq-7000Q device. T_L and T_H represent the low and high boundaries of a hysteresis-defined guard band that facilitates smooth operation by absorbing fluctuations in the temperature sensor output.

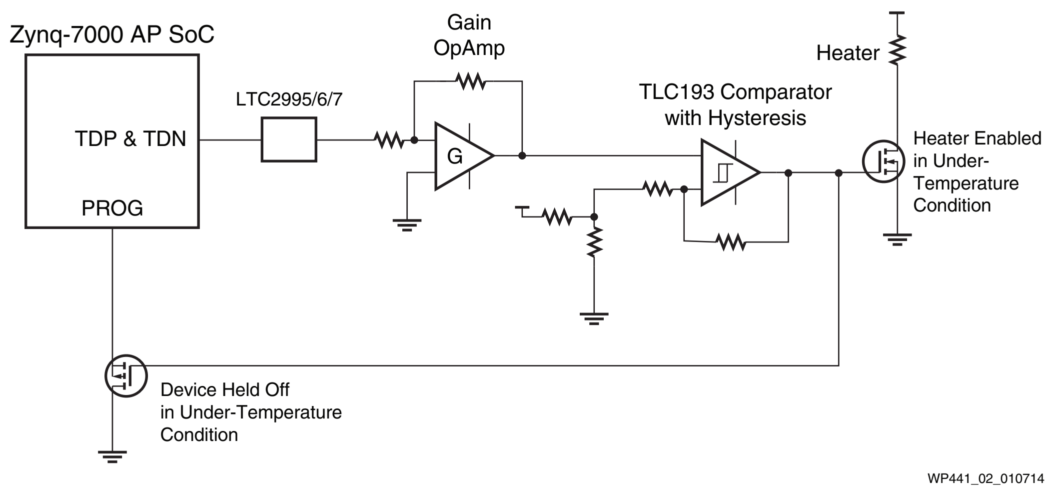

Figure 2: **Analog Temperature Reading and Thermal Controller Circuit**

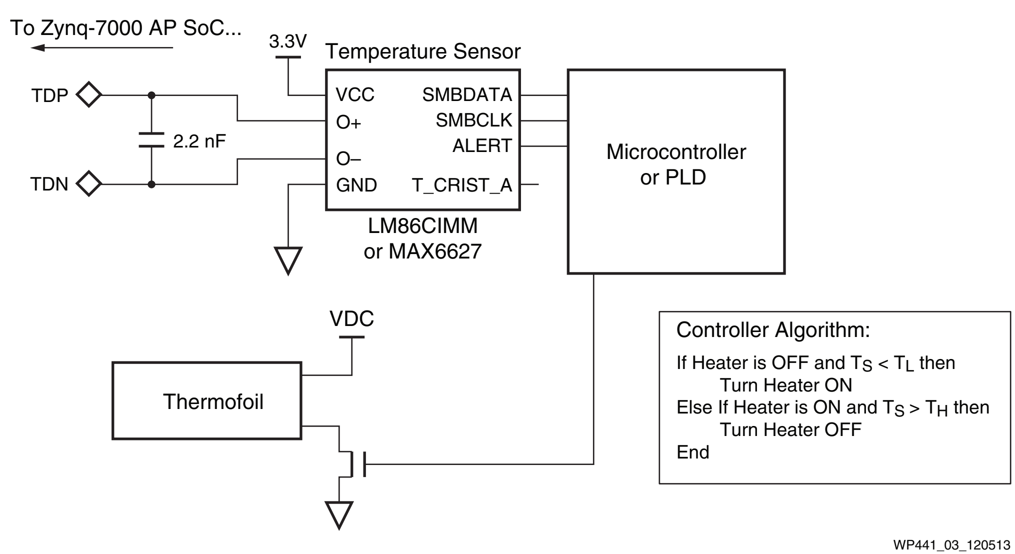

Figure 3: **Digital Temperature Reading and Thermal Controller Circuit**

As shown in Figure 4, when a decreasing T_S approaches T_L, the heater (thermofoil) is switched on until T_S is greater than T_H.

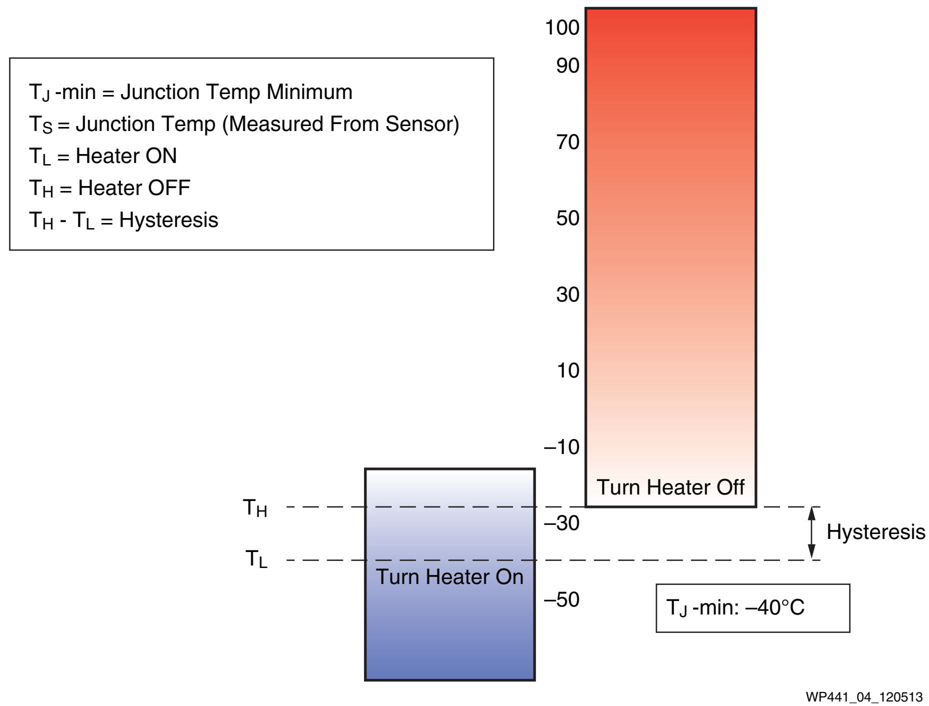

Figure 4: **Environmental Control and Hysteresis**

This example is targeted at keeping the Zynq-7000Q AP SoC within its junction temperature operational limits. The heater circuit activates and draws the SoC into a disabled state if the junction temperature is below the minimum operating temperature. Based on the application's operating characteristics, rate of ambient environmental fluctuations, and/or thermal response rate, the designer can choose to maintain a different minimum temperature window or change the hysteresis guard band size.

Table 2 and Table 3 provide some useful content to aid in assessing the applicability of the heater circuit option.

Table 2: **Thermofoil Heaters and Referenced Devices**

Manufacturer	URL
Watlow	**Polyimide flexible heater:** http://www.watlow.com/downloads/en/specsheets/colply0411.pdf http://www.watlow.com/products/heaters/polyimide-film-strip-heaters.cfm
Minco	**Polyimide flexible heater:** http://www.minco.com/~/media/WWW/Resource%20Library/Heaters/Polyimide%20Thermofoil%20Heater%20Tech%20Spec.ashx
Linear Technology	**Analog Output Temperature Sensor:** LTC 2997: http://www.linear.com/product/LTC2997 LTC 2996: http://www.linear.com/product/LTC2996 LTC 2995: http://www.linear.com/product/LTC2995
Maxim	**Digital Output Temperature Sensor:** MAX 6627/8: http://datasheets.maximintegrated.com/en/ds/MAX6627-MAX6628.pdf
Texas Instruments	**Comparator:** TLC193: http://www.ti.com/lit/ds/symlink/tlc193.pdf

Table 3: **Additional Information**

TITLE	URL
Zynq-7000 AP SoC Technical Documentation	http://www.xilinx.com/support/index.html/content/xilinx/en/supportNav/silicon_devices/soc/zynq-7000.html
Device Package User Guide (Xilinx)	http://www.xilinx.com/support/documentation/user_guides/ug112.pdf
Xilinx Temperature Sense Diode Answer Record	http://www.xilinx.com/support/answers/5738.htm

Summary

The Zynq-7000 family offers the flexibility and scalability of an FPGA, while providing performance, power, and ease of use typically associated with ASICs and ASSPs. The range of devices in the Zynq-7000 All Programmable SoC family allows designers to target both cost-sensitive and high-performance applications from a single platform using industry-standard tools.

The native Xilinx components in the Zynq-7000Q aerospace/defense device have always been rated over the full military temperature specification (–55°C to +125°C), but the embedded ARM Cortex-A9 processor core is rated only to –40°C, causing the Zynq-7000Q family specification to be downgraded to the same level.

Implementation of a simple analog or digital thermal management system, however, prevents the processor core temperature from dropping below –40°C when ambient temperatures fall below this level. A basic thermal management system incorporates an active heater, a temperature sensor, and a controller to maintain minimum operating junction temperature over the full military temperature specification during system start-up, configuration, and operation.

Revision History

The following table shows the revision history for this document:

Date	Version	Description of Revisions
01/06/14	1.0	Initial Xilinx release.
01/07/14	1.0.1	Typographical edit to label in Figure 2.
05/05/14	1.1	Updated Low-Temperature Specification Differences within the Zynq-7000Q Device.

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