Application Report
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AM570x Thermal Considerations

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ABSTRACT

This application report discusses thermal performance of the Sitara™ AM570x series processors. The data presented demonstrates the effects of different thermal management strategies in terms of processor junction temperature and power consumption across MPU loading and ambient temperature.

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Trademarks

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1 Overview

An internal AM570x board was used in this experiment to gather thermal data with different processor loading and ambient temperature. Ambient temperature was controlled with programmable environmental chamber.

The collected data can be utilized to correlate the thermal performance of the processor and power consumption at a given processor load and junction temperature, based on ambient temperature and thermal management.

Tests were repeated with the following thermal management:

- Bare package (no heatsink)
- Low-cost heatsink

2 Important Notes

The environmental chamber used to collect this data circulates air internally to maintain homogeneous internal temperature, and does not accurately simulate the environment on the bench or end product. This is important to consider in passive cooling applications where air circulation can significantly impact PCB, package, and heatsink power dissipation efficiency.

The data presented in this test was gathered with a typical device, representing nominal silicon process and leakage. Thermal performance and power consumption can vary significantly due to process variation. Extra margin must be designed in to account for worst case process variation (leakage).

3 Test Overview

The following CPU loading schemes were characterized with the internal AM570x board for this report.

3.1 OS Idle

The AM570x processor is idling after booting the out-of-box configuration of Processor SDK Linux® v04.02.00. No display was connected to the AM570x board. MPU, GPU, and IVA cores are powered but automatically clock gated while the DSP and IPU cores are both power and clock gated.

3.2 Dhrystone

Dhrystone is a single-threaded benchmark, capable of utilizing approximately 100% of one Arm® Cortex®-A15 core. Dhyrstone is included in the TI Processor SDK. Tests were conducted with the A15 running at 1.0 GHz (OPP_NOM).

3.3 Temperature Measurement

Reported temperature data is measured by on-die sensors to the approximate actual junction temperature. Temperature for each use-case is measured after soaking for 5 minutes. Under lab conditions, it was determined a 5 minute period allows the processor to reach stable temperature.

The TI Processor SDK provides Linux drivers for these sensors, and can be queried from the command-line, for example:

```
# cat /sys/class/thermal/thermal_zone0/temp
71800
```

3.4 OPP Definitions

Operating performance points (OPP) levels define a max frequency per fixed voltage level in each voltage domain. Table 1 lists frequency of each subsystem per OPP for the AM570x processor.

Dynamic Voltage Frequency Scaling (DVFS) refers to a software technique where the system-on-chip (SoC) supplies with AVS support are changed from one OPP level (voltage and frequency pair) to another in order to either adapt to a changing work-load, or in order to avoid device operation outside of desired temperature bounds.

This SoC does not support DVFS on any rails. OPP levels should be set during boot by the initial bootloader. Ensure that the selected OPP level meets the application's needs and all thermal testing is conducted at the desired OPP level.

Table 1. Supported OPP vs Max Frequency

Voltage Domain	Clock Domain	OPP_NOM Max Frequency (MHz)	OPP_HIGH Max Frequency (MHz)
VD_CORE	MPU_CLK	1000	N/A
	GPU_CLK	425.6	N/A
	CORE_IPUx_CLK	212.8	N/A
	L3_CLK	266	N/A
	DDR3 / DDR3L	667 (DDR3-1333)	N/A
VD_DSP	IVA_GCLK	388.3	532
	DSP_CLK	600	750

4 Data and Results

This section contains the raw data and graphs of the test experiments described above. All of the data was gathered running the latest Linux Processor SDK. All tests were conducted without an external display installed.

4.1 OPP Settings and Linux Thermal Framework

Tests were conducted with Processor SDK 04.02.00, with following default OPP levels:

Default OPP Levels			
MPU	**GPU**	**DSP**	**IVA**
NOM	NOM	HIGH	HIGH

The MPU, GPU, DSP and IVA cores are operating at fixed OPP levels. Only the OPP levels for DSP and IVA cores can be changed and that must be done by editing the U-Boot defconfig file with the desired OPP level and recompiling.

While not applicable to the AM570x, other devices can utilize the CPUFreq driver if they support multiple OPPs for the MPU domain. In that case, a desired max frequency must be set if seeking power consumption at a lower than max frequency.

Additionally, the Linux thermal framework needs to be disabled, otherwise, the max fequency is reduced as the MPU heats up to prevent thermal shutdown. This should only be done for data gathering purposes when the junction temperature exceeds the levels defined in the device tree and is not recommended for a production system.

4.2 Power and Thermal Chamber Measurements

The tables shown in the following sections contain power consumption and junction temperature measured running OS Idle and Dhrystone single-core use cases at different controlled ambient temperatures with and without an attached heatsink. This silicon process type is nominal. Dhrystone tests were repeated with MPU at OPP_NOM (1.0 GHz).

Junction temperature and power reported in the following sections were sampled at the same time, and are presented in separate tables to aid comprehension.

4.3 OS Idle

Therm Mgmt	Ta (°C)				
	25	**40**	**60**	**80**	**90**
No Heatsink (°C)	35	51	71	94	107
Heatsink (°C)	31	47	66	87	98

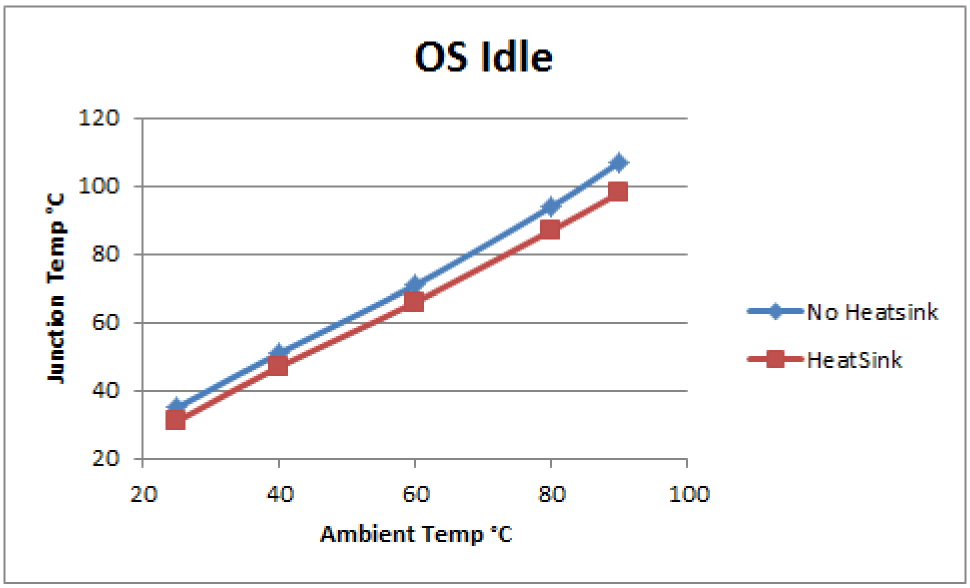

Figure 1. Junction Temperature vs Ambient Temperature

Therm Mgmt	Ta (°C)				
	25	40	60	80	90
No Heatsink (mW)	1338.2	1450.9	1700.6	2245.9	2684.1
Heatsink (mW)	1255.7	1427.4	1632.8	2004.0	2358.2

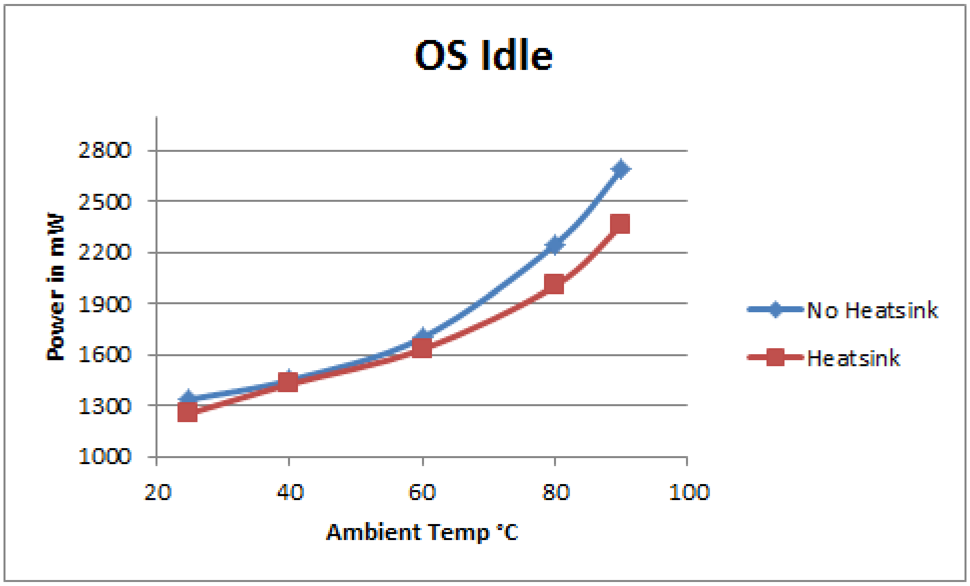

Figure 2. Power Consumption vs Ambient Temperature

4.4 Dhrystone

Therm Mgmt	Ta (°C)				
	25	40	60	80	90
No Heatsink (°C)	40	56	77	101	114
Heatsink (°C)	33	49	69	90	102

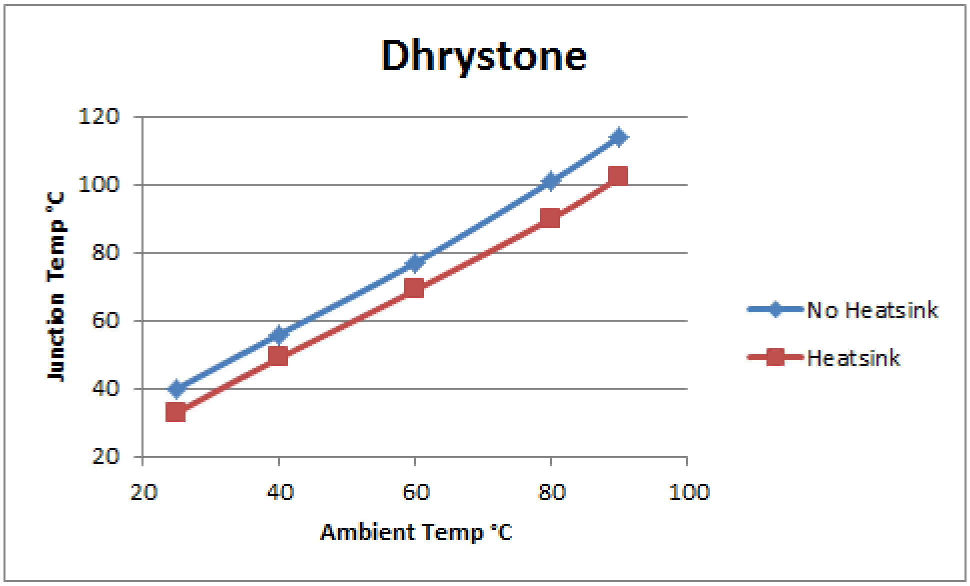

Figure 3. Junction Temperature vs Ambient Temperature

Therm Mgmt	Ta (°C)				
	25	40	60	80	90
No Heatsink (mW)	2198.7	2335.4	2682.8	3314.7	3893.5
Heatsink (mW)	2116.7	2281.7	2553.4	2980.5	3412.7

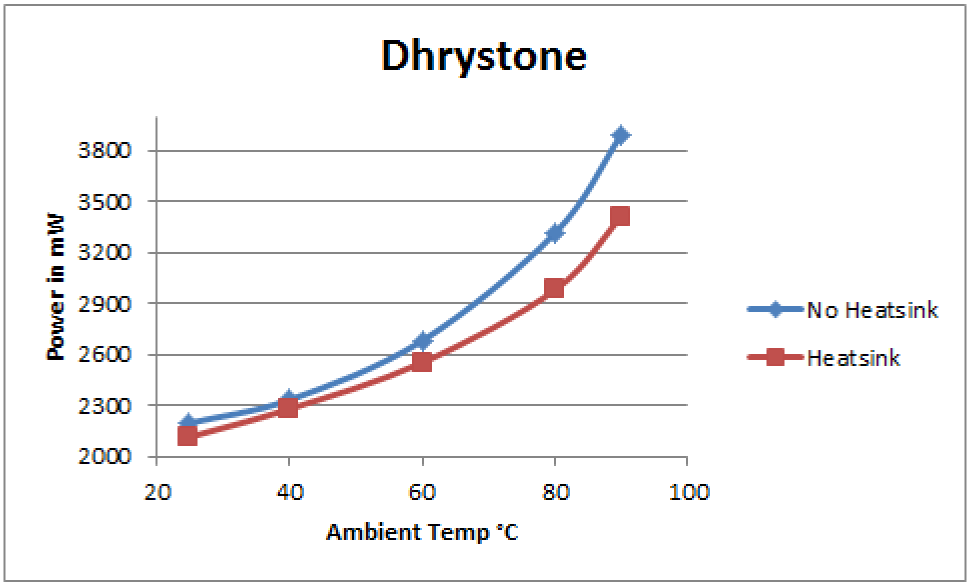

Figure 4. Power Consumption vs Ambient Temperature

5 References

- To learn more about thermal management, visit http://www.ti.com/thermal
- *Thermal Design Guide for DSP and ARM Application Processors*
- Thermal models can be found in the Models section of Tools and Software in the product folder: http://www.ti.com/product/AM5708/toolssoftware