Thermal Considerations for the Pentium® III processor at 550MHz Heatsinks & Airflow in ATX chassis

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1 INTRODUCTION

1.1 Overview

In various chassis the airflow will have different characteristics, these characteristics could have a possible effect on the performance of the Heatsinks used in the cooling of Pentium® III 550MHz microprocessors. This document will look at the airflow characteristics in two typical chassis and the effect this could have on the capacity of the Single Edge Contact Cartridge 2 (S.E.C.C.2) Organic Land Grid Array (OLGA), Heatsink to cool the processor. The type and specification of the heatsink and Thermal Interface Material (TIM) used will also need to be matched to the chassis airflow combination. All of the heatsinks tested were of the active type, in that a fan was fitted to the heatsink.

1.2 Background

As the power of motherboards and hardware increases, the requirement for the cooling capacity of any given system is increasing. The demand for quieter systems and stringent EMC regulations is causing an overall reduction in the capabilities of chassis to cope with this increase in thermal output.

The main source of cooling in a typical ATX system is the power supply unit (PSU). The PSU noise output has been reduced to meet noise emission requirements. The fan is the main contributor to this noise and the most effective way of reducing fan noise is to slow down the rotation of the fan blades, this has the effect of reducing airflow, so the PSU's ability to cool the ATX chassis has decreased.

Along with this reduction in PSU cooling power, the chassis have had to be designed to meet EMC emission regulations. The criteria for meeting EMC regulations is that the chassis should ideally be, fully enclosed with no gaps. Most chassis are not built fully enclosed but depending on the position and size of the chassis vents, this again can reduce the thermal management of the chassis with reduced airflow through the system.

The Pentium® III 550MHz microprocessor operates with a lower junction ($T_{junction}$) temperature than the previous 500MHz processors, the power density for OLGA packages is higher, due to the smaller die size, than the previous generation of Pentium® II processors, to meet this requirement extra cooling is required. Either the heatsink or the chassis must supply this cooling. This document will look at the requirements of the heatsink and airflow in 2 typical ATX chassis.

2 EQUIPMENT UNDER TEST (EUT)

2.1 EUT Configuration

representative ATX chassis were used for the testing of the Pentium® III 550MHz microprocessor and heatsink combinations configured as per **Error! Reference source not found.**.

Supplier	Description	Model/Part Number	Location
Chassis 1	ATX Mini Tower	N/A	N/A
Chassis 2	ATX Mini Tower	N/A	N/A
Seventeam* (Chassis 1)	ATX PSU	ST-251HR	Top Rear Chassis
Seasonic (Chassis 2)	ATX PSU	SS-235PS	Top Rear Chassis
Intel (IQL2794)	SE440BX-2 Motherboard	720938-208	N/A
Intel	Pentium® III Processor	80525PY550512	SL242
Memory Card Technology*	64MB 100MHz DIMM	PCSDRAM 374S823BTS	N/A
Teac*	Floppy Drive	FD-235HF	Top 3.5” Bay
Seagate*	H/D 9Gb 1” IDE	ST39140A	Bottom 3.5” Bay
Creative Labs*	x2 DVD ROM	DVD2240E	Top 5.25” Bay
Intel	i740 8MB AGP Card	N/A	AGP Slot
Diamond*	3DII Graphics Card	23150105-005	PCI Slot 3

Full Bios Revision	4S4EB2X0.86A.0017.P10
Socket Type	**SL242**
Add-in Card Slot Types	PCI, ISA, AGP
EUT Memory	3 X 64MB Dimm

Table 0-1 System configuration

2.2 Documentation References

2.2.1 Thermal support documentation

Supplier	Reference.
Intel	Application note, AP-586 Pentium® II Processor thermal design guidelines. June 1997
	Pentium® II Processor at 233, 266, 300 & 333MHz. June 1997
	Pentium® II Processor at 350, 400 & 450MHz. August 1998
	Pentium® II Processor specification update February 1999.
	Intel® Pentium® III Processor at 450, 500 and 550MHz. May 1999 P/N 244452-002
	Intel® Pentium® III Processor specification update May 1999. P/N 244453-003

Table 0-2 Support documentation.

2.3 Processor setup

Processor tested at 550/100MHz CPU/FSB speed.

No secondary fans were fitted in these chassis.

A standard fan was fitted in the PSU's. The PSU fans were extracting air from the Chassis.

2.4 Software utilities for stressing the Processor

Hi power stress software was utilized for these tests. The software was designed to run the processor core and the BSRAM L2 cache near to their respective maximum achievable power levels.

3 PENTIUM® III 550MHZ PROCESSOR HEATSINK COOLING

3.1 Setup

Thermocouples or the Maxim 1617 are attached to the specified components (see section 3.4) and the EUT is placed in a Thermal Chamber. During all thermal test runs thermal grease (Thermalcote II, Thermalloy Inc.) or a specified thermal interface material (TIM) was present between the EUT and it's Heatsink.

3.2 Equipment

The accuracy of the type "K" thermocouples used during this testing is +2.5/-0°C.

The accuracy of the Maxim 1617/Thermal diode is +/-3.0°C. With an off set of 4.8°C.

Supplier	**Description**	**Model/Part Number**	**Serial Number**
Thermotron	Thermal Chamber (walk in)	WP-499-THCM2-705	23065
Thermotron	Thermal Chamber	S-8SLE	24207
Cambridge Accusense	Airflow monitor	ATM-24	
Cambridge Accusense	Airflow probe	CAFS-220-5M	
Testo	Testo air volume flow tunnel	N/A	
Testo	Testo digital anemometer.	0560.4900	
Testo	Testo probe.	0635.1549	
Maxim	Thermal diode monitor	MAX1617EV	

Table 0-3 Thermal equipment.

3.3 EUT

See section 2

3.4 Method

Measurements were taken directly from the T_{plate}/T_{case}/T_{junc} or chassis of the EUT. The T_{junc} measurement is made via the thermal diode in the processor core and the Maxim 1617-evaluation kit, the T_{plate}/T_{case} measurements are made with type “K” thermocouples. The EUT was tested in a thermal chamber for 2 hours at a temperature of 35°C @ 35% Humidity, or until the EUT has reached thermal equilibrium.

KEY:

T_{plate} = Temperature measured at the point of contact between the metal plate on the processor and the heatsink attached.

T_{case} = Temperature measured at the point of contact between the case of the processor core or the case of the component under test and any heatsink attached to the component.

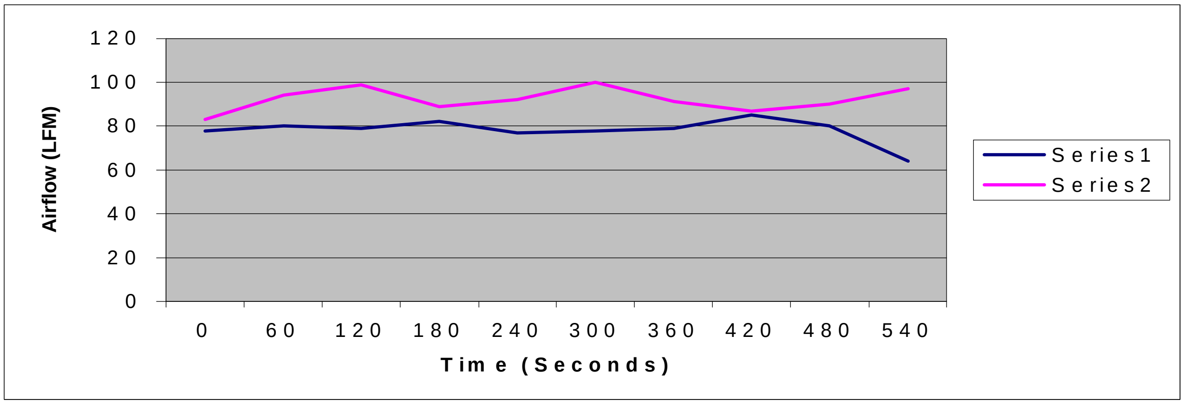
T_{junc} = Temperature measured by a diode built into the processor silicon.

3.5 Test results and Observations

3.5.1 Airflow tests

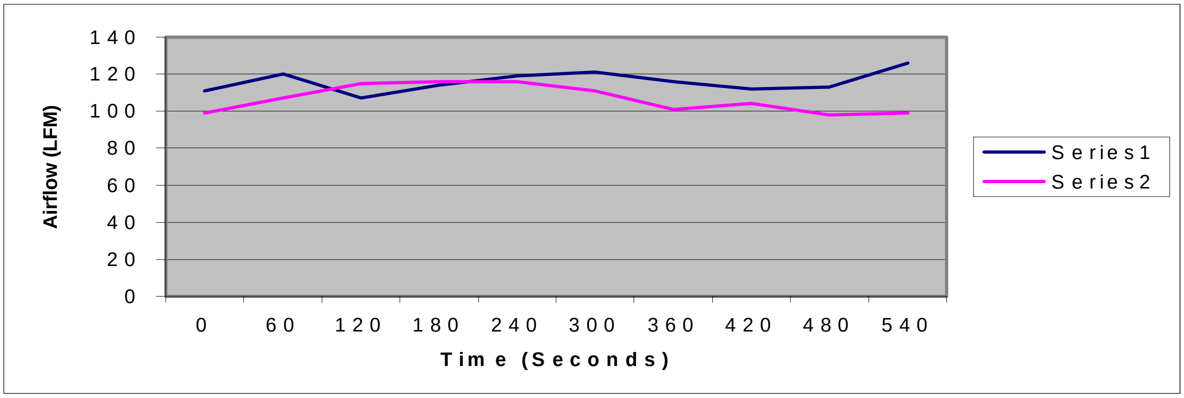
All airflow measurements are in Linear Feet / Minute (LFM). Please refer to Section 3.5.4 for probe placement.

3.5.2 Average Airflow for Chassis 1



Air Flow Probe	Position in Chassis.	Av. LFM
Series 1 (Probe 1)	Next to the PSU.	79.18
Series 2 (Probe 2)	On the nearest Dimm to the processor 5mm above the Dimm facing the processor.	92.82

3.5.3 Average Airflow for Chassis 2



Air Flow Probe	Position in Chassis.	Av. LFM
Series 1 (Probe 1)	Next to the PSU.	115.46
Series 2 (Probe 2)	On the nearest Dimm to the processor 5mm above the Dimm facing the processor.	103.76

3.5.4 Probe positions

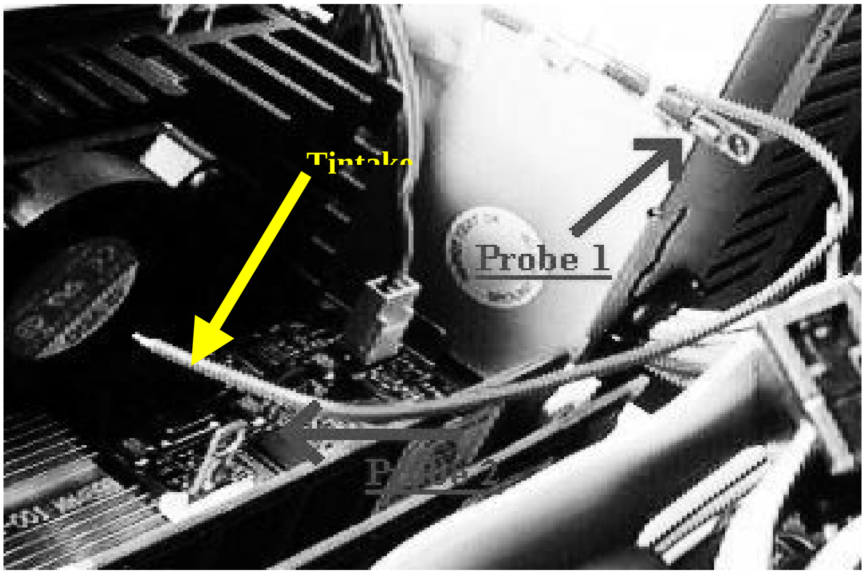


Figure 0-1 Chassis 1

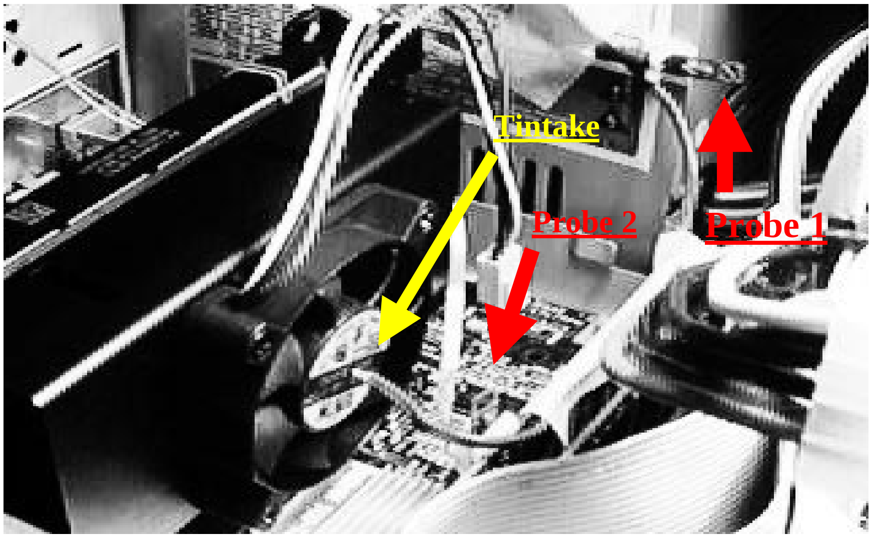


Figure 0-2 Chassis 2

Probe 1 = series 1
Probe 2 = series 2

NOTE.

The airflow measured by the probes below 30 LFM can be discounted as the accuracy of the probes is not guaranteed.

3.5.5 Airflow results

From the diagrams shown in the Airflow tests Section 3.5.1 it can be seen that the Average Airflow for Chassis 1 is 79 LFM for probe 1 and 92 LFM for probe 2, whereas the Average Airflow for Chassis 2 is 115 LFM and 103 LFM respectively. These averages are based on the airflow for all 5 of the heatsinks tested. This effectively highlights the effect of using the same heatsink in differing chassis. Both of the chassis had a similar internal layout but as shown in Table 2-1 System configuration, they used different PSU's.

For all heatsinks tested chassis 2 produced the lower $T_{junction}$ readings this reflects the higher average airflow through this chassis.

Average $T_{junction}$ for all 5 Heatsinks

Chassis 1	88°C
Chassis 2	79°C

The shape and design of the heatsink will have a marked effect on the airflow pattern seen. For example in chassis 1, one heatsink design, horizontal finned with ducting, gave 140 LFM for probe 1 and 84 LFM for probe 2. Where a vertical finned under the fan with 45° fin's either side, heatsink gave 21 LFM and 124 LFM. Similar results were seen for chassis 2.

3.5.6 Heatsink Mechanics

The design of the heatsink will play an important part in the overall thermal solution of the system. There are 2 basic heatsink shapes used for the Pentium® III Processor, Horizontal finned and Vertical finned. Also there are various thermal interface materials (TIM) used by the different heatsink manufacturers.

In separate tests it was found that for low profile systems (micro (µ)NLX etc.) the horizontal finned heatsink out performs the vertical. For ATX chassis as used for these tests neither horizontal of vertical finned heatsinks showed any discernable advantage over the other. The main difference noted was the interaction of the heatsink fan exhaust with the chassis airflow and the effect on the processor $T_{junction}$ temperature. See Section 3.5.5.

As an extreme example of the problems caused by using a poorly specified heatsink with very low thermal conductance TIM, a test was carried out in chassis 1. The active heatsink used was a Pentium® II heatsink designed to fit on the Tplate of the Pentium® II processor. An interposer was designed to adapt this heatsink to the Pentium® III OLGA package. When assembled the processor core was touching the TIM of the interposer the interposer was touching the TIM of the active part of the heatsink.

From cold it only required 34 seconds for the processor $T_{junction}$ temperature to reach 127°C, the limit of the Maxim test equipment in use. The $T_{junction}$ temperature maximum specification is 80°C. This heatsink is a real, currently available heatsink.

The type of TIM used by the heatsink manufacturer is a very important part of the heatsink specification, in the tests carried out a difference of 15°C was noted on one heatsink, if the pressure of the retention mechanism was increased. For this processor the pressure of the TIM to the processor core was insufficient for maximum heat transfer. In general the graphite type materials require a higher clamping force than the white tape materials. Caution should be used here that the clamping force does not exceed the specification for the Pentium® III Processor. In a separate test using chassis 1, a difference of 6ºC in $T_{junction}$ temperature was noted for the same heatsink using TIM from different manufactures.

The clip arrangement for the heatsink should be matched to the motherboard the heatsink will be used with, as the retention mechanism for some heatsinks could foul components behind the SL242 processor slot.

4 SUMMARY

The choice of heatsink should be matched to the chassis. If using a µNLX or similar type chassis then horizontal finned heatsinks are more suitable. For larger chassis then either horizontal of vertical heatsinks could be used.

For all chassis the type of heatsink and TIM used is crucial to the overall performance of the thermal solution. The fan exhaust from the heatsink will interact with the chassis airflow or visa versa. The result of this interaction could be to the benefit of the cooling solution but equally it could do the opposite and degrade the solution.

The only certain way to match a heatsink to the chassis is to carry out experiments with a range of heatsinks either from the same manufacturer or from different manufacturers. Alternatively if only 1 heatsink solution is available then test this solution with a range of different TIM’s.

Care should be taken when choosing the heatsink to ensure the retention mechanism will not make contact with any components around the processor and that the clamping force exerted by the mechanism will not exceed the maximum allowable for the processor core.

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