Application note

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Related Products	ETX-PM

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1. TABLE OF CONTENTS

2. BASIC INFORMATION

In order to use the high performance ETX modules listed below in the table you must ensure that a proper cooling solution for the CPU and chipset is used in order to meet the thermal specification outlined in the ETX-PM User Guide.

It is important to maintain the case temperature within the specification for normal operation. Some potential problems may arise if this specification is not followed. If for example the specification is exceeded this could possibly lead to functional failures as well as damage to the device. In some cases it could even result in a reduction of long term reliability.

article number	name	CPU power @ 100% workload under XP	ETX power @ 100% workload under XP	CPU thermal specification
18008-0000-13-1	ETX-PM 1.3GHz	24.5W	36W	0°C - +100°C
18008-0000-16-0	ETX-PM 1.6GHz	24.5W	42W	0°C - +100°C
18008-0000-18-0	ETX-PM 1.8GHz	21.5W	33W	0°C - +100°C

The heatspreader supplied with the board was designed to spread the dissipated heat and to offer the customer a thermal interface for their cooling solution. The limits of the heatspreader are at about 25 W power dissipation of the module depending on the cooling solution attached to the heatspreader.
When the performance and power dissipation increases, the heatspreader comes close to its efficiency limits. The heatspreader was designed to balance mechanical tolerances of the CPU die surface height to ensure a constant ETX module height specification. To meet these requirements Kontron has had to use compressible materials as a heat stack between the CPU and heatspreader, which leads to a compromise between hardness of the material and thermal conductivity.

The ETX-PM 1.6GHz and 1.8GHz variants mentioned in the above list can only be operated with the supplied heatspreader in low frequency modes, which are set by default during manufacturing. In the BIOS setup it is possible to increase the performance level to max frequency but you must ensure that a proper cooling solution is used.

The ETX-PM Celeron 1.3GHz does not have this ability to use lower performance modes and therefore is unable to operate with the supplied heatspreader as its only means of thermal interface.

For more information about this subject please refer to the ETX-PM User Guide.

In order to maintain the case temperature within specification the best solution is an effective thermal management system. The temperature of the processor case is not only dependent on the thermal characteristics and power dissipation of the processor but also the internal ambient temperature and air velocity. The internal ambient temperature is influenced by many contributing factors such as the thermal characteristics of the chassis, external ambient temperatures, electronic components, and peripherals. The thermal management system consists of integral parts and design considerations. For example the parts involved may be heatsinks, heatsink clips, fans, and thermal interface materials. Design considerations may involve chassis ventilation and component placement.

This application note is intended to provide a system designer some guidelines for developing an effective thermal solution for ETX-PM.

The following symbols and formulas were used for the calculations contained within this application note.

Symbol Definitions:

Power	P_{th}	[W]
Temperature	T	[K]
	ϑ	[°C]

Temperature Difference	ΔT	[K]
	$\Delta \vartheta$	[K]

Formulas:

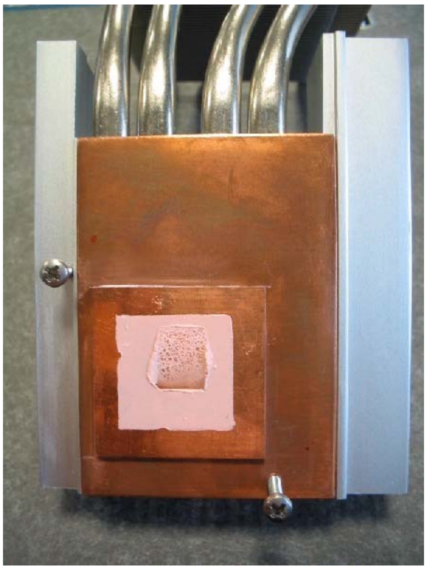
Thermal Resistance	$R_{th} = \frac{\Delta T}{P_{th}}$	$\left[\frac{K}{W}\right]$
e.g. R_{th} case-to-ambience	θ_{CA}	$\left[\frac{K}{W}\right]$
Thermal Conductivity	$\lambda = \frac{P_{th}}{\Delta T \cdot l}$	$\left[\frac{W}{m \cdot K}\right]$

3. THERMAL SOLUTIONS

To ensure the customer can operate the high performance boards together with our Eval system we have done some evaluation of standard cooling components in order to verify their ability to meet the necessary cooling requirements.

3.1. ETX-PM Shuttle Heatpipe PH4

To dissipate the CPU power of about 24W during 100% workload a high efficient active cooling device has to be used.
For the following measurements we have used the Shuttle PH4 Heatpipe assembly.



To mount the heatpipe assembly to the ETX some mounting holes had to be added as shown in the above picture.

3.1.1. Static measurements:

1. **Measurement:** the fan is connected to 12V,
   System settling time: 30 minutes

Measurement location	Temperature [°C]
ambience	24
radiator	31
CPU heatsink	36
CPU die	69

2. **Measurement:** the fan is connected to the 5V fan control connector on the ETX module
   System settling time: 30 minutes, active trip point 94°C

Measurement location	Temperature [°C]
ambience	24
radiator	53
CPU heatsink	57
CPU die	83

3.1.2. Static State Calculations

The following equations are based on a thermal model, which does not consider all thermal junctions, yet this approximation is accurate enough for the thermal design.
To gain e.g. 40°C ambience temperature you need to have an overall thermal resistance which is low enough to keep the CPU temp below spec. values.

Given:

$T_{amb} := 24\ ^\circ C$	ambience temp.
$T_{ambmax} := 40\ ^\circ C$	max. ambience temp.
$T_{radiator} := 53\ ^\circ C$	radiator & fan assembly temp.
$T_{heatsink} := 57\ ^\circ C$	CPU heatsink temp.
$T_{cpu} := 83\ ^\circ C$	CPU die temp.
$T_{cpumax} := 100\ ^\circ C$	max. CPU die temp.
$A_{die} := 10\ mm \times 7\ mm$	CPU die surface area
$P_{max} := 24\ W$	CPU thermal design power

Calculate the max. allowed temperature difference between max. ambience and max. CPU:

$$\Delta T_{total} := T_{cpumax} - T_{ambmax} \qquad \Delta T_{total} = 60 K$$

$$R_{total} := \frac{\Delta T_{total}}{P_{max}} \qquad R_{total} = 2.5 \frac{K}{W}$$

As we see our cooling solution should have a total thermal resistance of 2.5K/W or better.

The total thermal resistance is split up into 3 thermal junctions

- R_{dc}: case to heatsink
- R_{th}: heatsink to radiator
- R_{ha}: radiator to ambience

We will not take into consideration that the PCB will also radiate heat because it is negligible.

The different junctions calculate to:

$$R_{dc} := 0.03 \frac{K \cdot in^2}{W} \cdot \frac{1}{A_{die}} \qquad R_{dc} = 0.28 \frac{K}{W}$$

ThermFlow T725,
cpu to heatsink

$$R_{th} := 0.08 \frac{K \cdot in^2}{W} \cdot \frac{1}{A_{die}} \qquad R_{th} = 0.74 \frac{K}{W}$$

Heatpipe Shuttle PH4,
heatsink to radiator

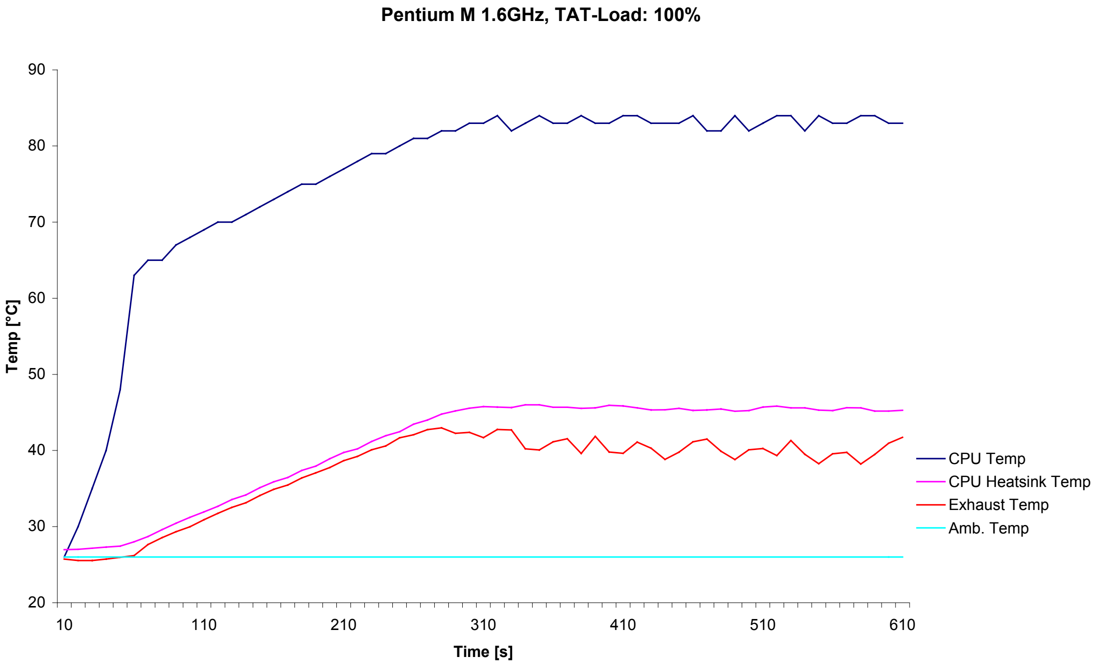
$$R_{ha} := \frac{T_{radiator} - T_{amb}}{P_{max}} \qquad R_{ha} = 1.21 \frac{K}{W}$$

Radiator to ambience,
measured value

$$R_{total} := R_{dc} + R_{th} + R_{ha} \qquad R_{total} = 2.22 \frac{K}{W}$$

The measured values show a total thermal resistance of 2.2 K/W, which is lower then, the above-calculated value. This means that this particular cooling solution meets our needs.

3.1.3. Dynamic measurements:

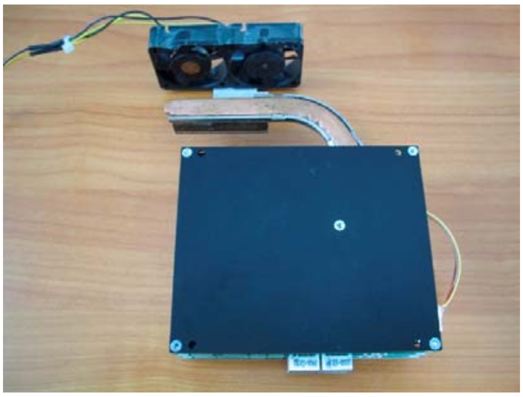


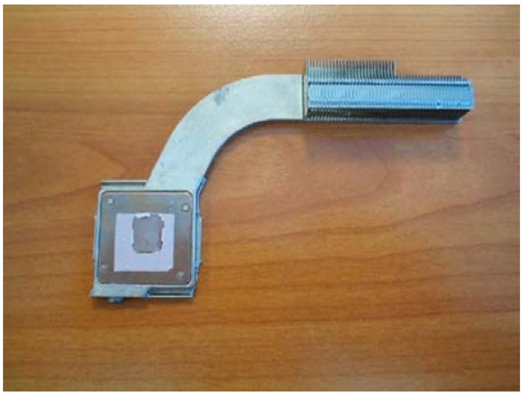
3.2. ETX-PM custom specific Notebook-Heatpipe

The heatpipe pictured below was supplied by Auras and made available to Kontron for testing purposes only.

If you require information about availability and purchasing of heatpipes for your thermal management system you can contact:

Auras at http://www.auras.com.tw
AVC at http://www.avc.com.tw





3.2.1. Static measurements:

Unfortunately we don’t have any technical documentation for this particular heatpipe assembly therefore no calculations can be made.

1. **Measurement:** the fan is connected to 5V, constant on
   System settling time: 30 minutes

Measurement location	Temperature [°C]
ambience	25
radiator	30
CPU heatsink	65
CPU die	88

2. **Measurement:** the fan is connected to the 5V fan control connector on the ETX module
System settling time: 30 minutes, active trip point 94°C

Measurement location	Temperature [°C]
ambience	25
radiator	42
CPU heatsink	62
CPU die	94

3.2.2. Dynamic measurements:

Fan active:

Time [s]	Temperature [°C]
0	100
30	95
60	90

Fan inactive:

Time [s]	Temperature [°C]
0	90
15	95
30	100

4. CONCLUSION

The information provided within this application note is strictly intended to be used as a guideline for designing a proper thermal management system. Although only two examples of possible solutions have been provided within this application note the formulas used for the calculations can be used to evaluate any prospective cooling solution.