Thermal Guidelines for ETX 802

ETX modules are an example of a growing trend of system OEMs and integrators using Computer-On-Module (COM) technology in their designs instead of either SBCs (Single Board Computers) or full custom designs. The COM approach allows the OEM to focus on added value and core competency with I/O, form factors, and integration rather than re-inventing the wheel with x86 CPU design. OEMs benefit from faster time-to-market, not having to design and debug the CPU, as well as future technology insertion with newer CPUs in the future.

Thermal Guidelines

The performance of the thermal solution depends on many parameters, including the processor's:

- Thermal design power (TDP)
- Maximum junction temperature
- Operating ambient temperature
- System airflow

According to Intel®, for Pentium® M processors, the thermal performance required is determined by calculating the junction-to-ambient thermal resistance Ψ_{JA}. This is a basic thermal engineering parameter that is used to evaluate and compare different thermal solutions. Intel's example for a high TDP processor (1.8GHz) calculated at a modest ambient temperature is:

$$\Psi_{JA} = \frac{T_{Jmax}\,°C - T_{LA}\,°C}{TDP(W)} = \frac{100°C - 50°C}{21.0W} = 2.38\,\frac{°C}{W}$$

Figure 1 further illustrates the required thermal performance for the Intel Pentium M Processor 745 (1.8GHz) at different operating ambient temperatures. The thermal solution used to cool the processor must have a junction-to-ambient thermal resistance less than or equal to the values shown for the given local ambient temperature.

The thermal resistance from junction to ambient is a sum of thermal resistance from junction to case, thermal resistance of the thermal adhesive (tape) and the thermal resistance from heat spreader/heat sink to ambient.

$\Psi_{JA} = \Psi_d + \Psi_t + \Psi_h$

Ψ_{JA} = thermal resistance from junction to ambient

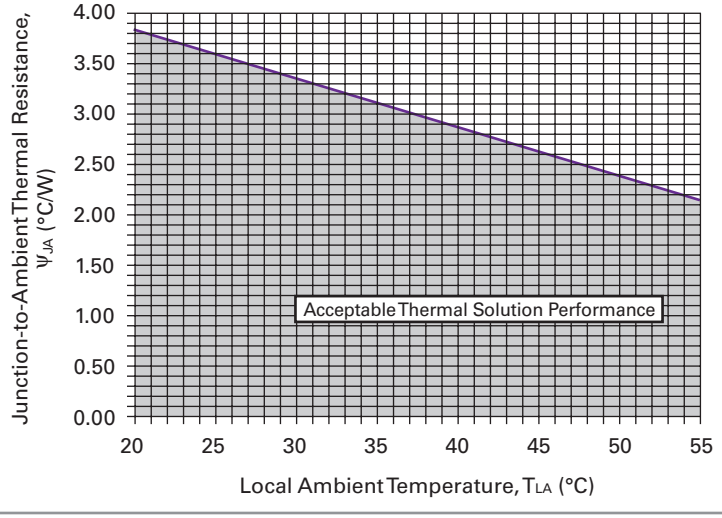
Ψ_d = thermal resistance from junction to case

Ψ_t = thermal resistance of the thermal adhesive (tape)

Ψ_h = thermal resistance from heat spreader/heat sink to ambient

The thermal resistance of thermattach T_{410} and T_{411} as provided by Chomerics is 1.1 and 1.0 respectively.

FIGURE 1



Junction to Case Thermal Resistance Calculation

The dimensions of the die (as modeled by Intel) are 10.0mm x 7.5 mm x 0.84mm where t, the thickness is 0.84mm.

The thermal conductivity K of the die (provided by Intel) is 120 W/(m.K).

The thermal coefficient of resistance is t/K per m^2.

The thermal resistance of the die (junction to case) is (t/K) / A where A is the area of the die.

Deriving from the above equation, the thermal resistance from the junction to case is:

$\Psi_d = (t/K) / A = (0.84 * 10^{-3}/120) / (10 * 10^{-3} * 7.5 * 10^{-3}) = 0.09°C/W$

Heatsink/Heat Spreader to Ambient Thermal Resistance Calculation

Deriving from the above equations, the thermal resistance from heat spreader/heatsink to ambient for a moderate ambient temperature of 70°C is:

$$\Psi_h = ((T_{JMAX} - T_{LA})/TDP) - (\Psi_d + \Psi_t)$$
$$= ((100 - 70)/10) - (0.09 + 1.1)$$
$$= 3.0 - 1.19$$
$$= 1.81°C/W$$

The above is the maximum thermal resistance from heatsink/heat spreader to ambient for the assumed ambient temperature.

The thermal solution used to cool the processor must have a heat spreader/heatsink-to-ambient thermal resistance less than or equal to the values shown above for the given local ambient temperature. †

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Ampro's Approach

Ampro supports the latest low power processors for the rugged environment so that it's not necessary to design a custom heat pipe thermal solution design. In addition, Ampro Uses a 50% thicker PCB (2.3mm / 0.093" instead of 1.6mm / 0.062") to absorb and spread the heat by conduction through power pins to copper in the circuit board.

Offers a choice of FX8 (short) and FX8C (tall) connectors on the module to increase the volume occupied by the entire assembly and reduce the power density.

The processors supported on ETX 802 are shown in the table to the right, along with their power consumption.

Ampro offers a choice of heat sink or a copper heat spreader for ETX 802 as shown in figure 2a and 2b on the right.

Ampro recommends heat sink as long as there is enough clearance in the system design for 1-inch (2.5cm) heat sinks. With a moderate amount of air flow, heat sinks can provide a complete thermal solution. The heat spreader approach offers the benefit of lower overall system height, but has the disadvantage of requiring active heat removal from the surface of the heat spreader. Therefore, the heat spreader by itself is not a complete thermal solution.

Thermal Calculations

Applying the equation to Ampro's design confirms that 100 Linear Feet per Minute (LFM) is more than adequate to operate the ETX 802 module within Intel's specifications.

The thermal solution Ampro selected for use with the Intel Pentium M Processor (RJ80536LC0172M) is the Radian Intercast Heatsink (INM35002-25P/2.6BU+T725). The projected performance with the heat sink based on the above calculation is (see right):

Model	Connectors	Processor	CPU TDP	Overall Module*	CPU Tjmax
ET1-802-R-08	FX8 (short)	800MHz ULV Celeron M	5.5W	13W	100°C
ET1-802-R-09	FX8C (tall)	800MHz ULV Celeron M	5.5W	13W	100°C
ET1-802-R-12	FX8 (short)	1.0GHz ULV Pentium M	5.5W	14.5W	100°C
ET1-802-R-13	FX8C (tall)	1.0GHz ULV Pentium M	5.5W	14.5W	100°C
ET1-802-R-22	FX8 (short)	1.4GHz LV Pentium M	10W	19W	100°C
ET1-802-R-23	FX8C (tall)	1.4GHz LV Pentium M	10W	19W	100°C

* With 128MB RAM, 100% loaded.

Figure 2a: ETX802 with heat sink

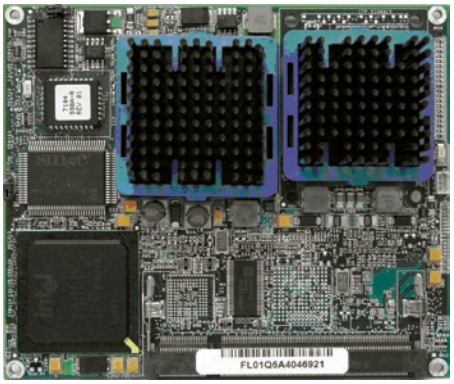
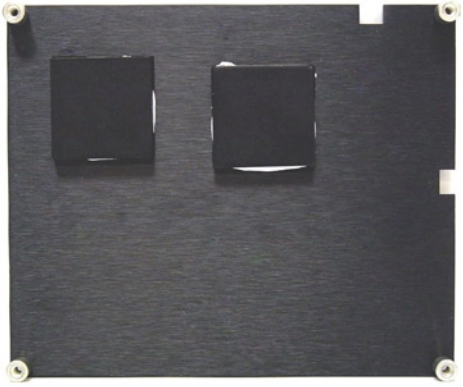


Figure 2b: ETX802 with heat spreader



$$\frac{T_J \text{ Max } °C - T_{LA} °C}{TDP\ (W)} = °C/W$$

$$\frac{100 - 70}{10} = 3\ °C/W$$

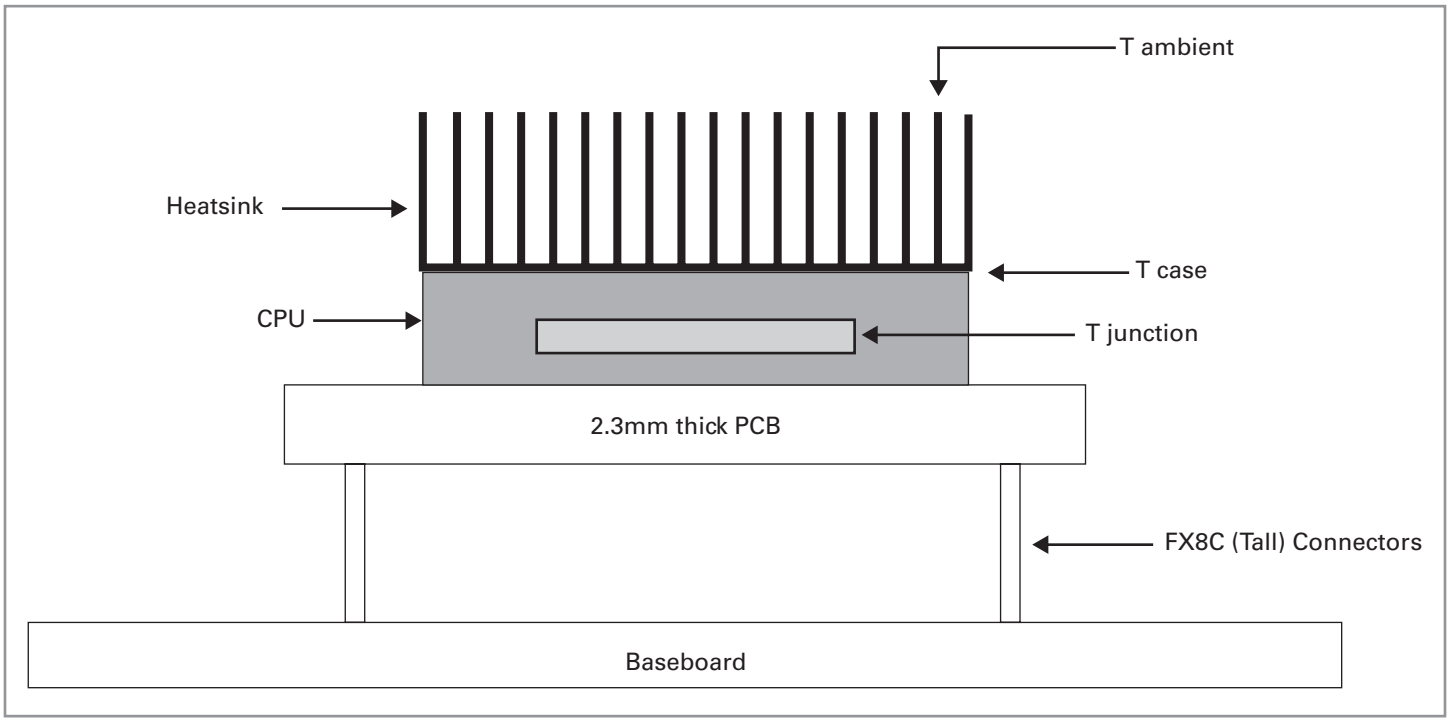
T_J = Thermal Junction Temperature
T_{LA} = Local Ambient Temperature
TDP = Total Disapated Power

Thermal Resistance (°C/W)					
Heat sink part number	100lfm	200lfm	300lfm	500lfm	700lfm
INM35002-25P/2.6	2.580	1.718	1.399	1.111	0.974

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FIGURE 3



Using Intel's formula for calculating the maximum thermal resistance allowable given the following conditions, ambient air temperature of 70°C, system airflow of 100LFM and the processor with a TDP of 10 Watts, we arrive at a maximum value of 3.0°C/W which exceeds 2.580°C/W.

Ampro's modules ship with the processor running at its full rated speed in the BIOS with the simple thermal solution as described in Figure 3 above. It is not necessary to pay more and clock down expensive CPUs to run at lower speed because of heat concerns.

Alternate Approaches

Alternatively, OEMs can design their own custom thermal solutions using the equation and example above and Ampro provides the ETX 802 module without heat sink installed for that purpose.

Because of Ampro's CPU selection (lower power) for rugged ETX modules, a heat pipe design is generally not necessary.

† Good approximations are achieved by performing these calculations, but they are only approximations. To achieve greater precision, thermal modeling software is recommended, such as the tools that Ampro uses in developing custom enclosure solutions. If you are an embedded system manufacturer and would like to discuss a customized thermal solution or a complete custom system with enclosure, please send your project details to sales@ampro.com to the attention of Ampro's Custom Solutions department. International customers can contact their local Ampro distributor.

About Ampro Computers, Inc.

Ampro Computers, Inc. is the leading global provider of modular embedded computing solutions for OEM applications. Ampro's mission is to provide time saving solutions for embedded systems designers that accelerate the product deployment process. Ampro pioneered the embedded PC industry creating the popular PC/104 and EBX standards, and recently co-invented the new EPIC standard. The ETX family is the first rugged Computers-on-Module (COM) solution which enables designers to obtain all the benefits of an off-the-shelf CPU solution while maintaining the flexibility of a full custom design. In addition to ETX, Ampro offers PC/104-compatible CoreModule CPUs and MiniModule expansion products, EBX form factor LittleBoard single-board computers (SBCs), EPIC form factor ReadyBoard SBCs, and Mini-ITX form factor MightyBoard SBCs, XTX Computer-On-Moudles and complete turnkey computer and Panel PC solutions.

For more information about Ampro visit www.ampro.com.

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