System Considerations for Dual AMD Athlon™ MP Processors in Tower and 1U Form Factors
Outline

• Introduction
• AMD Athlon™ MP processor power roadmap
• Thermal test methodology
• Tower chassis form factor
  – Chassis vendors and models
  – Power supplies
  – Heat sinks
  – Thermal test results
• 1U drawer form factor
  – Recommended 1U drawer floor plan
  – Heat sinks
  – Thermal test results
• Summary
Introduction

- **AMD-760\textsuperscript{TM}MP chipset**
- Support for two AMD Athlon\textsuperscript{TM} MP processors
- Support for 200 MHz and 266 MHz front-side bus
- Support for up to 3 GB PC2100 registered DDR RAM
- Extended ATX Form Factor
- AGP Pro slot, five 64-Bit PCI slots, VGA slot
- One serial port, one parallel port, two USB (four through optional cable), PS2 keyboard and mouse connections
- Up to four Enhanced IDE devices
- Dual 3COM LAN controllers
- Integrated ATI Rage XL graphics accelerator
AMD Athlon™ Processor Power Roadmap

Max Thermal Power (W)

AMD Athlon processor

AMD Athlon MP processor

Frequency (MHz)
Thermal Requirements

• Processor die temperature should not exceed the maximum temperature specification (90°C or 95°C).

• 35°C external ambient

• Maximum thermal power at specification

• Northbridge, power FETs, and other components in system should not exceed their temperature specifications.
Overview

• Single processor
  – Software—Maxtherm Option F run under DOS
  – Use single-processor thermal test Excel spreadsheet for analysis

• Dual processor
  – Software—BurnK6
    • Run two instances under Windows® OS
    • Run two instances for Linux OS (under two logins)
  – Available at http://users.ev1.net/~redelm/
  – Use dual-processor thermal test Excel spreadsheet for analysis

• Power dissipation: calibrate one or two processors
  – As function of software, voltage, and temperature
  – Run one test with one set of processors
  – Analyze data versus power specification

• Thermocouple locations of interest
Test Methodology

• Measurements taken at room temperature
  – Temperature-controlled fans in power supply are run with voltage at 35°C setting.

• Software used to power processor
  – Single processor tests use Maxtherm Option
  – Dual processor tests utilize either BurnK6 freeware or other software

• Thermocouples placed at following locations:
  – Back of ceramic of PGA package for each processor
  – Heat sink base for each processor
  – Ambient for each processor
  – FET case for each processor
  – Under motherboard at Northbridge
  – Power supply exhaust
  – System fan exhaust (if applicable)
  – External ambient

• Vcc core feedback monitored for each processor
Test Methodology (...cont.)

• Power supply fan voltage is monitored or set at voltage at which it would run at maximum external ambient temperature.

• Determination of processor power consumption
  – Processor placed in modified motherboard used for measuring power
  – Current readout measured with Vcc feedback voltage set to match voltage measured during thermal test
  – Maxtherm Option F and BurnK6 or other software run for test
  – Power measured at close to same temperature of test
  – Power used in spreadsheet = Vcc Voltage x Current (as measured through CoreFB– and CoreFB+ pins (AG11 and AG13) on the processors)
Indirect Temperature Measurement Method

- Simple, repeatable method
- Attach thermocouple to back of ceramic substrate of processor
- Centered on die area
- Use provided correlation for determining die temperature
Correlation for Indirect Die Temperature Method for Products without Diodes

- Correlation relates die temperature to backside ceramic temperature
- Referenced to local CPU ambient
- Measurements performed on a thermal test vehicle
- Power varied to create correlation
- Validated against multiple, more involved methods of making temperature measurement

Typical residual: ± 2°C for centered clip

\[
(T_{C3} - T_{ambient}) = 1.209x - 1.3778
\]

\[R^2 = 0.9998\]
CPU Ambient Thermocouple

- Thermocouple should be centered above the fan hub
- One inch above the center of the fan hub
- Tape it to stiff wire that can be formed to place it in this location
Evaluation Temperature Sensor Kits

• Maxim 1617A Evaluation Kit

• Analog 1021A Evaluation Kit
Connect to the On-Die Temperature Diode

- Attach temperature sense wires to the evaluation kit
  - S7 wire connects to the positive terminal (DXP1 or D+)
  - U7 wire connects to the negative terminal (DXN1 or D–)

Remove this remote diode
Positive terminal
Negative terminal
Connect to Vcc Core Feedback Pins

- Connect 30-gage wire to Vcc core feedback positive and negative pins AG11 and AG13 (see processor pinout on next page)
- Allows monitoring of exact voltage across processor
Processor System Data Analysis

- Room temperature data extrapolated to 35°C
- Die temperature calculated using following correlation for ceramic packages:
  \[-(T_{\text{die}} - T_{\text{amb}}) = 1.209 \times (T_{\text{ceramic}} - T_{\text{amb}}) - 1.3778\]
- $\theta_{\text{js}}$ and $\theta_{\text{sa}}$ calculated
- Maximum Allowable Power (MAP) at 35°C calculated:
  \[-\text{MAP} = (90 \degree \text{C or } 95\degree \text{C} - T_{\text{amb}})/ \theta_{\text{ja}}\]
- Projected die temperature calculated:
  \[-T_{\text{die}} = \text{Power(from MTP table)} \times \theta_{\text{ja}} + T_{\text{amb}}\]
Data Analysis

• MAP compared to Max Thermal Power (MTP)

• Example:
  – MAP = 54W
  – From table, maximum frequency support = 1000MHz

• Max thermal power
  – represents +3sigma power dissipation of product
  – at a given frequency and nominal voltage

### MTP Table:

<table>
<thead>
<tr>
<th>D/C power</th>
<th>Max Thermal power</th>
</tr>
</thead>
<tbody>
<tr>
<td>650</td>
<td>36.1</td>
</tr>
<tr>
<td>700</td>
<td>38.3</td>
</tr>
<tr>
<td>750</td>
<td>40.5</td>
</tr>
<tr>
<td>800</td>
<td>42.6</td>
</tr>
<tr>
<td>850</td>
<td>44.8</td>
</tr>
<tr>
<td>900</td>
<td>49.1</td>
</tr>
<tr>
<td>950</td>
<td>51.4</td>
</tr>
<tr>
<td>1000</td>
<td>51.0</td>
</tr>
<tr>
<td>1100</td>
<td>55.3</td>
</tr>
<tr>
<td>1200</td>
<td>59.6</td>
</tr>
<tr>
<td>1300</td>
<td>63.9</td>
</tr>
<tr>
<td>1400</td>
<td>68.2</td>
</tr>
</tbody>
</table>

AMD Athlon™ Processor 1.75 V SpecFP*

54 W max thermal power surpasses 1.0 GHz, but is not enough for 1.1 GHz.
Tower Form Factor Guidelines
Thermal Design for Dual AMD Athlon™ MP Systems in Tower Form Factor

• Layout motherboard using keepout region definition for single processor systems
• Use a single qualified heat sink for each processor
• Use system fans to reduce temperature rise from external to the chassis to the processor locations
• Manage acoustics of system through fan speed control
• Chassis are standard product offerings from various chassis vendors
Chassis

• ChenMing 601AE-F-D *
• Palo Alto 810*
• Chenbro 2012 / 2025*
• Evercase EC S5000
• Inwin QS5000

*Will present test results
Heat Sinks for Dual Processor Implementations in Tower Form Factor

• Use standard single processor desktop heat sinks.

• Heat sink frequency rating is based on the following criteria:
  – Maximum external system ambient = 35°C
  – External-to-internal temperature rise ≤ 14°C
  – Power dissipation is at the maximum specification.
  – Die temperature ≤ maximum specification

• External-to-internal temperature rise must meet the above criteria.

• IMPORTANT: System integrator must confirm that processor temperature specification is met.
Heat Sink Incorporating Copper

- **Foxconn PK0453AEDAU52**
  - 63 x 70 x 60 mm
  - Basic aluminum extrusion
  - 50 x 50 x 3mm Ni-plated Cu slug
    - Attached with four screws
    - Shinetsu G751 grease
Dual AMD Athlon™ Processor Tower System Integration Example
Tower Chassis—2P System Configuration

- **System configuration**
  - Processors: 1400 Mhz AMD Athlon™ MP processors
  - Motherboard: Tyan Thunder
  - Power supply: Delta 460W
  - SCSI drives: Quantum Atlas 9GB
  - Video card: Elsa Gloria II
  - Memory: 1024MB Samsung PC2100
  - DVD drive: Toshiba SD-M1402
  - Floppy disk drive: TEAC FD-235HF
  - Sound card: Sound Blaster Live
  - Tower chassis: ChenMing, Chenbro or Palo Alto
System Configuration Tested—ChenMing
Measurements from ChenMing Test

![Temperature over time graph]

- **Die 0**
- **Heatsink Base 0**
- **CPU Amb. 0**
- **FET 0**
- **Die 1**
- **Heatsink Base 1**
- **CPU Ambient 1**
- **FET 1**
- **SCSI Drive**
- **DIMM**
- **NB**
- **External Ambient**
Thermal Characterization Results

• Test Conditions
  - Dual processor mode running two instances of “BurnK6”—1400 MHz AMD Athlon™ MP processors
  - Foxconn PK0453AEDAUFB aluminum/copper heatsinks utilized
  - Optimal performance obtained with one 80-mm system fan located in front of chassis

• ChenMing Results
  - Supports dual AMD Athlon™ MP processor-based 1200-MHz system with above configuration
  - Rear processor --> processor 1 is always highest temperature

• Further optimization required to support beyond 1200 MHz
IR Image of Motherboard in Chenbro Chassis
Chenbro Thermal Characterization

- Test conditions
  - Dual processor mode running two instances of “BurnK6”—1400-MHz AMD Athlon™ MP processors
  - Foxconn PK0453AEDAUFB aluminum/copper heatsinks utilized
  - Optimal performance obtained with one 80-mm front system fan and one 80-mm rear system fan

- Chenbro Results
  - Supports dual AMD Athlon™ MP processor 1000-MHz system with above configuration
  - Rear processor --> processor 1 is always highest temperature

- Further optimization required to support beyond 1000 MHz
Palo Alto Thermal Characterization

• Test conditions
  – Dual processor mode running two instances of “BurnK6”—1400-MHz AMD Athlon™ MP processors
  – Foxconn PK0453AEDAUFB aluminum/copper heatsinks utilized
  – Optimal performance obtained with one 90-mm system fan in front and one 120-mm fan in rear of chassis

• Palo Alto Results
  – Support a dual 1200-MHz system
  – Rear processor --> processor 1 is always highest temperature

• Further optimization required to support beyond 1200 MHz
Future Development Focus

- Efforts to improve frequency support:
  - Ducting
  - Heatsinks with different fin orientation

- Efforts to improve heatsink testing:
  - Speed controlled fans to reduce noise at room temperature
  - Ducting to eliminate need for system fans
Recommendations for Dual AMD Athlon™ MP Processor-Based Systems in 1U Rack Mounted Form Factor
Thermal Design Approach for Dual AMD Athlon™ MP Processor-Based Systems in 1U Form Factor

• Layout motherboard utilizing keepout region definition for single processor systems

• Drawer floorplan is custom for the motherboard. Recommended floorplan is described using Tyan Thunder motherboard

• Utilize a single heat sink per processor
  – Heat sink is coupled to blower placed in close proximity to the board
  – Utilizes low profile extrusions used for desktop without dedicated fan on heat sinks

• Power supplies specification in review with development partners
Reference Design 1U Power Supply Requirements

Output | Tolerance | Max Current, Amps |
-------|-----------|------------------|
3.3 VDC | +/- 5%    | 8 A              |
5 VDC   | +/- 5%    | 15 A             |
12 VCPU | +/- 5%    | 16 A             |
12 VIO  | +/- 5%    | 5A (7A Peak)     |
-12 VDC | +/-10%    | 0.8 A            |
5 VR    | +/- 5%    | 2.0 A            |

> 8 cfm at low speed
> 10 cfm at high speed
Heat Sinks for Dual Processor Implementations in 1U Form Factor

• Address thermal design at the drawer layout/floor plan level
  – Low-profile fan sinks do not have sufficient pressure/flow characteristics for this form factor.
  – Standard 1U designs that have a simple front-to-back flow distribution do not provide adequate cooling.
  – Custom floor plan utilizing higher pressure/flow blowers for cooling the processor is required to support entire roadmap

• IMPORTANT: Entire floor plan evaluated to assess performance
  – Ducting and blowers
  – Cooling provided to drives, memory, and power supply

• Temperature specification guidelines
  – Maximum external system ambient = 35°C
  – Power dissipation is at the maximum specification
  – Die temperature ≤ maximum specification
Example Heat Sink Used in Reference Design

- **Base:** 60mm width x 60mm depth x 7.5mm thickness
- **Cu slug:** 45mm width x 60mm depth x 4mm thickness
- **Fin:** 22.6mm height x 0.92mm width x 2.04mm spacing
- **Crosscuts:** 3.05mm wide
- **Thermal interface material:** Thermagon TCP 905c
Example 97-mm Blowers Used in 1U Reference Design

• Nidec Model #A34124-16
  – 0.65A @ 12V
  – 23 cfm at 0” H₂O
  – 0.95” of H₂O at 0 cfm

• Delta Model# BFB1012 H
  – 1.2A @ 12V
  – 25 cfm at 0” H₂O
  – 1.0 ” of H₂O at 0 cfm

• Both blowers have been used with comparable results.
Matching Air Movers to System Resistance

- System curve for old ducting
- Two 97-mm blowers in parallel
- Four fans in parallel in series with two fans in parallel
1U System Integration Example
1U System Configuration

- **System Configuration**
  - Processors: 1200 MHz AMD Athlon™ MP
  - Motherboard: Tyan Thunder
  - Power supply: In development
  - SCSI drives: Quantum Atlas 10KII 18.4B
  - Onboard video card: ATI Rage 128
  - Memory: 1024Mb Samsung PC2100
  - CD drive: Toshiba XM-1902B
  - Floppy disk drive: TEAC FD-235HF
  - 1U server chassis: Computer and Control Solutions
AMD Proposed Configuration

Place power supply to center of drawer to allow placement of 97-mm blowers adjacent to processors.

Utilize drawer length of 27”–28”.

Duct flow from blowers directly to processor locations.
Reference Floor Plan in Lexan Chassis

Primary Exhaust  Three Blowers*  Power Supply

Ducted Heat Sinks  Yellow Line = Seal Against Flow

*Reduced to two blowers in the final configuration.
Temperature Measurements in 1U Floorplan

- Measured using 800-MHz AMD Athlon™ processors
- 3°C per 100MHz --> ~1000 MHz of margin to 95°C specification
Test Data for Floor Plan Proposed by Floor Plan AMD

<table>
<thead>
<tr>
<th>Configuration</th>
<th>CPU 0</th>
<th>CPU1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lexan chassis, dual 800 AMD Athlon™ processors, Taisol 20 Fin 60x60 heatsinks, three NMB blowers, dual 18G SCA drives</td>
<td>External Temp.</td>
<td>( \theta_{JA} ) C/W</td>
</tr>
<tr>
<td></td>
<td>4.3</td>
<td>0.666</td>
</tr>
<tr>
<td></td>
<td>6.5</td>
<td>0.595</td>
</tr>
</tbody>
</table>

- Floor plan covers up to 1600-MHz AMD Athlon™ MP processors
- Optimization being performed to push the performance higher
Future Development Focus

- Blower selection
- Optimization of pressure drops in ducting
- Optimizing heat sinks—Select fin density to match blower characteristics.
- Optimize the air flow path through the drawer to reduce the number of turns, expansions, and contractions.
Summary

• 2P Tower form factor
  – Three systems tested and validated
    • Chenbro—Qualified through 1000 MHz
    • ChenMing—Qualified through 1200 MHz
    • Palo Alto—Qualified through 1200 MHz
  – Further work ongoing to improve frequency coverage of above systems

• 1U form factor
  – Reference design developed
  – Working with system and chassis suppliers for enabled solutions
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