Application Note 126
Cyrix III CPU
Thermal Design Considerations

REVISION HISTORY

Date	Version	Revision
5/20/99	1.0	Updated Cyrix III Information
3/22/99	0.21	Changed name from MXs to Cyrix III processor.
3/1/99	0.2	Changed case temperature from 70 to 85 degrees.
1/29/1999	0.1	Initial Version C:\documentation\joshua\appnotes\cIII_thermal.fm Based on App Note 103

APPLICATION NOTE 126

Cyrix III Thermal Design Considerations

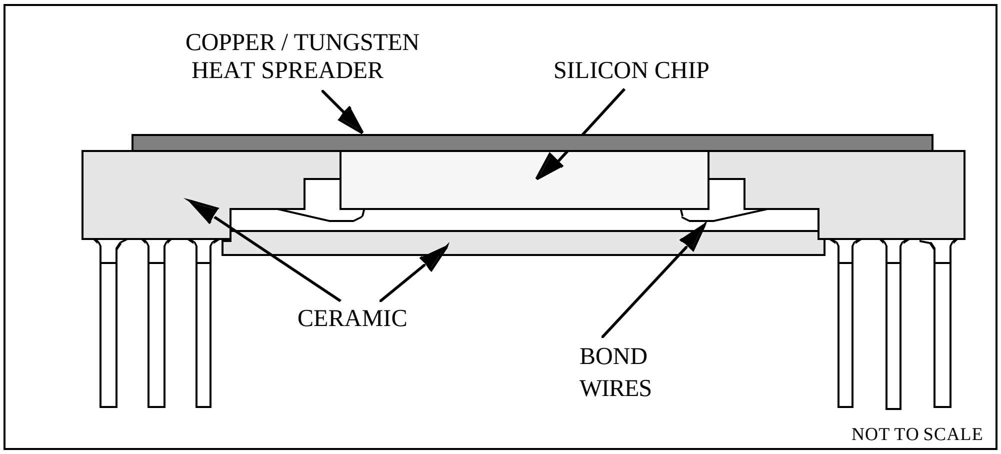
Introduction

This Application Report serves as a guide in the thermal design of a personal computer using the Via Cyrix III CPU™ Microprocessor. A simplified thermal model is presented that utilizes thermal resistances to describe the heat flow from the CPU. Two case studies are included to show how to measure the thermal performance of the microprocessor in a typical computer enclosure. Additional examples illustrate the calculation of expected maximum case and ambient temperatures. The D.C. Specifications and thermal data in the Cyrix III Microprocessor Data Book (when available) are expanded and updated by the Appendix in this Application Report.

Heat Flow

The Cyrix III CPU dissipates as much as 11.4 watts of power depending on the CPU clock frequency. The CPU is mounted up-side-down in a PGA package (Figure 1). Most of the heat is concentrated at the surface of the semiconductor chip and is passed to the package through three main paths: (1) through the bulk of the silicon chip to where the chip is mounted to the package, (2) through the bond wires to the package, (3) through radiation across the void between the chip and the bottom of the package.

The package is cooled by radiation, convection and conduction. Some heat is conducted through the pins and the socket, but most of the heat passes from the package into the flowing air stream that carries the heat out of the equipment enclosure. The transfer of heat from the package to the ambient air can be greatly enhanced through the use of a heatsink. Our thermal model will concentrate on the heat flow from the case and heatsink to the surrounding air.



Cyrix III CPU PGA Package Cross-Sectional View

Thermal Resistance Model

As heat flows from a heat source to a cooler object, there is a temperature drop (T_0-T_1) which is similar to the voltage drop (E) across an electrical resistor. Electrical power dissipated in the chip (P) generates heat. The heat flows away from the source analogous to electrical current (I). By dividing the temperature drop (T_0 - T_1) by the power producing the heat (P), we obtain thermal resistance (θ) expressed in Celsius degrees (°C) per watt (W).

$$\theta = \frac{T_0 - T_1}{P} \qquad \frac{°C}{W}$$

This equation is similar to (the dual of) ohms law:

$$R = \frac{E}{I}$$

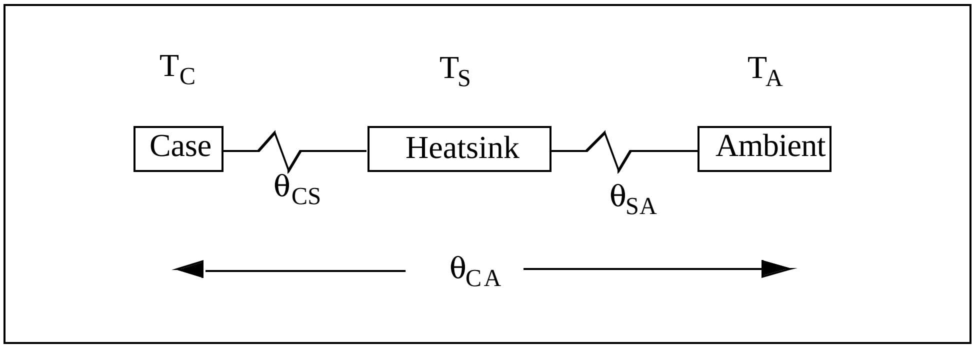
Thermal Resistances

Three thermal resistances (Figure 2) can be used to idealize the heat flow from the case of the Cyrix III CPU to ambient:

θ_{CS} = thermal resistance from case to heatsink in °C/W,
θ_{SA} = thermal resistance from heatsink to ambient in °C/W,
$\theta_{CA} = \theta_{CS} + \theta_{SA}$, thermal resistance from case to ambient in °C/W.

Additional symbols are used for the temperatures of the, case, heatsink and ambient air:
T_C = case temperature (top dead center) in °C,
T_S = heatsink in °C,
T_A = ambient (free air) temperature in °C.

The power applied to the semiconductor is:
P = power applied, $V_{CC} * I_{CC}$ in watts (W).



Thermal Resistor Model for Semiconductor

Controlling Case Temperature

Before power is applied, the case temperature is at ambient.

$$T_C = T_A$$

When power is applied, the case temperature rises as a function of the power applied and of the amount of heat lost to the ambient from the case.

$$T_C = T_A + P * \theta_{CA}$$

The case temperature of the Cyrix III CPU must be controlled in such a way as to maintain a 85°C maximum temperature.   The case temperature can be reduced by:

- decreasing the ambient temperature of the room
- improving the air flow geometry in the electronic enclosure to decrease the box ambient temperature (T_A).
- decreasing the case-to-ambient thermal resistance (θ_{CA}) through the use of a heatsink or a heatsink/fan
- reducing the power generated by decreasing the CPU frequency

Heatsinks and Heatsink/Fans

The case-to-air thermal resistance (θ_{CA}) can be greatly decreased through the use of a heatsink. Heatsinks improve radiation and convection efficiency. Using a heatsink, the thermal resistance (θ_{CA}) becomes the sum of the case-to-heatsink thermal resistance θ_{CS} and heatsink-to-ambient thermal resistances (θ_{SA}):

$\theta_{CA} = \theta_{CS} + \theta_{SA.}$

Note: Some manufacturers use the symbol $R_{\theta SA}$ instead of θ_{SA}

To take full advantage of the heatsink, it is important to provide a good case-to-heatsink fit. Using sufficient clamping force between the heatsink and case, and the application of thermal grease can reduce θ_{CS} to about 0.1 °C/W. This allows the following approximation to be made:

$\theta_{CA} \approx \theta_{SA.}$

The heatsink-to-ambient thermal resistance can be improved by a factor of about five using a heatsink/fan combination. A heatsink/fan reduces θ_{CA} by increasing the airflow across the heatsink.

Required Case-to-Ambient Thermal Resistance

If the maximum ambient temperature $T_{A(MAX)}$ inside the electronic enclosure is known, the required case-to-ambient thermal resistance can be calculated. The results of this calculation can be used to select which type of heatsink or heatsink /fan is required. The equation below calculates the thermal resistance of the heatsink required for an application. The table and chart below are based on Vcc2 = 2.2 V.

$$\theta = \frac{T_{C(MAX)} - T_{A(MAX)}}{V_{CC(MAX)} \times I_{CC(MAX)}} \quad \frac{°C}{W}$$

CYRIX III PERFORMANCE RATING	CYRIX III Actual MHz	MAX ACTIVE Current (A)	MAX ACTIVE POWER (W)	Θ_{CA} FOR DIFFERENT AMBIENT TEMPERATURES				
				25°C	30°C	35°C	40°C	45°C
PR 433	333 MHz	9.15	20.1	2.98	2.74	2.50	2.24	1.99
PR 466	366 MHz	9.76	21.5	2.79	2.55	2.33	2.09	1.86
PR 500	400 MHz	10.40	22.9	2.62	2.40	2.18	1.96	1.75
PR 533	433 MHz	10.85	23.9	2.51	2.30	2.09	1.88	1.67
PR 533	450 MHz	11.20	24.6	2.41	2.24	2.03	1.83	1.63

Required θ_{CA} to Maintain 85°C Case Temperature

Expected Results for Cyrix III - 500 CPU with Recommended Heatsink/Fan

The maximum CPU power dissipation is found in the previous table.

$P_{MAX} = 22.9\text{ W}$

Assuming the maximum ambient temperature of 40°C within the electronic enclosure and the case-to-ambient thermal resistance of 1.09°C/W, the maximum case temperature can be calculated using the equation below

$$T_{C(MAX)} = T_{A(MAX)} + P_{(MAX)} * \theta_{CA}$$

$$= 40°C + 22.9\text{ W} * 1.09°C/W$$

$$= 64.96°C$$

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