Technical Note

Thermal Applications

Introduction

This technical note defines a general method and the criteria for measuring and ensuring that Micron memory components and modules do not exceed the maximum allowable temperature. The specified temperatures will help ensure the reliability and functionality of Micron's memory components as defined in the production data sheets for each customer's application.

The primary consideration for functionality and reliability of Micron's semiconductor products is the junction temperature. Table 1 on page 2 and Table 2 on page 3 show an overview of junction temperature limits based on product families.

Temperature Definitions and Terms

Much of the discussion of this technical note is based on specifically defined temperature terms. These terms and parameters are defined here and used throughout this technical note as well as other Micron documents and Web sites.

Commercial/Industrial – Indicates allowable operating temperature range at which parts will perform to data sheet specifications. Industrial temperature parts are allowed a wider temperature range than commercial parts.

Junction Temperature, Reliability – Temperatures greater than those listed may cause permanent damage to the device. This is a stress rating only, and device functional operation at or above the conditions indicated is not implied. Exposure to absolute maximum rating conditions for extended periods may affect the reliability of the part.

Junction Temperature, Functionality – These temperature limits are derived directly from Micron's test temperatures. The junction temperature, functionality is the temperature below which the part should be designed to operate. Maintaining the temperature of Micron's semiconductor products below this temperature will guarantee the functionality of the product to the data sheet specifications.

P_B – The power dissipated down through the substrate where the component is attached.

P_C – The power dissipated up through the top case of the component.

Thermal Resistance – The resistance between two locations x and y is R_{xy} and θ_{xy}.

Thermal Resistance Parameters

Figure 1: Depiction of Thermal Resistance Parameters as Defined by JEDEC

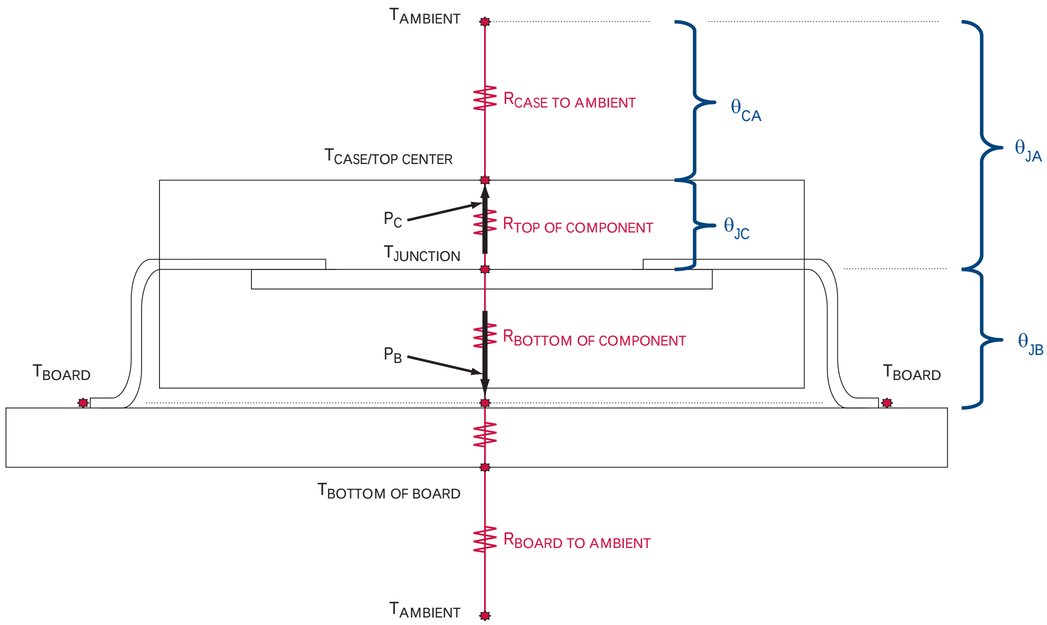


Table 1: Junction Temperature, Reliability

Device	Temperature (°C)
All memory products	110

Table 2: Junction Temperature, Functionality

Device	Application	Temperature (°C)	
		Min	Max
DRAM, SDRAM, DDR SDRAM	Commercial	0	85
	Industrial	–40	95
	Automotive[1]	–40	110
Mobile SDRAM, Mobile DDR SDRAM, Mobile DDR2 SDRAM	Commercial	0	85
	Industrial	–40	95
	Automotive[1]	–40	110
MCP/AIO	Commercial	0	90
	Industrial	–40	90
e·MMC™	Wireless	–30	90
	Industrial	–40	90
Flash	Commercial	0	90
	Wireless	–30	90
	Industrial	–40	90
DDR2 SDRAM	Commercial[2]	0	90
	Industrial[2]	–40	100
	Automotive[2]	–40	110
DDR3 SDRAM	Commercial[2]	0	100
	Industrial[2]	–40	100
	Automotive[2]	–40	110
PSRAM	Wireless[1]	–30	95
	Industrial[1]	–40	95
	Automotive[1]	–40	110
RLDRAM®	Commercial	0	100
	Industrial	–40	100

Notes:
1. Refresh rate is device dependant; please refer to data sheets.
2. Requires 32ms refresh to operate above 90°C.

Junction Temperature

The die temperature is very difficult to measure unless using a special setup with a test die. Generally, it is much easier to measure the case or board temperature and estimate the die temperature with θ_{JC} or θ_{JB} and a power estimate. The best method to use will depend on the application. Attempts to calculate the junction temperature using traditional θ_{JA} calculations are not recommended. Using the traditional method can produce significant errors because important parameters are not always accounted for, such as airflow, proximity of other components, and PCB thickness and layers.

Case Temperature

The case temperature should be measured by gluing a thermocouple to the top center of the component. This should be done with a 1mm bead of conductive epoxy, as defined by the JEDEC EIA/JESD51 standards. Care should be taken to ensure the thermocouple bead is touching the case. The case temperature can then be used to estimate the junction temperature using Equation 1.

(EQ 1)

$$T_J = T_C + (P_C \times \theta_{JC})$$

where:
T_J = Junction temperature
T_C = Case temperature
P_C = Power through case
θ_{JC} = Thermal resistance from junction to case

Note: P_C is typically 20% of P_{Total} for a personal computer module application, but can change greatly, depending upon the application. In many applications, the case and junction can be assumed to be the same temperature. However, this depends on the direction of the heat loss. See Table 3 on page 6.

Board/Lead Temperature

The board temperature should be measured by gluing a thermocouple to the center lead of the longest side, or the trace for BGA, of the desired component. This should be done with a 1mm bead of conductive epoxy, as defined by the JEDEC EIA/JESD51 standards. The board temperature can then be used to estimate the junction temperature using Equation 2. For most applications, this method is less desirable than using θ_{JC}, but is much better than using the traditional method of θ_{JA}:

(EQ 2)

$$T_J = T_B + (P_B \times \theta_{JB})$$

where:
T_J = Junction temperature
T_B = Board temperature
P_B = Power through board
θ_{JB} = Thermal resistance from junction to board

Note: P_B is typically 80% of P_{Total} for a module application, but can change greatly, depending upon the application. See Table 3 on page 6.

Component/Module Ambient

The component/module ambient should be measured as close as possible to the component. In a personal computer application, this could be between two modules. Generally, it should be within 5mm of the part. For a single module system, the temperature could be measured directly downstream of the module. The ambient temperature should not be used for predicting the junction temperature, but is useful for first-level measurement or design applications. An example of the ambient temperature location in a personal computer is shown in Figure 2 on page 5.

System Ambient

The ambient temperature can be measured in various locations, depending upon the application. If the system has poor access, the ambient air temperature can be determined by measuring the exiting system air temperature. If access is available to the system, the measurement should be made in the bulk airflow, well away from and upstream of the memory. The ambient temperature should not be used for predicting the junction temperature, though it is useful for first-level measurement or design applications. The measurement locations are illustrated in Figure 2.

Air Flow

For optimal cooling conditions, the memory should be exposed to 1m/s or more of moving air. It has been shown that in a personal computer environment, 1m/s can reduce the memory component temperature by as much as 20°C. Maintaining the component temperature at or below the required level will improve reliability of the component. The measurement should be made in the bulk airflow of the system. A local airflow measurement will be less accurate than the bulk measurement. This is illustrated in Figure 3 on page 6 showing a comparison of case temperature and bulk airflow for a typical personal computer application.

Figure 2: Examples of Ambient Temperature Measurement Locations in a Personal Computer Application

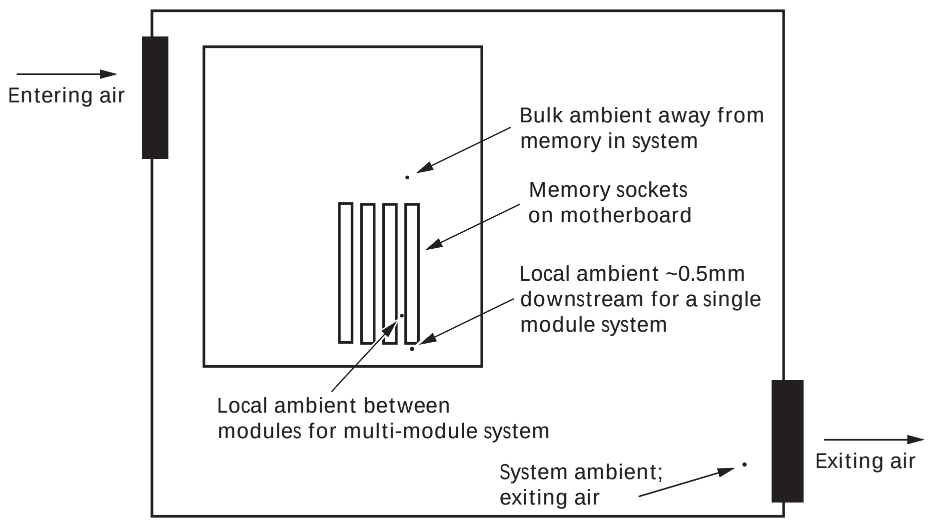
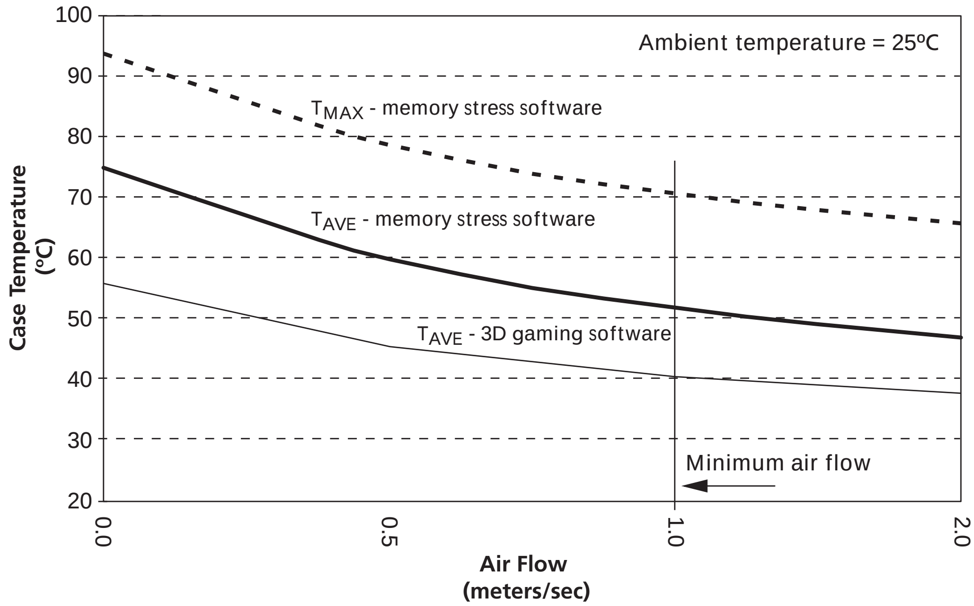


Figure 3: Case Temperature vs. Bulk Airflow for a Typical Personal Computer Application



Power Consumption (P_{TOTAL})

The power consumption of a component is a critical consideration because power consumption is what causes increased component temperatures. The numbers used in the above calculations should be based on system characterization data. In a PC application, parameters such as memory controller, number of memory components in a system, and software application all have a significant influence on the per component power consumption. For help on estimating the power, contact Micron Application Engineering or reference the relevant technical notes on the Micron Web site, www.micron.com/support. After the total power per component has been determined, the percent power dissipation through the case and board must be estimated. Some examples of typical power distribution are shown in Table 3.

Table 3: Power Distribution Examples

Application[1]	$\%P_C$	$\%P_B$
0m/s, 4 layer test board	5	95
0m/s, 2 layer test board	15	85
0m/s, DIMM module	20	80
1m/s, DIMM module	40	60
2m/s, networking board	45	55
Comm. board	55	45
Large heat sink	80	20

Notes: 1. These are examples only. Actual values should be based on modeling.

Modeling

If more accurate thermal predictions are required, computational fluid dynamics (CFD) and finite element analysis (FEA) modeling of the device is suggested. It is not recommended that JEDEC-standard thermal impedance measurements be used for determining die temperatures. These parameters are very application-dependent and will give erroneous predictions. The JEDEC-standard thermal resistance parameters are designed solely for comparing like packages under similar conditions. Micron can provide a variety of detailed and compact thermal models of components and modules.

Steady State

Prior to making measurements, the system should be allowed to reach steady state temperature conditions. Times may vary depending on substrates. This can be determined by taking measurements over a long period to ensure that the temperature does not change. For a personal computer application, thirty to forty-five minutes is recommended to reach steady state.

References

JEDEC standards, including JEDEC JESD51, are available from the JEDEC web site at www.jedec.org.

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Revision History

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- Updated Table 2, "Junction Temperature, Functionality," on page 3.

Rev. E 5/30/2008

- Updated Table 2, "Junction Temperature, Functionality," on page 3.

Rev. D 1/23/2007

- Updated template.
- Updated Table 2, "Junction Temperature, Functionality," on page 3.
- Revised text for readability.
- Created Rev History from MDM notes.

Rev. C 8/12/2003