THERMAL DESIGN CONSIDERATIONS (of Non-BGA products)

INTRODUCTION

As System operating frequencies increase, electronic components must dissipate more power to accommodate the needed reduction in access time. Thermal considerations become increasingly important in designs as power consumption approaches the limits of the package power dissipation. This application note addresses the general thermal performance of packaged die.

DEFINITIONS

T_A = Ambient Air Temperature, (measured in °C), at which the device is operated. The ambient temperature range of a device is listed under the "Absolute Maximum Ratings" section of each memory device data sheet.

T_C = Case Temperature, (measured in °C), of the memory device . In a packaged part, this is the surface temperature at any point on the package.

T_J = Junction Temperature, (measured in °C), of the active elements of the die. The absolute maximum recommended junction temperature of most WM devices is 150°C (a lower maximum junction temperature is recommended for normal device operation).

P = Average Device Power Dissipation, (measured in W), is dependent upon the operating conditions. Individual Device data sheets indicate maximum I_{CC} values that include significant guardband (margin to guard against process differences, test skew, etc.). Device power should be calculated to reflect the actual junction temperature, supply voltage, operating frequency, and output loading conditions.

θ_{JC} = Junction to Case Thermal Resistance, (measured in °C/W). The "junction" is the silicon die itself and the "case" is considered to be the surface of the package. θ_{JC} is a function of four component values, including: the die thickness, die area, the die attachment epoxy, substrate material, and the package material thickness.

θ_{JA} = Junction to Ambient Thermal Resistance, (measured in °C/W). This is the sum of $\theta_{JC} + \theta_{CA}$ Given the above definitions, T_J may be calculated using the following equation:

$$T_J = T_A + P(\theta_{JC} + \theta_{CA}) = T_A + Pq_{JA}$$

θ_{CA} = Case to Ambient Thermal Resistance, (measured in °C/W). θ_{CA} is a function of the environment (air movement) the surface area of the component (for convection and radiation) and the amount of heat conduction through the leads of the device. In applications where a heat sink is attached to the device,

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

Where θ_{CS} is the case to heat sink thermal resistance and θ_{SA} is the heat sink to ambient thermal resistance. θ_{CS} is normally very small, typically 0.3°C/W. θ_{SA} is mostly dependent upon the surface area of the heat sink.

DIE AND PACKAGE

The junction to case thermal resistance of our products is determined by the size of the die, the die attachment material method, the substrate size and layout, and the package materials and size. The basic industry trend is size reduction, which means smaller die and packages. A characteristic of thermal resistance is increasing as the die size and/or package size is reduced. This means more care related to thermal management is required in our package designs and in turn our customer's designs. In general, the specified maximum junction temperature of the die used at Mercury System is 150°C. The die's maximum junction temperature is the parameter that needs to be considered and controlled in the customer's design and application.

POWER

The power consumption of CMOS devices have the following characteristics: Power increases as the temperature decreases, power increases with supply voltage, power increases as the frequency increases and power increases as the duty cycle percentage increases. In general Mercury Systems specifies power by specifying the maximum I_{CC} current with frequency = 5MHz, duty cycle = 100%, V_{CC} = 5.5V. The maximum power at this specified condition can be calculated by multiplying I_{CC} x V_{CC}. The operational frequency and the duty cycle are variables that will change from application to application. In most cases WM can provide I_{CC} vs. Frequency data graphs and the duty cycle component can be added to the power equation, I_{CC} x V_{CC} x Duty cycle % = P.

THERMAL MANAGEMENT TECHNIQUES

To obtain a maximum operating temperature and at the same time keep the die junction temperature below its specified maximum the user may need to reduce the case to ambient thermal resistance, θ_{CA}. There are three basic methods for reducing θ_{CA}, heat sinking, forced air cooling and thermal vias in the PCB. Heat sinking can be done by making contact from the package to a material with a low thermal resistance. Thermal vias are used to assist in removing the heat that is dissipated from the power and ground leads of the device. Thermal vias need to be connected to the power and ground planes of the PCB.