Thermal Considerations

The temperature at which a semiconductor device operates is one of the primary determinants of its reliability. This temperature is often referred to as the "junction temperature," although this term is more appropriate for bipolar than MOS technologies. Heat dissipated in the device during operation escapes through a path, consisting of one or more series of thermal impedances terminating in the surrounding air (see Figure 1).

The presence of this nonzero thermal impedance causes the temperature of the device to rise above that of the air. Each of the components of the overall thermal impedance causes a rise in temperature that is linearly dependent on the power dissipated in the device. The coefficient is called θ, and has the units °C / W. The θ value for each thermal impedance represents the amount of temperature rise across the impedance as a function of the power dissipation. Usually, θ is given a subscript indicating the two points between which the impedance is measured. Thus, the junction temperature of an operating device is given by:

$$T_j = T_{AMB} + (Pd \cdot \theta_{JA})$$

where:

T_j = junction temperature of the device, in °C,

T_{AMB} = ambient air temperature, in °C,

Pd = power dissipation of the device, in W,

θ_{JA} = sum of all thermal impedances between the die and the ambient air, in °C / W.

The thermal impedance of a given device is dependent on several factors. The package type is the predominant factor; ceramic packages have much lower thermal impedances than plastic, and packages with large surface areas tend to dissipate heat faster. Another factor that is beyond the control of the device manufacturer, but is nonetheless important, is the temperature and flow rate of the cooling air. Secondary factors include the size of the die, the method of attaching the die to the package, and the organization of high power dissipation elements on the die.

Because all LOGIC products are built with low-power CMOS technology, thermal impedance is less of a concern than it would be for higher power technologies. As an example, consider a typical NMOS multiplier similar to the LMU16, packaged in a 64-pin plastic DIP. Assuming 1 W power dissipation and θ_{JA} of 50°C / W, the actual die temperature would be 50°C above the surrounding air. By contrast, the LOGIC Devices LMU16 has a typical power dissipation of only 60 mW. This device in the same package would operate at only 3°C above the ambient air temperature. Since operating temperature has an exponential relationship to device failure rate (see Quality and Reliability Manuals), the reduction of die temperature available with LOGIC's low-power CMOS translates to a marked increase in expected reliability.

FIGURE 1