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White Paper

THERMAL UPRATING: THE WHEN AND HOW

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Thermal uprating is the process to assess the capability of a device to meet the functionality and performance requirements of the application in which the device that are wider than the manufacturers' specified temperature range. Uprating should only be considered when the full lifecycle consequences of utilizing this approach have been fully evaluated and other possible options eliminated for sound engineering and business reasons.

Major concerns, by both the device manufacturers and the device users related to thermal uprating include the following:

- Device functionality (AC and DC timings, refresh for DRAMS, speed, leakage) cannot be assured or guaranteed
- Device reliability can be impacted; however, even when uprating the absolute maximum ratings of a device should never be exceeded. So, from a reliability standpoint, the primary concerns are related to degradation of the design and application functionality.
- Package reliability also needs to be considered, including interconnect and glass transition temperatures, especially if extended operation is close to the absolute maximum ratings.

Note that absolute maximum ratings (AMR) are typically provided by device manufacturers as an indication of the point where physical damage can occur to a device under stress. If the AMR is exceeded, damage to the device can occur. The margin that is understood to exist between AMR and the recommended operating conditions (ROC) is what is typically exploited when considering device uprating. Most device manufacturers state or imply that operating a device within this region (greater than ROC but less than AMR) should not damage the part, but performance and operation are not guaranteed. There is no guarantee that a device will function properly when exposed to these extreme conditions; only that when the extreme conditions are removed and the device is operated within the ROC region, it will still be functional and impact on useful life will be minimal.

The inherent variation of electrical parameters, and hence device performance must be considered when a device manufacturer develops ROC ratings. Semiconductor physics dictates the variation or changes in electrical parameters with temperature, and device manufacturers typically determine ROC limits through testing of devices and then provide the guaranteed parameter limits in their datasheets.

Several device manufacturers provide products for multiple specified temperature ranges. Most do not generally have different device designs and fabrication processes based on the expected temperature range of the target applications. Typically, commercial temperature-rated and industrial temperature-rated devices are from the same fabrication process, and therefore have equivalent intrinsic device reliability. The primary difference is that the industrial devices have either been sufficiently characterized to ensure proper operation in the wider industrial temperature range, or they have been screened for data sheet functionality at the necessary temperature extremes.

Risk Assessment

A risk assessment should be considered to help guide decisions regarding the capability assessment of each candidate device. The risk assessment should include:

- Application criticality into which the device will be used
- Consequences of failure at device, circuit and higher assembly level
- Type or technology of device under consideration
- Manufacturer data available for the device
- Quality/reliability monitors employed by the manufacturer
- Comprehensiveness of production assembly-level screens performed at extended temperature
- Identification of both managed and unmanaged risks and cost models for each

Details about the likelihood of occurrence, consequences of occurrence, and acceptable mitigation approaches for each identified risk should be generated. Each risk normally falls into one of the following categories:

- Functionality Risks – Risks for which the consequences of occurrence are loss of equipment, loss of mission, or unacceptable performance. Functionality risks impair the product's capability to operate to the customer's specification and can lead to loss of customers and market share.

- Producibility Risks – Risks for which the consequences of occurrence are primarily financial impacts (reduction in profitability). Producibility risks determine the probability of successfully manufacturing/fabricating the product (where "successfully" refers to some combination of schedule, manufacturing yield, quantity and other factors).

Cost of Uprating

Price information was not readily available for several of the parts being considered for uprating. However, based on a sampling of data available for Intel (memory and Ethernet devices) and Micron (memory devices), the cost differential between commercial temperature range parts and the industrial temperature range counterparts was in the range of 14%-20%. Direct use of a commercial temperature range part without any type of conformance testing, either at the device or the assembly level, should be considered high risk and is not recommended. The costs for implementation of associated testing should not exceed the premium for purchasing the higher temperature rated devices. The cost of risk avoidance should also be considered, especially in those cases where an uprated device may be applied in which an unspecified parameter (typically unknown) may be key to the application success. Future revisions to the device (e.g., die shrink) may impact unspecified parameters that ultimately impact the end application.

The overall cost of ownership is the primary criterion against which an equipment or end item performing a set of functions is judged. The designer/manufacturer should therefore consider the sum of all contributing cost factors, including a value on customer satisfaction. There should also be no justification for putting all efforts into reducing one cost factor by neglecting others.

RECOMMENDATIONS

- Utilize industrial temperature-rated devices when available
- If only commercial temperature-rated devices are available, contact the device supplier and discuss specific application details to determine if mitigating recommendations are available.
- If uprating is determined to be the desired approach, after performing appropriate risk assessments, then consider a parameter conformance testing approach that verifies parameter conformance for each part (or lot of parts via a defined, acceptable sampling plan) over the wider temperature range.
- The selection of higher assembly level or end item testing offers a potential minimum cost approach but is accompanied by extremely higher risk. To be effective, each and every end item or assembly must be tested over the wider temperature range of the product. This implies that effective test coverage is employed to ensure acceptable product functionality. The associated risk of discovering unacceptable variation in device parameters (due to die shrinks, etc) at this level and stage in the manufacturing process should have been assessed and well understood.