

Memory Solutions for Medical, Smart Grid, Industrial and Other Long-Lifecycle Applications

The memory needs of medical device and industrial equipment manufacturers are very different from those of personal computer (PC) and consumer product manufacturers. This presents unique challenges to the project team (i.e., product, design, quality and component managers, and engineers) requiring them to evaluate their memory solutions closely to ensure they can support their stringent requirements. The characteristics of a typical embedded system memory are defined below:

- Long product lifecycles: Seven to 10 years is typical, and often up to 15 years.
 - Significant development and qualification time.
 - Long production life.
- High-quality and reliability requirements: Over an extended temperature range, embedded systems place an emphasis on quality and reliability. The “five nines” expectation (99.999 percent uptime) means that quality starts from design and continues through manufacturing with the expectation of a long operating life.
 - Rugged products (e.g., including copper lead frame options for enhanced reliability at extended temperatures and long life without risk of “whiskering”).
 - Extended temperature range: must support negative 40 C to 85 C and have the option for extended temperatures to 105 C or 125 C.

High-mix, low-volume market segments have special needs in terms of industry specifications, strict qualification cycles, long-life requirements (without product changes permitted), and extremely long in-field use with the highest reliability standards expected.

The challenge for memory vendors is to ensure that by the end

of the design cycle they meet the requirement for long-term support covering extended production time with minimal design changes.

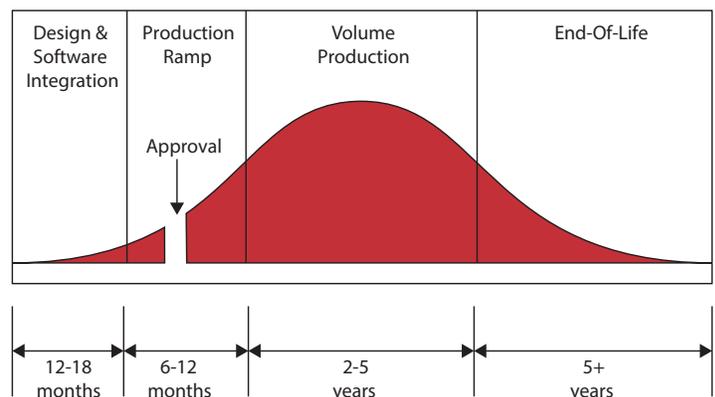
Medical and Industrial Embedded System Product Lifecycle

The typical industrial embedded system has a design and qualification cycle of one to three years, followed by a five- to 10-year production and ramp-down period. For many industrial systems, there is also an extended requirement to support installed equipment, requiring “spare” products to be available for an additional five years or more.

Example: Embedded Systems Requiring Long-term Support for Memory

Embedded systems have a significant development and qualification time, as well as production time. A typical product lifecycle (Figure 1) helps explain why it is critical to have a memory partner that guarantees long-term support.

Figure 1. Typical Embedded System Product Lifecycle



System	Design	Approval	Production
Medical Device	Prototype & software development	Federal Drug Administration (FDA) defines different classifications for medical devices, requiring different level of approval / qualification. May take up to 12 months for approval.	For Class 3 products, any component change may require FDA re-certification.
Factory Automation / Logic Controller	Often redesign a card to fit in existing form factor or set of interfaces.	After reliability testing at the PCB level, the end user will qualify the new card within their deployed system.	In complex systems, component or software changes are often prohibited.

Phase 1: Design, Approval and Production Ramp

In the design, approval and production ramp phase, it is critical that the selected memory vendor does not change a die revision for a product undergoing approval. Many commodity memory vendors perform frequent die revisions, making it extremely costly if an embedded system must be requalified by a regulatory body.

Embedded system microcontroller units (MCUs) typically have built-in support for a memory interface via a port such as an external memory interface (EMIF) with an integrated dynamic random access memory (DRAM) controller. At the time a MCU series is designed, the semiconductor vendor selects the type of memory interface (i.e., product family) to support (e.g., synchronous dynamic random access memory (SDRAM) or double data rate 2 (DDR2) SDRAM). With leading embedded processor vendors offering “product longevity programs” guaranteed to support defined devices for a minimum period of 15 years, the question the system engineer must ask is “Will my memory devices still be available in 15 years?”

Phase 2: Volume Production

Once in production, the memory vendor needs to maintain long-term support for the product family, preferably with the initially qualified die revision. In addition, the memory vendors have to ensure the highest levels of quality and reliability. At some point during an extended product lifecycle, the memory vendor may introduce a die shrink product. However, those vendors with a strategy for long-term support continue to offer the product family in both current and next-generation processes to minimize any requalification for the embedded system designer.

The phrase “design shrink” is often used by semiconductor vendors to denote a new generation of product manufactured on a more advanced process node (e.g., moving from 90 nanometer to 65 nanometer nodes). Memory devices such as DRAMs are designed to JEDEC-defined standards to ensure functional and pin compatibility between different vendors’ products. While a vendor may claim “100 percent compatibility,” many embedded system engineers have learned from experience that while the devices may meet all published datasheet specifications, when they are tested in a real-

world environment they often experience incompatibilities due to the unique nature of their application.

Phase 3: End-of-life/Sustaining Mode

Successful products continue to sell in low-to-medium volumes even as new generations are released. Furthermore, products with a large installed user base still require support for spares. All of this requires a memory vendor who can offer seven- to 10-year support. In such scenarios, memory vendors need to support an extended life with high-mix, low-volume manufacturing strategies.

The product life between consumer memory shrinks may be as short as six to nine months, which is not usually an issue for consumer products, but is a major headache for embedded systems. Embedded system engineers must consider the following memory issues for long-life markets:

- **Requalification of a new die revision:** Are the two products 100 percent compatible in the target application?
- **Time:** How long does it take to qualify the new die revision in the system and at end customers compared to the short-term availability of the consumer memory product?
- **Resources:** With engineering resources typically focused on new product development, who can support the requalification? Plus, for many older systems, the original engineer may not even be with the company.
- **Cost:** Requalification can be a significant expense, particularly if the complete system needs to undergo regulatory approval with extra testing and delays.
- **End-of-life (EOL):** The worst-case scenario is where the memory vendor has made the product type obsolete and announces an EOL. Semiconductor vendors usually support a last time buy (LTB), but the length of time where a product can be ordered is typically only around 12 months. If the embedded system is in the early part of its product life, this forces the company to forecast total volume over the lifecycle to purchase and store the memory as inventory. This can be extremely costly with significant upfront cash flow required, and there is always the potential concern of system demand exceeding the forecast.

Industrial Equipment Requiring Enhanced Quality and Reliability

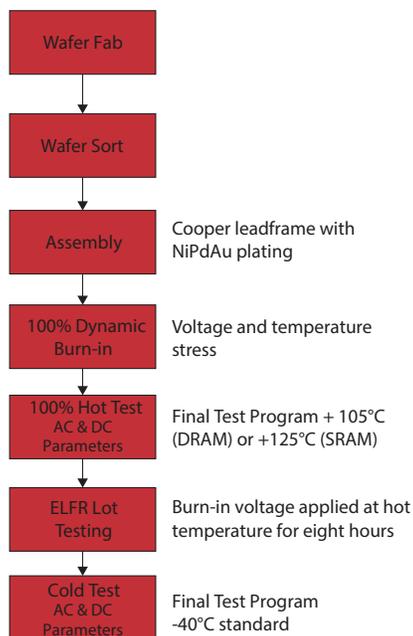
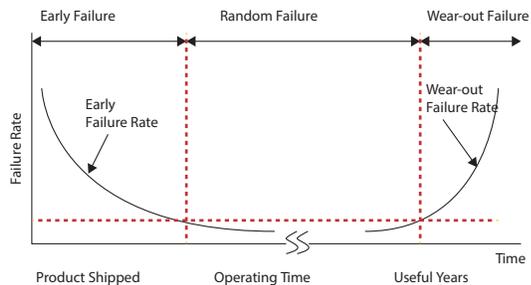
Industrial equipment is often exposed to extended temperatures and harsh environments, requiring at the die and packaging levels higher quality and long-term reliability from the semiconductor components. To address these applications, memory vendors must design and test rather than screen for quality.

Die-level Reliability

For industrial applications, the memory must be tested to ensure operation at both temperature extremes, typically 85 C or 105 C for hot and negative 40 C for cold. In addition, the test flow needs to consider how to remove both infant mortality effects (i.e., early failure) as well as ensuring long-term reliability. Reliability engineers are familiar with the “bath tub” curve shown in Figure 2. The memory flow shown in Figure 2 addresses infant mortality with 100 percent burn-in using both temperature and voltage acceleration factors. In addition to testing over the full temperature range, the test flow uses wafer lot-based sampling to perform a calculation for early life failure

rate (ELFR) to predict low failure-in-time (FIT) performance and ensure long-term reliability.

Figure 2. Bath Tub Curve with Enhanced Reliability Test Flow



Package-level Reliability

One key point to consider when selecting a semiconductor device for long operating life is package reliability. The use of copper for leadframe material has been shown to enhance long-term reliability by contributing to the durability of solder joints and improving thermal dissipation. By using nickel-palladium-gold (NiPdAu) for the solder plating of the leads, this eliminates the potential for “whiskering.”

Enhanced Joint Reliability and Improved Thermal Dissipation

During the service life of an electronics system, the printed circuit board (PCB) and the soldered components may be subjected to repeated thermal changes over a period of time from negative 40 C to 85 C. Every type of material on the PCB has a different coefficient of thermal expansion (CTE). The differing expansion rates can result in pushing and pulling stresses being concentrated at the points where they interface, which are often the solder joints. Over a long lifecycle, the effects of the stress may accumulate to the point that a crack appears, causing an electrical discontinuity.

Thin small outline package (TSOP) types used for memory use leadframes with Alloy42 (CTE of about 5 parts per million (ppm)/C), which match to the chip inside (CTE of about 3 ppm/C) and expand at similar rates, minimize internal forces. However,

parts are mounted on a PCB with copper traces and landing pads. Copper has a CTE of 17 ppm/C and expands more readily than those made of Alloy42. Memory manufacturers can enhance joint reliability by using a copper leadframe, which expands and contracts proportionally to the copper pads on the PCB, minimizing the stresses at the respective solder joints.

In theory, the higher the temperature levels at the die level, the shorter the lifespan of a part. A copper leadframe with improved thermal conductivity has the benefit of reducing the thermal resistance of the component and improving heat transfers by allowing better heat dissipation from the die to the leadframe and eventually to the free air. The die (or junction) temperature is given by the formula $T_j = T_a + \theta_{ja} \times P$, where P is the power the device consumes in watts, and θ_{ja} is thermal resistance. Using a copper leadframe with a lower θ_{ja} provides a substantial reduction in junction temperature of typically 5 C to 10 C.

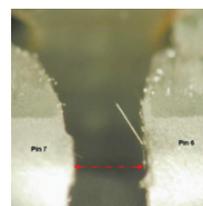
Whiskering

One of the disadvantages of lead-free plating solutions for packaging is a phenomenon called “whiskering,” where over long-term operation, a component can sprout “whiskers” from the solder plating on its terminals. If not prevented, these whiskers can bridge metal contacts causing a short circuit.

Figure 3. Whiskering



Whiskers forming on anonymous part. (Photo by NASA)



If a whisker bridges this gap across the pins, or it breaks, there could be a short-circuit and a system could fail. (Photo by NASA)

One whisker mitigation method recommended by JEDEC is to use pure matte tin (Sn) as the lead-free plating material and to anneal this. The International Electronics Manufacturing Initiative (iNEMI) recommends an improved method, which lists NiPdAu as the preferred plating material for eliminating the risk of whiskering. By offering memory devices with copper leadframes and NiPdAu, plating memory vendors can guarantee improved long-term reliability at both die and package levels.

Summary

A number of memory vendors have recognized the requirements to support markets with long-life and quality demands, including extended temperature applications. When selecting memory, the system engineer needs to consider qualifying multiple sources for each component to mitigate the risk of component obsolescence. Furthermore, the system engineer needs to select a memory vendor with a well-defined product strategy to ensure long-term availability of each product family so the engineer is not forced to redesign the complete system or carry out a very expensive and risky LTB. ■