Understanding Quality Levels for HiRel-rated Components

TI gives designers the confidence in their designs for applications such as personal electronics, automobiles, avionics systems, munitions and satellites. Supporting these applications requires different levels of quality and reliability, which TI provides through:

- Commercial off-the-shelf (COTS) products.
- The Automotive Electronics Council (AEC)-Q100 automotive standard.
- Enhanced Products (ruggedized COTS and the Aerospace Qualified Electronic Component [AQEC] standard).
- Qualified Manufacturers List (QML) Class Q (Military Performance Specification [MIL-PRF] 38535).
- QML Class V (space-grade, radiation-tolerant MIL-PRF 38535).

HiRel Enhanced Products

Enhanced Products (easily identifiable by the "-EP" ending of the product name) are the answer for avionics and defense designers who need a higher level of quality and reliability than COTS products provide. TI worked with key avionics and defense designers to produce a level of plastic-encapsulated microcircuits (PEMs) that would be reliable in critical applications yet low-cost enough for wide use.
Enhanced Products are certified to meet Government Electronics and Information Technology Association (GEIA)-STD-0002-1 for AQEC, as well as meeting the qualification and processing requirements of MIL-PRF 38535 for QML Class N components. Enhanced Products mitigate the risks that the avionics and defense markets face with COTS integrated circuits (ICs) by:

- Ensuring a single controlled baseline flow.
- Extending temperature ranges from -55°C to 125°C.
- Ensuring no tin (Sn) content >97%.
- Using only gold bond-wires.
- Performing extended highly accelerated stress testing (HAST).
- Using rugged material sets.
- Offering an extended obsolescence policy.

Additionally, each Enhanced Product is documented in a Defense Logistics Agency (DLA) vendor item drawing (VID) to eliminate the need for an original equipment manufacturer (OEM) to create a custom drawing for procurement.

Let's describe the features in Enhanced Products further.

- A single controlled baseline flow: COTS and Q100 products often have multiple fabrication facilities, assembly sites or test sites to allow for high-volume production and redundancy. Each unique flow has slight differences that can cause issues in HiRel application field use. Because of this, each individual Enhanced Product goes through one fabrication facility, one assembly site and one test site, and uses one material set. Thus, every reel of product that designers receive will have as little variation as possible reel to reel. This is particularly important in the avionics or defense industries, which perform additional testing or qualification at the lot or reel level. An Enhanced Product requires only one test instead of one for each reel.
- Extended temperature ranges: Most Enhanced Products are qualified from -55°C to 125°C, extending from COTS products' 0°C to 70°C or -40° to 85°C. This is especially useful for avionics designers designing systems for the exterior of an aircraft, or defense applications with temperature-cycling requirements. Temperature cycling for Enhanced Products happens during qualification, with a temperature range from -65°C to 150°C for 500 cycles.
- No high tin content: TI ensures that Enhanced Products' tin content will not be greater than 97%, extending to tin-silver-copper (SAC) solder at exactly 97%. When tin is subjected to large amounts of stress, it can crystallize and create a tendril that can cause electric shorts. Enhanced Products continue to use tin-lead solder balls on ball-grid array (BGA) packages, although the rest of the COTS and Q100 world have moved to high-tin-content SAC solders. Enhanced Products also use nickel-palladium-gold when possible for leaded parts, which allows Restriction of Hazardous Substances qualification on those devices.
- Gold bond-wires: Due to cost optimization, COTS and Q100-products are moving toward copper bond-wires across the industry. Although copper bond-wire has been proven acceptable in commercial and automotive applications, the aerospace and defense industries have identified some risks to using copper bond-wire in high-stress environments. The use of only gold bond-wire in Enhanced Products mitigates the following risks:
  - Bond integrity: copper bonding to aluminum requires much tighter process controls and environments, meaning a higher risk of issues.
  - Sporadic defective-parts-per-million (DPPM)-level corrosion caused by mold compound interaction.
  - Bond-wire neck breaks during temperature cycling: The co-efficient of thermal expansion (CTE) of copper is higher than gold, resulting in a higher failure rate in the presence of delamination compared to gold.
- Extended HAST: HAST evaluates moisture sensitivity and capability for long-term storage. This is often a necessary trait in defense environments because assembled equipment remains in long-term storage but must function when needed. Enhanced Products receive 250 hours of HAST testing during qualification, which is more than automotive Q100 (196 hours) and COTS products (96 hours). This gives defense designers confidence that the device will function when required.
- Rugged material sets: Enhanced Products will use the best available material set from the selected controlled baseline, a roughened leadframe, improved mold compound (encapsulation) and mount compound (die attach). This is different from COTS products, which will generally have a material set based on cost.
- Extended obsolescence policy: TI provides a process change notification (PCN) for Enhanced Products through an electronic system, with a 180-day notification before implementing a change, one year for order placement and six months for delivery. A published TI PCN is automatically picked up by Government Industry Data Exchange Program (GIDEP) systems. This differs from COTS products, which offer a 90-day notification.

QML Class V (space grade)

TI offers the largest selection of radiation-hardness-assured (RHA) and radiation-tolerant products for space flight. With a proven legacy of more than 60 years in the space market supporting countless space programs both domestically and internationally, TI is a trusted partner. We focus on radiation assurance and best-in-class size, weight and power (SWaP) to enable leading-edge designs. TI's space-grade products are easily identifiable by the "-SP" ending of the product name.

The breadth of TI's space portfolio provides a full signal-chain solution, including the smallest radiation-hardened point-of-load power solutions, best-in-class sensor products and some of the world's highest-performance data converters. TI space products include MIL-PRF-38535 QML Class V and RHA components. These devices are typically supported with total ionizing dose (TID) and single-event effect (SEE) test reports to address potential product degradation in a space environment. The test results for these devices are available at www.ti.com/radiation. All processing, screening and quality conformance inspection (QCI) is performed in compliance with the test methods of MIL-STD-883, Microcircuits Test Method Standard, with exceptions as allowed by Paragraph 1.1 of MIL-PRF-38535. Standard microcircuit drawings (SMDs) are located under Technical Documents in each QML Class V product folder on TI.com or the DLA website.

TI provides in-depth lot documentation with each QML Class V shipment. For detailed information, see TI's QML Lot Documents.

Certificate of Conformance to DLA SMD include:

- Processing conformance report (PCR) summarizing:
  - Assembly lot traceability.
  - Wafer lot traceability.
  - 100% screens performed.
  - Quality conformance inspection group A.
  - Quality conformance inspection group B (generic).
  - Quality conformance inspection group C (generic).
  - Quality conformance inspection wafer lot acceptance testing.
- Quality conformance inspection group B (generic) lot test summary report.
- Quality conformance inspection group D (generic) lot test summary report.
- Quality conformance inspection wafer lot acceptance/life test report.
- Quality conformance inspection Group E lot test summary report for RHA devices, with a detailed radiation lot acceptance test (RLAT) report available for electronic download.

For detailed information about TI's QML Class V flow and optimizations, see the Simple QML Class V/ QML Class Q Test Flow Matrix.

Space Enhanced Products

Much like the defense industry moved from QML Class Q ceramic devices to PEMs like Enhanced Products, the space industry is beginning the same shift from QML Class V for low earth orbit (LEO) missions with a short mission life, and requirements for small size. However, there are unique challenges with the space environment that are different from the military environment: radiation requirements, thermal cycling, and outgassing. TI has addressed this with a new line of rigorously developed products, Space Enhanced Products (SEP or Space-EP). These products are easily identifiable by the "-SEP" ending of product name.

Space-EP devices offer the following advantages over standard catalog products:

- A controlled baseline with one wafer fab, one assembly site and one material set.
- An optimized material set with die attach, mount

compound and mold compound are both used in a device, leadframe and bond-wire all selected to maximize reliability.
- No high tin (>97% Sn) construction including terminations (SAC solderballs and Matte-Sn plating) or internal package components (die bumps or substrate plating).
- No copper bond-wire; the product is either flip-chip mounted (no bond-wire) or uses gold bond-wire.
- Additional assembly processing, including 100% temperature cycling or 100% single-pass reflow simulation in lieu of temperature cycling.
- Characterization over a target temperature range (-55°C to +125°C).

Additionally, Space-EP offers the following beyond commercial, Q-100 and standard Enhanced Products:
- Parametric testing is standard at both room and high temperatures, with guardbands to assure data-sheet limits at cold temperatures.
- Assembly lot acceptance, including X-ray sampling and Confocal Scanning Acoustic Microscopy (CSAM) sampling.
- Wafer lot acceptance, using MIL-PRF-38535 QML Class V as the baseline.
- RLAT (group E) to 20-krad TID for each wafer lot per MIL-STD-883.
- Single-event latchup (SEL) characterization to 43 MeV-cm^2/mg.
- Outgassing qualification for each product per American Society for Testing and Materials (ASTM) E-595.
- Qualification to Space and Missile Systems Center Standard (SMC)-S-011.

Space applications require known radiation performance. Not only are TI Space-EP products characterized for total dose and single-event radiation performance, but in many cases TI uses different wafer fabrication processes or alternate die designs to achieve specified levels of radiation tolerance. This is further ensured with an RLAT or group E performed on each Space-EP wafer lot.

An OEM may be tempted to characterize one lot of a product and then assume that subsequent material will perform the same. This is not always true. Depending on the process technology, some devices exhibit significant wafer-lot-to-wafer-lot variation and, in some cases, wafer-to-wafer variation. Since traceability of COTS material is only to the wafer lot level, it creates a substantial risk to the OEM.

Texas Instruments (TI) Space-EP products provide a very cost-effective way to mitigate the risks associated with using COTS PEMs. TI's approach, combining the best of the Enhanced Product methodology and Class V-like wafer processing, ensures a product that meets published specifications in critical space and launch vehicle applications, while providing small size and reduced system cost.

QML Class Q (military-grade) and high-temperature products

TI is committed to a long-term continuous supply of hermetically sealed QML Class Q components for harsh environments. TI's QML products have a 60-plus-year history of longevity, reliability and wide availability. TI follows Joint Electron Device Engineering Council (JEDEC) standards for obsolescence on military-grade products, and is committed to nonobsolescence for convenience.

TI partners with an authorized aftermarket distributor to maintain a limited stock of obsolete devices for the aerospace and defense markets. TI also has the ability to reactivate obsolete devices on a limited basis. Contact your TI representative to inquire about the potential availability or reactivation of obsolete material.

TI also offers a wide selection of high-temperature products, up to 210°C, to support the petroleum exploration and production industry, as well as avionics OEMs. TI offers three types of packages to support the different application and size requirements of high-temperature electronics: ceramic packaging for 210°C, known good die (KGD) for 210°C and plastic packaging for 150°C to 175°C.

TI high-temperature ceramic and KGD parts are characterized for operation over an extended temperature range of -55°C to 210°C, and have a high-temperature operating life of 1,000 hours. In a number of cases the die is modified by TI (for example, removing thermal shutdown features) to enable extended operation. TI uses a different package material set than commercial/industrial devices to improve reliability and survivability at high temperatures for our PEMs, -55°C to 175°C devices.

	Commercial	AEC-Q100	Enhanced Products	QMLQ	Space EP Products	QMLV	QMLV-RHA
Packaging	Plastic	Plastic	Plastic	Ceramic	Plastic	Ceramic	Ceramic
Single controlled baseline	No	No	Yes	Yes	Yes	Yes	Yes
Bond-wires	Au/Cu	Au/Cu	Au	Al	Au	Al	Al
Can be pure tin (Sn)	Yes	Yes	No	No	No	No	No
Production burn-in	No	No	No	Yes	No	Yes	Yes
Radiation tested	No	No	No	No	Yes	Yes	Yes
Radiation assured	No	No	No	No	Yes	No	Yes
Typical temperature range	–40ºC to 85ºC	–40ºC to 125ºC	–55ºC to 125ºC*	–55ºC to 125ºC	–55ºC to 125ºC*	–55ºC to 125ºC	–55ºC to 125ºC
Extra qualification and process monitors	None	X-ray and reflow, outlier control	extended HAST, X-ray and reflow, outlier	MIL-PRF-38535 group A,B,C,D	MIL-PRF-38535 “like” A, D, E	MIL-PRF-38535 group A, B, C, D	MIL-PRF-38535 group A, B, C, D, E
Life test per wafer lot	No	No	No	No	No	Yes	Yes
Description	Tailored for high-volume commercial applications and flexible supply.	High reliability for automotive applications with flexible supply. Packages can use matte Sn and Cu bond-wires.	Controlled baseline ensures more homogenous performance across lots. No high Sn material content or Cu bond-wires. Uses increased reliability material set, homogeneous performance across lots.	Ceramic military-grade parts released to a MIL spec. Intended for extreme environments and long-term dormant storage.	Space-grade parts meant for low-orbit missions. Screening for TID (radiation assured). High-reliability material set, similar to Enhanced Products.	Space-grade parts release to a MIL spec. Meant for long lifetime, high-reliability missions.	Same as QMLV but additional lot testing and screening for TID (radiation assured).

** The majority of products in this category are qualified to this temperature range, but it is not a requirement.*

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