National Aeronautics and Space Administration

# EEE Parts Bulletin

Electrical, Electronic, and Electromechanical

A periodic newsletter of the NASA Electronic Parts Program / NASA EEE Parts Assurance Group and the Jet Propulsion Laboratory

**June–July 2017 • Volume 9, Issue 2 (Published since 2009), October 2, 2017**

**Special Edition on Crystal Oscillators**

Crystal clock oscillators form a critical component of any spacecraft design. Figure 1 is an example of a typical crystal oscillator. While auditing space crystal oscillator manufacturers, the auditors noted that no one was procuring standard space crystal oscillators, the prime reason being that the MIL-PRF-55310 specification for crystal oscillators had not evolved with the technological advances. The space customers are procuring catalog parts from the manufacturers. This lacks standardization and support from the Defense Logistics Agency (DLA). This bulletin provides the background and details work in progress to alleviate this problem.

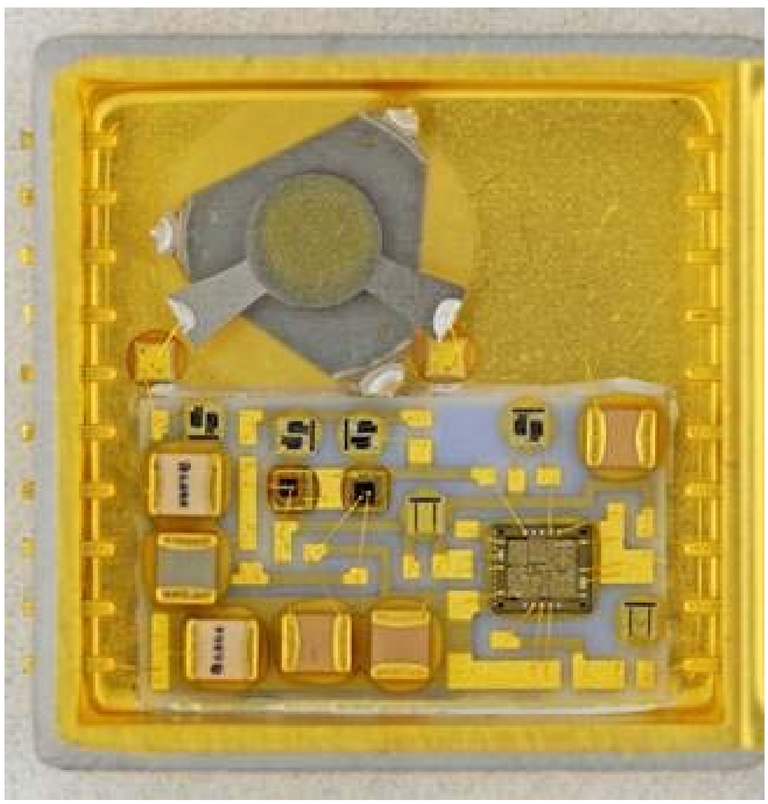

**Figure 1. Photo of a typical crystal oscillator, containing an exposed crystal element (upper left) along with the discrete passive components, discrete active components, and an integrated circuit chip (lower right) characteristic of a hybrid microcircuit. (Image from JPL Destructive Physical Analysis report 11036 (internal report).)**

## Specification Overhaul: MIL-PRF-55310 Crystal Oscillators

Crystal oscillators are a crucial part of virtually every spacecraft design. An effort has recently been undertaken to extensively revise MIL-PRF-55310, the performance specification for hybrid crystal oscillators. The present-day reality is that this document has become almost irrelevant to the industry. In recent months, efforts have begun to rectify this situation with an overhaul of 55310 by a cooperation of the DLA, which manages the document, and NASA, working through the NASA Electronic Parts Assurance Group (NEPAG), soon to involve manufacturers and other customers via the possible formation of a new JEDEC task group.

### *A. Where We Now Stand*

A crystal oscillator is an electronic device that contains a disk of material, usually quartz, that is tuned to vibrate at a very carefully controlled frequency, thousands or millions of times per second. This vibration is used as a timing reference in countless applications, including telecommunications, global positioning systems (GPS), measurement instruments, and guidance systems. A crystal oscillator also includes supporting electronics to enable interfacing with the outside world.

It has been 46 years since the crystal oscillator general specification, MIL-O-55310, was first published in 1970. It had five classes of oscillators stated, all quartz. By Revision B in 1988, eight varieties of crystal oscillators were listed. Since then, there have been 40 slash sheets published, though the first ten have been inactivated:

1) The most basic crystal oscillator (XO) – Active slash sheets exist
2) Voltage-controlled crystal oscillator (VCXO) – Never any slash sheets
3) Temperature-compensated crystal oscillator (TCXO) – Inactivated
4) Oven-controlled crystal oscillator (OCXO) – Inactivated
5) Temperature-compensated voltage-controlled crystal oscillator (TCVCXO) – Never any slash sheets
6) Oven-controlled voltage-controlled crystal oscillator (OCVCXO) – Inactivated
7) Microcomputer-compensated crystal oscillator (MCXO) – Never any slash sheets
8) Rubidium crystal oscillator (RbXO) – Never any slash sheets

What remain are only 30 slash sheets for XOs. There have thus never been any procurable DLA-approved VCXOs, TCVCXOs, MCXOs, or RbXOs; and there are no longer any DLA-approved TCXOs, OCXOs, or OCVCXOs. As a result, anyone who wants to buy one of these devices must buy either a manufacturer-specified design or their own custom source control drawing (SCD). These are symptoms of the problem.

As with any product in a free market, manufacturers of crystal oscillators will manufacture devices that their customers want to buy. And that is the crux of the problem with the crystal oscillator specification now designated as MIL-PRF-55310: By and large, it does not specify products that customers want to buy.

There are currently six suppliers on the Qualified Manufacturer's List (QML): Frequency Management International, M-Tron Industries, Precision Devices, Q-Tech Corporation, Vectron International, and Xsis Electronics. One driver for this overhaul of 55310 is that these manufacturers receive very few orders for 55310-specified parts. Even for their military and space customers, the large majority of their orders are for non-MIL-spec parts.

### *B. Rekindling Interest*

At the August 2016 JEDEC meeting, DLA's Chris Hancock, a Sourcing and Qualifications Division (VQ) representative for 55310, offered an invited presentation called "Evolution of Crystal Oscillators vs. the QPL Program (MIL-PRF-55310)." In this presentation, he examined the evolution of demand for military crystal oscillators. His objective was to promote awareness of and stimulate discussion about current goals and procurement practices. His experience has been that production of components on the Qualified Parts List (QPL) has been low or, for some part types, nonexistent. Chris presented a variety of examples of how some requirements had gone astray. For instance,

- MIL-PRF-55310 calls out MIL-PRF-3098, the general specification for the discrete quartz crystal units used in Class 1 55310 devices. However, for more than 5 years, one of the requirements of 3098 was for 100% Group A residual gas analysis (RGA) testing. This is akin to testing a box of matches by striking each match: you'll know whether each match worked, but you've destroyed your product in the process. Since RGA testing punctures a device's package and destroys its hermeticity, this essentially made it impossible for crystal manufacturers to deliver functional Class S product that met spec. This requirement was in place in 3098 for over 5 years before a manufacturer pointed out the absurdity to DLA during a facility audit. Of course, product was not manufactured this way, but this gives an idea how out-of-touch the specification was.
- MIL-PRF-3098 lacks slash sheets for crystal designs, frequencies, and performance desired by customers; without the appropriate 3098 crystal slash sheets, the desired crystal oscillators could not be manufactured as 55310 parts.
- Manufacturer qualification to 55310 had become valuable primarily as a formality, demonstrating that a manufacturer had the facilities, equipment, processes, and quality controls necessary to build MIL-spec crystal oscillator hybrids, while the products being ordered and shipped were built to their own or customer SCDs.

Some of these problems have been remedied by revisions to 3098 and the addition of new slash sheets. With input from qualified crystal manufacturers, DLA's Document Standardization Division (VA) is in the process of making further revisions, including expanding scope of accuracy measurements and addressing radiation-hardness characterization options. However, the problems in 55310 remain. As a result, Mr. Hancock concluded that, "Industry [had] developed alternative, parallel, and/or supplementary guidance," to meet its needs without 55310.

While industry has been able to get by like this, this is not an ideal situation. Manufacturers like to be able to offer product with "No SCD required" by having their own specifications for their products. However, if no manufacturer's product meets a designer's needs, the customer must expend the time and effort to create an SCD because there are no standard products. Or, if a certain manufacturer's catalog product does meet a customer's needs, the customer then becomes dependent on that manufacturer as a sole source since there is no expectation of interoperability between different manufacturers' catalog products. Customers would then be vulnerable to these sole sources changing or obsoleting products upon which they have become dependent.

### C. *This Part Type—How to Define It?*

Another symptom of the problem is the name of the 55310 document: Oscillator, Crystal Controlled, General Specification for. Naturally, these devices could be seen as evolving from discrete crystal devices as tighter requirements and frequency variability became necessary and achievable with more complex devices since the inception of MIL-C-3098 discrete quartz crystal units in 1949. In recent revisions, MIL-PRF-55310 has specified three classes of crystal oscillators:

- Class 1 devices use "discrete technology," meaning internal circuit elements that are individually packaged, such as the old-fashioned discrete sealed crystal units.
- Class 2 devices use "microelectronic (hybrid) technology [using] microelectronic circuit elements electrically and mechanically interconnected on an insulating substrate upon which resistors, capacitors, or conductors have been deposited, and used in a package that will be backfilled with an inert gas."
- Class 3 devices use "mixed technology (i.e., a combination of discrete technology and microelectronic technology)."

Note that only the description of Class 2 devices uses the word "hybrid," yet the definition of Class 3 devices as using "mixed" technology also clearly describes a hybrid structure. In fact, even Class 1 devices are hybrid microcircuit structures, with semiconductor and passive elements mounted on a substrate in the same device package, even if individual circuit elements are also individually packaged. Indeed, all classes of 55310 crystal oscillators are in fact hybrids in terms of construction.

Hybrid crystal oscillators are built like hybrids, yet the 55310 specification for them treats them more as crystals than as hybrids.

MIL-PRF-55310 does in fact call out the MIL-PRF-38534 hybrid spec in a variety of places. This is appropriate, as the electrical characteristics and failure mechanisms inherent to crystal oscillators go far beyond those of two-terminal discrete crystal units. Whether the crystal elements are packaged or free-standing within the oscillator package, requirements unique to crystals are also vital for crystal oscillators. The problem is that while 55310 has done a good job of incorporating 3098 requirements, it has not kept up with the 38534 hybrid requirements that must also be considered. This is to some degree understandable, as the original MIL-H-38534 specification was not published until 2008, 19 years after the original MIL-O-55310, in 1989.

### D. *Contributing Factor: the JEDEC Structure*

How could this have happened, that the 55310 crystal oscillator specification did not keep up with the requirements of the 38534 hybrid specification? This again goes back to the question: Is this device a crystal or a hybrid? Restated—is it a component part or a solid-state device? In a word, Yes! Industry customers and manufacturers have the greatest opportunity for influencing what is in the military specifications at the JEDEC JC-13 and SAE SSTC G-11 and G-12 meetings held three times a year. Individual sessions within these meetings are held in a few parallel tracks to fit all of the business into a one-week time frame. One track of meetings includes the G-11 Component Parts Committee, which focuses on component parts such as capacitors, resistors, transformers, and crystal devices such as 3098 discrete quartz crystals and 55310 crystal oscillators. The G-12 Solid State Devices track of meetings discusses requirements for microcircuits and 38534 hybrids. As a result, those responsible for 55310 crystal oscillators don't attend the meetings at which hybrid requirements are discussed, and those discussing 38534 hybrid requirements never hear what is lacking in the crystal oscillator specification.

### E. *A Path Forward*

To address this, DLA se sent out an Engineering Practices (EP) study, the results of which will be discussed at the JEDEC/G-11/G-12 in September 2017. The hope is to include broad representation of the customer and manufacturer communities, collecting enough input to recommend the right changes to make MIL-PRF-55310 both realistic in terms of what space and military customers need and reasonable in terms of what manufacturers can build and guarantee. As a starting point, NASA JPL has shared with DLA our internal general specification for crystal oscillators, which we use for most of our procurements rather than 55310. This comparison is highlighting key differences with 55310 such as in the areas of qualification, life testing, and radiation requirements, all of which will have to be negotiated.

In terms of DLA's leadership in addressing this issue, the lead is now being taken by Ms. Yeasvina Afroz and Mr. Kurt Anderson of DLA Land and Maritime's Document Standardization Division (VA). The VQ Sourcing and Qualifications Division will be in a support role. One next step is to conduct an Engineering Practice (EP) study to find out from the QPL suppliers of 55310 whether they are using different test flows for crystal oscillators other than those defined in 55310, and what product they are providing to military and space customers for which there are currently no active slash sheets. The goal of this effort is not only to revise MIL-PRF-55310, but to revise current slash sheets and publish new ones useful to space and military customers as-is. This goal has a variety of benefits:

- Customers would not have to write their own vendor item control drawings based only on what is available.
- As with other MIL-spec devices, manufacturers would have to go through qualification activities only once (with periodic renewals) to get their parts on the QPL, rather than separately for each customer.
- Customers would have the benefit of competition in procuring a common product from one of a few qualified sources, rather than being constrained to one manufacturer's proprietary design.
- Customers and manufacturers would have the resources of DLA available to them in resolving any issues that might arise with the new QPL parts.

Given the present state of MIL-PRF-55310 and the current industry paradigm of working around this document rather than using it, we don't expect to be able to decide upon and publish the necessary changes overnight. However, we at NASA are optimistic that collectively, we can make MIL-PRF-55310 every bit as useful as all of the other MIL specs that we use every day.

### *References*

**JPL DPA 11306**, *Destructive Physical Analysis, Hybrid Quartz Crystal Oscillator, 10.000 MHz* (internal report), Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, 2012.

**MIL-PRF-3098**, *Crystal Units, Quartz, General Specification for*, DLA Land and Maritime, U.S. Department of Defense, Columbus, OH, 2014. https://landandmaritimeapps.dla.mil/programs/milspec/ListDocs.aspx?BasicDoc=MIL-PRF-3098

**MIL-PRF-38534**, *Hybrid Microcircuits, General Specification for*, DLA Land and Maritime, U.S. Department of Defense, Columbus, OH, 2015. https://landandmaritimeapps.dla.mil/Programs/MilSpec/listdocs.aspx?BasicDoc=MIL-PRF-38534

**MIL-PRF-55310**, *Oscillator, Crystal Controlled, General Specification for*, DLA Land and Maritime, U.S. Department of Defense, Columbus, OH, 2006. https://landandmaritimeapps.dla.mil/Programs/MilSpec/listdocs.aspx?BasicDoc=MIL-PRF-55310

**For more information, contact**

**Jerry Martinez, 818-354-2019,**

**Gerald.M.Martinez@jpl.nasa.gov**

**Shri Agarwal, JPL**

**DLA Focals:**

**Yeasvina Afroz, Yeasvina.Afroz@dla.mil**

**Kurt Anderson, Kurt.Anderson@dla.mil**

## The Paths from Issues to Microcircuit Process Improvements

NASA, Aerospace Corporation, and other organizations often participate along with the Defense Logistics Agency (DLA) Land and Maritime personnel in DLA audits. The primary purpose of DLA audits is to get better electronic parts by monitoring compliance with the MIL specifications and by providing advice to the manufacturers on better ways of producing their parts.

In addition, NASA has conducted surveys of manufacturers, and those surveys produced recommendations regarding electrostatic discharge (ESD) mitigation and control.  These recommendations are not enforced, but the surveyed companies all implemented the suggestions.

However, as shown in Figure 2, there is much more that comes from these audits and surveys. These visits help identify concerns and/or opportunities that are then addressed by other means. This is a path that has worked in resolving major issues found during the audits and surveys that may require community involvement. It may evolve or be adjusted over time.

The new technology infusion of nonhermetic parts began entering the world of commercial microcircuits in the 2010s. Often referred to as flip chips, they provided many advantages such as high input/output density, short interconnects, self-alignment, better heat dissipation through the back of the die, smaller footprint, lower profile, and high throughput. The outstanding merits of flip-chip have made them one of the most attractive techniques in modern electronic packaging.

They were developed with controlled collapse chip connection (C4) compared with conventional packaging using wire-bonding technology, but a major concern of flip-chip technology is the thermal mechanical fatigue life of the C4 solder joints. This thermal mechanical issue mainly arises from the coefficient of thermal expansion (CTE) mismatch between the silicon chip (~ 2.5 ppm/ C) and the substrate (4-10 ppm/ C for ceramics and 18–24 ppm/ C for organic FR4 board). To overcome the thermal mechanical fatigue life issue, underfill materials were invented. These are low-cost organic materials that are applied between the chip and the substrate after flip-chip interconnection. The underfill buffers a portion of the of the CTE mismatch by distributing the stress, and it supports the chip.

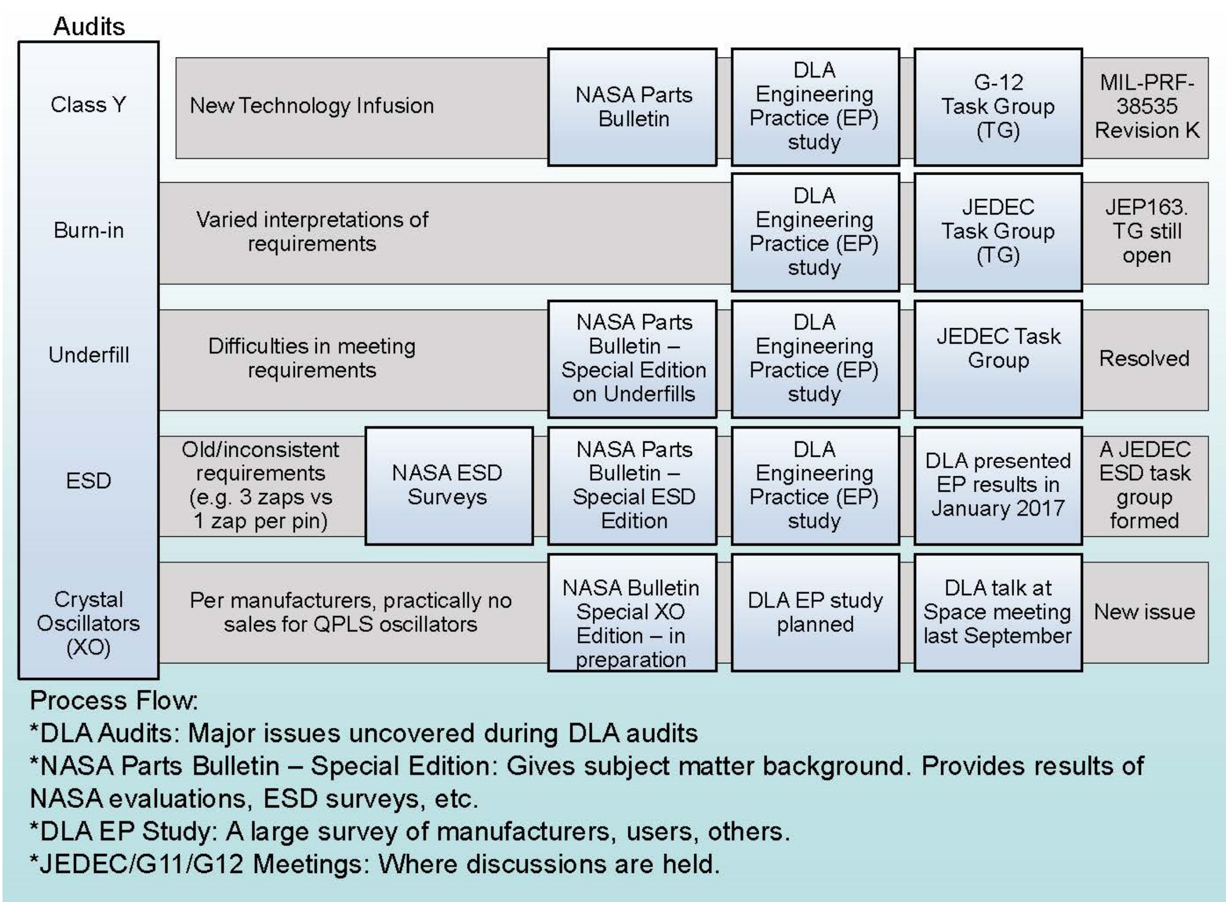


**Figure 2. Issues from Microcircuit / Other Audits and Methods of Resolution.**

Although flip chips had great potential, there were no space flip chips in the MIL system of part specifications. This situation was described in a special issue of the NASA *EEE Parts Bulletin* [1]. With increased interest, DLA generated an engineering practice (EP) study [2]. A G-12 task group eventually created a new class Y of non-hermetic ceramic parts, which was documented in proposed changes to the MIL-PRF-38535 specification. These changes were discussed and eventually approved as MIL-PRF-38535, Revision K [3].

Another issue was raised from a subsequent audit of the requirements for underfills. The audit results indicated that there were inadequacies in how the underfills were specified. These were met with two other NASA *EEE Parts Bulletins* [4, 5], discussion by the task group, and Change to 38535, which was accepted by a vote in the JEDEC, and the Underfill Task Group has now been closed.

Similarly, auditors noted highly varied interpretations of the burn-in requirements. DLA generated an EP study [6], and a task group was formed at the subsequent JEDEC. The task group proposed changes to JEP 163 [7], which were incorporated at the September 2015 JEDEC meeting. However, several issues were still unresolved, and the Burn-in Task Group is continuing.

Many audits and evaluations noted insufficient ESD protection. As with other issues, that was met by a NASA *EEE Parts Bulletin* special issue [8], a DLA EP study [9], and formation of a JC-13 level task group in January 2017. This group will hold its first meeting at the May 2017 JEDEC.

Christopher Hancock of DLA and Shri Agarwal noted in audits that very few crystal oscillators were being procured through the MIL spec, MIL-PRF-55310 [10]. The spec has not evolved along with changing technology, so the manufacturers have developed their own manufacturer specifications with the detail they require for production of crystal oscillators. However, these manufacturer specs can vary among the different manufacturers, and they are not under MIL spec control. Thus, there is no quality control from DLA audits and any of them could change at any time, without notification to DLA.

Christopher Hancock presented this issue to the G-12 Space Subcommittee held in September 2016. A NASA *EEE Parts Bulletin* special issue on crystal oscillators is this issue, a DLA EP study is planned, and it is anticipated that a task group will be formed to investigate the issue.

## References


[1] *EEE Parts Bulletin*, vol. 5, issue 4, includes "Class Y, a New Class of Space Microcircuits," August/December 2013. https://trs.jpl.nasa.gov/discover?query=eee+parts+bulletin

[2] Muhammad Akbar, *Practice Study: Flip Chip Underfill and Thermal Interface Materials (TIM) Requirements to Propose Test Method TM 5011 of MIL-STD-883 and MIL-PRF-38535, Final Report*, EP Study Project Number 5962-2015-004, DLA Land and Maritime, Columbus, OH, Aug. 15, 2016.

[3] *Integrated Circuits (Microcircuits) Manufacturing, General Specification for*, MIL-PRF-38535, DLA Land and Maritime, Columbus, OH, Dec. 20, 2013.

[4] *EEE Parts Bulletin*, vol. 7, issue 2, "Special Issue Flip-Chip Underfills," NASA NEPP/NEPAG/JPL, June–July, 2015. https://trs.jpl.nasa.gov/discover?query=eee+parts+bulletin

[5] *EEE Parts Bulletin*, vol. 7, issue 3, includes "Update on Flip-Chip Underfill Requirement for Space Products," NASA NEPP/NEPAG/JPL, August–December, 2015. https://trs.jpl.nasa.gov/discover?query=eee+parts+bulletin

[6] Muhammad Akbar, *Standardization of Standard Microcircuit Drawings (SMD) Burn-in Requirements*, EP Study Project Number 5962-2016-003, DLA Land and Maritime, Department of Defense, Columbus, OH, July 1, 2016.

[7] *Selection of Burn-in/Life Test Conditions and Critical Parameters for QML Microcircuits*, JEP 163, JEDEC, Sept. 20, 2015.

[8] *EEE Parts Bulletin*, vol. 8, issue 1, Rev. A (ESD special issue, 1 of 2), March 14, 2017. https://trs.jpl.nasa.gov/discover?query=eee+parts+bulletin

[9] Muhammad Akbar *Proposed Changes for ESD Requirements to MIL-PRF-38535*, EP Study Project Number 5962-2016-008, DLA Land and Maritime, Department of Defense, Columbus, OH, March 1, 2017.

[10] *Oscillator, Crystal Controlled, General Specification for*, MIL-PRF-55310, DLA Land and Maritime, U.S. Department of Defense, Columbus, OH, 2006. https://landandmaritimeapps.dla.mil/Programs/MilSpec/listdocs.aspx?BasicDoc=MIL-PRF-55310



**For more information, contact**

**Shri Agarwal 818-354-5598**

**NASA Parts Specialists Recent Support for DLA Land and Maritime Audits performed at**

- Crane Electronics, Inc., Redmond, WA
- Oneida Research Services, Inc, Whitesboro, NY
- Sawtech, Garland, TX
- Solid State Devices Inc (SSDI), La Mirada, CA

**Upcoming Meetings**

- JEDEC/SSTC G-11 & G-12 meeting, Columbus, OH, Sept. 11–14, 2017

## Contacts


**NEPP** https://nepp.nasa.gov/

Michael J. Sampson 301-614-6233
michael.j.sampson@nasa.gov

Kenneth A. LaBel 301-286-9936
kenneth.a.label@nasa.gov

Shri Agarwal 818-354-5598
Shri.g.agarwal@jpl.nasa.gov

Roger Carlson 818-354-2295
Roger.v.carlson@jpl.nasa.gov

**NEPAG (within JPL)**
http://atpo.jpl.nasa.gov/nepag/index.html

**ATPO** http://atpo.jpl.nasa.gov
Doug Sheldon 818-393-5113
Douglas.J.Sheldon@jpl.nasa.gov

---

**JPL Electronic Parts** http://parts.jpl.nasa.gov
Mohammad M. Mojarradi 818-354-0997
Mohammad.M.Mojarradi@jpl.nasa.gov
Jeremy L. Bonnell 818-354-2083
Jeremy.L.Bonnell@jpl.nasa.gov


---

**Previous Issues:**

**Other NASA centers:**

http://nepp.nasa.gov/index.cfm/12753

**Public Link (best with Internet Explorer)**:
https://trs.jpl.nasa.gov/discover?query=eee+parts+bulletin




**www.nasa.gov**
National Aeronautics and Space Administration

**Jet Propulsion Laboratory**
California Institute of Technology
Pasadena, California