The Various Shades of Microcircuits

EEE Parts for Class D and Cubesats Workshop
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S. Agarwal
NASA - Jet Propulsion Laboratory, California Institute of Technology
Pasadena, California, USA
Shri.g.agarwal@jpl.nasa.gov

Artists conception Mars Science Laboratory Curiosity ChemCam instrument firing a laser to identify chemical elements in target rocks. (Note: the red beam is for illustration; the actual infrared beam is invisible to human eyes.)

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Agenda

- QML Microcircuits
- COTS
- PEMs
- Dual-use Technology
- JEDEC's PEM Subcommittee
- Next Generation of (Nano) Devices
- Automotive Microcircuits

- Background:

(Material will not be presented--only for information)

  - Detailed definitions

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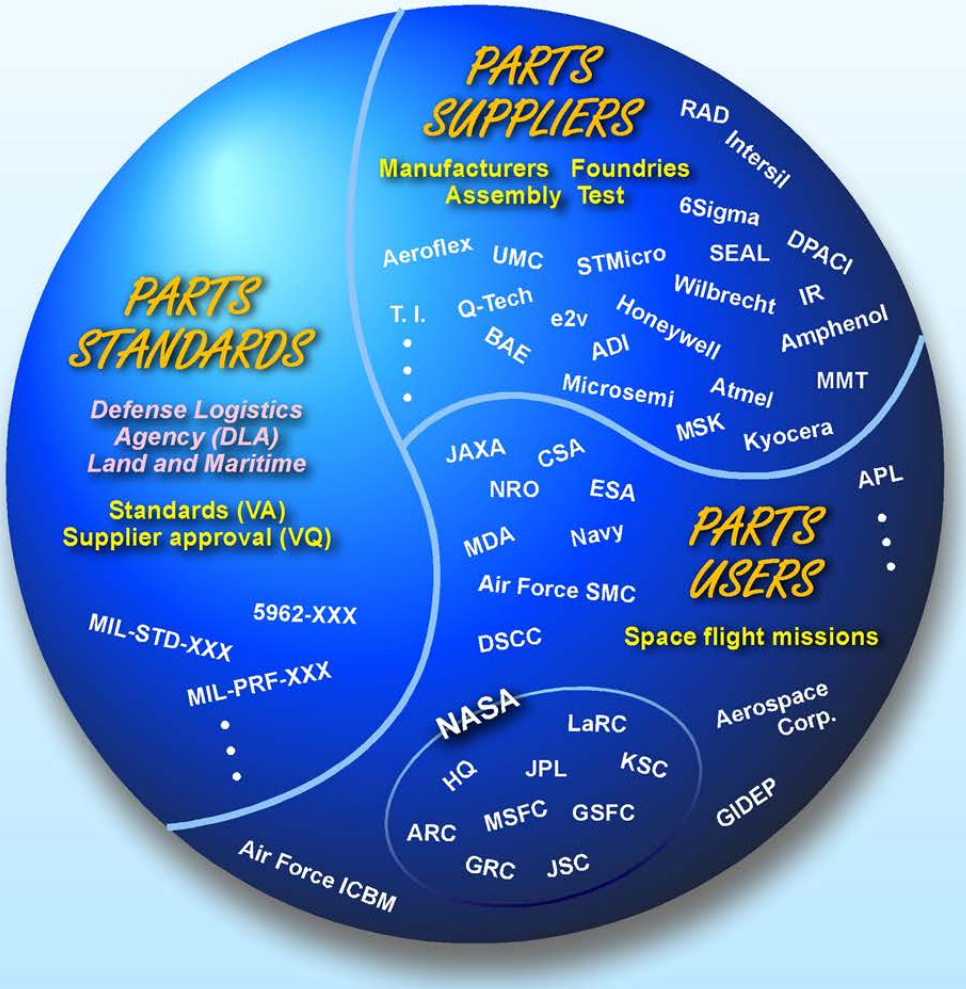
Space Parts World



NEPAG is actively involved with the procurement process - parts users and standards organizations join hands to ensure timely delivery of reliable parts from suppliers.

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QML Microcircuits

- QML
  - Qualified Manufacturer Listing.
  - Program is administered by the Defense Logistics Agency (DLA) Land and Maritime, Columbus, Ohio.
  - Technical support provided by NASA, the Aerospace Corporation and others

- Monolithic Microcircuits.
  - Governing Specification: MIL-PRF-38535.
  - QML classes: QMLQ, QMLV and others (details on pages 17-18)
  - QMLY in development

- Hybrid Microcircuits.
  - Governing Spec: MIL-PRF-38534.
  - QML Classes: QMLH, QMLK and others (details on pages 19-20)

- MIL-STD-883.
  - Test Method Standard
  - Supports all microcircuits

- The QML system is based on having trust in your supplier

Monolithic vs. Hybrid Microcircuits and Related Issues

Standard Microcircuits	Monolithics	Hybrids
# Elements	Single	Multiple
Mil Spec	MIL-PRF-38535	MIL-PRF-38534

Changes in Last Few Years: The boundary between monolithics and hybrids has become blurred.

	Capacitors Inside IC Packages	Single Die Hybrids
Issues: (First Reported by NASA)	Signal Integrity capacitors Used In IC packages	Manufacturers building single die hybrids
Mitigation:	Added capacitor screening requirements In 38535 Spec (Para 3.15)	Encouraging suppliers to also get 38535 Certification (M.S. Kennedy has already received it.)

A New Issue: No MIL capacitors to satisfy the needs of new high-speed, low voltage designs. They are using Commercial **BME** (Base Metal Electrode) capacitors with unproven space heritage. Affects Class Y.

BME Used?	Yes, but not tested to 3.15 (Xilinx V-4/V-5 FPGAs, Class Y candidates)	Yes, but meet existing element evaluation requirement which are not as stringent as for 38535.
Mitigation	**Evaluate** BMEs (NASA, Aerospace, Suppliers, ESA, JAXA) Double Derating ?	**Stop use** until evaluation done. (Ref: G12 letter to DLA)

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QML Rad Hard Microcircuits

– Rad Hard Assurance (RHA) program.

- 18 vendors are qualified to provide RHA SMD products: Aeroflex Colorado Springs, Aeroflex Plainview Inc, Analog Devices, Atmel Nantes, BAE Systems, Crane Electronics, Honeywell, Interpoint, Intersil, International Rectifier, Linear Technology, MS Kennedy, ST Microelectronics, TI, TI SVA (dba National Semiconductor), Xilinx, Rochester Electronics and VPT.

- Number of RHA SMD Devices: there are 865 active SMD with RHA requirements, 7894 RHA devices available and 864 RHA die

- Consult DLA website for more details

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COTS

- COTS = Commercial-Off-The-Shelf.
- A NASA team, led by Oscar Gonzalez of GSFC, is addressing the use of COTS in NASA missions
- What is COTS and what is not COTS is yet to be ironed out.
- PEMs are considered COTS. See slide 9.
- Some consider dual use technology as COTS. See slides 10.
- A recent reference on COTS: “Thoughts on COTS Electronics for Space” by Ken LaBel and Mike Sampson, presented at ETW13.

Plastic Encapsulated Microcircuits (PEMs)

- Upscreened PEMs have been used at NASA for many years.

- Some lessons learned:
  - A small percentage could fail as received at incoming electrical test
  - Considerable electrical test fall out can be expected over the operational temp range which is typically broader than the commercial range of 0 to 70C
  - Extensive engineering analysis would be required
    - Which wouldn't result in any cost savings
  - Glass transition temp measurements could be lower than advertised
    - Which would require burn-in temperature/time adjustments

- PEMs when upscreened with accompanying engineering analysis of data would stand a good chance of success

- Would the PEMs work as is, i.e., without any reliability or radiation evaluation?
  - Depends on mission risk posture
  - Consult parts specialist
  - Vendors do not recommend use of PEMs in space hardware
  - Slow/lack of vendor application support. No DLA intervention.

Dual Use Technology

- Infusion of commercial microcircuits into DoD (Department of Defense) system.
  - Evaluation for DoD use of parts built on commercial foundries, e.g. the use of domestic and overseas foundries by Aeroflex.
  - Adding their unique processing steps to the existing commercial processes, e.g. MRAMs being offered by Honeywell (in collaboration with Everspin)

- This has resulted in paradigm changes, a couple of examples:
  - Not all parts are specified over the full military temperature range, -55C to +125C. These differences are now clearly shown in the standard microcircuit drawings (SMDs). See slide page xx
  - Supply chain management issues. More and more processing steps are being out-sourced. NASA and the rest of the Space community have been working with DLA to ensure the audit and approval of all entities in such supply chains.

- So, dual use technology as currently implemented by the manufacturers can be viewed as an informed infusion of COTS into DoD standards.

- (*From Google/wikipedia: Dual use goods are products and technologies normally used for civilian purposes but which may have military applications.)

Dual Use Technology

- Basically an infusion of commercial microcircuits into DoD system.
  - Building parts on commercial foundries, e.g. the use of domestic and overseas foundries by Aeroflex.
  - Adding their unique processing steps to the existing processes, e.g. MRAMs being offered by Honeywell (collaboration with Everspin)
  - Upscreening selected products from commercial portfolio (Analog Devices)

- This has resulted in paradigm changes, a couple of examples:
  - Not all parts are specified over the full military temperature range, -55C to +125C. These differences are now clearly shown in the standard microcircuit drawings (SMDs). See slide page 20.
  - Supply chain management issues. More and more processing steps are being out-sourced. NASA and the rest of the Space community have been working with DLA to ensure the audit and approval of all entities in such supply chains. Slide 19.

- So, dual use technology as currently implemented by the manufacturers can be looked upon as an informed infusion of COTS into DoD standards.

- A new issue:
  - Non-uniform distribution of heat across the die
  - Using thermal imaging to look for “hot spots.”

Changing Landscape
A New Trend – Supply Chain Management

When auditing your suppliers, should you be auditing your suppliers' suppliers?
Your purchase order to a manufacturer provides a part that may have required careful handling from all the companies in the fictitious but typical supply chain below (and they all will need DLA approval).

Die design	Part Manufacturer
Fabrication	Operation A (could be performed by the manufacturer or Company A)
Package design Package manufacturing	Operation B
Wafer lap and dice	Operation C
Assembly	Operation D
CGA column attach Solderability	Operation E
Screening/electrical/package Tests	Operation F
Complete electricals per SMD	Operation G
Internal water vapor content	Operation H
Radiation testing	Operation I
And so on……	

The Hubble Space Telescope (HST) is a 2.4-m (7.9-ft) aperture space telescope. It was carried into low Earth orbit by a Space Shuttle in 1990, and it remains in operation.

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Changing Landscape for Operating Temperature Range:
Use Caution, Many Newer Parts Are No Longer Guaranteed over The MIL Temperature Range

Example: DLA SMD 5962-99607

Device Type	Generic No.	Circuit Function	Access Time
01	8Q512	512K X 8-bit rad-hard low voltage SRAM (MIL Temp)	25 ns
02	8Q512	512K X 8-bit rad-hard low voltage SRAM (Extended Temp)	25 ns
03	8Q512	512K X 8-bit rad-hard low voltage SRAM (MIL Temp)	20 ns
04	8Q512	512K X 8-bit rad-hard low voltage SRAM (Extended Temp)	20 ns
05	8Q512E	512K X 8-bit rad-hard low voltage SRAM (MIL Temp)	20 ns
06	8Q512E	512K X 8-bit rad-hard low voltage SRAM (Extended Temp)	20 ns

Operating case temperature, (T_C) (Device 01, 03, and 05) ..... –55 ºC to +125 ºC
Operating case temperature, (T_C) (Device 02, 04, and 06) ..... –40 ºC to +125 ºC

This SMD implies that there may be a performance issue at low temperatures.
Use caution for operation at low temperatures. Work with the manufacturer; get product test/characterization data.

Some other Memories (e.g., 5962-01533 and 5962-01511) are specified as follows:

- Device type 01, –40 ºC to +125 ºC;
- Device types 02 and 03, –40ºC to +105 ºC.

These may have performance problems at both low and high ends.

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JEDEC PEM Subcommittee (PEMSC)

Charter: The PEM subcommittee's function is to direct and coordinate the activities of the PEM Task Groups. It also serves as a forum for the Exchange of information and feedback between the task Groups and the Membership.

VID activity (i.e., quantity, number of suppliers, new suppliers, etc…) **by Muhammad Akbar**
Note: VID devices require usage to avoid economic cutbacks due to low usage.

Manufacturer data accuracy vs. independent monitoring. Performing failure analysis of independent tests to determine root cause and providing feedback to manufacturers. Molding Compound anomalies. As a part of their ongoing "PEM" testing DoD is seeing delaminations on products directly from manufacturers before testing that appear to be failing J-STD-020 criteria, specifically around wire bonds. Some are getting worse after environments and some are failing electricals (not all).

Question: Has any progress been made regarding upscreen of plastic TVS diodes and has this been expanded to include a variety of diode families, transistors, and ICs? **Response: The VID and class N processes were created to address the use of plastic packaged 5962 devices. Plastic devices are allowed on some MIL-PRF-19500 slash sheets. There is currently not a task group in the PEM Subcommittee or G-12 on this topic.**

Use of copper wire **By Ed Jacoby.** Update on the conversion of microcircuits to copper bond wires from gold. DoD has concerns with Cu bonded products.

PEM Hybrid Modules **by John Nirschl**

Future Goals

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Evaluating the next generation of (Nano) Devices

- The next generation of nanodevices will be built on 450-mm wafers in 28-nm and smaller feature sizes. This will increase device complexity tremendously.
- As the next-generation nano devices are developed, the candidates for infusion into the military standards should be identified and evaluated.
- The evaluation for reliability and radiation would follow the requirements as given in MIL-PRF-38535.
- It is anticipated that most of the new devices would be microcircuits. Such devices should be classified in one of the quality assurance levels as defined in MIL-PRF-38535.
- In case any of the devices is a hybrid circuit, the classifications for those devices should be per the quality assurance levels as defined in MIL-PRF-38534.
- Ref: S. Agarwal,"Infusion of Next-Generation Nano Devices into Military/Space Standards," Advanced Technology Workshop on Packaging Next Generation of Nano Devices, Albany, NY, April 30-May 1, 2013.

Automotive Microcircuits

- AEC = Automotive Electronic Council. AEC-Q100 document

- NASA/Navy team
  - Gaining knowledge of AEC system
  - Will perform limited evaluation of representative devices
  - For the possible use in NASA missions
  - Some related questions/comments:
    - Audits by automotive companies: by who, how often, thoroughness
    - Audited by ISO? How often? Thoroughness
    - Sell AEC parts to non-automotive customers? If yes, support provided to customers, particularly for space customers
    - The user has to understand what they are buying
    - The close ties and interdependency between the manufacturer and the user that is integral to the AEC process is a challenge for government users.

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Electronic Parts - Microcircuits
AEC-Q100 vs QML/QPL

Summary: All applicable tests of AEC-Q100 are covered by QML/QPL microcircuits

Q100 Test	Description	QML/QPL
-01	Wire bond shear	Specified
-02	ESD HBM	Specified
-03	ESD MM	Not specified, characterized for sensitive products
-04	Latch up	Specified
-05	Data retention, OLT	Specified
-06	Gate leakage	Not specified, plastic package specific test
-07	Fault Simulation	Specified
-08	ELFR	Specified
-09	Electrical distribution	Specified
-10	Solder ball shear	Being added
-11	ESD CDM	Not specified, characterized for sensitive devices
-12	Power devices	Specified

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- NASA Electronic Parts Assurance Group (NEPAG)

Background Material

(Material will not be presented--only for information)

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Existing Quality Assurance Levels: Microcircuits

Eight quality assurance levels are provided for in the microcircuit specification MIL-PRF-38535.

- Class M. Items which have been subjected to and passed all applicable requirements of appendix A herein and are documented on an SMD. This product is intended for military applications.

- Class N. Items which have been subjected to and passed all applicable requirements of this specification including qualification testing, screening testing, and TCI/QCI inspections, and are encapsulated in plastic. This product must be assessed by the user to determine if it is appropriate for use in users' application.

- Class Q. Items which have been subjected to and passed all applicable requirements of this specification and applicable appendices including qualification testing, screening testing, and TCI/QCI inspections.

- Class V. Items that meet all the class Q requirements, and have been subjected to, and passed all applicable requirements of appendix B in MIL-PRF-38535.

Existing Quality Assurance Levels: Microcircuits (Contd)

- Class Y. The class Y device will be defined as a microcircuit employing a ceramic non-hermetic package, which meets all applicable requirements of this specification including qualification, screening and TCI/QCI requirements, and all applicable requirements of Appendix B in MIL-PRF-38535.

- Class B. Items which have been subjected to and passed all applicable requirements of this specification including qualification testing, screening testing, and TCI/QCI inspections and are documented on a MIL-M-38510 specification sheet.

- Class S. Items that meet all the class B requirements, and have been subjected to, and passed, all applicable requirements of Appendix B in MIL-PRF-38535 and are documented on a MIL-M-38510 specification sheet.

- Class T. Class T is a quality level whose requirements are defined by para 3.4.8 of MIL-PRF-38535 and as documented on an SMD. Class T is not for use in NASA manned, satellite, or launch vehicle programs without written permission from the applicable NASA Project Office (i.e., cognizant EEE parts authority).

Existing Quality Assurance Levels: Hybrids

Seven quality assurance levels are provided for in the hybrid specification MIL-PRF-38534. Four of these classes, in highest to lowest order, are K, H, G and D, as defined below. The fifth class is Class E, the quality level associated with a Class E device is defined by the acquisition document. The sixth and seventh classes are L and F for non-hermetic devices, with Class L being the higher quality assurance level.

- Class K. Class K is the highest reliability level provided for in this specification. It is intended for space applications.

- Class H. Class H is the standard military quality level.

- Class G. Class G is a lowered confidence version of the standard military quality level (H), a possibly lower temperature range (–40ºC to +85ºC), a manufacturer guaranteed capability to meet the Class H conformance inspection and periodic inspection testing, and a vendor specified incoming test flow. The device will meet the Class H requirements for in-process inspections and screening.

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Existing Quality Assurance Levels: Hybrids
(Contd)

- Class D. Class D is a vendor-specified quality level available to this specification. This is a possibly lower temperature range (0ºC to +70ºC) part with a vendor specified test flow available from a QML listed manufacturer.

- Class E. Class E designates devices which are based upon one of the other classes (K, H, or G) with exceptions taken to the requirements of that class. These exceptions are specified in the device specification; therefore, the device specification should be carefully reviewed by the user to ensure that the exceptions taken will not adversely affect the performance of the system.

- Class L. Class L is the highest quality class for non-hermetic devices.

- Class F. Class F is the standard quality class for non-hermetic devices.

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AMERICA'S COMBAT LOGISTICS SUPPORT AGENCY

DLA Land and Maritime

Document Standardization Division

Vendor Item Drawing (VID) Program

JEDEC Memphis, Tennessee

May 20-23, 2013

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Vendor Item Drawing (VID) Program

VID Update Approach

- Single standardization document available to the DLA Land and Maritime web site:
  http://www.landandmaritime.dla.mil/Programs/Smcr/
- Controlled baseline.
- Enhanced product change notification of processes, materials, electrical performance, finish, molding compounds and manufacturing locations.
- Extended temperature performance.
- Enhanced pedigree - reliability and electro migration checks and electrical characterization over temperature.
- Also available in small plastics package.
- Package performance over temperature.
- Enhanced obsolescence management.

DEFENSE LOGISTICS AGENCY
AMERICA'S COMBAT LOGISTICS SUPPORT AGENCY

Vendor Item Drawing (VID) Program

As of January 2013	As of May 2013
❖ 492 VID Dated	❖ 507 VID dated
❖ 884 Part Types included in the VID	❖ 901 Part Types included in the VID
❖ 61 VID drawings in-process	❖ 49 VID drawings in-process
❖ 4 Manufactures: TI, Intersil, Maxim and Analog Devices	❖ 4 Manufactures: TI, Intersil, Maxim, Analog Devices

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Microcircuit
New Technology Evaluation

- Scope. The qualified manufacturers listing (QML) program applies quantifiable measurement techniques that evaluate a manufacturer's ability to define and follow a baseline of its process. This baseline can include innovative and improved processes that result in an equivalent or higher quality product, provided that the methods used to evaluate and document these changes have been reviewed and approved.

- Once QML status is achieved, the manufacturer's Technical Review Board (TRB) may approve change(s) to the process baseline based on appropriate reliability and quality data upon notification of and concurrence from of the Qualifying Activity (QA).

- The approach outlined in MIL-PRF-38535, Appendix H contains a proven baseline that includes details of the certification, validation, and qualification programs. The necessary characterization (including wafer-level), screening, and qualification testing applicable to new technologies (including new packaging) are also included. Appendix H of MIL-PRF-38535 is a mandatory part of the specification. The information contained therein is intended for compliance.

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Microcircuit
Radiation Hardness Assurance (RHA) Levels

Qualification to RHA levels. Qualification to a RHA level shall consist of characterization to the highest offered RHA level of total ionizing dose (TID) and irradiation conditions testing by performing step stress dose level testing as a minimum 10 krad(Si), 30 krad(Si), 50 krad(Si), 100 krad(Si), 300 krad(Si), 500 krad(Si) and 1 Mrad(Si) or to the highest dose level offered. The radiation testing plan (QM Plan) and qualification to the appropriate quality and reliability assurance level of device class B, Q, S, V, Y, or T shall be submitted for QA approval. The designator RHA levels are defined below:

RHA level designator	TID in Rad (Si)
/ or -	No RHA
M	3000
D	10^4
P	3×10^4
L	5×10^4
R	10^5
F	3×10^5
G	5×10^5
H	10^6

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http://nepp.nasa.gov

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