Approach for Passive Parts Procurement for Space in New Space Scenario

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Olga Ramos, David Nuñez, Manuel Morales
ALTER Technology TÜV Nord
Tomas Alba Edison 4, PCT Cartuja; 41092 Seville, Spain
email: olga.ramos@altertechnology.com
david.n@altertechnology.com
manuel.morales@altertechnology.com

INTRODUCTION:

During the last decade, more than 1,480 satellites were put in orbit. However, the current forecast for the next 10 years is exceeding the number of 9,000 satellites.

Many of these satellites will be based in the so called "New Space" concept, where an emerging demand of solutions based in lower cost, faster development time and higher technical performance exists.

Under this environment, it is required to identify, not only technologies but also validation approaches capable to generate the required confidence and reliability for the intended applications.

Not much focus on passive parts has been placed under this new approach. Partially because the cost of some of these parts (i.e. resistors, capacitors) is lower with respect to other families. Additionally, some passive families (i.e. relays, connectors) where the cost is much higher are also considered critical from the reliability point of view.

Considering all the above, it is required to consider and adopt a new process for product selection and validation steps ensuring we are meeting the defined targets (low cost, lower delivery time and higher performance) without a significant compromise of the final product reliability.

During this paper two main topics will be addressed:

1. When the selection of non hi-rel passive parts makes sense from the cost and performance point of view.
2. How making those non hi-rel parts a safe choice by the usage of validation techniques allowing gaining the required confidence in the reliability of the parts.

SELECTION OF EEE PARTS. CONSIDERATIONS.

Typical European project are classified as class 1 (top level) to class 2 and class 3. Although dedicated product assurance requirements are tailored for each project, ECSS-Q-ST-60 is still the baseline in terms of understanding the additional test (if any) to be considered in each project.

In the last 5-10 years and in view of the forthcoming necessities, industry has considered many possible scenarios and has been struggling to consider the possible additional test to mitigate the risk of considering commercial parts in Space equipments. This common effort leaded by Space Agencies, industry and main users resulted to a set of documentation currently considered as the baseline for the procurement of testing of COTS for space applications. Basically, the main documents under consideration are:

- ECSS-Q-ST-60-13C Commercial Electrical, Electronic and Electromechanical (EEE) components from ECSS
- PEM-INST-001 Instructions for Plastic Encapsulated Microcircuit (PEM), Selection screening and Qualification from NASA/GSF
- EEE-INST-002 Instructions for EEE Parts Selection, Screening, Qualification and Derating.

Unfortunately, despite EEE-INST-002 have minor references about additional requirements for commercial passive components, none of the documents above mentioned includes a dedicated analysis for screening, evaluation and qualification for passive components.

Active devices have always leaded, because complexity, performance, cost and lead time issues, the need of standardization rules to support the characterization of commercial devices.

However, there is disruptive tendency not only in term of the exponential grow of satellites but particaularly in passive components in the last years:

- Increasing lead time for Space passive components, even dramatically for particular technologies like Tantalum and Thin Film resistors.

- Increasing of unit price despite recent decrease of raw material

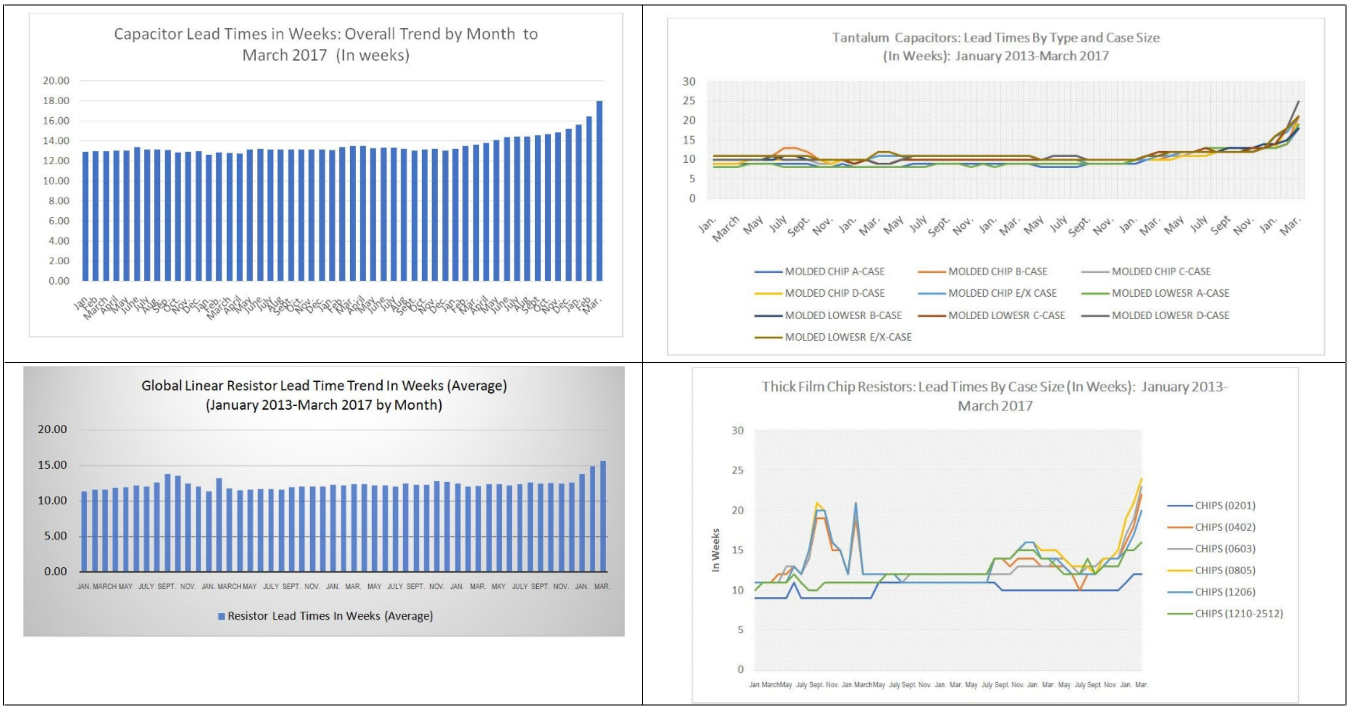


Figure 1. Source: Passive Electronic Components: World Market Outlook: 2017-2022 ISBN#1-893211-99-1 (2017)

These tendencies are not only related to commercial but also to Hi-rel/Space parts. In addition, because of more severe screening and quality procedures, parts designed for Space applications have in general an additional 100-500% lead time adder to their commercial equivalents.

Therefore, Space users are facing even the dilemma (sometimes a must) to consider commercial parts for their design because of lead time constrains in addition to standard unit price reduction pressure.

The new macro constellations have entered in the space business breaking the rules in terms reliability, shifting the risk analysis and reliability from the EEE part itself to the system or board perspective. In these cases, automotive parts are usually considered the closest option to Space requirements without having the complete screening and reliability features. Examples of these considerations are well described in several conferences in last ESCCON 2016 and SPCD 2016. However the main question is still when it makes sense to change from pure space parts to a different approach (COTS, COTS+, commercial, automotive…..) as a function of the project requirements.
Although this exercise has to be done for every particular project, partnumber and considering the quantities involved in each procurement, the following tables are typical figures for MLCC (CDR caps) and tantalum (CWR11) as a function of the project class requirements and the class of component procured:

	FM QTY				
	10pcs	100pcs	1000pcs	>10000pcs	Upscreening cost/lot
Class 1 project	Class1&2: 0.5-1.5$	Class1&2: 0.5-1.5$	Class1&2: 0.5$	Class1&2: 0.32$	N/A
	Class 3: 0.5-1.0$	Class 3: 0.5-1.0$	Class 3: 0.4$	Class 3: 0.27$	5K$
	Autom: 2500pcs@0,05$	Autom: 2500pcs@0,05$	Autom: 2500pcs@0,05$	Autom: 0,02$	15K$
Class 2 project	Class1&2: 0.5-1.5$	Class1&2: 0.5-1.5$	Class1&2: 0.5$	Class1&2: 0.32$	N/A
	Class 3: 0.5-1.0$	Class 3: 0.5-1.0$	Class 3: 0.4$	Class 3: 0.27$	N/A
	Autom: 2500pcs@0,05$	Autom: 2500pcs@0,05$	Autom: 2500pcs@0,05$	Autom: 0,02$	10K$
Class 3 project	Class1&2: 0.5-1.5$	Class1&2: 0.5-1.5$	Class1&2: 0.5$	Class1&2: 0.32$	N/A
	Class 3: 0.5-1.0$	Class 3: 0.5-1.0$	Class 3: 0.4$	Class 3: 0.27$	N/A
	Autom: 2500pcs@0,05$	Autom: 2500pcs@0,05$	Autom: 2500pcs@0,05$	Autom: 0,02$	0-5K$
Constellation project	Class1&2: 0.5-1.5$	Class1&2: 0.5-1.5$	Class1&2: 0.5$	Class1&2: 0.32$	N/A
	Class 3: 0.5-1.0$	Class 3: 0.5-1.0$	Class 3: 0.4$	Class 3: 0.27$	N/A
	Autom: 2500pcs@0,05$	Autom: 2500pcs@0,05$	Autom: 2500pcs@0,05$	Autom: 0,02$	0-5K$

Figure 2: Typical cost for CDR capacitors vs project requirement vs intrinsic quality level required

	FM QTY				
	10pcs	100pcs	1000pcs	>10000pcs	Upscreening cost/lot
Class 1 project	Class1&2: 50$	Class1&2: 40$	Class1&2: 25$	Class1&2: 20$	N/A
	Class 3: 25$	Class 3: 20$	Class 3: 12$	Class 3: 8$	6K$
	Autom: 2000pcs@0,52$	Autom: 2000pcs@0,52$	Autom: 2000pcs@0,52$	Autom: 0,25$	18K$
Class 2 project	Class1&2: 50$	Class1&2: 40$	Class1&2: 25$	Class1&2: 20$	N/A
	Class 3: 25$	Class 3: 20$	Class 3: 12$	Class 3: 8$	N/A
	Autom: 2000pcs@0,52$	Autom: 2000pcs@0,52$	Autom: 2000pcs@0,52$	Autom: 0,25$	12K$
Class 3 project	Class1&2: 50$	Class1&2: 40$	Class1&2: 25$	Class1&2: 20$	N/A
	Class 3: 25$	Class 3: 20$	Class 3: 12$	Class 3: 8$	N/A
	Autom: 2000pcs@0,52$	Autom: 2000pcs@0,52$	Autom: 2000pcs@0,52$	Autom: 0,25$	0-5K$
Constellation project	Class1&2: 50$	Class1&2: 40$	Class1&2: 25$	Class1&2: 20$	N/A
	Class 3: 25$	Class 3: 20$	Class 3: 12$	Class 3: 8$	N/A
	Autom: 2000pcs@0,52$	Autom: 2000pcs@0,52$	Autom: 2000pcs@0,52$	Autom: 0,25$	0-5K$

Figure 3: Typical cost for CWR capacitors vs project requirement vs intrinsic quality level required

Upscreening cost is the major driver for the selection from the pure cost point of view. In addition, the activities to be performed in these ‘upscreening’ are not clearly defined because lack of standard similar to ECSS-Q-ST-60-13 for passive component in Europe. Proposal for potential upscreening are discussed in this paper in the following sections

However, we have currently discussed only about typical capacitors and resistors widely used. The performance and technical requirements (mass saving, higher frequencies, power reduction, cryogenic temperatures, ….) of new challenging projects either required for highly demanding missions like JUICE and SOLAR ORBITER or massive quantities of satellites like macro-constellations lead again to the need of dedicated evaluation, upscreening and qualification procedures.

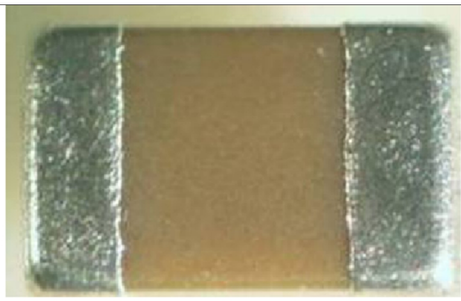
RISK CONSIDERATIONS FOR COTS

COTS parts can be selected in a space application for a set of different reasons that can lead to different approaches for product evaluation and characterization.

In any case, the use of COTS components must be considered a high risk scenario and handled in a way risks are minimized. In general, there are no controls in commercial industry that are imposed uniformly upon all manufacturers to build in a common acceptable quality level as required for space application. No specification system or specific quality controls are imposed to the manufacturer by third parties. This can lead to significant variation in the risk associated between parts from different manufacturers, as well as between different part types and also different lots from the same manufacturer, depending on process maturity and stability. For this reason, it is very important to carefully select parts, manufacturers and procurement channels.
The consideration of acceptable risk for the project, as well as the budget limitation, will allow optimizing the selection/evaluation/testing sequence and must be defined on a case by case basis.
To minimize risks, the main focus of requirements will be oriented to ensure that the selected COTS will be able to sustain their use in Space environment.

Counterfeit

Counterfeit issue is no longer exclusive of expensive active devices. Even commercial MLCC are now susceptible of counterfeit threat.



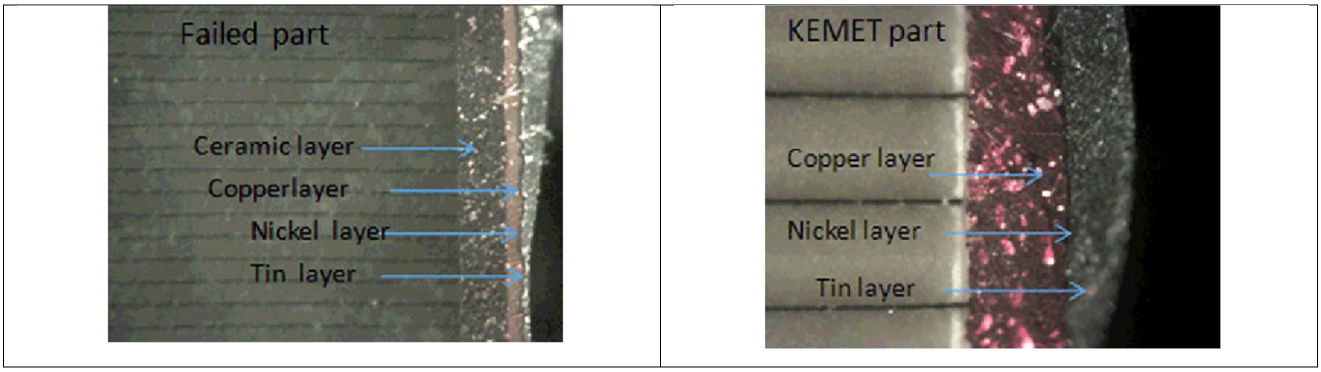


Figure 2: Anshul Shrivastava and Michael Pecht Counterfeit capacitors in the supply chain (Article in Journal of Materials Science Materials in Electronics, February 2014)

Anti-counterfeit measures must be implemented during the procurement and the acceptance phase. Starting with the exclusive use of trusted and validated sources and following with External Visual Inspection, Electrical measurements for lot validation…

Lot homogenity

The homogeneity in Space EEE parts is controlled and documented, but this is not the case for COTS and previous data collected could not be too representative of current lot. In the event that no evidence of lot homogeneity is available and the information obtained cannot provide enough confidence in the product homogeneity, it is required to evaluate the additional actions to increase the confidence on the validity of results obtained from testing.

Technology

The technology used by a commercial part may be so new that it requires deeper analysis of the maturity level and new failure modes. In addition to that, long term reliability may not be completely assessed by the manufacturer so special attention must be paid while defining the screening and qualification sequence.
Manufacturers of commercial of the shelf products are on a continuous process to improve quality and reliability of their products, reducing yield of each manufactured lot. The technology evolution, reducing the life cycle of these products is not favoring long term studies and thus, they are difficult to be considered, even for technologies and products in production for several years.

Material restriction

Pure tin is the standard termination for COTS components. In order to save the inherent risk of using pure tin in space applications (mainly due to tin whiskers growth) several steps must be taken into consideration, as identifying RoHS products, re-tinning process feasibility, material analysis, etc. All materials must meet the requirements of ECSS-Q-ST-70 regarding off-gassing, out-gassing, flammability, toxicity and any other criteria specified for the intended use or must be validated by the appropriate risk assessment.

Temperature range

COTS are usually rated for industrial or commercial temperature ranges. Parts will be selected with the highest available temperature range. If the COTS have to operate outside of their operating temperature, it must be specifically noted in order to ensure the complete characterization in the extended temperature range is performed.

Product Life Cycle

As COTS are subject to the standard market commercial rules and shorter life cycles, the risk of unavailability in a short term is higher. As a general guide, COTS components have a short manufacturing life cycle, often as little as two years from release to the user community to cessation of production. So, it is important to evaluate manufacturer process for obsolescence notification and program for last time buys.
This means that a stocking plan must be taken into account in the pre-procurement activities to maintain a stock of useable components. However, this plan should be calculated case-by-case.
ATN have demonstrated that COTS components can be stored for extended periods of time with no evidence of degradation if proper conditions are used. However, several manufactures do not guarantee its products a period of time (~2 years) after the manufacturing date. A specific watchdog and validation before mounting procedure is required to ensure usability of parts and validity of parts before assembly in order to guarantee the good function of COTS.

Critical Parameters

During the process selection it is required to identify the key parameters that the selected product must meet from the reliability and technical point of view. The early definition of critical parameters will allow the optimization of the electrical testing flow and parametrical table.

The selection of components should be done considering all above mentioned points, and put in special attention to reliability figures, statistic information, such as number of failures detected, number of manufactured lots, state of the market, for example life cycles, estimated component market permanence, production volume, current alerts.

SCREENING AND QUALIFICATIONS VS PROJECT CLASS

Different documents available from each system (NASA, ESCC….) already determines which test has to be performed for the different families of components as a function of the project class. However, as previously discussed, this is basically true for microcircuits and other so called active devices.

Multilayer Ceramic Capacitors (MLCC) and Thin/Thick Film chip resistors are massively used also in space applications. Therefore the potential screening/qualification proposal will be focused over these particular families.
Based on the consideration that automotive market is providing potential candidates for space missions, we will analyze potential working flow as example for the different missions and the additional test to be performed.

All these information should be collected and rationally exposed in a Justification Document (JD), in a similar way that ECSS-Q-ST-60-13C is currently requiring for active parts especially on class 1 projects. This JD shall include general information about the type to be considered, quality and reliability data (automotive qualification status, qualification/evaluation mfr data, periodical test data from mfr ….supporting reliability data about life test, humidity test and thermal cycling). It is highly recommended that life test, humidity test and themal cycling test data shall be compared to the its mission needs .This document would help to define additional activities required to be carried in the different phases (Evaluation, screening and qualification).

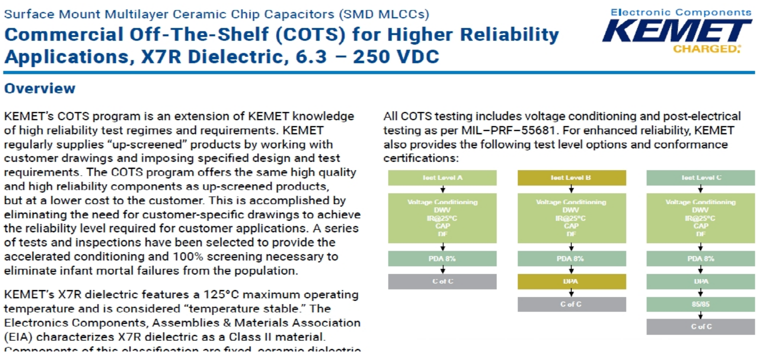
		Evaluation		Screening		Qualification/LAT	
Project Class	Class 1	Y(1)	Y(1)	Y	Y	N(1)	N(1)
	Class 2	Y(1)	N	Y	Y(2)	N(1)	N
	Class 3	Y(2)	N	Y	Y(2)	N(1)	N

(orange) Parts not qualified to AEC-Q200
(green) Parts qualified to AEC-Q200

(1) If evaluation test is performed directly on flight lot, evaluation can be used as lot acceptance test
(2) Light version, not all test required (JD)

Figure 3: Evaluation, screening and qualification vs project class requirements for MLCC capacitors

Based on the AEC-Q 200 self-qualification, some automotive grade parts are sometimes considered flight worthy without additional test or very limited testing. Even some manufacturers have developed some intermediate high-rel / COTS parts for the new market trend:


Surface Mount Multilayer Ceramic Chip Capacitors (SMD MLCCs)

Commercial Off-The-Shelf (COTS) for Higher Reliability Applications, X7R Dielectric, 6.3 – 250 VDC

Electronic Components KEMET CHARGED.

Overview

KEMET's COTS program is an extension of KEMET knowledge of high reliability test regimes and requirements. KEMET regularly supplies "up-screened" products by working with customer drawings and imposing specified design and test requirements. The COTS program offers the same high quality and high reliability components as up-screened products, but at a lower cost to the customer. This is accomplished by eliminating the need for customer-specific drawings to achieve the reliability level required for customer applications. A series of tests and inspections have been selected to provide the accelerated conditioning and 100% screening necessary to eliminate infant mortal failures from the population.

KEMET's X7R dielectric features a 125°C maximum operating temperature and is considered "temperature stable." The Electronics Components, Assemblies & Materials Association (EIA) characterizes X7R dielectric as a Class II material. Components of this classification are fixed, ceramic dielectric

All COTS testing includes voltage conditioning and post-electrical testing as per MIL–PRF–55681. For enhanced reliability, KEMET also provides the following test level options and conformance certifications:

Ordering Information

C	1210	T	104	K	5	R	A	C	TU
Ceramic	Case Size (L" x W")	Specification/ Series	Capacitance Code (pF)	Capacitance Tolerance	Rated Voltage (VDC)	Dielectric	Failure Rate/Design	Termination Finish[1]	Packaging/ Grade (C-Spec)
	0402 0603 0805 1206 1210 1812 2220	T = COTS	Two significant digits and number of zeros	J = ±5% K = ±10% M = ±20%	9 = 6.3 8 = 10 4 = 16 3 = 25 5 = 50 1 = 100 2 = 200 A = 250	R = X7R	A = Testing per MIL-PRF-55681 PDA 8% B= Testing per MIL-PRF-55681 PDA 8%, DPA per EIA-469 C = Testing per MIL-PRF-55681 PDA 8%, DPA per EIA-469, Humidity per MIL-STD-202, Method 103, Condition A	C = 100% Matte Sn L = SnPb (5% Pb minimum)	See "Packaging C-Spec Ordering Options Table" below

Figure 4: Kemet Datasheet for COTS for higher Reliability applications

Sometimes these products are manufactured in the same production line and with same raw materials that MIL qualified capacitors/resistors but with lower or custom screening. In addition, the test carried out on these components can rely on a high number of accumulated hours, leading to failure rates similar to the ones achieved by pure space components. Access to the periodical reliability figures and statistics are definitely key information to be taken into account at the time of considering a pure commercial or automotive part for space applications (concept to monitored reliability got non Hi-rel parts).

As summary, Figure 5 includes the proposal of the different options for evaluation, screening and qualification test versus the project quality levels usually managed for European projects

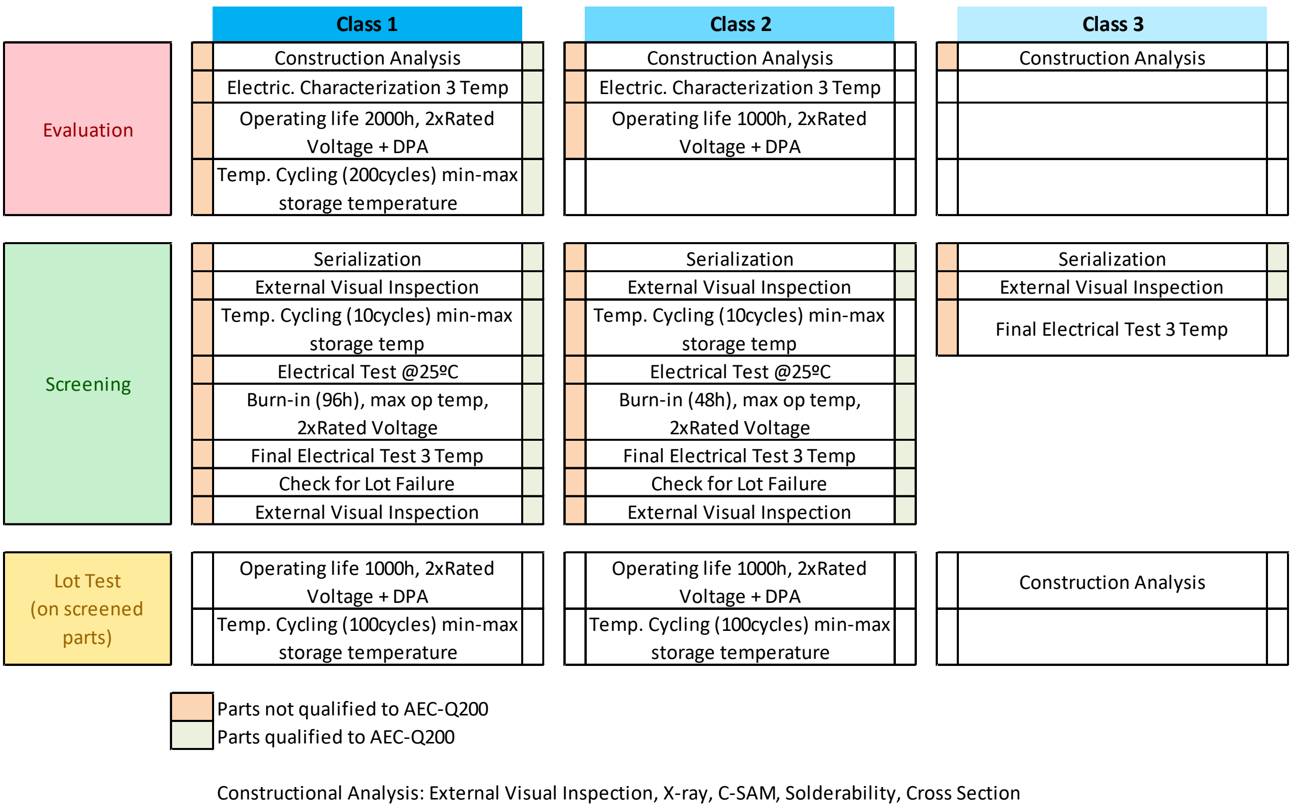


Figure 5: Proposal for MLCC devices. Evaluation, screening and Lot Acceptance

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