COTS Automotive Capacitors Procurement and Evaluation Case Study for SME Space Hardware Manufacturer

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1 SCOPE

This report summarizes outcomes of ESA ESTEC contract **Automotive Capacitor Procurement Assessment** on COTS, automotive tantalum & MLCC commercial capacitors procurement and evaluation case study for SME space hardware manufacturer.

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2 PROJECT BACKGROUND & OBJECTIVES

2.1 Project Background

Currently, there is an on-going update of the commercial EEE components ECSS-Q60-13 in order to include Automotive passive parts certified according to AEC-Q200 automotive qualification standard. Capacitors are the most critical EEE passive components for space applications due to their various number of applications and performances' reliability.

Some manufacturers of automotive capacitors are implementing a monitoring of their production line. However, access to these data is not always available freely. Therefore, the only way to verify this information is by procuring automotive batches directly from the component manufacturer or through a distributor.

It is important to underline that the automotive qualification standard AEC-Q200 does not include any screening of the procured capacitors, which means that early failure rate cannot be properly assessed.

2.2 Objectives of the Activity

The aim of this activity is to procure batches of automotive and COTS/CECC tantalum and MLCC capacitors in order to verify the procurement documents and reliability data on procured capacitors and to assess the percentage of early failure on unscreened batches of capacitors.

3 TECHNOLOGY BACKGROUND

3.1 Component Grades

Applications for the use of High Reliability Components include anything from static ground applications – e.g. test equipment, support equipment, etc through to flight in Deep Space. Subject of this study is evaluation of Commercial-off-the-shelf (COTS) & Industrial Grade tantalum and MLCC capacitors i.e. standard catalogue components that are intended for general usage.

Commercial Grade

A commercial grade electronic component is manufactured to datasheet specifications only. A large amount of flexibility surrounds the design, materials, processes, and testing. The electronic component manufacturer is therefore without restriction and can change the fundamentals of the electronic component, to suit internal / external commercial and technical objectives.

Qualification or testing requirements tend not to be mandatory, components are designed and manufactured for the best performance, cost, or a ratio of both.

Automotive Grade

AEC-Q200 is a Stress Test Qualification for Passive Components, it has been defined by the Automotive Electronics Council (AEC). Scope of this report is to test the automotive parts – **in further report text if "commercial" part level is mentioned it refer to the automotive commercial parts.**

For a manufacturer to state their passive Electronic Component is AEC-Q200 qualified, the product must be tested, and the results logged, as outlined in the qualification document. These tests are performed at different temperatures and dependent on the ability of the passive component to pass or fail at a particular temperature will result in a grading between Grade 0 -> Grade 4. These grades correspond with different automotive applications from Non-Automotive to All Automotive.

Unless changes are made to either the product or process no further testing is required to supply AEC-Q200 qualified passive Electronic Components.

GRADE	TEMPERATURE RANGE		PASSIVE COMPONENT TYPE Maximum capability unless otherwise specified and qualified	TYPICAL/EXAMPLE APPLICATION
	MINIMUM	MAXIMUM		
0	-50°C	+150°C	Flat chip ceramic resistors, X8R ceramic capacitors	All automotive
1	-40°C	+125°C	Capacitor Networks, Resistors, Inductors, Transformers, Thermistors, Resonators, Crystals and Varistors, all other ceramic and tantalum capacitors	Most underhood
2	-40°C	+105°C	Aluminum Electrolytic capacitors	Passenger compartment hot spots
3	-40°C	+85°C	Film capacitors, Ferrites, R/R-C Networks and Trimmer capacitors	Most passenger compartment
4	0°C	+70°C		Non-automotive

Source – AEC-Q200 REV D Stress Test Qualification for Passive Components

COTS-Plus

The product is designed and manufactured to commercial standards, the production batch is then up-screened typically with testing in "accordance" to a particular MIL-PRF specification, it may also include known methods specific to the manufacturer resulting in an increased reliability versus the commercial rating, this allows the user to calculate expected failure rates of the particular passive component.

The Infant mortality rate is reduced leading to a much higher reliability component compared to the standard commercial grade option.

To further increase reliability and depending on the passive component technology, possibilities include the ability to specify reliability grading, surge current & group testing.

IECQ-CECC

CECC qualified components were, historically, the preference of European companies designing products for an intended use in Hi-Rel markets i.e., aerospace or military for use on land, sea and airborne applications. It was common for multiple manufacturers to provide parts to a particular CECC specification therefore providing consistent quality and performance specifications. In today's market, many passive component manufacturers have decided that the reduction in business they

once enjoyed no longer supports the costs incurred to supply this standard, we therefore see multiple manufacturers listed for a particular CECC spec or, only one.

Product qualification is granted within the IECQ-CECC system when the manufacturer can demonstrate an electronic component or range of components meets the specification, routine periodic testing is then required of the component, for example: Visual, Dimensions, Value, Destructive Physical analysis, Solderability. Further to this, a rolling test program is mandatory including tests as: High Temperature Exposure, Temperature Cycling, Operational Life, Thermal Shock, etc.

For a manufacturer to maintain IECQ-CECC facility accreditation, periodic audits of the manufacturers quality management systems are required by an independent certification body.

Furthermore, CECC parts can only be sold and released by authorised distributors which the manufacturers appoint, therefore, a listing as a franchised source for the manufacturer is not enough to supply CECC released products. Only distributors who are appointed by the manufacturer and audited to the referenced CECC specification can sell and release the product to CECC.

MIL-PRF

MIL-PRF was developed and is maintained by the United States Military. It is a performance specification which details the functional requirements, allowing the user to obtain predictable quality levels for the component they are considering.

For a manufacturer to state they offer a MIL-PRF approved product ,they must be listed on the QPL (Qualified Product List), which requires approval of the manufacturers QA (Quality Assurance) program, extensive documentation is mandatory to prove each part will be manufactured identically, therefore the design is strictly controlled and certain changes must be qualified and submitted to the DLA (Defense Logistics Agency) for approval, lot basis testing is mandatory for the manufacturer to maintain qualification.

With a MIL-PRF Passive Electronic Component, depending on the type of component selected, the environment and intended use, the user selects a failure product level or failure rate level which is acceptable for the program, these include:

Exponential FRL % per 1,000 hours

M = 1.0%
P = 0.1%
R & U = 0.01%
S & V = 0.001% – space

Weibull FRL % per 1,000 hours

A = non ER (Established Reliability)
B = (0.1%
C = (0.01%
D = (0.001%
T = (0.01%) – space, includes additional mandatory testing and inspection.

An additional test normally specified when high reliability customers are looking to use Solid Tantalum capacitors in their designs is surge current screening. Solid Tantalum capacitors are subjected to a peak current charge, this is to remove parts which may fail on start-up, this screening option includes:

Solid Tantalum capacitors

A =10 cycles, +25°C
B =10 cycles, -55°C & +85°C
C =10 cycles, -55°C & +85°C before Weibull
Z = None required

DLA Land and Maritime, DESC, and DSCC drawings

Drawings are intended for use when military QPL (Qualified Product List) products are not available or will not adequately perform the required function of the application. They also help to facilitate in reducing duplication of documentation. To be eligible for a manufacturer to list as an approved source of supply against the drawing, it is normally stipulated that manufacturer is listed on the QPL or has agreed on an inspection program to the referenced MIL-PRF and is detailed in the scope of the drawing.

Part must be purchased to DSCC part numbers to assure that all performance requirements and tests are met.

ESCC QPL

The ESCC QPL (European Space Components Coordination, Qualified Parts List) makes available space components which have been fully evaluated, qualified and maintained with regards to the required standards for use in European Member states space programs. This allows Passive Electronic Components to be purchased from a list of Qualified Component types and Manufacturers to a detailed specification, this strictly controls the design, process control, inspection and documentation.

To further ensure the assurance of the product depending on the technology, additional testing can be stipulated via the part number or on the purchase order, examples included LVT (Lot Validation Testing) and LAT (Lot Acceptance Test)

EPPL

The EPPL (European Preferred Part List) serves the purpose of providing users with component availability suitable for use in space missions but which are not fully space qualified and do not appear on ESCC QPL.

3.2 MLCC and Tantalum Capacitors Introduction

MLCC class II and tantalum solid electrolytic capacitors are standard capacitor technologies available on the market in different reliability grades from commercial, through industrial, medical and automotive to COTS+, MIL or ESA QPL.

MLCC class II are electrostatic multilayer capacitors, where high capacitance is achieved by using of high K dielectric $BaTiO_3$ material deposited and stacked in thin layers with metal electrodes into a multilayer structure. The construction features high design flexibility, low ESR and low ESL parameters and non-polar operation. Usage of many thin layers within the small space on the other hand present some reliability concerns over thermo-mechanical, mechanical and electrical robustness.

The maximum available CV and construction differences (design rules) may be significantly different for specific applications as also is reflected in maximum available CV (capacitance time voltage factor) between the component reliability classes as it can be demonstrated in Fig.1. Maximum available capacitance for consumer applications is XX times higher compare to automotive grade parts in the same package.

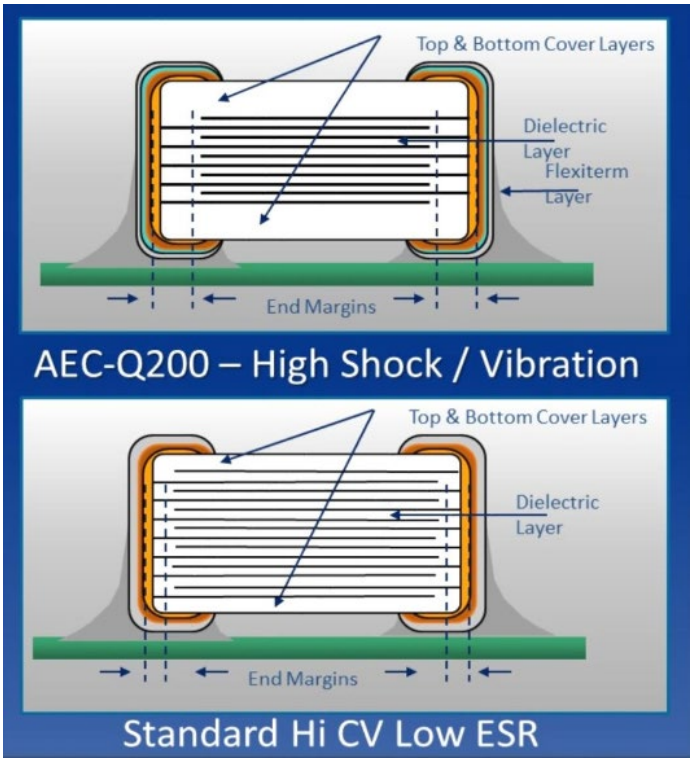


Figure 1. MLCC construction comparison AEC-Q200vs standard grade; source: AVX

Tantalum solid electrolytic capacitors present polarized components with solid firm construction highly robust from principle against environment harsh conditions including mechanical shocks and vibrations. The higher-grade component series are mostly similar in construction (except undertab construction that is restricted from high reliability applications due to its limited soldering visual inspection).

The higher specification parts are using more conservative design parameters / higher safety margins to achieve lower failure rates. In consequence, the higher-grade parts are "just" one or two steps lower CV compare to the highest available parts on the market dedicated to consumer applications. See Fig.2.

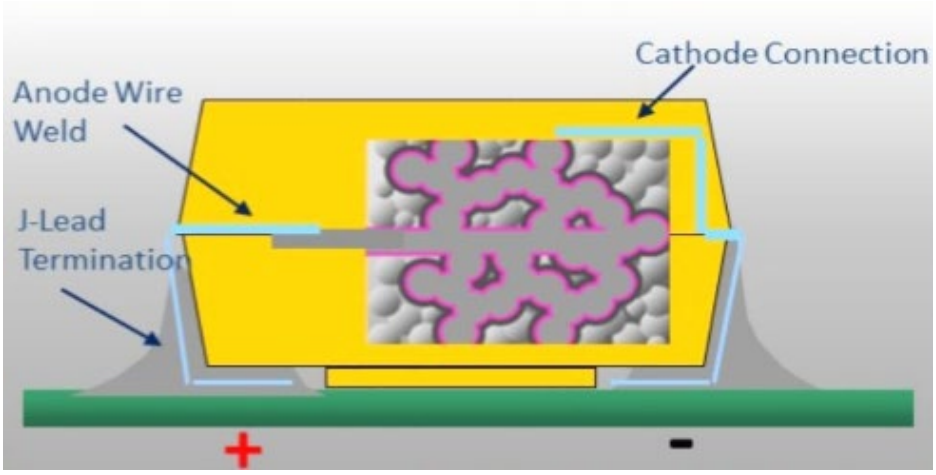


Figure 2. tantalum capacitor construction – common structure for AEC-Q200and standard grade; source: AVX

In consequence, as also visible in Figure 1., while in consumer applications MLCC high CV capacitors present in many cases an equivalent or close-by alternative to tantalum capacitors, this is not so true on higher grade components class level as the need for higher internal design safety margins significantly limits maximum CV values on MLCC capacitors.

4 PROCUREMENT REVIEW

4.1 AEC-Q200Requirements

Definition of AEC: "AEC documents are designed to serve the automotive electronics industry through eliminating misunderstandings between manufacturers and purchasers, facilitating interchangeability and improvement of products, and assisting the purchaser in selecting and obtaining the proper product with minimum delay."

The latest AEC-Q200 Revision D base document issued on June 1st 2010 defines the minimum stress test driven qualification requirements and references test conditions for qualification of passive electrical devices.

In base document the general requirements include:

- Qualification and Requalification conditions
- Qualification Tests
- Qualification Sample Size Requirements

Specific to tantalum and ceramic capacitors:

- Methods Referenced Tantalum and Ceramic Capacitors
- Ceramic/Tantalum Process Change Qualification guidelines for the Selected Test
- Acceptance Criteria for Ceramic COG, X7R and X5R SMD Capacitors
- Acceptance Criteria for Tantalum and Niobium Oxide Capacitors

Note: AEC-Q200 define qualification test requirements only. Quality system documents such as PPAP/APQP are now part of the latest IATF 16949 quality system certification.

Wearout Reliability Tests (End of Life Testing)
Testing for the failure mechanisms specific to each component technology should be available to the user whenever a new technology or material relevant to the appropriate wearout failure mechanism is to be qualified. The data, test method, calculations, and internal criteria need not be demonstrated or performed on the qualification of every new device but should be available to the **user upon request**.

Note: This information may be subject to a confidentiality agreement, since it contains proprietary information of the supplier.

AEC-Q200 vs ESCC Test Requirements Delta Analysis

The following table shows result of delta analysis between the AEC-Q200and ESCC qualification test requirements on X7R SMD ceramic and tantalum capacitors.

Automotive vs ESCC specification delta analysis

Tantalum and MLCC Class II Capacitors

		Tantalum	MLCC
Tantalum	AECQ-200	ESCC 3012	ESCC 3009
Burn-in	not required	168h level B with serialisation	96h 2xVr
100% X-Ray	not required	level B	not required
Electrical Measurement RT	at 25±5°	at +22 ±3°C	at +20 ±2°C
Storage 1000hrs, no BIAS	Hi Temp 125C	-55/85/125	not required
Temp Cycling -55/125C	1000 cycles	5 cycles	10 cycles
Humidity	85/85 1k hrs, Vr biased	56days damp heat	85/85 1k hrs, 1.5V
Operation Life	125C, 2/3Vr Ta; 125C Vr MLCC, 1k hrs	125C,2/3Vr and 85C Vr 2k hrs	125C 2xVr 2k hrs
Mechanical Shock	1500g for 0.5s	50g 11ms	not required
Vibration	5g 20min 12cycles	20g 20min 12cycles	not required
Resistance to soldering heat	260C for 10s	not required	not required
Solderability	+235°C 4 s	+235°C 4 s	+235°C 4 s
Electrical Characterisation	-55/85/125 ta, 125C MLCC	-55/85/125	125C
Terminal Strength	17.7N 60s	5N 10s	5N 10s
Climatiq Sequence	not required	Dry Heat, Damp Heat, Cold, Low Air Pressure	not required
Board Flex	MLCC only, 60s holding time	NA	not required
Beam Load Test	MLCC only	NA	not required
Surge Voltage	not required	1000cycles 33Ohms	not required

more strict requirements

Table 1. AEC-Q200vs ESCC 3012/3009 delta analysis

Summary of AEC-Q200Requirement Relevant to this Contract

- Component can be purchased under individual purchasing specification that replace AEC-Q200 requirements, but to be considered as "qualified part" it has to meet the AEC-Q200 conditions as the minimum requirements.
- Specific part number qualification data can be replaced by a "family" group data on maximum CV at corners of its specification.
- Testing results of each component technology should be available to the user. The data, need not be available of every new device but should be available to the user upon request. Nevertheless, providing of the test reports can be conditioned by confidentiality agreements.
- In conclusion from above – **AEC-Q200 datapackage is not necessary publicly available document. It should be available upon request; however, manufacturer has the right to request confidentiality agreement prior providing this document.**
- Delta analysis of AEC-Q200vs ESCC was performed as an input for ETP.

4.2 Procurement Process and Documents Availability

4.2.1 Original passive component manufacturers

Three passive component manufacturers were questioned on
a] 100unit order for tantalum and ceramic automotive grade capacitors
b] technical question about automotive parts reliability

with following observations:

- The response from manufacturers on 100unit order can vary by individual person handling the request. Feedback received sorted from the most often:
  - "for non-modular quantities please check our distributors contact list, in case of sample request please fill up this form"
  - "you can request such quantity as samples for your evaluation board, please see the link here."
  - "no response" within two weeks after the online/email request
- The handling of technical question:
  - "we have forwarded your question to our colleagues that will answer to you in follow up email"
  - "for technical questions please check our online knowledge library with most of the common answers"

Summary of procurement process issues

- Procurement of small quantities and non-modular quantities on automotive components **IS NOT**, in difference to space grade parts, generally supported **as a direct business by passive manufacturers.** Purchases are re-directed to their **distributors.**
- Small volume of parts ~100 units is possible to get as a "sample" free of charge upon justification of "high" business opportunity or "interesting opportunity". The "interesting

opportunity" may include also space applications as for many manufacturers getting a "space" heritage on automotive parts is of their current interest and they are open to support it.

- In general, it does not look to be a good idea to combine request for purchasing and technical question in one email. There are different group of support people handling such requests and co-ordination is sometimes fuzzy on side of manufacturers.
- Some manufacturers however are introducing direct contact email to their FAEs and experts online for technical questions. New trend is to have even a live chat with their experts. This seems to be a better way for getting direct, high quality response to technical questions then contacting a local manufacturer representative or writing an email to their general support email address.

4.2.2 Distributors

Three distributors were contacted with the same questions as passive component manufacturers e.g. availability and order for 100units non-modular quantity of tantalum and ceramic capacitors and technical question on reliability data available.

The contacted distributors types under the survey:

- global "universal" distributor of wide range of electronic active and passive components
- global "specialist" distributor focusing passive components
- "catalogue" parts distributor

Observations:

- No issue to order 100units of non-modular samples from all distributors, automotive AEC-Q200 parts are mostly clearly marked including soft termination MLCC capacitors.
- Some distributors request "extra fee" in range of 5 EUR for non-modular quantities = "if they have to cut the parts from original tape".
- The tape cut by distributor may be link with other issue for MSL sensitive parts as the distributors have to open the originally dry packed bag and "re-pack" it to a properly sealed bag. It looks some "universal" and "catalogue" parts distributors are not aware about how critical the MSL issue can be and purchasing of MSL sensitive parts in non-modular quantity requires special attention and trust-building.
- Automotive documentation availability: there is a clear indication of automotive AEC-Q200 parts in the distributor online stocks and selection guides. Standard support is to provide a link to manufacturers materials and datasheets.
- Request for AEC-Q200 datapackage (AEQD) is a legitimate request even for 100units of automotive parts. Per the survey, no distributor is requesting AEQD documents from their suppliers when adding new PN to their portfolio. The common practice is to save AEQD documents in distributors internal database once any other customer asks for AEQD (or even PPAP) on this part, they can re-use the AEQD from their database immediately. When there is a request for AEQD on a PN not in their internal database they contact manufacturer to get it. This means that on specific, common parts it is possible to get AEQD quickly, on others/unique parts the distributor has to contact manufacturer that may take some time to get the AEQD documentation. No one in the survey asked for any

confidentiality agreements. One the other hand, this process may raise some concerns about AEQD issue control on side of distributors from my view. AEQD documents may not be practically updated very often, but this point is not handled satisfactory in my opinion. In some cases (not rare) AEQD is not available from manufacturers on specific PN, but it is supplied for a series / group of products, that agrees with AEC-Q200 as described in Chapter 3.1. There were reported issued about AEQD and PPAP available upon some fee (~ 600 USD), in case of re-sellers / re-branding companies, nevertheless this shall not be applicable for common manufacturers and PNs. All distributors in survey are providing AEQD documents as free of charge service.

4.2.3 Summary – Recommendations of commercial products procurement strategy

In summary of this chapter on commercial products procurement:

- Manufacturers are not willing in general to support orders for small, non-modular quantities on automotive parts as a direct business (in difference to space grade components).
- On the other hand, they can be interested to discuss use of their parts in space to get a space heritage of commercial automotive parts (in current market conditions) and in this case to provide extra support (technical assistance, direct shipment of parts and free samples).
- The small quantities can be ordered directly from all distributors with clear identification of automotive AEC-Q200 products. In general, link to individual and series datasheets are provided for download. Attention must be paid for ordering of small quantities of MSL sensitive parts as the distributor has to open/cut/re-tape the originally sealed dry pack components inhouse. OR (if the project allows) the safest way would be to purchase a full modular reel of the originally dry packed MSL rated parts to be extra sure on moisture control maintenance.
- AEC-Q200 datapackage documentation is not generally published/downloadable, but available upon request mostly free of charge. The documentation control may however raise some concerns on issue control, thus it can be suggested to make sure the latest datapackage version is supplied under request to the distributor or by a direct request to the manufacturer through their dedicated contact on their website/online.
- For technical support and asking for specific data it may be better to contact the original manufacturers directly - if they have a dedicated contact on their web or even live chat support. Note: this “effective, immediate technical support function” can be also a differentiator between the manufacturers.

4.2.4 CECC / COTS components procurement

The COTS/CECC parts leadtimes were in range of 17 weeks. It means much longer compare to commercial parts from the stock available mostly online (unless a special part is selected).

The parts were ordered via High Rel test & distribution house with clear communication, tracking and continuous follow up information. Planned delivery was confirmed in the time of order, delivery status was updated monthly, and the parts were delivered as scheduled. CECC parts were delivered including CECC conformance certificate.

4.3 Parts Proposed for Procurement

Observations:

- The advanced automotive components are available under a shorter leadtime with better availability compare to the cost saving scenario. This is since "space grade" capacitors CV is conservative and very low compare to what other industries, especially consumer, is using as a high-volume runner. In consequence, the low CV "space grade" parts are non-standard, not available in general stocks and often it must be manufactured from the beginning under longer leadtimes. Also, there is a limitation on number of vendors, as high volume MLCC manufactures discontinued such "low CV" parts.
- As described in chapter 2 – there is a small CV step difference between conservative "space grade" tantalum capacitors and highest CV automotive parts available. While the difference on MLCC class parts is quite significant.
- Request for "automotive" grade parts have to be usually "refined" as there can be more automotive ready series within one capacitor types such as – lower ESR variant, surge robust or high temperature series on tantalum capacitors and flexible termination options on MLCC.
- Attention has to be paid to a number of administrative errors on distributors' online capacitor selection guides, at least one issue found in all three distributors:
    - irrelevant training material linked (link to wrong series) – Disty 1
    - error in part description (0.47uF capacitor described as 206uF) - Disty 2
    - **non-AEC-Q200 declared part (per mfg datasheet) linked as AEC-Q200** in product comparison and search engine – Disty 3

Recommendations:

- Tantalum capacitor selection: Select the lowest ESR variant available in standard automotive design, in case of different "automotive grade" series select the highest available grade … For example supplier1 provide three automotive grade series (i) "automotive ready" series for lower grade automotive, (ii) "automotive designed series" for enhanced reliability and (iii) high temperature automotive series. Recommendation would be to use low ESR/surge robust variant of the (ii) automated designed product, if available.
- Ceramic capacitor selection: Select the automotive AEC-Q200 series from market leader with soft term flexible termination.

4.3.1 COTS / CECC parts proposed for procurement

Procurement of the parts subjected to additional testing were intended to verify effectiveness of ESA ageing test procedures on COTS/CECC parts. **500units each** of higher grade but **NON-AGED** tantalum and MLCC capacitors were selected plus one control commercial automotive MLCC capacitors of the same CV.

4.3.2 Test Procurement Parts

The following types are proposed to select for testing according to ETP (described in following Chapter 6) based on the above survey:

Tantalum capacitor type:

A case 1206, 10uF, 10V

Test Sample	MFG	GRADE
#1	Supplier 1	Automotive
#2	Supplier 2	Automotive
#3	Supplier 3	Automotive
#4	Supplier 1	COTS

MLCC capacitor type:

The maximum CV available on AEC-Q200MLCC capacitors is 10uF 25V, X7R, 1210 case that is 20x! CV factor higher compare to 0.47uF 25V maximum CV parts qualified on space level. Commercial automotive parts with flexible termination design (flexiterm) were add to the test as a control group with the same CV as the CECC/COTS parts.

10uF 25V, X7R, 1210 case:

Test Sample	MFG	GRADE
#1	Supplier 4	Automotive
#2	Supplier 5	Automotive
#3	Supplier 6	Automotive

470nF 25V X7R 1210

Test Sample	MFG	GRADE
#4	Supplier 1	Automotive
#5	Supplier 1	CECC/COTS

5 PROCUREMENT

5.1 Communication with Distributor

Selected distributor with all considered capacitor types in stock was contacted.

The following issues were reported on tantalum capacitors:

- "special" low ESR or surge robust series is not in stock and also full reel orders are accepted only
- distributor showing incorrect database search results: Supplier 3 series in distributor database was not marked as AEC-Q200 qualified (while manufacturer datasheet state that the series IS AECQ-200).
- Alternative PNs available in stock were identified and ordered on-line
- The feedback was immediate, and parts on stock received within three days

Datapack request:

- Manufacturer product datasheets are available in pdf to download from distributor website.
- Request for AEC-Q200 data on the capacitors after placement of order:
- Calling distributor telephone hotline at weekday 1PM: "all operators are busy, please hold the line" … after waiting 10minutes I give up and wrote an email to their contact email
- Email communication: Response to AEC-Q200 request: "What is AEC-Q200datapackage?". I explained and sent back. Response within 24hours: "For AEC-Q200 please contact manufacturers directly, we do not provide this data".

Communication with manufacturers:

Online request: "*I have recently purchased capacitors type … from your authorized distributor. Is it possible to get AEC-Q200 datapackage for this type or at least for the series? This is requested by the end automotive customer. The distributor asked me to contact manufacturer directly. Thank you.*"

Response to AEC-Q200 request:

Tantalum Capacitors						MLCC capacitors					
Supplier 1		Supplier 2		Supplier 3		Supplier 4		Supplier 5		Supplier 6	
who	response	who	response	who	response	who	response	who	response	who	response
supplier	30 days	supplier	15 days	distributor	15 days*	distributor	declined#	distributor	declined#	distributor	declined#

* including PPAP

CANNOT PROVIDE DOCUMENT TO SPACE APPLICATION CUSTOMER

Note: all three MLCC manufacturers: CANNOT PROVIDE DOCUMENT TO SPACE APPLICATION CUSTOMER

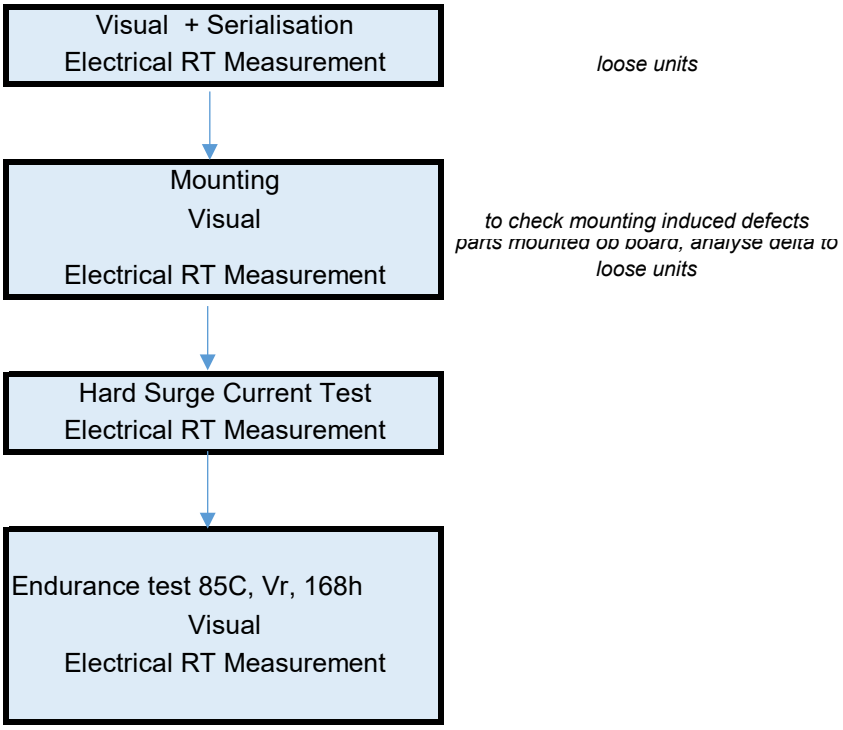
Observations:

- There is no clear rules/distributor customer service awareness about who is in charge to provide AEC-Q200 package
- The most common way is that the (franchised) distributor is in charge, but in our case the distributor customer service was not aware how to deal with this request
- There was no issue from the manufacturers to support space SME HW project with tantalum capacitors and AEC-Q200 datapackage.
- No one from three MLCC manufacturers supported AEC-Q200 datapackage request based on the fact that this product is not dedicated to space project and they take **NO LIABILITY for use of MLCCs in space projects**.

6 TEST PLAN

The test plan is reflecting the main scope of the activity in evaluation of early failures, it means to test more statistical reasonable file (250 units commercial grade and 500units CECC/COTS grade) with a typical ageing time 168 hours. The parts will be measured also in loose stage, directly from the tape, to check the impact of board mounting process. Hard surge current screening is added in case of tantalum capacitors in order to check its surge robustness as a critical characteristic.

ETP proposal tantalum capacitors (250 commercial and 500 COTS components)



ETP proposal MLCC capacitors (250 commercial and 500 CECC components)

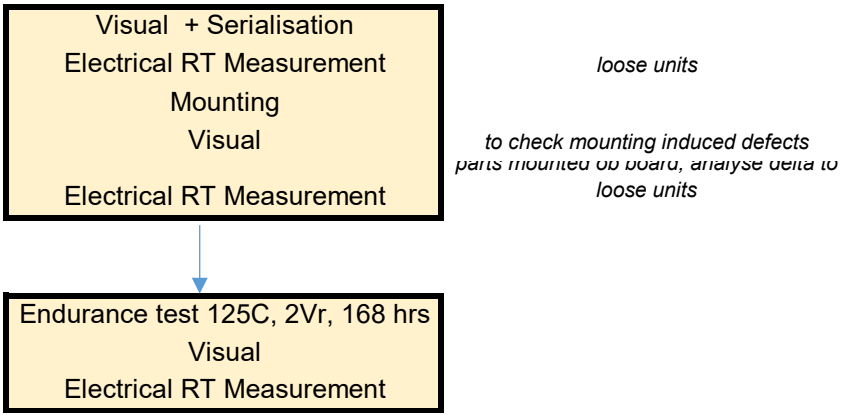


Fig3. Evaluation Test Plan chart

7 TEST RESULTS

7.1 Tantalum Capacitors

250 commercial tantalum capacitors from three manufacturers plus additional 500 COTS parts were subjected to the ETP.

Fig. 4. and Fig. 5. below shows median electrical parameters value measured after the each ETP step.

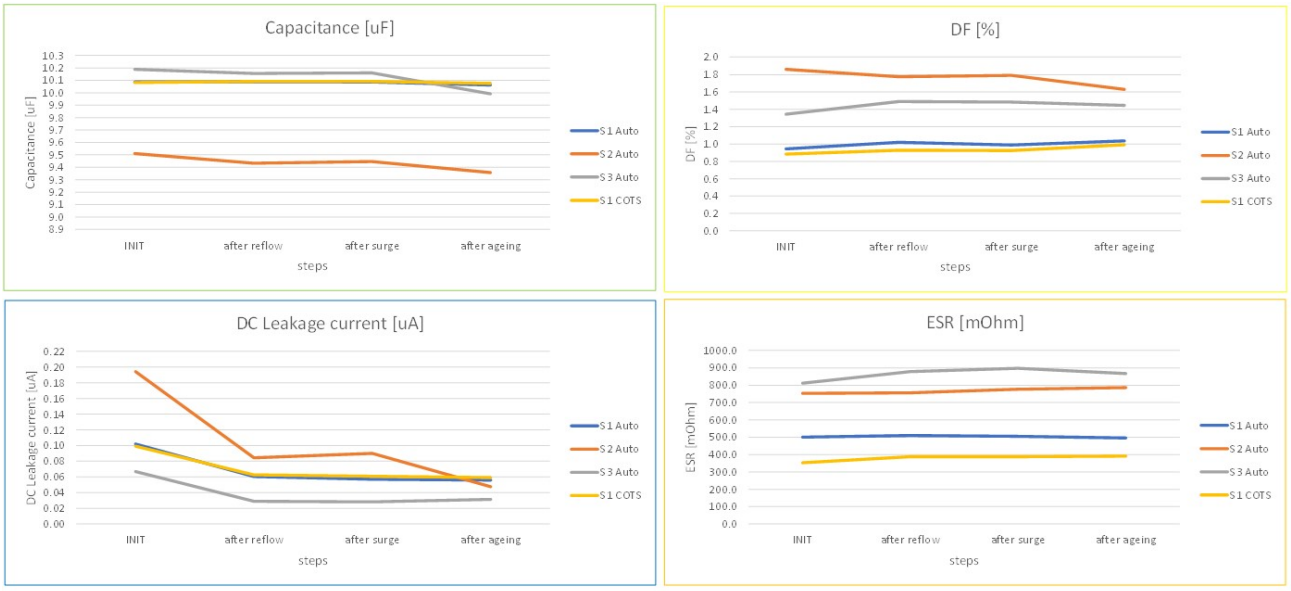


Fig.4. Tantalum capacitors 10uF 10V A case 1206 median el. parameters after each ETP step table

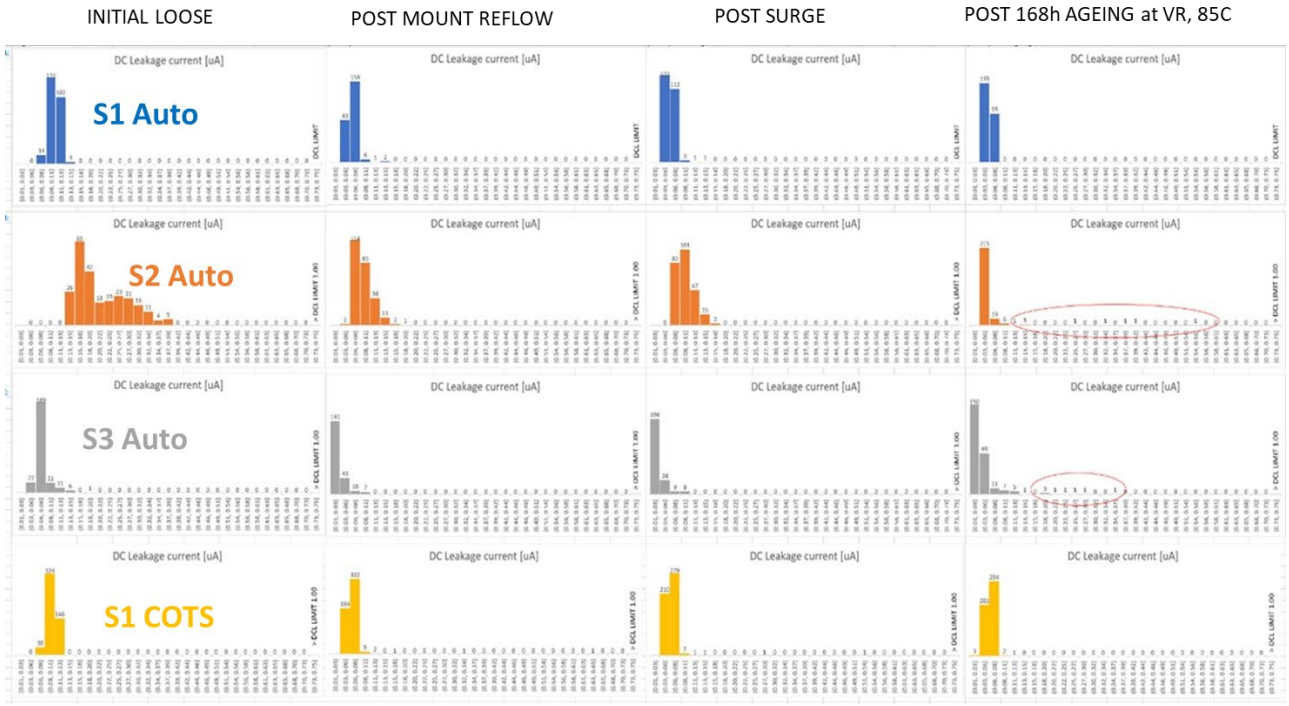


Fig 5. tantalum capacitors 10uF 10V A case 1206 DCL histogram after each ETP step chart

Median of basic electrical parameters is consistent for all three manufacturers with minimum influence of ETP steps apart the DCL. Capacitance and DLC values of AVX parts are nearly identical for its automotive commercial grade and COTS versions. COTS parts have a little lower losses DF and ESR.

Board mounting and ageing reduced overall median DCL value that can be explained as temperature stress release impact to the dielectric layer. The similar can be observed also as a small capacitance decrease at these steps due to drying of capacitors after higher temperature exposure. The surge test did not have any significant effect to the median electrical parameters.

Median can provide guidelines about behaviour of typical parts within the distribution, nevertheless it is important also to evaluate drift of the tail. See Fig.4.

No electrical parameters failures were observed during the ETP and all parts comply with safe margin to the manufacturers' specification limits.

There is practically no impact of the ETP steps to the capacitance parameter distribution of all tested manufacturers, while the distribution shape itself is specific to the manufacturer. COTS parts distribution is closest to an "ideal" statistical normal distribution.

The same as on capacitance distribution can be said on ESR, there is no significant move of distributions during ETP at any of the manufacturer and capacitor grade. Also, distributions of DF parameter do not show any dramatic movements during the test. Ageing on Supplier2 and Supplier3 parts increased marginally tail of its distribution. COTS parts are featuring the lowest and the narrowest DF distribution.

The most noticeable impact of the ETP on tantalum capacitors is to the leakage DCL distribution. DCL of most of the parts stabilize and decrease after the first temperature shock during board mounting process, nevertheless DCL on some few units increase and form tail of the distribution beyond statistical limits. The next surge stress helps part to self-heal and reduce DCL even more, while does not hurt the distribution tail showing all three manufacturer's parts good robustness against the hard surge stress.

168 ageing has a quite strong impact to the DCL values. It either helps specifically the tail parts / damaged during the previous steps / to self-heal and return to the main DCL distribution (one manufacturer) or move further away / degrade/ to higher DCL level easier to identify and reject (two manufacturers - see Fig.5 red marked zone).

Both Supplier1 automotive and COTS types showed high robustness to the ETP stress. Some COTS parts increased DCL after board mounting (high thermal stress) but all of them self-healed during the ageing step and overall DCL improved in whole distribution.

The observation of 168h ageing impact to DCL distribution may justify its importance for tantalum capacitors screening capability and high reliability level.

7.2 MLCC Capacitors

250 10uF 25V 1210 X7R MLCC capacitors from three manufacturers were subjected to the ETP plus 500 samples of 470nF 25V X7R 1210 MLCC at CECC/COTS and automotive commercial levels.

Fig. 6a and 6b. show median electrical parameters value measured after the each ETP step.

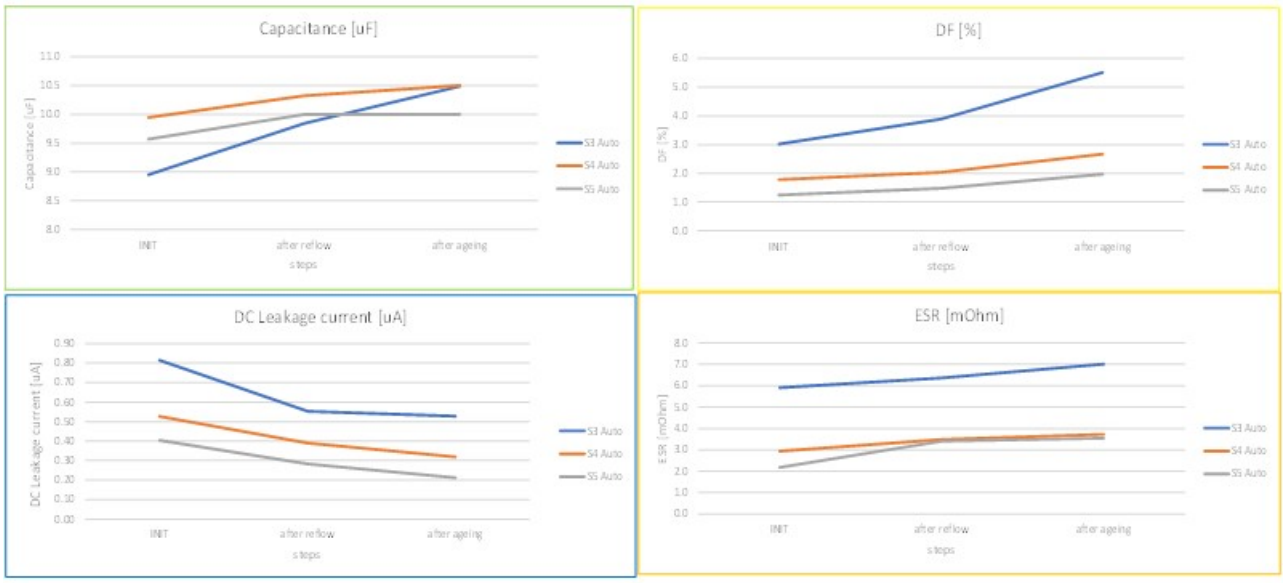


Fig 6a. MLCC capacitors 10uF 25V 1210 median el. parameters after each ETP step chart

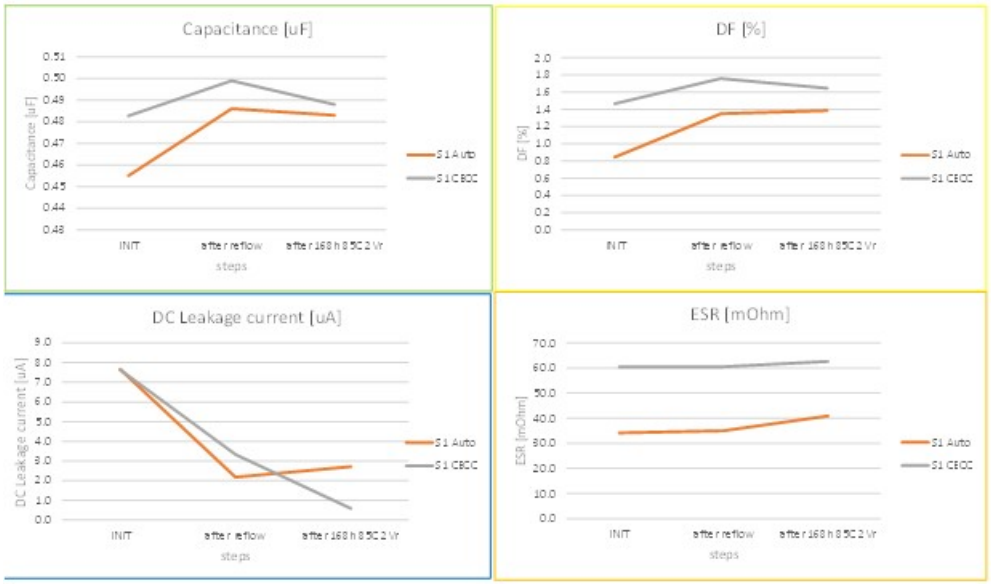


Fig 6b. Median of MLCC 470nF 25V X7R 1210 el.parameters after each ETP step chart

Median values of tested commercial 10uF 25V 1210 MLCC capacitors' basic electrical parameters are showing similar characteristics and behaviour after the individual ETP step. One manufacturer is showing inferior ESR, DF, DCL and R values compare to the other two, while still within the manufacturer specification.

All measured electrical parameters on the 470nF 25V parts are also within the manufacturer specification and there were no failures during the ETP test. One note is on measured higher capacitance on CECC/COTS parts that are above the rated capacitance + 10% tolerance, nevertheless MLCC capacitors reference tolerance field is specified at 1000hrs Vr load to reflect its capacitance drop. If we count with 5% capacitance drop at 1khrs that would be about the typical on X7R capacitors the capacitance values shall be within the capacitance reference tolerance filed and thus it is not considered as failure in our case. Nevertheless, this "issue" suggests that CECC/COTS may have more conservative design with set capacitance values higher compare to the Auto commercial parts.

The biggest difference in electrical parameters on CECC vs commercial automotive 470/25V parts are typical ESR values that are half on Auto commercial parts. This may support conclusion that the CECC/COTS parts have a different internal design (thickness of dielectric and number of layers, layer structure etc) compare to the Auto commercial parts. (so the CECC/COTS parts are different by design not "just" by screening).

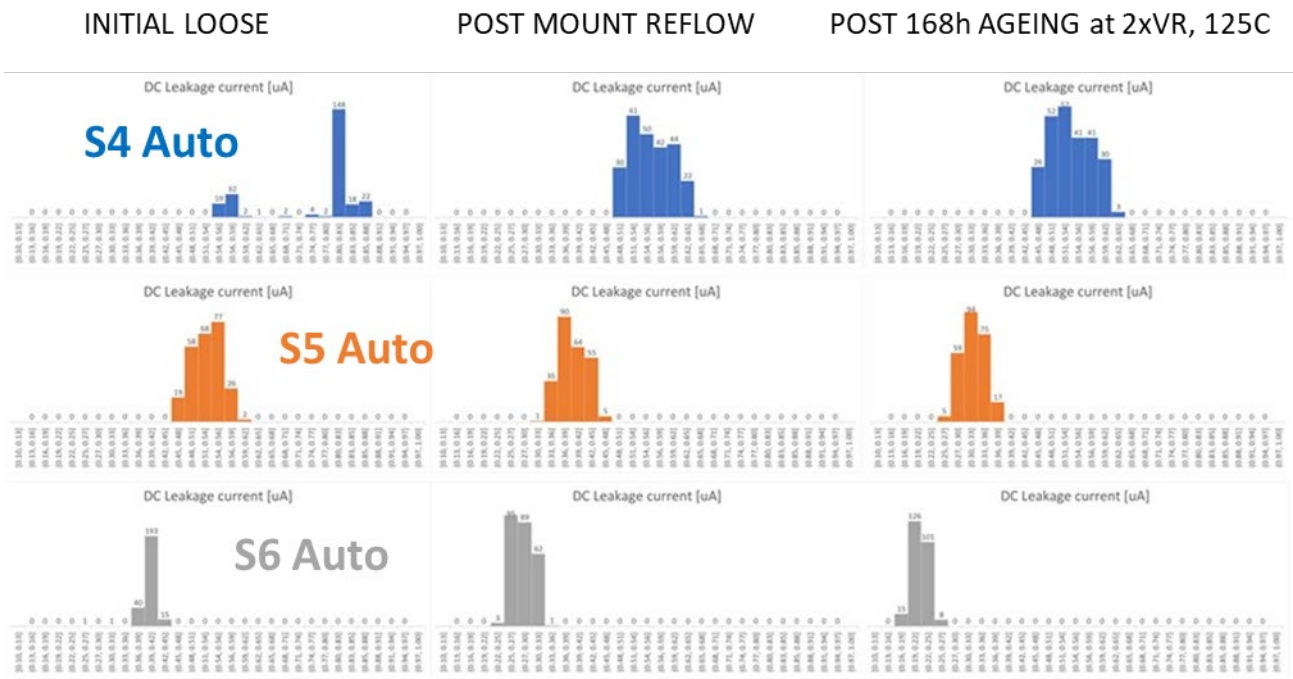


Fig 7a. MLCC capacitors 10uF 25V 1210 DCL histogram after each ETP step chart

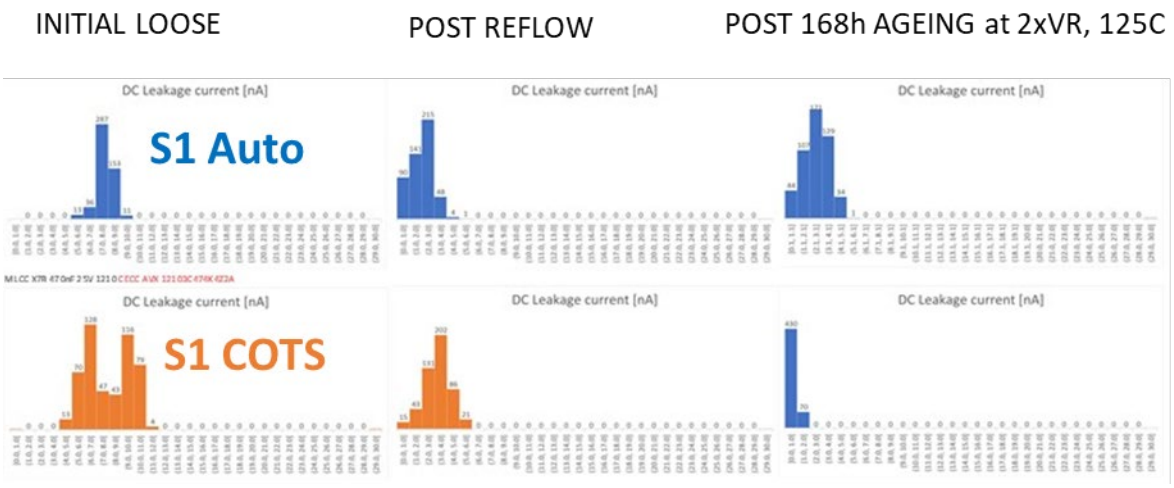


Fig 7b. MLCC capacitors 470nF 25V X7R 1210 DCL histogram after each ETP step chart.

Surprisingly DCL significantly decreased (and IR signifficantly increased) after 168h 125C 2Vr ageing in the case of CECC/COTS parts unlike the Auto commercial parts that remained stable – see Figure 7a and 7b. Such behaviour would be expected on tantalum capacitors as self-healing impact but not on MLCC parts. AVX have been contacted and questioned om physical mechanisms that would explain such behaviour on MLCC CECC/COTS parts.

8 SUMMARY

Procurement Summary

- Common automotive capacitors are readily available from the stock with delivery within days. Single units modular quantity is usually available on parts without dry pack (MSL3 for example)
- However, specific parts such as lower ESR, surge robust have to be ordered upon leadtime depending to the current market situation. The minimum ordering quantity is also one full reel = couple of thousands parts typically.
- AEC-Q200 package is not a public document available for free download, manufacturer may refuse or ask for confidentiality agreement before providing it.
- The general rule is that AEC-Q200 datapackage shall be requested by tier 1 manufacturer customer – usually franchised distributor. Nevertheless, this rule may not be commonly know to the distributors' customer service or even manufacturer's online support contact that is causing some confusion within the supply chain to find out who is in charge to provide it.
- The delivered automotive capacitors were clearly marked, trackable with a distributor and manufacturer labels including bar code, specific ordering No., country of origin, ROHS statement etc.
- All three tantalum capacitor manufacturers supplied the components and AEC-Q200 datapacks without any issue even when they were informed about a potential space hardware usage by a small SME space hardware manufacturer.
- All three automotive MLCC manufacturers declined to provide AEC-Q200 datapack upon information about SME space hardware potential use and made clear statement that: **They take no liability for use of their automotive MLCC capacitors in space projects**.
- The COTS/CECC parts were ordered via Alter Technologies with clear communication, tracking and continuous follow up information. Planned delivery was confirmed in the time of order, delivery status was updated monthly and the parts were delivered as scheduled. CECC parts were delivered including CECC conformance certificate.
- The COTS/CECC parts leadtimes were in range of 17 weeks. It means much longer compare to commercial parts from the stock available mostly online (unless a special part is selected).

Test Summary

Based on the measurement and analysed data of 250 commercial automotive 10uF 25V X7R 1210 MLCC capacitors from three manufacturers and CCN additional 470nF 25V X7R MLCC 500 capacitors at automotive commercial flexiterm and CECC/COTS grades, the following observations can be made:

- Electrical parameters of all automotive & COTS/CECC grade tantalum and MLCC capacitors measured in loose and after board mounting are showing standard distribution of parameters without flyers and units in tail that confirms effective screening testing and limits during manufacturing.
- All tested tantalum and MLCC capacitors passed the ETP testing without any failures and meet manufacturer specifications.

- All tantalum capacitors from all vendors in automotive and COTS grade exhibited high grade of robustness against hard surge current.
- The COTS tantalum capacitors exhibited high grade of robustness against hard surge current. DCL current and other el.parameters were stable and all parts successfully self-healed during the 168h 85C 1xVr ageing without any flyers.
- 168h ageing at 85°C/1xVr on tantalum capacitors have been proved as an effective process to stabilise its DCL with potential to improve reliability by removal of suspicious distribution tail parts by dynamic screening limits post ageing.

- 168h ageing at 125C 2xVr on 10uF 25V X7R 1210 MLCCs capacitors does not show any major impact to the measured electrical parameters.
- There were some differences observed in behaviour between the 470nF 25V X7R 1210 MLCC automotive commercial grade and CECC/COTS capacitors in test.
    - Differences in capacitance distribution and DF/ESR values suggests that the two capacitor groups may have a different design (thickness of dielectric, layer structure, number of layers).
    - ESR and DF of Auto CECC parts split into two distributions after board mounting thermal stress and stabilised after the 168h ageing. This was not the case of CECC/COTS parts
    - DCL of CECC/COTS parts significantly decreased after the 168h ageing that was not case of automotive commercial parts. This phenomenon has not yet been explained - pending discussion with the manufacturer.

9 CONCLUSION & DISCUSSION

Procurement of automotive grade capacitors can be very quick process with the component delivery within few working days in case of a common types used in commercial/automotive industry. In comparison, typical leadtime of COTS/CECC grade parts in the test exceeded 17weeks.

There are few issues observed during the purchasing process on automotive commercial parts that can be summarised in the following notes and recommendations:

- Some component types and construction knowledge is required before purchasing. It is better to study, understand and select appropriate component type from concrete manufacturer before the procurement process. If the user is SME and have to buy through distributors there is a number of errors in their database and thus the search function may not be reliable. Technical support from distributor may be also varying.
- Traceability of the products is at very high level (required by automotive standards) and it should not be considered as an issue for space industry.
- AEC-Q200 datapackage is not a public document and may not be necessary available. Getting the AEC-Q200 through supply chain and distribution may also take some time and communication resources.
- Tantalum capacitors seems to be very robust and manufacturers are not so concerned about using their automotive products in SME space hardware. This is not the case of MLCC

capacitors, where all manufacturers declare NO LIABILITY to their automotive parts for space application and refused to provide AEC-Q200 datapackage.

There were no failures observed during the evaluation test phase neither on COTS/CESS parts neither on commercial automotive parts. All tantalum and MLCC capacitors meet their specification limits after 168h ageing test.

The test quantity may not be reasonable to make a general conclusion, nevertheless, **there were no significant issues with the robustness of automotive grade tantalum and MLCC capacitors** and they performed well in the evaluation testing.

On the other hand, testing of the original COTS / CECC level suggests that these parts have a different component design focusing more reliability and robustness. This can be observed on lower shift of electrical parametric during the stress conditions and/or better recovery during ageing step.

Looking at the individual component electrical parameters we can make some observations about the 168h ageing process impact:

Tantalum capacitors

168h ageing process on both automotive and COTS 10uF 10V A 1206 tantalum capacitors has been found as an effective tool to stabilise DCL and potential to remove non-statistically reasonable flyers, thus ageing test is considered as a valid requirement for maximum reliability on tantalum capacitors.

The performed tests suggest that the automotive and COTS AVX 10uF 10V A case capacitors may have a different internal design. While stability of the AVX automotive parts itself was excellent (better than the other manufacturers in the test), all AVX COTS parts successfully self-healed after board mounting induced damage suggesting its high ability to re-cover. It suggests its superior reliability and robustness.

MLCC capacitors

168 ageing test on MLCC capacitors showed a different behaviour on 10uF 25V X7R 1210 (high CV) parts versus conservative low CV design of 470nF 25V X7R MLCC capacitors.

There was no real impact of the 168, 2xVr, 125C ageing test on 10uF 25V X7R 1210 MLCC capacitors, nevertheless some DCL improvement was measured on 470nF 25V 1210 X7R parts, and significant DCL stabilisation on the CECC/COTS parts.

The results suggest, same as in the case of tantalum capacitors, that CECC/COTS grade parts are different in its internal designing aiming maximisation of the component robustness.