The latest activities related to the passive components in JAXA

9-12 October 2018
ESA/ESTEC, Noordwijk, The Netherlands

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INTRODUCTION

In the present day, there are 147 models of passive and active components in Japan which fulfil the requirement of space components. They are qualified as JAXA qualified components by JAXA. These components contribute to the realization of the high-spec and high quality space satellites or rockets which are not only government satellites but also commercial satellites. In recent years, the satellites which require lower cost and have shorter life time, called "New space" satellites, are rapidly increasing. Although the high quality and high cost components may not be required for such new space satellites, we believe the needs for space satellites are becoming polarized. The satellites will become larger as the space missions become more complex and more difficult. Such satellites should be accepting even fewer failures than the current satellites. Therefore, high-spec and high quality components will be required even more.

This paper describes overall introduction of JAXA qualified passive components, some of which are listed in EPPL. As a recent news, a manufacturer of the JAXA qualified Printed Circuits Board (PCBs) has been replaced. Before replacement, the equivalences of the products made by the new and the replaced manufacturers were evaluated. The evaluation result made by the new manufacturer rather than the replaced one is also reported in this paper. Note that what they call "component" in Europe is called "part" in Japan ("Component" indicates "subsystem" in Japan). However, in this paper "component" is used for the same meaning as "part."

JAXA QUALIFIED PASSIVE COMPONENTS

There is a total of 147 models of JAXA qualified components, of which 100 models are passive components. Note that the PCBs and materials such as thermal control films are also included in JAXA qualified components. A list of JAXA qualified passive components and EPPL listed components are shown in Table 1.

Table 1. List of JAXA qualified passive components.

Comp. family	Description	Detail spec.	Manufacturer
Capacitors	Mica	4	Soshin Electric
	MLCC	3	Murata
	Chip, Solid, Electrolytic, Tantalum EPPL	1	Matsuo Electric
Resistors	Chip, Thick Film	1	Tateyama Kagaku
		2	Hokuriku Electric
	Wire-Wound (Power Type)	2	Seiden Techno
		1	Sanada KOA
	Film	3	Sanada KOA
	Networks, Film	1	Sanada KOA
	Chip, Thin Film EPPL	1	Sanada KOA
Thermistors	Chip, Negative Temperature Coefficient EPPL	1	Tateyama Kagaku
	Lead, Negative Temperature Coefficient	1	Tateyama Kagaku
Fuses	Subminiature, Current-Limiting EPPL	2	Tateyama Kagaku
Temp. Sensors	Platinum EPPL	3	MHI*
Osc. Crystals	Quartz Crystal Units	4	Nihon Dempa Kogyo
Transformers and Inductors	Power	2	Tamura
	Others	6	Tamura
Wires and Cables	Fluoroplastic, Polyimide Insulated Wires	4	Hitachi Metals
	Differential Transmission Cables EPPL	2	Junkosha
Connectors	Rectangular, Miniature	2	JAE**
		1	Nihon Maruko
	Rectangular, Miniature, High Density	2	JAE**
		1	Nihon Maruko
	Rectangular, Microminiature	1	Nihon Maruko
	Rectangular Miniature Mixed	1	Nihon Maruko
	Coaxial, RF	3	Waka Manufacturing

* MHI=Mitsubishi Heavy Industries ** JAE=Japan Aviation Electronics Industry

As of August 2018, there are 15 passive component manufacturers whose abilities to manufacture the products to satisfy the requirements for space application defined by JAXA. In Table 1, components indicated in red are currently listed in EPPL. These components can be used for European space mission because their quality and the reliability have been already verified. We plan to add a crystal oscillator to the JAXA qualified components list within this year. The qualification tests for this crystal oscillator have already been completed, and the results showed satisfactory. More information about JAXA qualified components can be found in the JAXA EEE parts database [1]. The detail specifications and the applicable documents for all JAXA qualified components are available therein.

COMPARISON OF JAXA/ESCC QUALIFICATION TEST SPECIFICATION

JAXA qualified components are examined in the qualification test which are described in the generic and detail specification documents. As described in last SPCD presentation [2], there are three kinds of specification documents in JAXA; General / basic specification called “JAXA-QTS-2000 [3]” defines basic requirements that are common for all component families. The generic specification defines common requirements for each component family. Detail requirements for each component family are defined in its detail specification. It has been verified that JAXA qualification system based on the above documents is similar to the ESCC (European Space Components Coordination) qualification system in the previous JAXA-ESA cooperation framework. The summary of the comparison results is shown in Table 2. The document tree of JAXA qualification system compared with that of ESCC qualification system is shown in Fig.1.

Table 2. Summary of JAXA and ESA qualified system comparison results

System	**JAXA**	**ESCC**
Basic document	JAXA-QTS-2000	-ESCC 20100 (component qualification) -ESCC 25400 (technology flow)
Subject	Manufacturing line	-Components (component qualification) -Manufacturing technology (technology flow)
Duration	3 years	2 years
Manufacturing line	Commercial lines may be used	Same as JAXA-QML system
Change control of QA program	Decision is made by TRB	-Review and approved by ESCC (component qualification) -Same as JAXA-QML system (technology flow)
Test optimization	Decision is made by TRB Change must be described in the detail specification with rationale	-Restricted. Review / approval required by ESCC (component qualification) -Same as JAXA-QML system (technology flow)

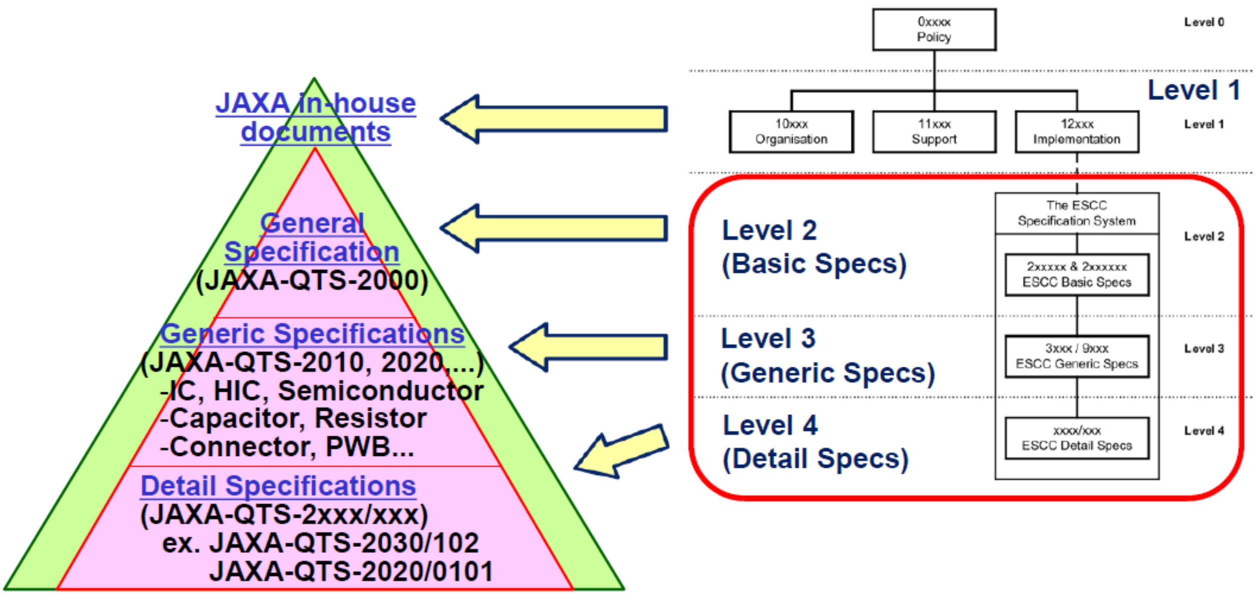


Fig. 1. Document tree of JAXA qualification system and ESCC qualification system

One major difference between the qualification system of JAXA and ESCC is that the basic requirements that are common for all component families are defined in one document (general specification (JAXA-QTS-2000)) [3] in JAXA qualification system. Another difference is that JAXA doesn't have its own specifications for test methods. The common requirements for each component family are defined in a generic specification. Detail requirements for each component are defined in its detail specification. Approval procedure for component qualification is defined in JAXA in-house documents. All the specifications are available through JAXA EEE parts database [1]. Duration of the certification is also different between JAXA/ESCC qualification systems. The certification is valid for 3 years in JAXA qualification system whereas it is valid for 2 years in ESCC system. There is no other major difference when compared JAXA system with ESCC system.

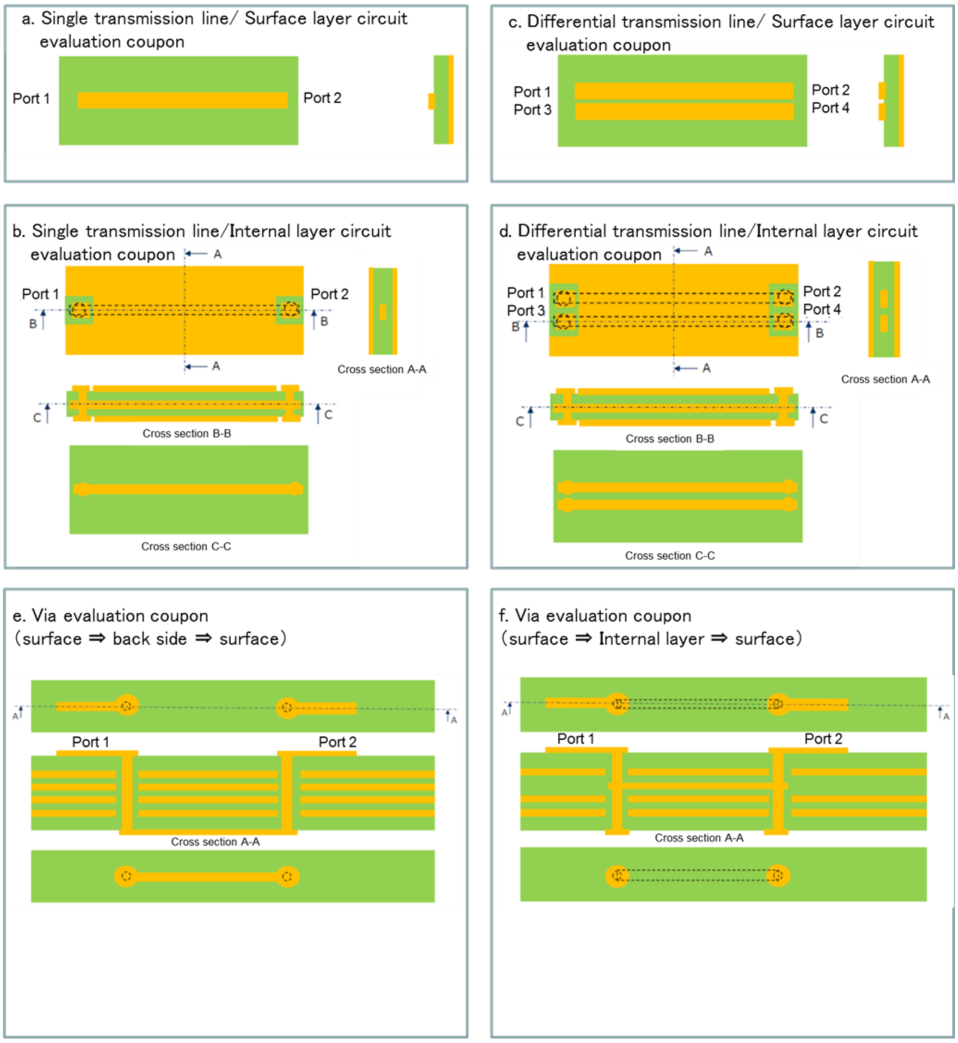
Same comparison activity has been performing among the specification of DLA (Defence Logistics Agency) and the specification of JAXA and ESCC. Although there are some differences that come from the different background ideas, the equivalence was confirmed among the specification of DLA, ESCC and JAXA QTS.

RELIABILITY TEST OF PRINTED CIRCUIT BOARD FOR SPACE-USE

Conventionally, the PCBs for space-use were provided by almost one qualified manufacturer (Manufacturer A) for Japanese space project. However, the manufacturer A could not continue to provide their products due to shutting down of the factory since the development for magnetic levitation train was planned through their factory premises. Due to such serious situation, the manufacturer of PCBs for space-use recently transferred the qualified processes to an alternative JAXA qualified manufacturer (Manufacturer B). Although we thought there would be few impact in regard to the characteristics of the PCBs due to replacing the manufacturer, prior to the actual replacement, we evaluated the electrical characteristics of the printed circuit test boards manufactured by each manufacturer under the same conditions. In addition, we performed Interconnect stress test (IST) for the purpose of evaluating the long-term reliability of the PCBs.

Electrical characteristics evaluation

To evaluate the electrical characteristics of PCBs, eight types of test coupons manufactured by each manufacturer under the same condition were prepared. The images of each test coupon are shown in Fig.2.



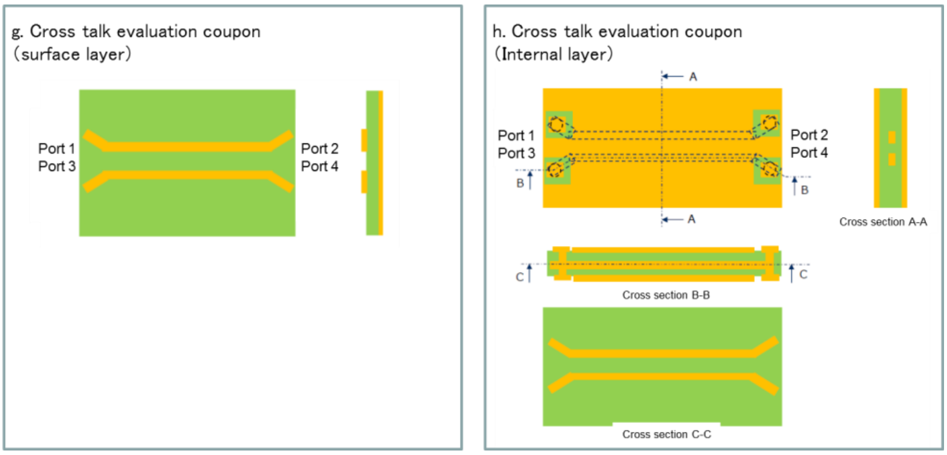


Fig. 2. Test coupons for electrical characteristics evaluation

All the test coupons are made by glass epoxy or modified polyimide materials and consist of eight layers. In addition, to determine the difference on the flexible PCBs products, another type coupons, a, c, and g are made by polyimide and consist of two layers.

Scattering parameters (S parameters) of each test coupon were measured by network analyser. The comparable simulation based on the measured S parameters about characteristic impedance, dielectric constant and transmission loss which have a possibility of an impact on circuit operation was performed. The transmission characteristics evaluation on single transmission line and differential transmission line was performed by using coupons a, b, c, and d shown in Fig.2. The results showed that there was no significant difference which may exert an impact on electrical characteristics of circuits. The examples of the measured S parameters are shown in Fig.3 and 4. Although a slight difference existed on reflection coefficient below the frequency of 1 GHz between two manufacturers, the difference was less than -20 dB. Therefore, we consider it a negligible difference for electrical characteristics.

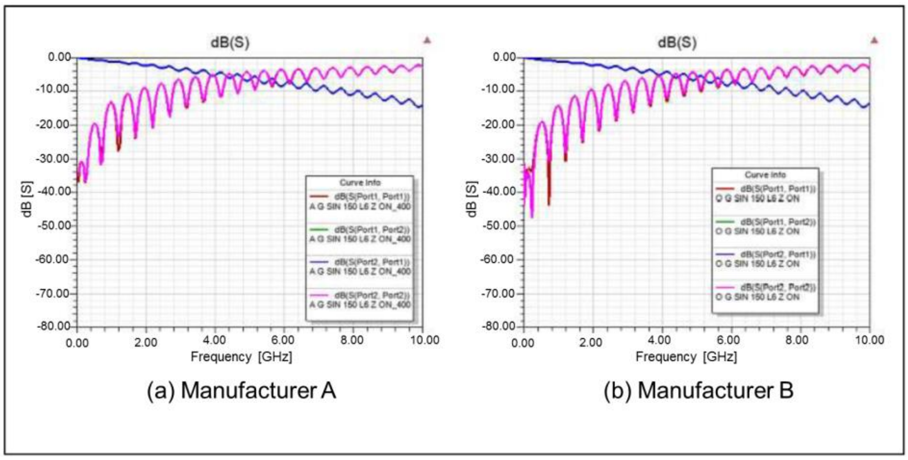


Fig. 3. S parameter measurement results of coupons a and b

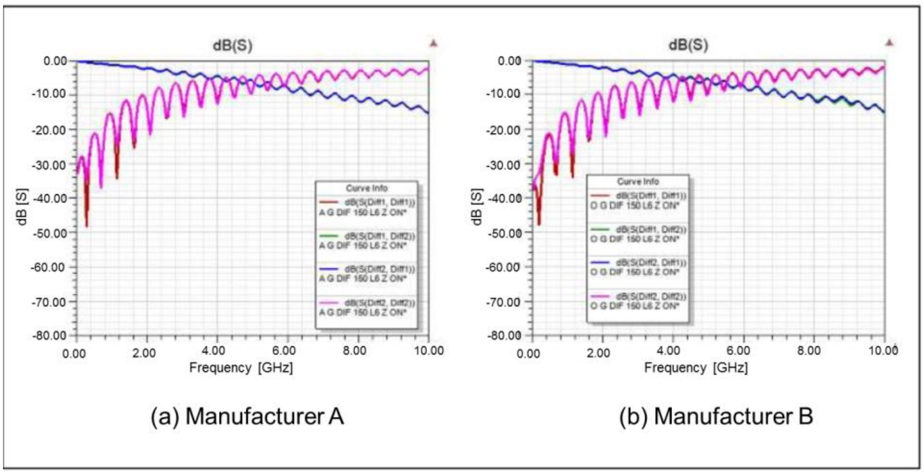


Fig. 4. S parameter measurement results of coupons c and d

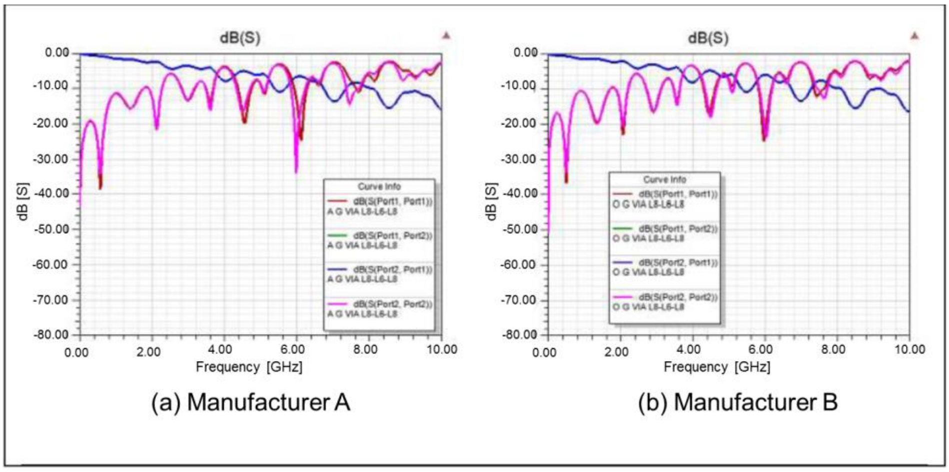


Fig. 5. S parameter measurement results of coupons e and f

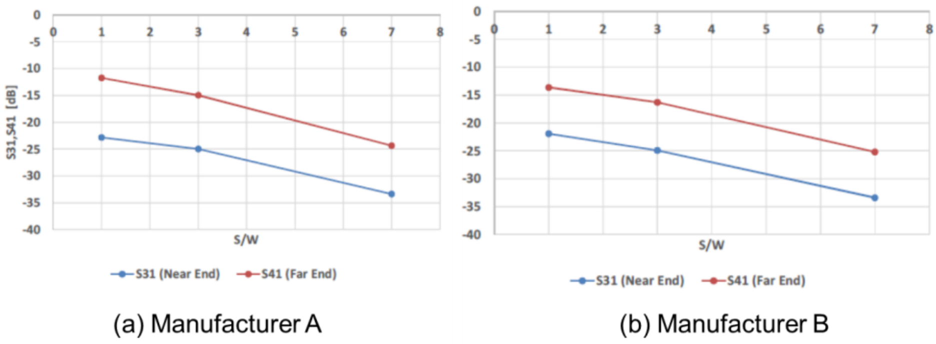


Fig. 6. S parameter measurement results of coupons e and f

The transmission characteristics on PCBs which have via structure were evaluated by using coupons e and f. S parameter measurement results of two manufacturers are shown in Fig. 5. There is a slight difference on the peak around 6 GHz, but the difference has no effect on the circuit electrical characteristics or the function.

The cross-talk characteristics evaluation were performed by using the coupons g and h. The results are shown in Fig. 6. In Fig. 6, X-axis is the width between wire lines in the coupons, and Y-axis is the amplitude of cross talk level. And “Near End” (blue line) means the cross talk between port 1 and port 3 or port 2 and port 4, “Far End” (red line) means the cross talk between port 1 and port 4 or port 2 and port 3. Coupons made by manufacturer B indicated lower cross talk level than Manufacturer A’s coupons. This result suggests that the risk of switching the printed board manufacturers is low related to the cross-talk characteristics. According to the results of simulation based on the measured S parameter, there is no difference between two manufacturers’ coupons in the characteristic impedance. And there was no difference in the dielectric constant on the coupons made by glass epoxy materials. A slight difference in dielectric constant was observed on the coupons made by modified polyimide materials (Manufacturer B coupons: 4.3 [F/m], Manufacturer A coupons: 4.5 [F/m]), and on the coupons made by polyimide materials (Manufacturer B coupons: 3.2 [F/m], Manufacturer A coupons: 3.0 [F/m]). However, this difference is within the acceptable range and the impacts on the circuit characteristics are negligible. Based on the evaluation results indicated above, we concluded that there is no risks for replacing the manufacturer related to electrical characteristics.

Interconnect stress test (IST)

IST is the world standard test which was standardized by Institute for Printed Circuits (IPC) as the effective test method for the PCB’s long-term life tests. We applied this test method for the PCBs made by manufacturer A and manufacturer B to evaluate the difference related to the long-term reliability. In thermal cycle test of the PCBs, the difference of thermal expansion coefficients (CTE) between Copper and Substrate materials becomes a source of stress causing cracks in the through holes, resulting in failures such as resistance increase, open circuit, separation of plating from base metal etc. In IST, the samples are heated directly by a current flowing through a self-heating circuit in the samples, and cooled by forced air cooling. By repeating this cycle, the temperature cycling is carried out and stress is applied to the PCBs in a short period of time. The test coupons of IST are shown in Fig. 7.

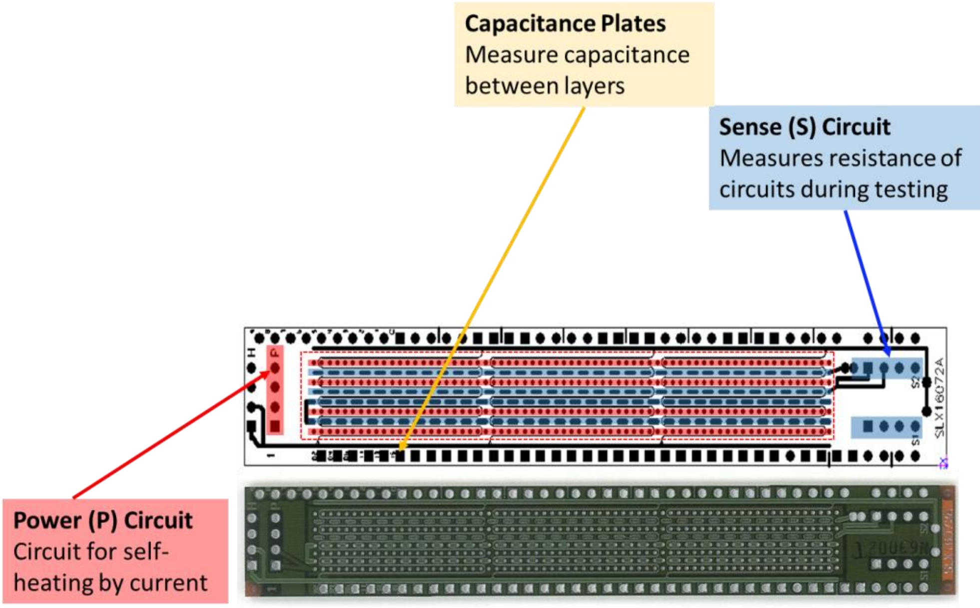


Fig. 7. IST coupon recommended for HiRel application (18mm x 100mm)

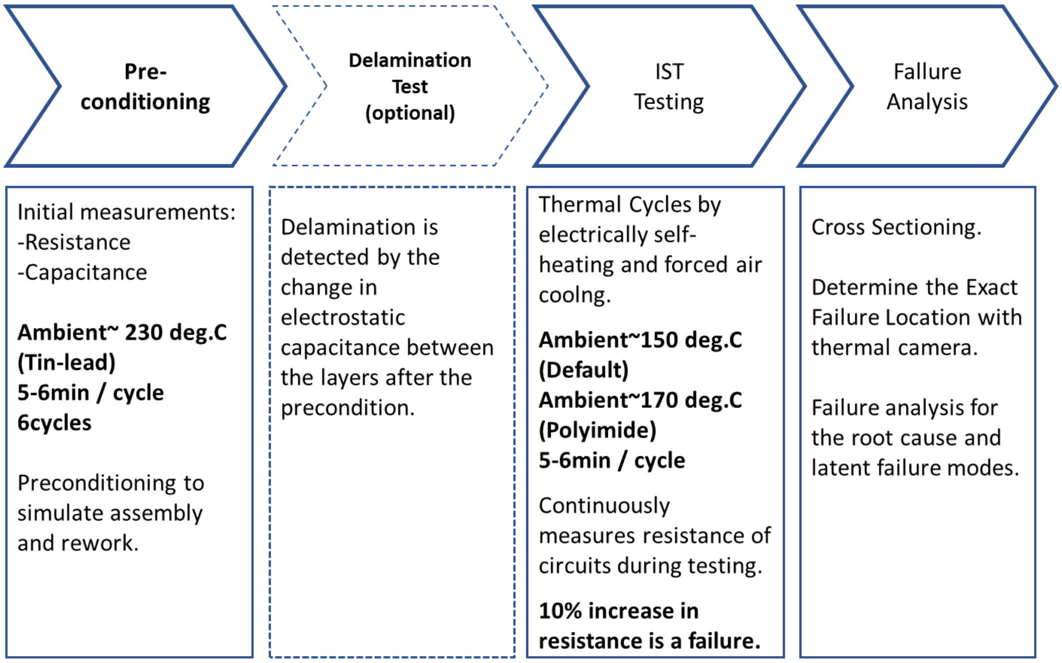


Fig. 8. Test flow of IST

The coupon includes the sense circuit to measure the resistance, and power circuit to increase the temperature by current flow. The coupon also includes the capacitance plates to identify the delamination. The test flow of IST is indicated in Fig. 8. To simulate assembly and rework stress, pre-conditioning is applied to the test coupon. After the pre-conditioning, IST is performed on the test coupon. The resistance of the circuits is measured continuously during the IST. 10% increase in resistance is identified as a failure. After the IST, the exact failure location can be detected by thermal camera. The specifications of the test coupons made by two manufacturers are specified in Table 3. And IST test conditions are shown in Table 4.

Table 3. Specification of test coupons

	FR-4	**Polyimide**
Board Material	Epoxy(FR-4)	Polyimide(GI)
Layer count	6	12
Board Thickness	2.4 mm	3.2 mm
Drilled Hole Diameter	0.7 mm	0.35 mm
Number of samples	6 coupons (6 circuits)	6 coupons (12 circuits)

Table 4. Test conditions of IST

	IST condition
Temperatures	Ambient~150 deg.C(#1.FR-4) Ambient~170 deg.C(#2. Polyimide)
Test time (min/cycles)	5min
Test termination	Max. 2000 cycles or Resistance Change10%

Table 5. Summary of the IST results

Coupon IST Cycles	**FR-4**		**Polyimide**	
	Manufacturer A	**Manufacturer B**	**Manufacturer A**	**Manufacturer B**
Min	304	285	>2000(6.0%)	649
Max	628	400	>2000(3.6%)	859
Mean	455	352	>2000(4.9%)	786
StDev	120	39	-	72
Range	324	115	-	213

IST test results are indicated on Table 5. Both types of manufacturer B coupons increased resistance by 10% with fewer IST test cycles. No difference in drill condition or copper plating quality etc. were observed. According to the destructive physical analysis (DPA) results, cracks on the through hole wall were observed and the shape and the position of cracks were similar. The difference in copper plating thickness was observed between two manufacturers' coupons. The copper plating thickness of each sample is listed in Table 6. Manufacturer B's copper plating thickness was thinner than Manufacturer A's. It is considered that the difference in the number of cycles of the IST depends on the copper plating thickness.

Table 6. Copper plating thickness of each sample

	FR-4		**Polyimide**	
Manufacturer	A	B	A	B
Copper Plating Thickness	39μm	28μm	41μm	31μm

As a result of DPA, the difference in the number of IST cycles for 10% increase of resistance between two manufacturers is simply due to the difference in the thickness of copper plating. Therefore, it can be concluded that the long-term reliability of these PCBs are practically equal. Note that, it is significantly important to combine the IST and DPA because the IST cycle is affected by the copper plating thickness and when this happens, other factors influencing IST cycle, such as drill condition and copper plating quality etc., cannot be detected. In addition to the aforementioned verification, a thermal cycle test was also conducted on Manufacturer B's PCBs with the conditions required in JAXA qualification test for confirmation. As a result, it was verified that Manufacturer B's PCBs satisfied the JAXA qualification test requirements.

SUMMARY

An overview of JAXA qualified passive components and their qualification requirement was introduced. Currently there are 100 JAXA qualified passive components and 11 of them are listed in EPPL. Most of them are qualified using JAXA-QML system, which is similar to the technology flow qualification in ESCC system. The qualification system in JAXA is quite similar to that in ESCC and its general requirements are outlined in comparison with those in ESCC system. As the result of comparison, the qualification test requirements of JAXA qualification system are verified to be equivalent to that of ESCC system. As a recent news, for the replacement of PCB manufacturer, the comparison evaluation results of PCBs which made by two manufacturers were reported. Electrical characteristics evaluations and IST for long-term reliability were performed and it was confirmed that the quality and performance of two products from these manufacturers are practically equal. Therefore, we concluded that there is no risks for replacing the PCB manufacturer.

REFERENCES

[1] Database of JAXA qualified EEE Parts and Materials, https://eeepitnl.tksc.jaxa.jp/en

[2] N.Ikeda, K,Suzuki, *"Introduction of JAXA qualified Passive Components and Their Qualification Requirement in Comparison with ESCC Qualification Requirement", 2nd Space Passive Components Days*, 2016

[3] JAXA-QTS-2000 Common Parts/Materials, Space Use, General specification for.