Qualification Situation and Future Deployment of PWBs for Space Development Use

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Abstract

The requirements for the size and weight reduction of electronic devices should also be met by the printed wiring boards (PWBs) used for space development through the maintenance of high reliability in this special environment. To make this possible, Yamanashi Avionics, Co., Ltd. (YACL) is continuing production activities by applying evaluation testing based on the specifications for the acquisition of JAXA qualifications. This paper reports on the design specifications of NEC's JAXA-qualified parts together with perspectives on their future deployment.

Keywords

PWB, density/function improvement, low thermal expansion, high reliability, application data sheet, outgassing

1. Introduction

The recent trends of enhancing chip part integration and reducing the size of electronic devices, such as passive parts, are accelerating the density increase of PWBs and consequently increasing the packaging density of mounted parts. As a result, electronic equipment is decreasing in size and weight and improving in functionality and speed faster than ever. Against this background, PWBs for space use are also subject to development requirements for density/function improvement in the special environment in which they will be used.

In particular, PWBs for space use can never be put to practical use until they pass severe evaluations on their heat cycle (which is negligible on the Earth), material behavior in a high vacuum, radiation resistance, etc.

Following these requirements, we developed PWBs and acquired their qualification by the Japan Space Exploration Agency (JAXA). Examples are a high-density PWB with extended specifications and a high-heat-dissipation PWB using thick copper foil (105 μm) in 2007 and a low-thermal-expansion PWB developed in 2010. In this paper, we describe our JAXA qualification acquisition situation up to the present, as well as perspectives on the future of PWB development, which is expected to be subject to severer requirements in the future.

2. Qualification Situation

YACL boasts more than 20 years of history manufacturing high-reliability PWBs for space use and is the first Japanese company qualified by JAXA as a PWB manufacturer. Still, at present, we maintain a system capable of dealing with any PWB specifications that may be requested, including the specifications for the JAXA-qualified PWBs of which YACL is the sole manufacturer, such as the "flexible PWB", "flex-rigid PWB" and "CIC- core PWB". In this way, we play a part in space development by meeting various requests from spacecraft manufacturers.

Fig. 1 shows the situation of our JAXA qualification acquisitions up to the present. It shows that the range of PWB types is expanding to meet various purposes.

Our PWB development began in the 1980s with the initial qualification of a flexible PWB and spread in the 1990s to general PWBs based on requirements for high-density

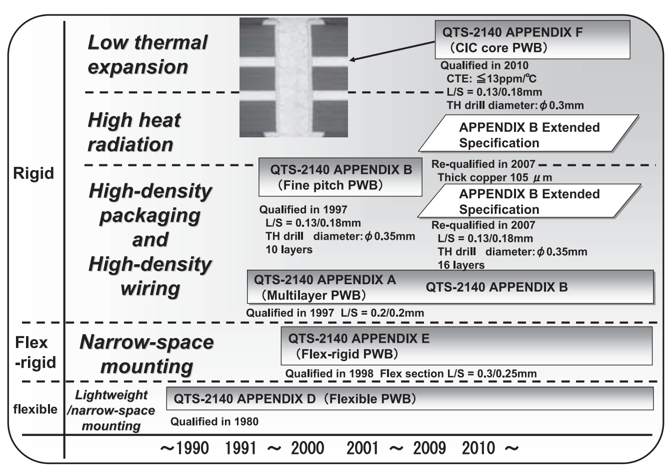

Fig. 1 JAXA qualification acquisition situation.

packaging and wiring. Since then, the efficiency of the mounting space has been improved, and more recent development aims at improving reliability further through heat generation countermeasures and linear expansion reduction.

3. JAXA Qualification Specifications

Fig. 2 shows the specification system for JAXA-qualified PWBs. In this system, the requirements of the Detailed Specifications are in general given the highest priority because they describe details of items that are not described in upper-level documents such as the General Specifications and the Appendices.

The Application Data Sheets describe design specifications, qualification test results and cautions for use. They include the conditions for baking before packaging, and we use them as "guidelines for the specification selection, design and packaging" of PWBs.

The JAXA qualification specifications for PWBs currently include six Appendices from A to F, and we at YACL have acquired qualifications for five of them. **Table** outlines the design specifications in Appendices B, D, E and F (The design specifications in Appendix A are included in Appendix B).

Appendices A and B specify the structure of a general multilayer PWB. This structure features the use of woven glass containing polyimide resin or epoxy resin in the base and is the structure most widely adopted by space-use PWBs.

Appendix D gives the specifications for a flexible PWB using a polyimide resin base. This is developed for use in wiring between PWBs or wiring with a connector or connector

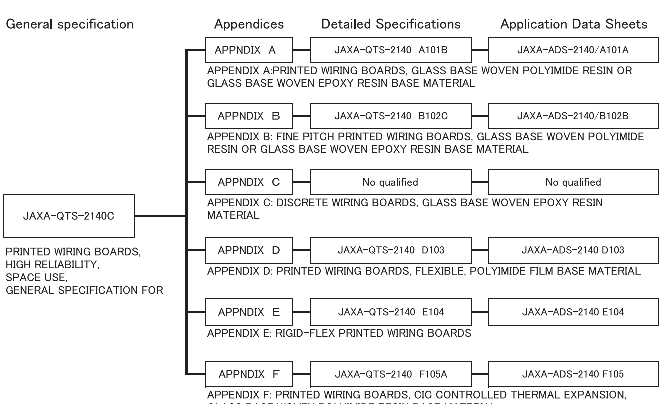

Fig. 2 Specification system for JAXA-Qualified Parts (PWB).

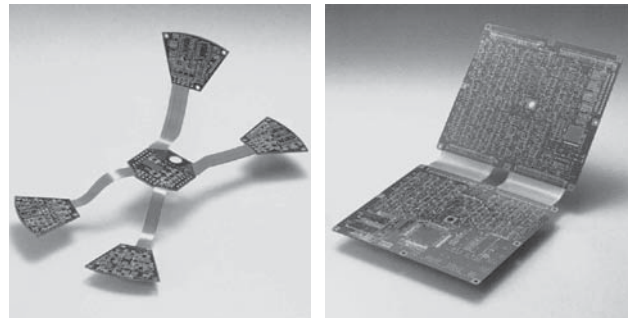
Photo Flex-rigid PWBs for high-reliability applications.

part.

The flex-rigid PWB specified in Appendix E is a device implementing a connection between PWBs in advance, built in to the structure of those PWBs. It makes the cable assemblies of multiple packaged PWBs unnecessary, and its flexibility allows it to be mounted into a narrow space in the equipment (See **Photo** for examples of these products).

Appendix F, which was newly qualified in FY2009, specifies a PWB in which CIC (Copper-Invar-Copper) is sandwiched within the PWB. It was designed as a PWB with low linear expansion by making use of the properties of CIC. It was developed in order to meet the packaging reliability requirement and is backed by the use of a multi-pin design of electronic parts.

As the actual measurement of its coefficient of expansion is no more than 13 ppm/C°, it is expected to be the design for a new line of PWBs for space use in the future.

The specialized staff in the YACL departments in charge support this series of qualified PWBs by giving detailed explanations, from design specifications through to product implementation, and by answering questions, such as those on the application standards of each specification, etc. (As Appendix C specifies a discrete wiring board that is not handled by YACL, it is not discussed in the present paper).

4. High Reliability Requirements for Space Development

Needless to say, with PWBs for space use, even those evaluation items which are also used for general industrial and consumer products are tested under much severer conditions. In addition, more evaluation items are added to their testing to ensure high reliability. Specific reliability requirements for

Table JAXA-qualified PWB design specifications.

Specifications \ Structure	Appendix B		Appendix D	Appendix E		Appendix F
	High-density wiring (copper foil thickness ≥ 35μm)	Thick copper foil structure (copper foil thickness: all layers 105 μm)	Flexible PWB	Inner type	Outer type	CIC-core
Insulation material	Woven glass base, unmodified polyimide resin	←	Polyimide film / Reinforced board: woven glass base, unmodified polyimide resin	Rigid material: woven glass, unmodified polyimide resin / Flexible material: polyimide film	← / ←	Woven glass base, unmodified polyimide resin
Max. number of layers / board thickness (mm)	16/2.4	12/3.2	2 / not specified	8 (4 flex layers) / 1.6	10 (1 flex layer) / 1.6	12 / 2 (incl. 2 CIC layers)
SVH	8/1.1	6/1.4	Not specified	Not specified	Not specified	SVH, 4 layers / 0.33
IVH	14/1.7	10/2.5	Not specified	Not specified	Not specified	Not specified
Min. conductor width (mm)	0.13	←	0.3	Rigid/flex: 0.25/0.30	Rigid/flex: 0.13/0.30	0.13
Min. conductor interval (mm)	0.18	←	0.3	Rigid/flex: 0.25/0.25	Rigid/flex: 0.18/0.20	0.18
Min. drill diameter (mm)	–	–	–	–	–	–
Through hole	ϕ 0.35	←	ϕ 0.60	ϕ 0.70	ϕ 0.35	ϕ 0.30
SVH	ϕ 0.20	←	Not specified	Not specified	Not specified	ϕ 0.15
IVH	ϕ 0.20	←	Not specified	Not specified	Not specified	Not specified
Min. land diameter (mm)	–	–	–	–	–	–
Through hole	(Finish dia. + 0.5)	←	(Finish dia. + 0.6)	(Finish dia. + 0.6)	(Finish dia. + 0.5)	(Finish dia. + 0.5)
Via holes, SVH, IVH	(Drill dia. + 0.4)	←	Not specified	Not specified	(Drill dia. + 0.4)	(Drill dia. + 0.4)
Solder resist diameter (mm)	–	–	–	–	–	–
Through hole	Land dia. + 0.2	←	Coverlay: according to manufacturer's drawing	Land dia. + 0.2	←	Land dia. + 0.2
Via holes	= Land dia.	←	Not specified	Not specified	= Land dia.	= Land dia.
SVH	Covered by Solder resist	←	Not specified	Not specified	Not specified	Covered by Solder resist
Surface finish	Solder coating (note 1)	←	Solder coating, electrolytic solder	Solder coating (note 1)	←	←
CIC specifications						–
Thickness (mm)						0.15
Number of CIC layers						< 2
Min. connection through hole diameter (mm)						ϕ 0.6
Thermal expansion coefficient						< 13 ppm/°C

Note 1: Electro-nickel or electro-gold plating is partially permitted (for edge connectors).

space use include long-term thermal shock resistance and long-term radiation resistance, as well as the control of outgassing, which is a common material behavior in a high vacuum.

In developing the elemental technologies used in PWB manufacturing, satisfactory results must be obtained with every evaluation test. For this purpose, it is not only necessary to develop dedicated manufacturing systems but also to set processing condition targets so that the final product can manifest higher-than-requested characteristics.

Outgassing testing is conducted according to ASTM595 in order to measure the total mass loss (TML) and collected volatile condensed material (CVCM). The evaluation criteria are defined by JAXA by referencing the NASA-recommended values (TML $\leqq$ 1%, CVCM $\leqq$ 0.1%). For instance, the measurement results of a flexible copper-clad laminate were TML = 0.450% and CVCM = 0.003%, which meet the requirements for a PWB for space use.

Apart from the test items for qualification, we also conduct extended evaluations of other characteristics, such as high-temperature shelf testing, vibration testing and impact testing, so as to meet more advanced equipment requirements. The results of the qualification tests and additional characteristic tests are listed in the application data sheets for the convenience of users.

5. Future Deployment

The electronic parts mounted on space-use PWBs are expected to further improve their integration and functionality in the future, and wiring with higher density and higher heat radiation capability will be requested for them. On the other hand, as the use of surface-mounted components will increase in the future, it is expected that technical innovations such as optimization of the thermal expansion coefficient will be necessary for reliability.

To meet these requirements, PWBs for space use should be equipped with higher reliability based on ultra-high multilayer and fine pattern technologies, which are presently more advanced in industry-oriented products.

Currently, we set it as an immediate priority to advance the development of a flex-rigid PWB with high-density wiring beyond the currently applied JAXA qualification specifications in order to contribute to space-saving in spacecraft.

In the future, we also believe that it will be indispensable to develop PWBs equipped with a structure capable of tracing the progress of packaging modes based on trends in pin increase and pitch decrease in surface mounting (the trend toward ball grid arrays or BGAs), such as high-definition built-up boards, part-incorporating boards, boards with special RF countermeasures, etc. (**Fig. 3**).

The trend of placing severe environmental restrictions on electronic products is expected to lead to a requirement for complete lead-free and consequently a problem of availability for various general parts. As the effects of this problem, expected on space-use equipment in the future, may also extend to PWBs, we should deal with this problem by assuming additional problems, such as a surface finish to replace the traditional solder coating finish, as well as its reliability in mounting.

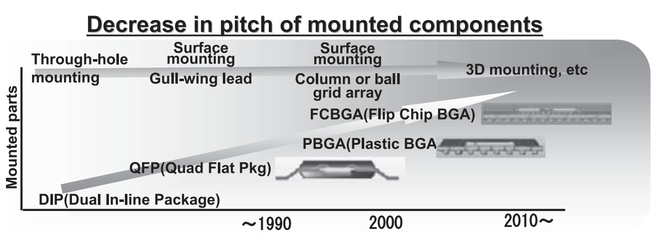

Fig. 3 Roadmap of mounted components.

6. Conclusion

YACL has been engaged in many space development projects up to the present. For example, our PWBs were used in the MUSES-C (HAYABUSA) that recently returned to the Earth in 2010 after a seven-year mission. We have been highly acclaimed, receiving letters of appreciation from the Japanese Minister of State for Space Development and the Minister of Education, Culture, Sports, Science and Technology.

We are proud that we have been contributing to space development as a JAXA-qualified parts manufacturer throughout the long history of the manufacture of high-reliability space-use PWBs. In the future, too, we are determined to promote the development of the PWBs required for space development. We endeavor to maintain and manage our large range of products so that they can assume their roles in space, while at the same time advancing reforms in MONOZUKURI (manufacturing).

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