Application Validation Technologies of Aerospace EEE Components

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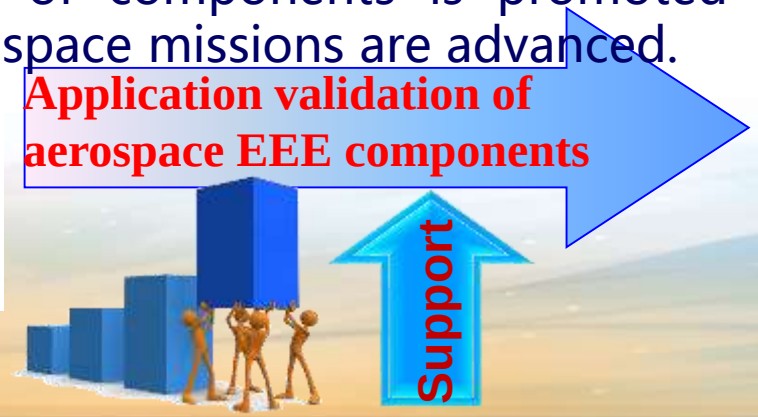
Contents

1 General

1.1 Connotations of application validation

In order to lower the application risks of newly developed components for aerospace and accelerate their application process, application validation should be done to such components. Application validation of aerospace components refers to that a series of tests, experiments and comprehensive evaluations are carried out to newly developed components in accordance with actual application environments of aerospace missions before they are applied to the aerospace missions so as to draw a conclusion of usability for aerospace missions.

The application guidelines can be prepared and distributed by means of the application validation. Consequently, the TRL (technology readiness level) of components is promoted and their successful application in aerospace missions are advanced.



1 General

1.2 Focus of application validation technologies

Application validation of components for aerospace application is a critical bridge between development and application of aerospace components.

Currently, the existing R&D processes of components include tackling problems in key technologies, prototype development, flight model development, screening test, qualification conformance inspection (QCI), product trial use, etc. However, application validation of components are mainly done by users, and there are both distinctions and connections between application validation and the above processes.

Application validation of components for aerospace application is carried out after R&D and assessment, and the results of component R&D, qualification and evaluation are inputs of application validation.

1 General

1.3 Relationship between application validation and qualification

Component qualification (including screening test and QCI) is aimed at evaluating whether components conform to R&D requirements and product specifications; generally, conformity tests and experiments are implemented as per predefined standards to draw a conclusion about conformance with the specification requirements;

Application validation is a product assessment process that provides proofs related to application requirements; it carries out analyses, tests, assessments and comprehensive evaluations in the light of application requirements and gives evaluative conclusions concerning aerospace mission application adaptability, etc.

2 Technical Framework

Intrinsic functional performances	Construction analysis	Limit test	Accelerated life assessment
• Completeness of function • Test coverage • Consistency of parameters	• Design • Manufacture process • Materials	• Temperature limit test • Electrical stress limit test	• 2000h

Analysis of validation item necessity	Functional performance of application	Environmental adaptability	Assembly adaptability	Adaptability to development environment	Comprehensive evaluation and typical application
• Identification of validation items • Design of validation methods	• Basic functional performance • Electrical characteristics of application • Special functional performance	• Electrical environment • Thermal environment • Mechanical environment • Space radiation environment • (SEU,SEL, TID) • Combined space environment	• Assembly process features • Assembly structural features	• Adaptability to development software • Compiler adaptability	• Evaluation on aerospace availability • Analysis of application notes • Design of typical application

2 Technical Framework

2.1 Analysis of intrinsic functional performance

- **Completeness of functional performance:** Covering validation of conventional functions, important functional performance and limit functional performance of components;
- **Test coverage:** Analyzing the test data in the screening process of components, and analyzing whether the test items can fully cover functional performance of components;
- **Consistency of parameters:** Selecting a certain amount of samples and analyzing the consistency of parameters in the light of key functional performance of components, thereby obtaining consistency results of components.

2 Technical Framework

2.2 Construction analysis

- To confirm the ability of component design, manufacture process, materials, etc. to meet evaluation requirements and relevant aerospace application requirements through a series of destructive and nondestructive examinations, analyses and tests.
- **Approaches to implement construction analysis:**
  - ✓ Internal moisture content analysis;
  - ✓ Decapping analysis;
  - ✓ Internal visual inspection;
  - ✓ Scanning electron microscopy (SEM);
  - ✓ Bonding strength test;
  - ✓ Die shear strength test;
  - ✓ Micro-profile analysis.

2 Technical Framework

2.3 Limit test

- To obtain critical stress value that meet requirements under the specified stress conditions via limit test. Limit test includes temperature limit test and electrical stress limit test.
- Approaches to implement temperature limit test:
  - ✓ Step temperature storage test;
  - ✓ Step temperature cycling test.
- Approaches to implement electrical stress limit test:
  - ✓ Power limit test;
  - ✓ Operating frequency limit test;
  - ✓ Power voltage limit test.

2 Technical Framework

2.4 Accelerated life assessment

- To obtain long-term operational reliability of components for aerospace application through accelerated life test.
- Implementation approaches:
  - ✓ First, carry out a 1000-hour life assessment under certain temperature;
  - ✓ Then, carry out another 1000-hour life assessment for long-term operational reliability.

2 Technical Framework

2.5 Analysis of validation term necessity

1) Identification of application validation items should meet the following requirements:

- ✓ Analyze the expected application environment of components, and analyze the necessity of carrying out application validation items concerning functional performance, reliability, environmental adaptability and other aspects in the light of component features;
- ✓ Analyze the stress exerted for validation in accordance with application features, so as to determine the stress used in application validation test of components;
- ✓ Validation items should cover space environment, thermal environment, mechanical environment, etc. where components are used.

2) Identify validation methods (board or equipment) according to application requirements and component features.

2 Technical Framework

2.6 Validation of application functional performance

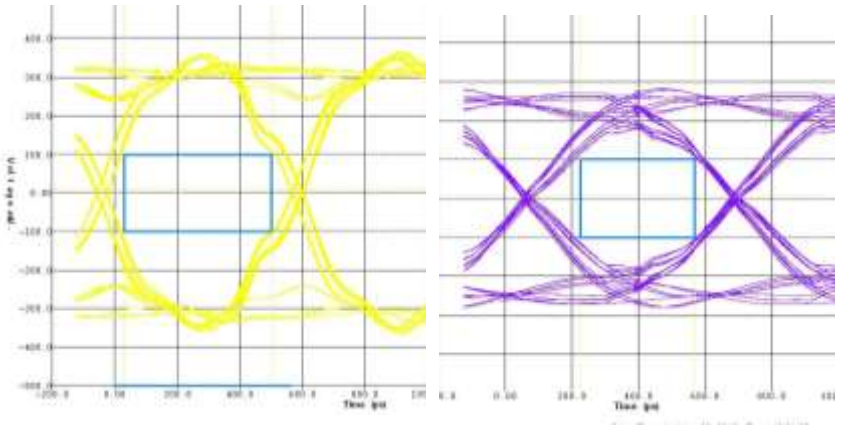
1) Validation of basic functional performance: To validate basic functional performance of components via board-based or system-based method.
2) Validation of electrical properties of application: To validate by combining with application status based on application requirements and functional performance features of components.
   - Characteristics of DC, AC and switches within the full stress range
   - Characteristics of transient application
   - Characteristics of interface matching
   - Characteristics of software-hardware collaboration, etc.
3) Validation of special functional performance
   - Special application functions
   - Special application conditions

2 Technical Framework

2.7 Validation of environmental adaptability

1) Validation of adaptability to electrical environment of application

- Electromagnetic compatibility
- Tolerance and redundance
- Signal integrity
- Electrical noise adaptability



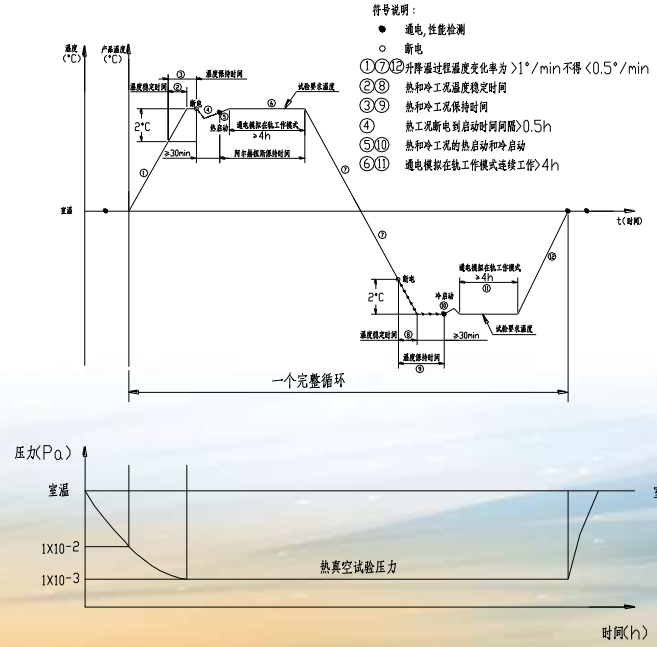
1.6Gb/s LVDS transmission eye diagram of two components (reflecting difference in signal integrity of components)

2 Technical Framework

2.7 Validation of environmental adaptability

2) Validation of adaptability to thermal environment of application

- Adaptability to thermal environment
- Adaptability to high-low temperature environment
- Adaptability to thermal vacuum environment



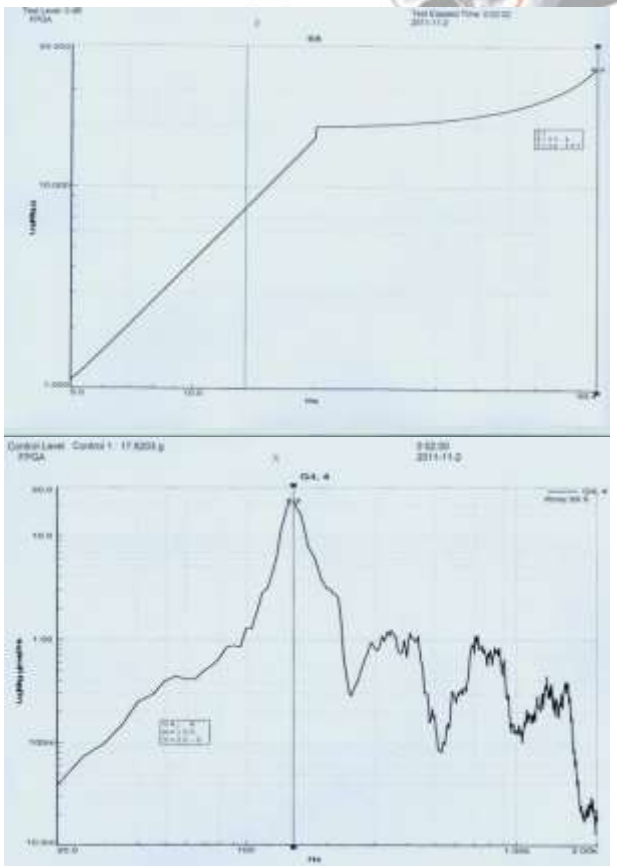
Curve of thermal test conditions

2 Technical Framework

2.7 Validation of environmental adaptability

3) Validation of adaptability to mechanical environment

- Determine which of the following mechanical environment tests to be done in line with component features and application requirements:sinusoidal, random, mechanical shock;
- Carry out the test by using corresponding conditions used in qualification test for the equipment;
- Monitor the status of test components during the test.



Sinusoidal vibration curve and random vibration response curve for a certain component obtained by test

2 Technical Framework

2.7 Validation of environmental adaptability

4) Adaptability to special space environment

- Single event effects
  - ✓ Single event upset (SEU)
  - ✓ Single event latch-up (SEL)
  - ✓ Single event transient (SET)
- TID effects and displacement effects
- Adaptability to atomic oxygen environment

Single event and TID test equipment

2 Technical Framework

2.7 Validation of environmental adaptability

5) Validation of adaptability to combined space stress environment

It is a validation way to assess whether components' adaptability to space environment meets the requirements by means of actual on-orbit flight. Whether carrying out validation during flight phase depends on the overall requirements and feasibility of validation. It mainly applies to components such as large-scale digital ICs of which the reliability is closely related to space environment, complex and critical.

The contents mainly include carrying out on-orbit test and ground-injection programs for special on-orbit test according to flight test procedure, test data analysis and processing as well as comparative analysis with ground test data, etc. There are two methods for application validation work during the flight phase: backup spaceflight validation and formal spaceflight validation, which can be selected based on the specific validation requirements.

2 Technical Framework

2.8 Validation of assembly adaptability

Assembling steps

Validation steps

2 Technical Framework

2.9 Validation of adaptability to development environment

Validation of adaptability to development environment mainly includes validation of components' adaptability to development software, compilers, and debuggers.

Validation of adaptability to component development software mainly validates components' adaptability to design software, integrated software, simulation software, debugging software and supporting software. Validation of compiler and debugger adaptability mainly validates the component-compiler and component-debugger matching features.

2 Technical Framework

2.10 Comprehensive evaluation

After identifying the element evaluation indexes used in the life cycle of components, we need to evaluate the availability of components and present the validation conclusion. The validation conclusion mainly consists of three circumstances:

1) All indexes of validated components meet space application requirements;

2) Some performance indexes of validated components do not fully meet the expected requirements, yet the components can be applied conditionally, and using the components in line with the conditions set by the application validation will not influence the overall performance indexes;

3) Component indexes do not meet the application requirements. The validation results are fed back to the manufacturer for the convenience of its timely improvement.

2 Technical Framework

2.11 Application guidance

Prepare the component application guidelines through comprehensive analysis of the validated test data and validation results. Give out aerospace application notes and typical application of components, provide comprehensive application validation data packets, and instructs application designers in terms of model application of components. Application guidelines at least contain the following contents:

- Component description
- Application notes and
- typical application
- Extreme environment
- Characteristics
- Radiation hardness characteristics (where applicable)
- Storage requirements

2 Technical Framework

2.12 Summary

At present, the common component evaluation mainly carries out a series of analyses, tests, and evaluations to components themselves, such as life assessment, limit test and construction analysis, etc.

However, application validation carries out the above tests but also validates the board-level or equipment-level functional performance, reliability and space environmental adaptability in the light of aerospace application of components by adopting covering or equivalent state and predictable aerospace application states.

3 Implementation Flow

Implementation flow

Demand analysis

- Analysis of intrinsic properties of components
- Application analysis

Scheme preparation

- Validation content identification
- Validation item identification
- Identification of implementation ways and approaches

Validation implementation

- Development of test equipment
- Implementation of validation test

Validation summary

- Validation result evaluation
- Preparation of application guidelines

4 Example of Application Validation

4.1 Validation necessity analysis

1) A 1553B bus component is developed according to the application needs. The component has complex functions with consisting of transceiver chips, memories and protocol chips, etc.

2) The bus transport protocol of the component can't be evaluated completely only by common qualifications. There are some application risks used in aerospace for the first time if the component would not be validated according to its application.

4 Example of Application Validation

4.2 Identification of validation items

Application functional performance

- Functional performance test
- Power current test
- Software-hardware compatibility and communication protocol test
- Operation timing test

Environmental adaptability

- Adaptability to thermal environment
  - Thermal cycle test
  - Thermal vacuum test
- Adaptability to mechanical environment:
  - Shock
  - Sinusoidal vibration
  - Random test
  - Constant acceleration
- Adaptability to space environment.

Assembly adaptability

- Shaping
- Tin coating
- Rinsing
- Three proofings
- Fixing and packaging

4 Example of Application Validation

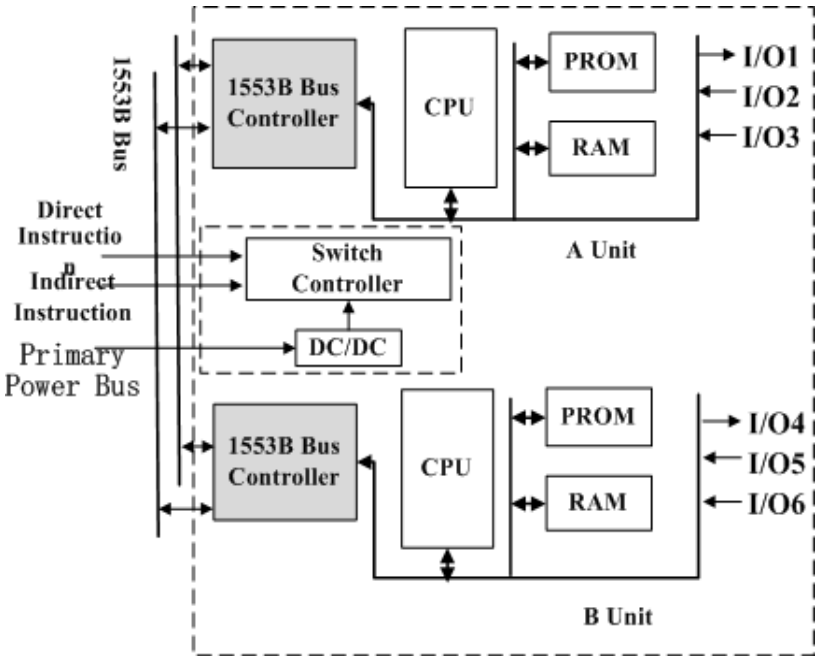
4.3 Validation devices

1) Special testing devices for 1553B bus

Special testing devices for parameters and communications protocol of 1553B bus controller: Adopt special test procedures to conduct VTP test, noise suppression test, DRIVER test, ATP test and transmission test.

2) The device based on remote test unit (RTU)

RTU receives control commands from data-handling computer via interfaces of 1553B, for instance: outputting indirect instructions, sending on-board instructions, transmitting telemetry data, setting working state of RTU, and performing corresponding actions.



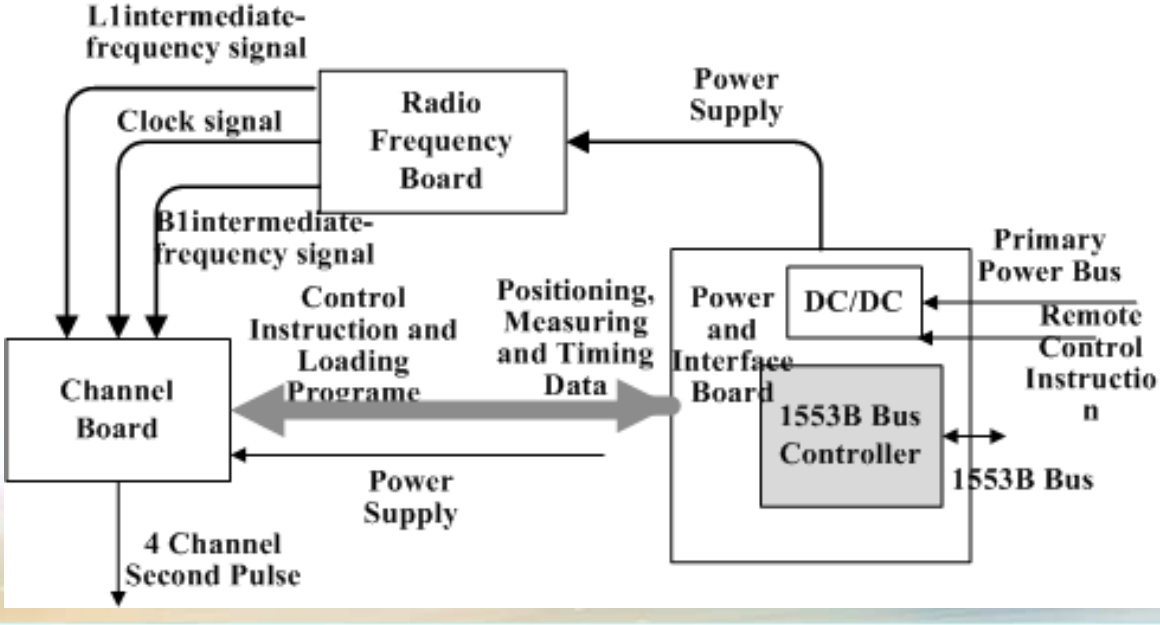
The device based on RTU

4 Example of Application Validation

4.3 Validation devices

3) The device based on a receiver

In this device, the component works with the controller power supply being 3.3V while the component is validated with the power supply being 5V. Validating adaptability of interface levels under this circumstance is representative to some degree. The functional block diagram of the device is shown as following.



Functional block diagram of the device based on a receiver

4 Example of Application Validation

4.4 Test conditions

1) Application functional performance

a. Special testing devices for 1553B bus

Carry out validation test of components by referring to 'Digital time division command / response multiplex data bus test plan' (remote termination validation test plan) with the following testing flow: VTP test → noise suppression test → DRIVER test → ATP test → transmission test.

4 Example of Application Validation

4.4 Test conditions

1) Application functional performance

b. The device based on remote test unit (RTU)

- Function comparison test : The A unit is compared with B unit as to all functions.
- Parameter bias test: The device functions is tested under the conditions of ±10% the power supply.
- Software and hardware performance test : The power current, interface electrical level and communication protocol are tested.
- Operating stability assessment: The device runs 360h totally.

4 Example of Application Validation

4.4 Test conditions

1) Application functional performance

c. The device based on a receiver

Appropriate tests or testing are conducted in line with the following conditions to components applying the receiver:

- Detailed regulations for debugging of equipment or subsystem of receiver;
- Detailed regulations for debugging of power interface board of receiver;
- Test program for qualification-level environment of receiver subsystem.

4 Example of Application Validation

4.4 Test conditions

2) Environmental adaptability

a. Adaptability to thermal environment

The device based on RTU

- **Ambient pressure: Normal**
- **Test temperature: -35℃～+70℃**
- **Cycle times: 37.5 times**
- **Ramping rate: 3～5 ℃/min**
- **Retention time: Working continuously for 4 hours after circulating to and stabilizing at the max. and min. temperatures respectively each time**

The device based on a receiver

- **Heat balance test: Components meet Level I derating requirements**
- **6.5 times of thermal vacuum cycle and vacuum discharge test**
- **25.5 times of thermal cycle test**

4 Example of Application Validation

4.4 Test conditions

2) Environmental adaptability

b. Adaptability to mechanical environment

The device based on a receiver

- **Shock**
- **Sinusoidal**
- **Random vibration**
- **Acceleration**

4 Example of Application Validation

4.4 Test conditions

2) Environmental adaptability

c. Adaptability to space environment

Group	Test	Test methods and conditions	Sampling size
E1	Ionizing radiation (TID) test Terminal electrical test	As per provisions of MIL-STD-883 method 1019, endpoint electrical parameters for A1 and A7 groups	11
E5	Single event test	As per provisions of MIL-STD-883 method 1021 and 1023, monitor the functions of component	3

4 Example of Application Validation

4.4 Test conditions

3) Assembly adaptability

- Test according to process requirements of shaping test and tin coating test;
- Test according to process requirements of rinsing, three proofings, and fixing and packaging;
- Assemble according to assembly process requirements and carry out metallographic analysis to prove that: mechanical performance of lead base material is good, lead coating and base material bond well, component lead and tin soldering bond well without dry joint, and the welding quality is reliable;
- Determine whether the electrical properties meet current environment test requirements by mechanical test and thermal test, thereby further proving the reliability of welding spot quality.

4 Example of Application Validation

4.5 Validation summary

1) Application functional performance: Results of the various test items are acceptable and conform to application requirements.

2) Environmental adaptability

- Adaptability to thermal environment: During the test, validation devices are in communication state all the time, bus communication is normal, and there is no error code phenomenon.
- Adaptability to mechanical environment: communication function of 1553B bus is normal, bus telemetry data of receiver are correct, and positioning and orbit determination accuracy and other indicators meet the general requirements.

4 Example of Application Validation

4.5 Validation summary

2) Environmental adaptability

- Adaptability to space environment: total radiation hardness dose is no less than 1×10^5 rad(Si); threshold value of single event latch-up (SEL) is no less than 75 MeV·cm^2/mg; the LET threshold value of single event upset (SEU) is no less than 37 MeV·cm^2/mg.

3) Assembly adaptability: There is no abnormality in the component body and the results conform to the requirements.

Results of application validation of domestic 1553B bus component show that the component can be applied in aerospace missions. The application guideline for the component is developed and given out to spacecraft application designers. And the 1553B bus controller has been selected and applied in a few spacecrafts.

The End.