General

JERG-2-200-TP001

Template for Electrical Design Criteria for Scientific Spacecraft

May 16, 2017

Japan Aerospace Exploration Agency

This is an English Version of JREG-2-200-TP001. Whenever there is anything ambiguous in this document, the original document (the Japanese version) shall be used to clarify the intent of the requirement.

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1. Scope

This “Template for Electrical Design Criteria for Scientific Spacecraft” (hereinafter referred to “design criteria template” or just “templates”) is a requirements document applied to electrical design of the spacecraft systems developed by JAXA, which covers both common requirements not only for electrical interfaces but also ~~and~~ the like applied according to the applicable document (5) in 2.1 and fundamental electrical design requirements regarding electric power and EMC. For communication and data processing, this design criteria template is applicable to the function and interface to interconvert logical data and electrical signals concerning HK data/commands.

This template does not cover electric power generation and storage, because they are addressed in a separate design standard and not in the applicable document (5).

Projects shall define own electrical design criteria which incorporates these aspects referring to the relevant design standards described above.

Note that this template includes requirements which are not in the applicable document (5). They are added after deliberating the information of the former Design Criteria for Scientific Spacecrafts (JERG-2-020) and the design criteria of the past scientific spacecraft projects.

Where this template does not specify numerical values, it is intended that projects specify them in their electrical design criteria. The table of contents of this template is compliant to the one of JERG-2-200A “Electrical design standard” as its upper applicable document, in order to enhance traceability. The structure of this template is consistent with that of the superordinate document, but some requirements are described as “N/A”, because they are not appropriate to be included in this template. On the other hand, there are some added requirements in the template as explained above. When the superordinate document is revised, the clause numbers of this template shall also be revised accordingly.

2 Related Documents

2.1 Applicable Documents

The following documents are applied within the scope called for by this template. When any inconsistency is found, report to the Secretariat of JAXA Standards or a relevant standard working group. Unless otherwise specified in the applicable documents, this template takes precedence. The latest version of applicable documents shall be used.

(1) JMR-001 System Safety Standard
(2) JMR-002 Rocket Payload Safety Standard
(3) JERG-0-041 Space-purpose Electric Wiring Stage Standard
(4) JERG-2-143 Radiation Design Standard
(5) JERG-2-200 Electrical Design Standard
(6) JERG-2-211 Charge/Discharge Design Standard

(7) JERG-2-212 Wire Derating Design Standard
(8) JERG-2-213 Insulation Design Standard
(9) JERG-2-214 Power Supply System Design Standard
(10) JERG-2-215 Solar Cell Paddle Design Standard
(11) JERG-2-241 EMC Design Standard
(12) ISO15389 Space systems - Flight-to-ground umbilicals
(13) CRA-99004 Shinraisei Gijutsu Jouhou (Alert: JERS-1 Wire Harness anomaly)

2.2 Reference Documents

Reference documents relating to this template are as follows:

(1) ANSI/TIA/EIA-422-B-1994
Electrical Characteristics of Balanced Voltage Digital Interface Circuit
(2) MIL-STD-1553B
Digital Time Division Command/Response Multiplex Data Bus
(3) MIL-HDBK-83575
GENERAL HANDBOOK FOR SPACE VEHICLE WIRING HARNESS DESIGN AND TESTING
(4) JERG-2-400 Communication Design Standard
(5) DOD-E-8983C
Electronic Equipment, Aerospace, Extended Space Environment, General Specification for
(6) JAXA-QTS-2060D
Connector Common Specification
(7) SAE-AS50881
WIRING, AEROSPACE VEHICLE
(8) MIL-W-16878/4
WIRE, ELECTRICAL, POLYTETRAFLUOROETHYLENE (PTFE) INSULATED, 200 DEG. C, 600 VOLTS, EXTRUDED INSULATION
(9) MIL-HDBK-4001
ELECTRICAL GROUNDING ARCHITECTURE FOR UNMANNED SPACECRAFT
(10) MIL-STD-464A
ELECTROMAGNETIC ENVIROMENTAL EFFECTS REQUIREMENTS FOR SYSTEMS
(11) NASA-HDBK-4002
AVOIDING PROBLEMS CAUSED BY SPACECRAFT ON-ORBIT INTERNAL CHARGING EFFECTS
(12) NASA Technical Paper 2361

DESIGN GUIDELINES FOR ASSESSING AND CONTROLLING SPACECRAFT CHARGING EFFECTS

(13) MIL-STD-1686C
ELECTROSTATIC DISCHARGE CONTROL PROGRAM FOR PROTECTION OF ELECTRICAL AND ELECTRONIC PARTS, ASSEMBLIES AND EQUIPMENT (EXCLUDING ELECTRICALLY INITIATED EXPLOSIVE DEVICES)

(14) JIS C 0617 Graphical symbols for diagram

(15) ISO/TC20/SC14 International Spacecraft Specifications
(a) ISO/DIS 24637 Electromagnetic interference (EMI) test reporting requirements
(b) ISO/CD 26871 Pyrotechnics
(c) ISO 14621-1 EEE parts – Parts Management
(d) ISO 14621-2 EEE parts – Control program requirement
(e) ISO 15389 Flight-to-ground umbilical

(16) ISO14302 Electromagnetic compatibility requirements

(17) JERG-2-200-TM001 Example of signal interface

(18) JERG-2-200-TM002 High Speed Data Interface Application Notes

(19) JEITA ED-5007 Consolidated High Supply Voltage CMOS interface

(20) MIL-STD-461C Requirements for the control of electromagnetic interference characteristics of subsystems and equipment
（To use Version D or later, carefully examine their requirements because they are drastically changed)

(21) MIL-STD-462C Measurement of electromagnetic interference characteristics
（To use Version D or later, carefully examine their requirements because they are drastically changed)

(22) MIL-STD-1541 Electromagnetic compatibility

(23) EEE-INST-002 Instructions for EEE Parts Selection, Screening, Qualification, and Derating

(24) NSI/TIA/EIA-644-A-2001, Electrical Characteristics of Low Voltage Differential Signaling (LVDS) Interface Circuits

(25) Telemetry Command Design Criteria for Scientific Spacecraft (To be issued in 2017)

(26) Spacecraft SpW User’s Manual (of each Project)

3 Definitions and Abbreviated Terms

3.1 Definitions

Definitions of terms in this template are as follows:

(1) System
A spacecraft unless specified.

(2) Sub-system
A part of a larger system, divided according to functions.

(3) Power system

A subsystem capable of handling power generation, power control, power storage, and power distribution (except for power supply harnesses to load equipment) functions, not necessarily "power system = solar cell paddle system + power source system".

(4) Primary power supply

A power source that is generated and controlled by the power system of a spacecraft and commonly distributed to the load equipment installed in the spacecraft. (A power source is a secondary power supply when the electric power is stepped up or stepped down from a primary power supply bus within the power system and commonly distributed to the load equipment in the spacecraft).

(5) Secondary power supply

A power source that is stepped up or down from a primary power supply bus inside or outside a power system of a spacecraft.

(6) Unregulated bus

A power bus for commonly and directly distributing power from the battery to each load equipment in the spacecraft.

(7) ODC bus

A power supply bus to distribute electric power exclusively for ordnance ignition.

(8) HK data

Data indicative of an operating condition and status of onboard equipment.

(9) Payload data or mission data

Observation data and such acquired by the payload.

(10) Telemetry

A remote communication of HK data and payload data.

(11) Command

A directive transmitted from a ground station to a spacecraft or a directive produced or executed by the spacecraft.

(12) Telecommand

A remote communication of a command.

(13) Interruption/Momentary Interruption

Interruption means that either a power supply voltage or a supplied current becomes zero, and is not restored.

Momentary interruption means that either a power supply voltage or a supplied current becomes zero, but is restored.

(14) Hazard

Human injury; physical damage to public property, private property of a third party, a system, launch site facility, etc.; and environmental effects.

(15) Hazardous

A hazard potential.

(16) Damage

A loss of function.

(17) Transmission path

A driver, a connector, a harness, a receiver, and such.

(18) Array circuit

A solar array connected in a parallel mode in correspondence with one shunt device.

(19) Autonomization function

The function which allows the spacecraft to constantly monitors own telemetry, judge whether its value exceeds the prescribed value, and issue necessary commands. Also called autonomous function.

3.2 Abbreviations

Abbreviations related to this design standard template are given as follows:

AC	Alternative Current	
BTS	Battery Test Simulator	
CMD	CoMmanD	
DC	Direct Current	
DH	Data Handling	
EED	Electro Explosive Device	
EMC	Electro-Magnetic Compatibility	
EMI	Electro-Magnetic Interference	
ETFE	Ethylene TetraFluoroEthylene	
FDIR	Failure Detection, Isolation and Reconfiguration	
FG	Frame Ground	
FMEA	Failure Mode Effect Analysis	
HCE	Heater Control Electronics	
HK	House Keeping	Spacecraft monitoring
LET	Line Energy Transfer	
LISN	Line Impedance Simulation Network	
MD	Manual Disconnect	
MLI	Multi Layer Insulation	
NEA	Non Explosive Actuator	
ODC	OrDnance Controller	
PBT	PolyButylene Terephthalate	
PSU	Power Supply Unit	
PTFE	PolyTetraFluoroEthylene	

PWM	Pulse Width Modulation
RD	Remote Disconnect
RF	Radio Frequency
RTN	ReTurN
SAS	Solar Array Simulator
SG	Signal Ground
SMU	Spacecraft Management Unit
TLM	TeLeMetry
TN	Turn On
UPG	Uni Point Ground
UMB	Umbilical Connector

4 Common design requirements

4.1 Electrical interfaces

This clause specifies the requirements on electrical interfaces described below within spacecraft as well as between spacecraft and external equipment.

(1) Power supply interface

Interfaces at equipment with the power supply of the system.

The non-regulated primary bus power supply obtained from solar cell and batteries (hereinafter referred to as "bus power supply") are fed to each equipment by the power supply distribution equipment (DIST) and used in each equipment after conversion and stabilization to the necessary voltages by secondary power supply units. The secondary power supply is sometimes fed to each equipment from the converter unit (Power Supply Unit: PSU) outside the equipment.

(2) Command/telemetry interface

Command/telemetry interfaces of equipment

Note: A scientific spacecraft is sometimes provided with a SpaceWire (SpW) interface, and may interface through it. The communication system devices, attitude sensors and other equipment that only have limited commands/telemetries shall be connected to an equipment with a SpW indirectly interfacing with a SpW. As for the details of the SpW interface, refer to documents "the Spacecraft SpW user manual" and "the design standard of telemetry commands".

(3) Passive analog/active analog interface

Interfaces to measure the analog signals of the equipment without SpW.

Ex. 1: The passive analog signals of thermal sensors and such interface with HCE or HK equipment.

Ex. 2: After A/D conversion, the active analog data are output to SMU via the equipment with a SpW.

(4) Heater control interface

The collective term for heater control circuits, temperature measurement circuits for heater control, and interface circuits for other equipment.

Ex.: The heater to maintain the operating temperature range of an equipment onboard on a scientific spacecraft shall be controlled by HCE. The special heater for controlling the temperatures of the limited hardware items inside the equipment shall be controlled individually by the equipment.

(5) Hold/Release Mechanism Control Interface with Pyrotechnics/Non- pyrotechnics.

The interface to control driving of the hold/release mechanism using pyrotechnics or non-pyrotechnics devices.

(6) External interface of spacecraft

Interfaces to access inside the spacecraft from outside for system tests and launch site operations. The interfaces have the following three functions.

[1] UMB connector

The interface to connect the spacecraft to the ground system with wires until immediately before the launch. (The interface is separated at the launch.)

[2] MD connector

The interface to connect the spacecraft to the ground system for system tests and launch site operations. (It is not usable after the spacecraft is mounted on a rocket.)

[3] TN connector

The separate interface er forconnect the circuits,etc at the groud test.spacecraft It should be used with attached for the launch.

(7) Signal interface between equipment

This is the generic name for the signal interface between equipment.

4.1.1 Signal interface

4.1.1.1 Overview

Signals handled in spacecraft operations are classified into 1) signals of mission data acquired by payloads to achieve the purposes of the spacecraft and 2) signals of housekeeping (HK) data and 3) command data for spacecraft operations (monitor and control).

Interface points of signals are present among equipment which handle these signals or among onboard equipment. Generally speaking, these interfaces are provided with connectors for exclusive use of designated harnesses. Figure 4.1-1 is a conceptual diagram of signal interfaces.

In the diagram, wide solid lines indicate paths for the signals of the payloads, narrow solid lines represent paths for the HK data and the command signals for the operations of the spacecraft, and dotted lines show paths for connections with respect to a ground station. This conceptual diagram (an example) shall be replaced with the official diagram by the project.

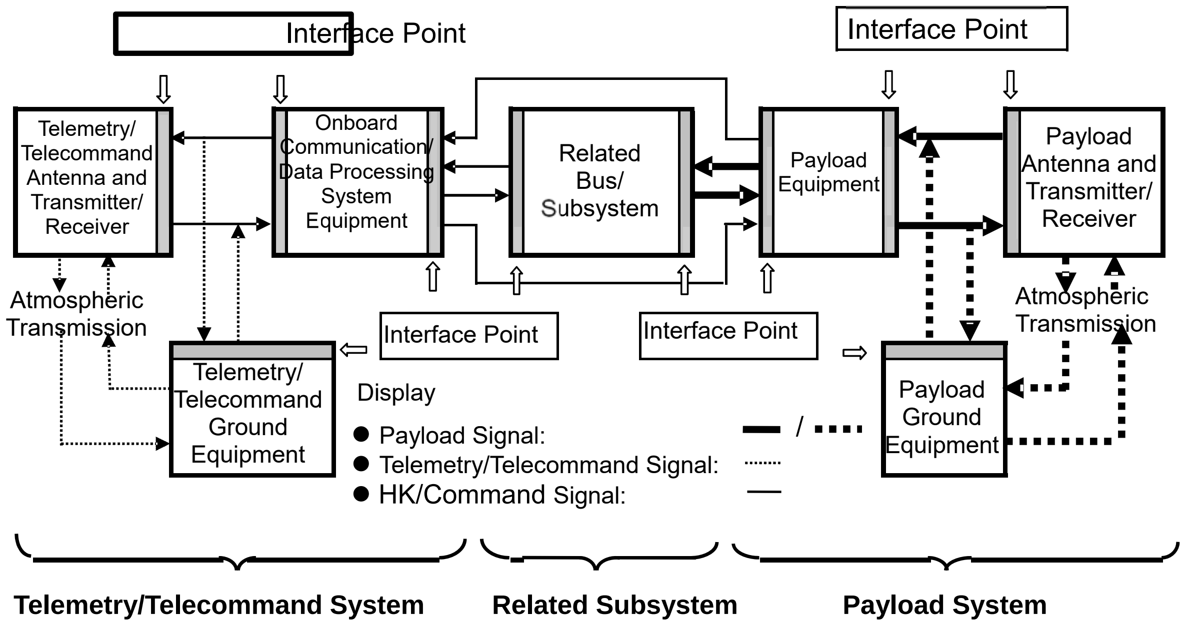


Figure 4-1 Signal Interface Conceptual Diagram

4.1.1.2 Interface Requirements

(1) For an interface signal, the characteristics of input and output signals (e.g., connecting harness, groundings on input side and output side, characteristic impedances, and influences of EMC) shall be in compliance

(2) The number of interface circuits types shall be minimized by utilizing the signal interface types shown in this design standard template to the extent possible and use corresponding standard interface circuits.

(3) Both the function and performance of onboard equipment shall not be damaged even

if a signal is input when a power supply is turned OFF.

(4) Onboard equipment shall not fail or be damaged even if an undefined command is input when a power supply is turned ON.

(5) A signal interface circuit shall not be damaged and shall not cause a secondary failure even if adjoining signals come in contact. If it is difficult to meet this requirement due to resource constraints and such, clause 4.1.1.3 shall be applied.

(6) If a transmission paths consist of a primary and secondary path, any one of the following conditions shall be satisfied.

(a)A failure occurring in one path shall not have an adverse influence on the other path between primary and secondary transmission paths.

(b)When the failure in one path has an adverse influence on the other path, a proper function shall be provided outside the transmission path to preserve transmission function.

4.1.1.3 Signal interface between equipment

4.1.1.3.1 Digital signal interface

The digital signal interfaces between equipment shall be the interfaces shown in Table 4-1, except for the interfaces between the sensor and the sensor signal processing circuit.

Table 4-1 Digital Signal interfaces between equipment

Signal	Input Side		Recommended Signal Frequency(Hz)	Use of Secondary Power Supply (*)	
	Circuit Type	Spec (Element Type)		Common	Individual
Digital Signal	Pulse	Mechanical Relay	DC	YES	YES
		Opto-isolator	DC	YES	YES
	Bi-level	Comparator with MUX	DC	YES	YES
	Single end	C-MOS (4050/4049)	DC～65k	YES	NO
	Differential	EIA(RS)-422A	65k～600k	YES	YES

	(Low Power)	(incl. HS26C32)			
	Differential (Standard)		600k～10M	YES	YES
	Differential (Hi-Speed)	ANSI/TIA/EIA-644-A (incl. DS90C32)	10M～	YES	YES

* Shows the applicability of the circuit types depending on the case that interfacing circuits have the same (common) secondary converters or the case with different (individual) secondary converters.

(1) Pulse signal interface

The pulse signal interface is used for outputting commands to the onboard equipment via the dedicated line. It is used for transmitting very slow signals including the pulse to drive the latching relay for turning on and off the equipment. Thus, recommended signal frequency is DC. Because commands are usually exchanged between the equipment having different returns, both HOT and RTN signal lines on the received side are not grounded.

A. As for the relay interface, the command issuance side directly drives the relay on the onboard equipment side. An example of the interface circuit is shown in Fig.4-2.

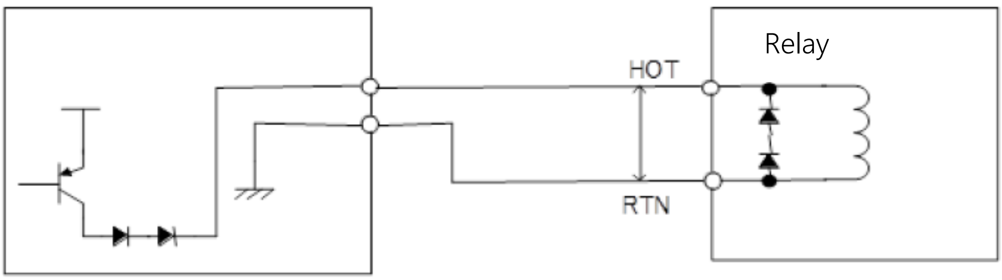


Fig.4-2 Relay interface circuit

B. Regarding the photo-coupler interface, the onboard equipment receives pulse signals with the photo coupler, and generates the driving power of the relay under its own power. An example of the interface circuit is shown in Fig. 4-3.

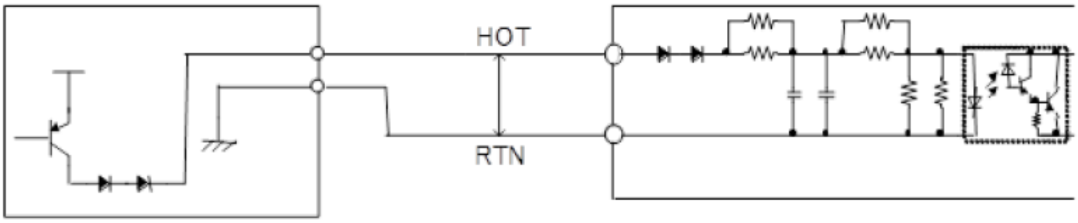


Fig. 4-3 Photo-coupler interface circuit

(2) Bi-level signal interface

The bi-level signal interface is used for collecting the low frequency of state change is low by the dedicated line. Since the on-board processor for collecting telemetry (or the equipment in the upstream of the onboard equipment) usually reads out many channels serially by the multiplexer, the recommended signal frequency is DC.

A. The active bi-level signal interface transmits and detects the predetermined binary (two-valued) voltage that is output by the onboard equipment. It is used for transmitting the on/off status, etc. of the onboard equipment and their internal circuits. An example of the interface circuit is shown in Fig. 4-4.

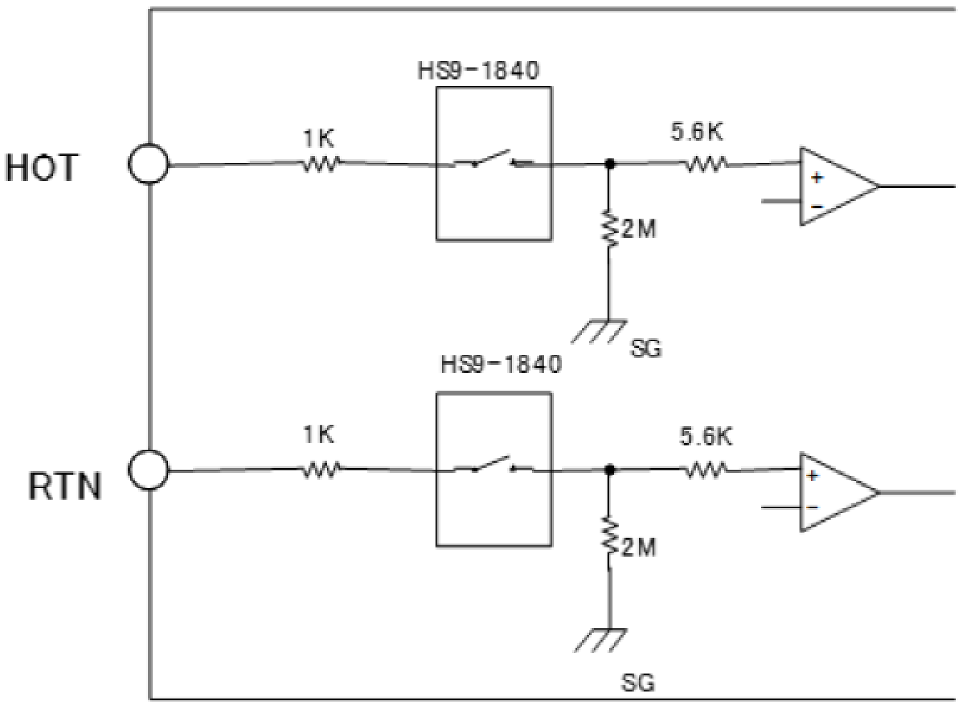


Fig. 4-4 Active bi-level signal interface circuit

B. The passive bi-level signal interface detects the open/close status of the no-voltage contact(s) in the onboard equipment. It is used for the open/close status of switches in the onboard equipment, etc. An example of the interface circuit is shown in Fig. 4-5.

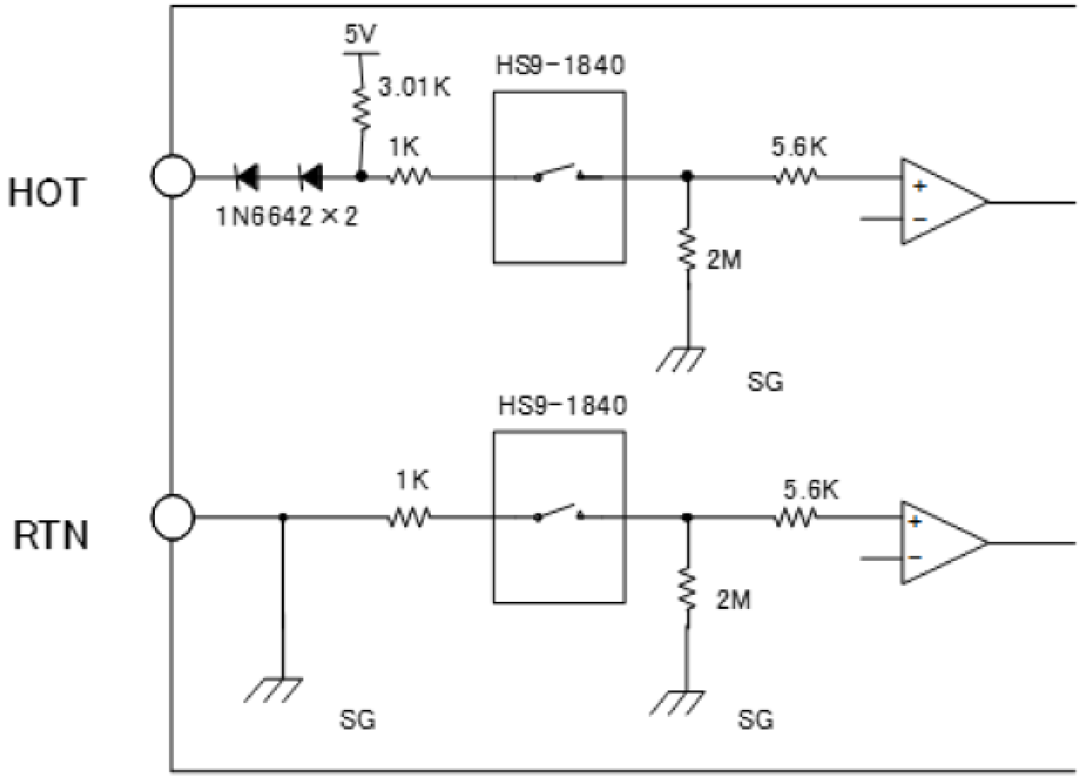


Fig. 4-5 Passive bi-level signal interface circuit

(3) Single-end digital signal interface

The single-end digital signal interface is a C-MOS interface using a +3.3 V or +5 V power supply. It shall not be used between the equipment with different returns (grounds). As for the interface between equipment by C-MOS, the element without the input protection diode for the power supply side shall be used for the input circuit. This is intended to prevent an input signal from flowing into the power supply via the input protection diode of C-MOS when power is off, causing the C-MOS at the subsequent stage to malfunction. Specifically, use the standard logic 4050/4049. However, since 4049 has less noise margin than 4050, it is recommendable to use 4050. Furthermore, although the interface is also defined for the case where the other side is the TTL device, it shall not be used unless it is unavoidable (from the viewpoint of current route and noise margin).

A. Interface circuit

Any of the single-end digital signal interface circuits shown in Table 4-2 (A) to (G) or the circuit compatible with those shall be used. When power supply voltage of the output side element is +3.3 V, it is desirable to use a +3.3 V system for the input side element as well in order to keep a sufficient margin between the output voltage and the input threshold.

B. Output signal level

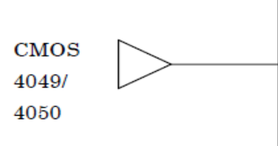
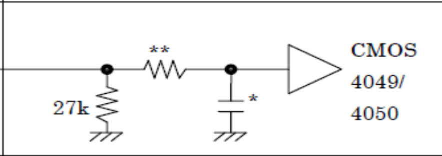
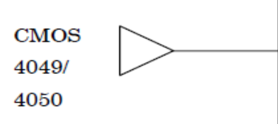
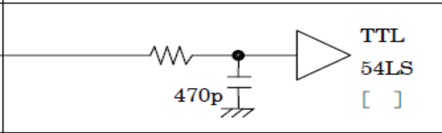
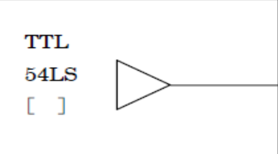
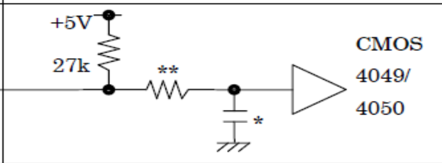
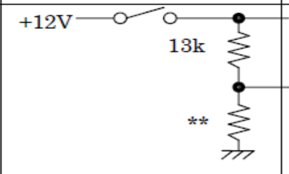
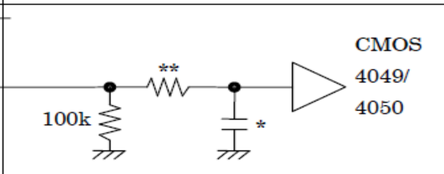
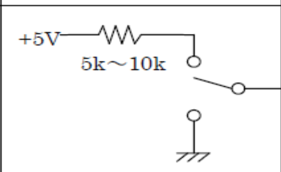
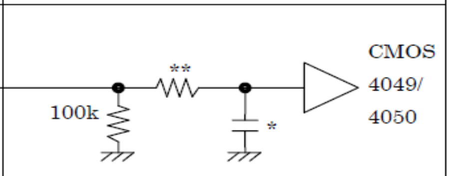
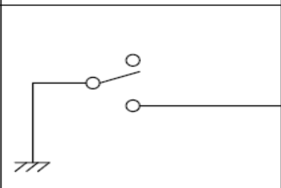
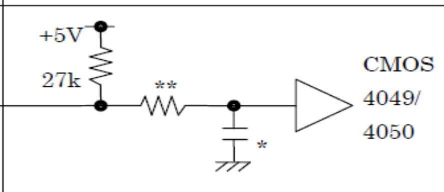
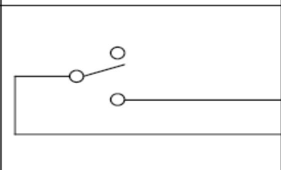
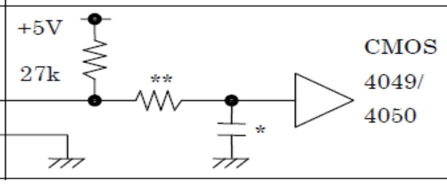
(1) +3.3 V system (based on the JEITA ED-5007 "Unified wide power supply voltage range CMOS DC interface standard for non-terminated digital integrated circuits")

- High level: $0.7V_{dd}$~V_{dd} +0.3 (V_{dd} = +3.3V power source voltage at input connector, relative to signal GND voltage at input)
- Low level: –0.3 ~ $0.3V_{dd}$ (relative to signal GND voltage at input)

(2) +5 V system

- High level: (V_{dd} – 0.5) ~ V_{dd} (V_{dd} = +5V power source voltage at input connector)
- Low level: (V_{ss} – 0.3) ~ V_{ss} + 0.3 (V_{ss} = signal GND voltage at input connector)

Table 4-2 Single-end digital signal interface
(Between the equipment using the common secondary power supply converter)

TYPE	出力側	入力側	備考
(A)			
(B)			Using LS-TTL **DEPRECATED** **Shall not be used**
(C)			
(D)			Power ON/OFF Status
(E)			
(F)			(Limit SW | Mechanical Relay) (Open | Close) Status
(G)			

Note 1 ⫽⫽: signal GND.

Note 2: Recommended capacitor capacity, resistance *:220 pF, **: 10KΩ.

(4) Low power differential digital signal interface

This is used for the digital signal interface between the equipment under the following conditions.

・It is not possible to directly connect the secondary power supply converters return because different secondary power supply converters are used.

· The interface signal is within the range of 65 kHz ~ 600 kHz.

A. Interface circuit

The interface circuit is shown in Fig. 4-6. In order to prevent widespread failure in the substrate when the failure of any element/device occurs, the power supply on the output side and input side shall be unified to the same voltage system (+3.3 V system or +5 V system).

B. Interface conditions

(1) Line driver/receiver: EIA (RS)-422A Compatible

(2) Output signal level: "1" $V_{AB} < -1.0V$

"0" $V_{AB} > +1.0V$, V_{AB} =point A-pointB

(3) Terminal type: Source Termination

(4) Current limit resistor: 33Ω (Nominal)

(5) Input protection resistor: 511Ω (Nominal)

(6) Electrical transmission cable: twisted pair shield wires

(7) Length of electrical instrumentation cable: 10m or less

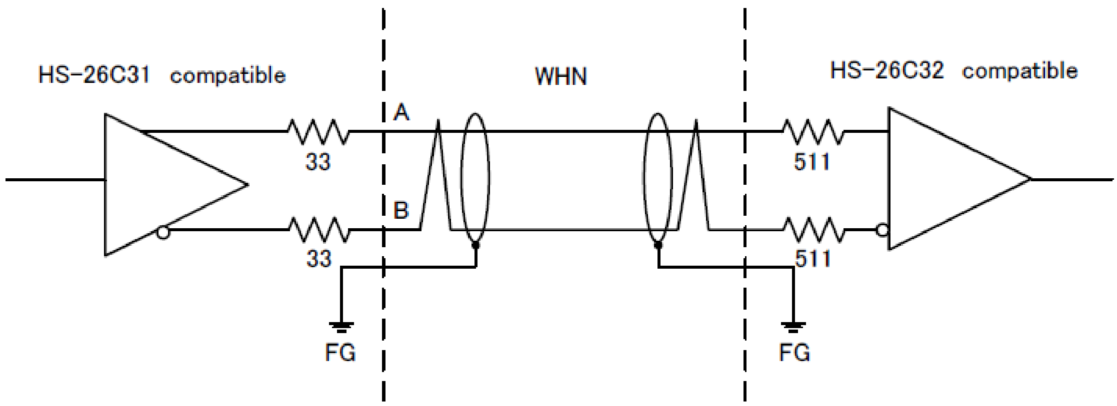


Fig. 4-6 Low power differential digital signal interface (EIA (RS)–422A, low power type)

The above method of connecting to the ground reference point of the shield ground in the differential interface is different from the method described in the reference document (17) JERG-2-200-TM002. However, the present method is adopted from the viewpoint of EMC (that the signal grounds that use different secondary power supplies shall not be connected).

(5) Standard differential digital signal interface

This is used for the digital signal interface between the equipment under the following conditions.

- It is not possible to directly connect the secondary power supply return because different secondary power supply converters are used.
- The interface signal is within the range of 600 kHz ~ 10 MHz.
  (Regarding the use at 10 MHz or higher, adjustment shall be coordinated with the person in charge of the system.)

A. Interface circuit

The interface circuit is shown in Fig. 4-7. In order to prevent widespread failure in the substrate when the failure of any element/device occurs, the power supply on the output side and input side shall be unified to the same voltage system (+3.3 V system or +5 V system).

B. Interface conditions

(1) Line driver/receiver: EIA(RS)-422A Compatible
(2) Output signal level: "1" $V_{AB} < -1.0V$
"0" $V_{AB} < +1.0V$, V_{AB} =Point A- Point B
(3) Terminal type: Shunt Termination
(4) Terminal resistor: 100Ω (Nominal)
(5) Input resistor: 160Ω (Nominal)
(6) Current Limit resistor: 33Ω (Nominal)
(7) Pull up or Pull-down resistor: 2kΩ (Nominal)
(8) Electrical transmission cable: Twisted pair shield wires

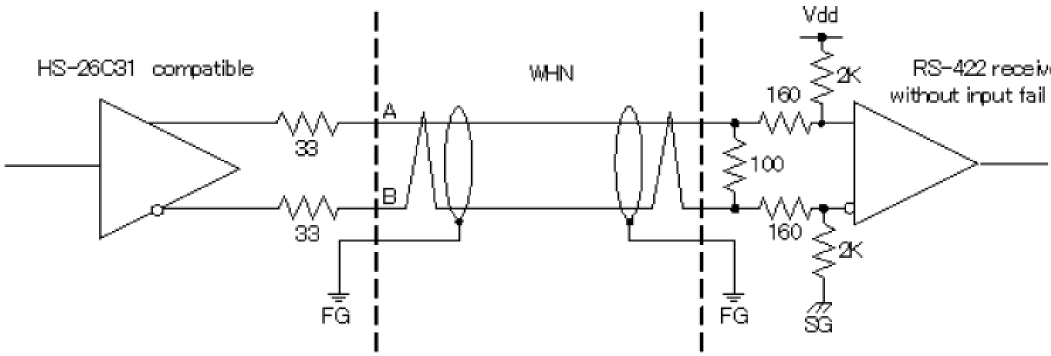


Fig. 4-7 Standard differential digital signal interface (EIA (RS)–422A, standard type): In the case where the level determination circuit (the so-called fail safe, etc.) is not installed in the receiver IC.

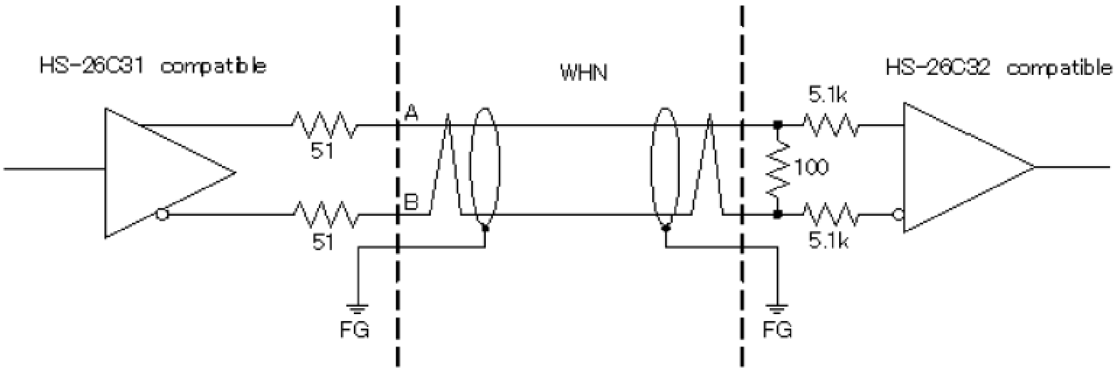


Fig. 4-8 Standard differential digital signal interface (EIA (RS)–422A, standard type): In the case where the level determination circuit (the so-called fail safe, etc.) is installed in the receiver IC.

The above method of connecting to the ground reference point of the shield ground in the differential interface is different from the method described in the reference document (17) JERG-2-200-TM002. However, the present method is adopted from the viewpoint of EMC (that the signal grounds that use different secondary power supplies shall not be connected).

(6) High-speed differential digital signal interface

This is used for the digital signal interface between the equipment under the following conditions.

- It is not possible to connect the secondary power supply return because different secondary power supply converters are used.
- The interface signal is 10 MHz or higher.
  (Regarding the maximum frequency, adjustment shall be coordinated with the person in charge of the system.)

A. Interface circuit

The interface circuit is shown in Fig. 4-9. The interface circuit of the SpaceWire network that uses LVDS as the physical layer is shown in Fig.4-10. For the processing of unused/unconnected pins, the method recommended by the parts manufacturers providing data sheet, etc. shall be followed. Specifically, even as for the elements/devices where the unconnected state is not prohibited, take measures to fix the level, because there are cases where the output varies/oscillates due to induction from the surrounding environment. Also, in order to prevent the common mode voltage between the transmission side and reception side from exceeding the absolute maximum rating of the elements/devices, control the ground voltage of both substrates.

B. Interface condition

(1) Line driver / receiver : TIA/EIA－644A compatible

(2) Output Signal Level : "1" VAB < -100 mV

: "0" VAB > +100 mV, VAB= point A－Point B

(3) Terminal Type : Shunt Termination

(4) Terminal Resistance : 100 Ω (Nominal)

(5) Instrumentation Cables : Twisted Pair Shield Wire

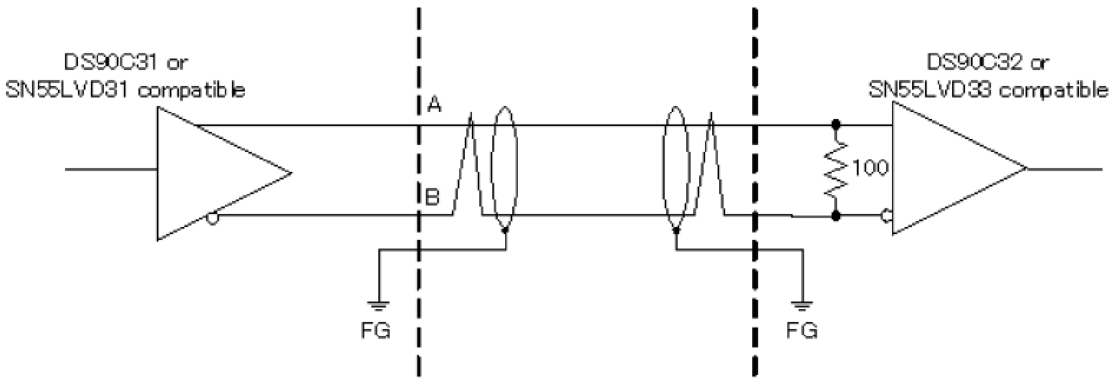


Fig. 4-9 High-speed differential digital signal interface (TIA/EIA – 644A, standard type) In order to prevent the common mode voltage between both elements/devices from exceeding the absolute maximum rating of the elements/devices, control the ground voltage of both substrates.

The above method of connecting to the ground reference point of the shield ground in the differential interface is different from the method described in the reference document (17) JERG-2-200-TM002. However, the present method is adopted from the viewpoint of EMC (that the signal grounds that use different secondary power supplies shall not be connected).

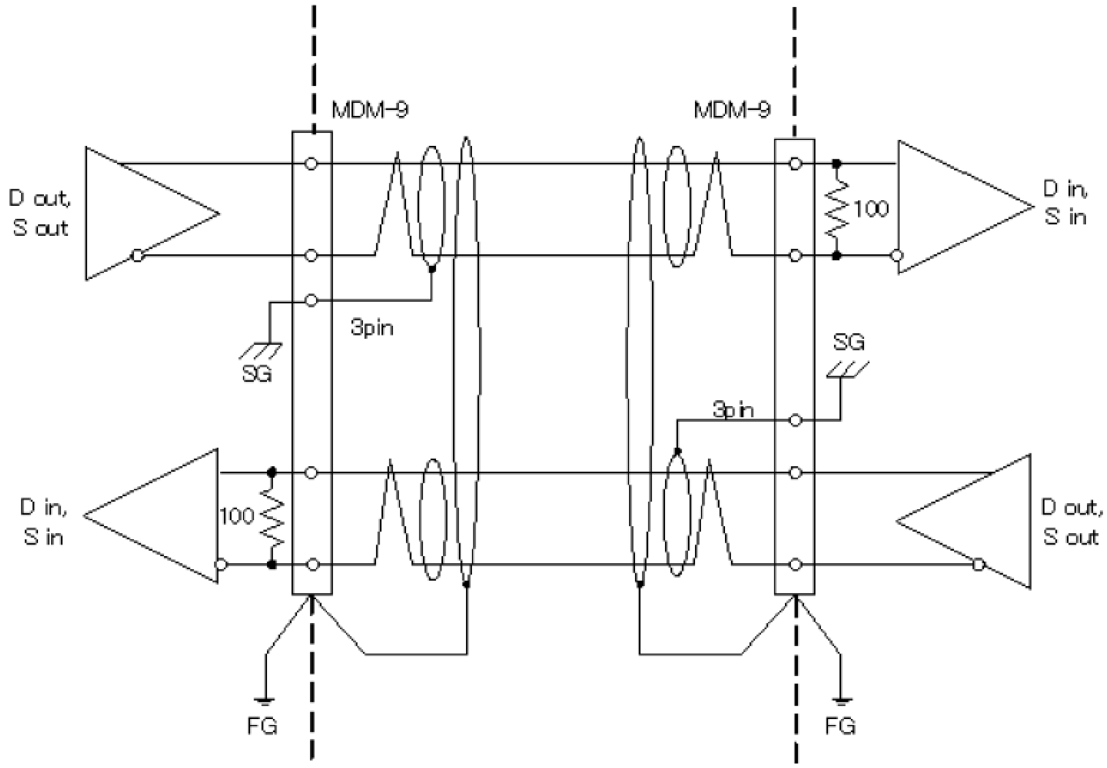


Fig. 4-10 SpaceWire interface circuit

4.1.1.3.2 Analog signal

This clause shows the handling of the analog signals used between the system and the subsystem and between subsystems in a spacecraft. Addition/correction/deletion shall be made in the project as needed.

The details of the analog signal interface except for the following items shall be specified individually by the ICD of each equipment.

(1) Active analog interface

This interface where the on-board processor for collecting telemetry (or the equipment in the upstream of the onboard equipment), with the output voltage from the onboard equipment, performs A/D conversion. It is used for monitoring the secondary voltage and sensor output in the onboard equipment, etc.

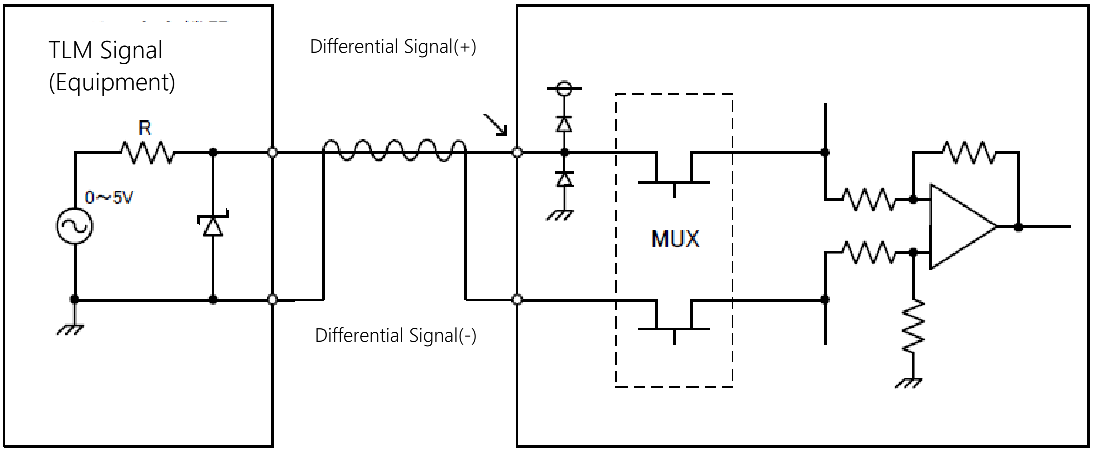


Fig. 4-11 Active analog interface circuit

(To be replaced with the official version by the project)

(2) Passive analog interface

The interface where the on-board processor for collecting telemetry (or the equipment in the upstream of the onboard equipment), with current supplied to the resistor in the onboard equipment, performs A/D conversion. It is used for monitoring temperature with a thermistor or platinum sensor, etc.

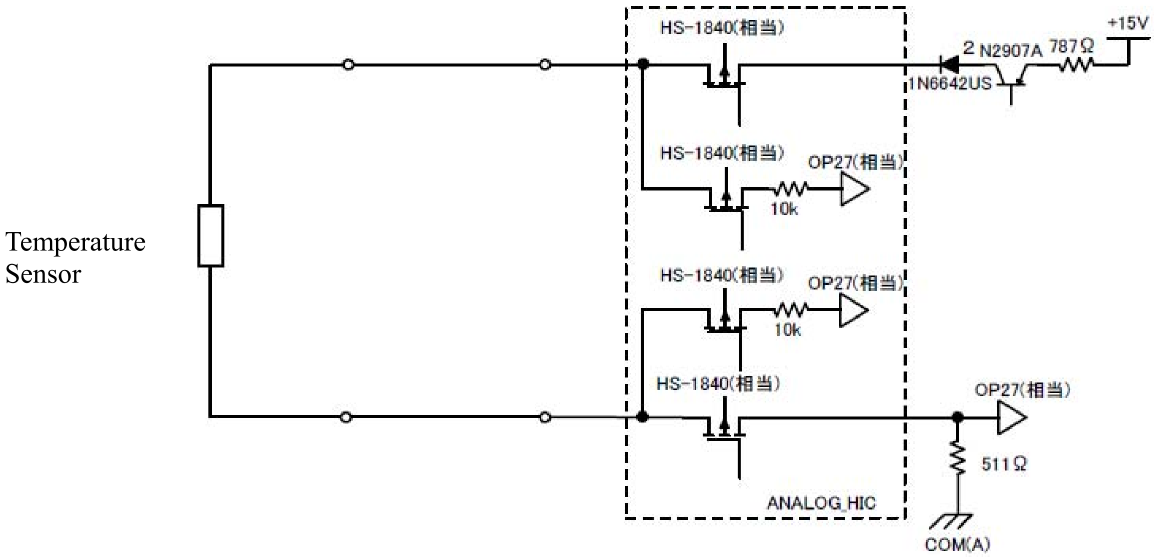


Fig. 4-12 Passive analog interface circuit (temperature)

(This diagram shall be replaced with the official version by the project)

4.1.1.4 External interface

The following interfaces are used in scientific spacecrafts.

(1) Umbilical (UMB) interface

From just before launch until launch, it connects with wires the signals that are required to be connected to outside the spacecraft (ground systems and rockets).

The equipment that outputs signals from the UMB connector to outside the spacecraft shall have an interface that can turn on/off the output signals by the control signal output from the ground control system with wires. (When pulling out the UMB connector, turn off the monitor from the ground control system, so that voltage is not applied to the pins of the UMB connector.)

The protection resistor to shield from short circuits between pins or ground faults shall be inserted since the mating surfaces are exposed after separation.
An example of the signal interface of MONI ON/OFF is shown in Fig. 4-13. In addition to the method described in Fig. 4-13, MONI can be turned off by turning off the power of the output device.

It is not acceptable to set the output at a high impedance while the power supply of the device is turned on.
This is to prevent secondary failures of other elements when an abnormal short circuit has occurred on the output pin and the device is damaged.

(2) MD connector interface

A signal interface required to be connected to the ground system with wires for system tests.
The interface using this connector shall be specified individually by each project.

(3) TN connector interface

Each project shall define this clause after considering the necessity from the viewpoints of safety design, testability, maintainability of onboard equipment, etc. Each project shall identify installation locations with consideration of electrical viewpoint and accessibility.

A signal interface to be connected as a regular circuit only at the time of launch, with a pyrotechnic, power supply, etc.
Separation and connection of signals shall be performed by dismounting/mounting of the TN connector. The interface of a TN connector shall be coordinated individually including the use of the TN connector itself.

Examples of the TN connector are shown below.

•TN-SC: Separation of the solar array output line in a test
•TN-BAT: Separation of the battery line in a test, and insertion of the fuse in a test
•TN-RCS: Separation from the drive circuit on the spacecraft side for connecting the propulsion system control signal line and the ground test equipment
•TN-IG: Separation of the line between pyrotechnics from the power supply for the igniter
·TN-NEA: Separation of the line between NEAs from the NEA drive unit
·TN-NEBAT: Separation of the power supply for NEAs and the NEA drive unit

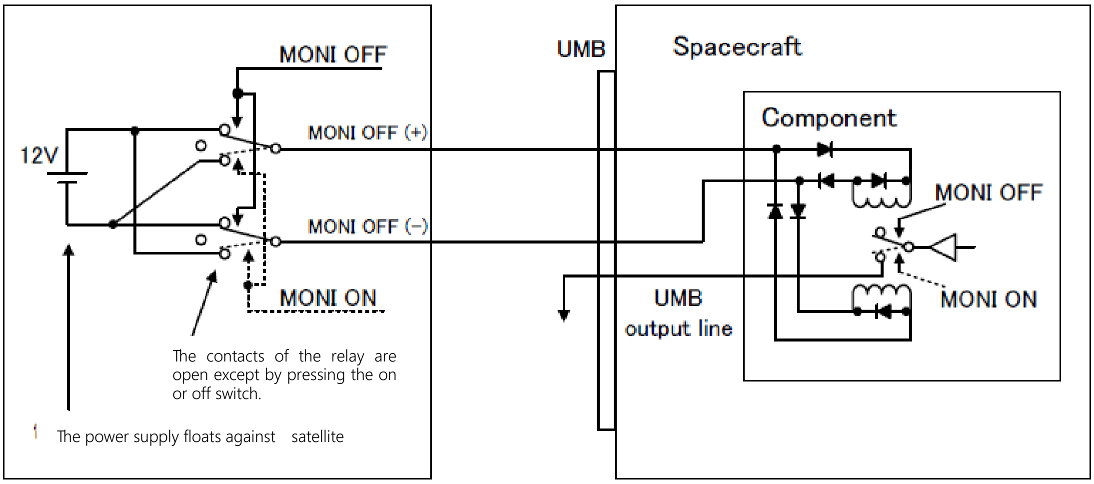


Fig. 4-13 example of RD MONI ON/OFF interface

4.1.2 Power supply interface

4.1.2.1 Overview

The requirements for power supply interface of the spacecraft shall include the distribution function from the power generation function to the input interface point of the loading equipment. In this standard design, the output interface points of the power supply and the input interface point of the loading equipment shall be clarified.
The power supply characteristics specified here shall be defined at the output interface point of power supply.

Fig. 4-14 shows the concept of the power supply interface point specified by this document. Each project shall specify the interface points of other power supply buses as needed.

The requirements for the loading equipment shall be specified at the input interface point of the loading equipment considering the electrical instrumentation wiring. This provision shall be based on Fig. 4-14.

The requirements from the output interface point of power supply to the input interface point of the loading equipment shall be specified under design of electrical instrumentation wiring in clause 4.6.

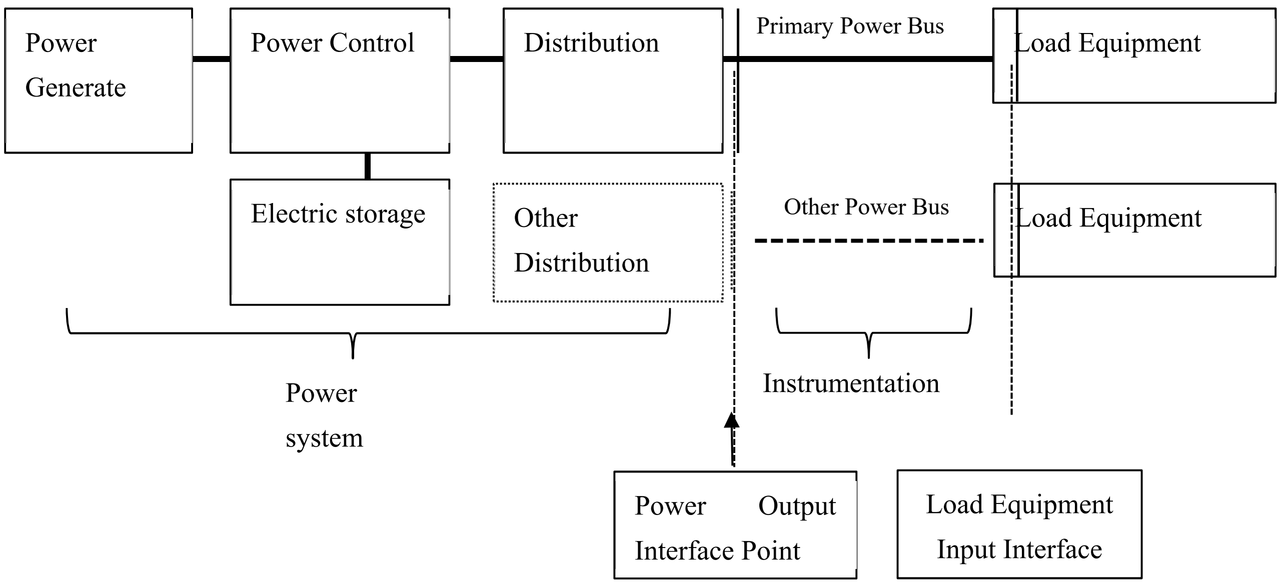


Fig. 4-14 Concept of Power interface

4.1.2.2 Characteristics of power supply bus

Each equipment uses the bus power distributed by the bus power supply distribution equipment by performing voltage conversion and stabilization to the secondary power supply.

Voltage conversion and stabilization to the secondary power supply in each equipment are carried out by the secondary power supply converter inside the equipment or by the secondary power supply converter of PSU outside the equipment.

Equipment with small power consumption may share secondary power supply converter.

4.1.2.2.1 Primary power supply bus

(Each project shall define this clause. The project shall clearly describe the bus types (regulated/unregulated/battery) to be used and specify their characteristics in compliance with JERG-2-200A "Electrical design standard" clauses 4.1.2.2.2 to 4.1.2.2.4. Note that conventional scientific spacecrafts use unregulated buses but recently small scientific spacecrafts and MMO elected to use completely unregulated buses)

This clause describes the requirements for the interface of primary power supply bus.

(1) Bus power supply

[1] Power supply system: Regulated or Unregulated DC power supply

[2] Output voltage: +16.3 V ~ +27.5 V or +32.5 V ~ +52.0 V (the power supply distribution output port)

Note: The bus power supply voltage that is input into an equipment has voltage drops due to electrical instrumentation. The electrical instrumentation shall be designed so that voltage drops of the bus power supply are minimized to 200 mV or less on the both HOT side/RTN sides.

[3] Bus power supply output impedance

Each project shall specify the output impedance characteristics of the power bus.

[4] Rate of change in bus voltage = Bus transient

The bus voltage varies due to transient generated by on/off of the high-power equipment and change in the operation mode of the power supply system at the boundary of the sunlit/eclipse areas. The equipment using the bus power supply shall normally operate under this rate of change.

- Transient by on/off of the high-power equipment: shall be specified by each project
- Change in sunshine/eclipse: shall be specified by each project

(2) Current monitor

The current consumption of the bus power supply is measured in the power supply distribution equipment on a distribution system basis and is output to the telemetry.

(3) Turning on/off the bus power supply for the equipment

The power supply distribution equipment shall provide the function to turn on/off the bus power supply to separate the bus power supply at the overload during failure of the bus power supply equipment and release the single event latch-up.

The power supply distribution equipment shall be designed so that a single failure cannot cause a permanent short circuit failure of the bus power supply.
Each equipment shall protect the device from the single event latch-up as shown in clause 4.1.2.6.

(4) Overcurrent protection of bus power supply

The power supply distribution unit shall have an overcurrent protection function (current limiter or circuit breaker) for every distribution system to protect the spacecraft power supply system from overload in the equipment failure and to separate the failure. A block diagram of the overcurrent protection function is shown in Fig. 4-15. Recovery after cutoff shall be done by command only after confirming the failed element by telemetry.

The overcurrent protection circuit shall have the following functions.

[1] An on/off (FET) switch for the bus power supply

[2] Current limiter or circuit breaker

[3] Current monitor

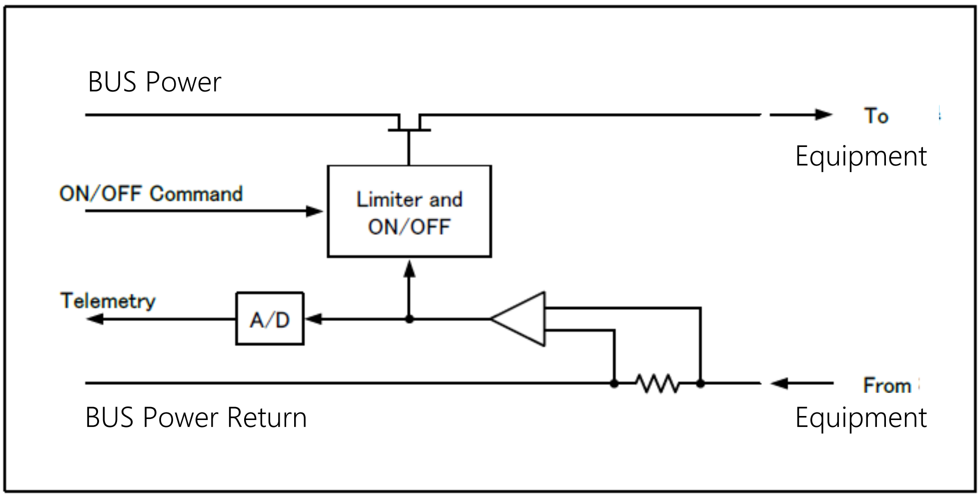


Fig. 4-15 Block diagram of the overcurrent protection function in the power supply distribution equipment(Example)

(5) Stability

The stability of the bus voltage under sunshine shall be 1 V (TBD) or less as a nominal value in the steady state at the regulation point. In eclipse, it shall be in accordance with the battery characteristics.

(6) Ripple and spike

In this document, ripple is the value of cyclic voltage variation that is superimposed on the power supply bus voltage. The ripple does not include spikes and transience due to load variation (Fig. 4-16).

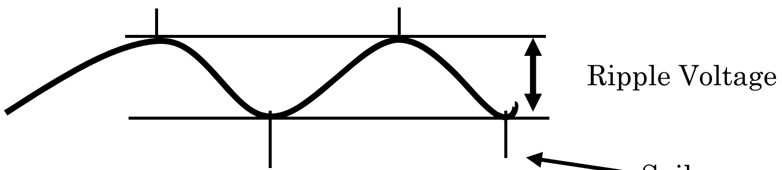
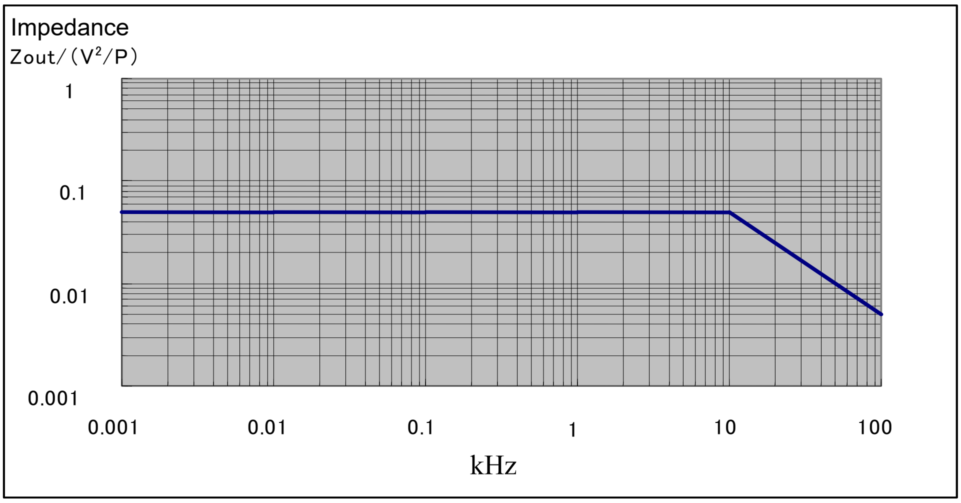


Fig. 4-16 Ripple and spike

The ripple voltage in sunlit shall be 1 Vp-p (TBD) or less. The frequency components of the ripple shall be individually specified by each project as needed.
Spikes in sunlit (switching noise) shall be 2 Vp-p (TBD) or less and shall remain within a time domain of 1 μs (TBD) or less.
In eclipse, both the ripple and spikes shall be in accordance with the battery characteristics.

(7) Power supply impedance
At the regulation point, the impedance of the one operating power source (battery, solar array, etc.) shall be lower than the impedance value shown in Fig.4-14. The power supply output impedance shall include the power supply control system, and it shall be represented by frequency characteristics.
An impedance defined as when a power supply side is viewed from each of input impedance points of load equipment shall set up as an "LISN (line Impedance Simulation Network)" obtained by adding impedances of power distribution and wire harness to a power supply output impedance, and the LISN shall be specified in clause 5.2.4.2.1.



Zout:Power Supply Impedance V:Bus Voltage (V) P:Consumed Power (W)

Figure 4.-17 Power Supply Impedance

(Confirm each project and change as necessary)

4.1.2.2.2 N/A

4.1.2.2.3 N/A

4.1.2.2.4 N/A

4.1.2.2.5 Transient characteristics of primary power supply bus

This clause shall specify the requirements related to transient characteristics of primary power supply buses.

(1) Disturbances during Normal State

Both a power supply bus voltage and a time under a load transient state of a power supply system during nominal operations are defined based upon both a stationary disturbance voltage and a disturbance voltage limiting time (T) shown in Figure 4-18.

Each project shall define specific values.

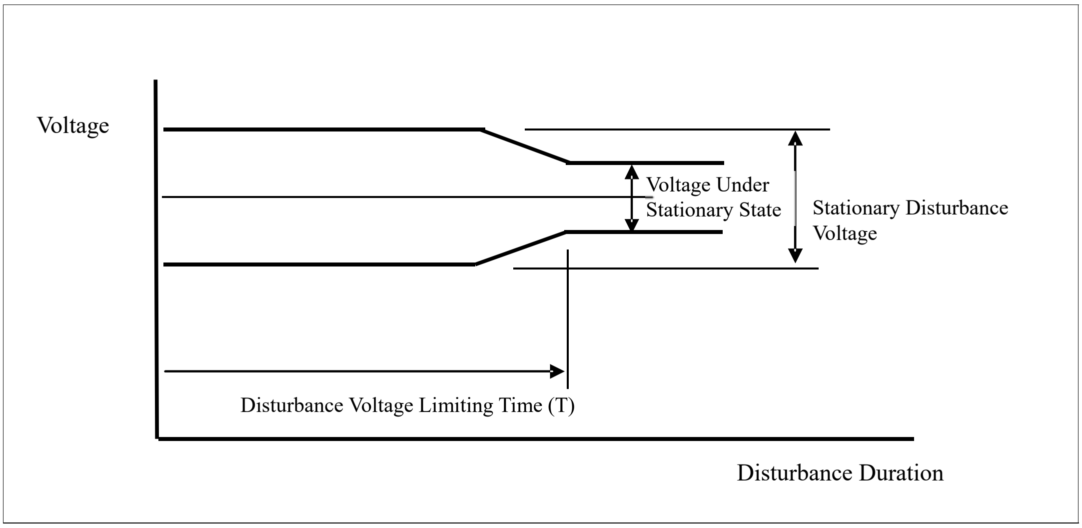


Figure 4-18 Disturbance During Stationary State

(2) Disturbances during Abnormal State

A disturbance during abnormal state is a primary power bus drop caused by the failure of loading equipment, etc. and specified based upon an abnormal time (T) and a dropped voltage as indicated in Figure 4-19. A voltage drop rate and a voltage rise rate shall be also specified as necessary. Recovery from the fuse blown state shall be similarly specified.

Both a power supply and loading equipment shall never be damaged or fail due to disturbances during an abnormal state. The onboard equipment shall be restored by commands.

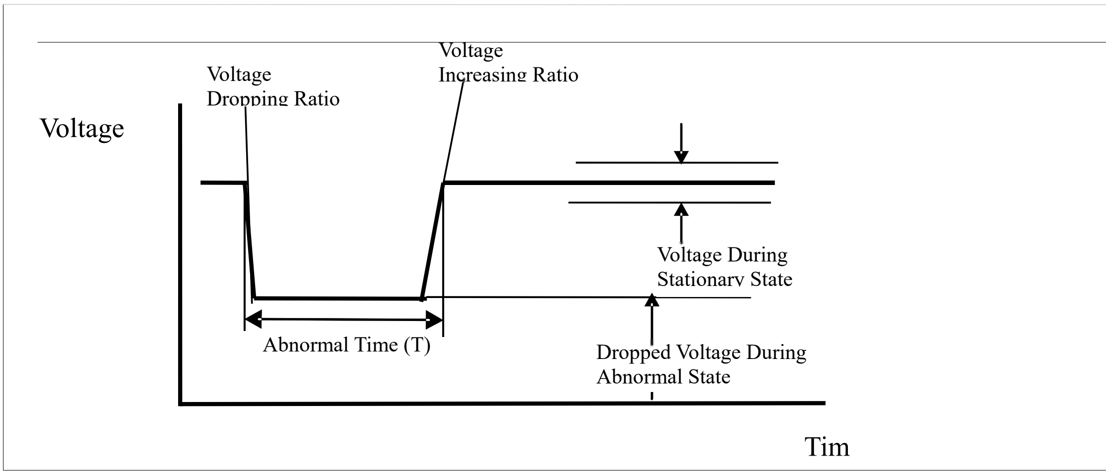


Figure 4-19 Disturbance During Abnormal State

(3) Disturbances during Test

Any of loads shall not generate an aliasing capable of damaging other requirement's or operations of a spacecraft within a variation of bus voltages such as an increase of bus voltage and a drop of bus voltage between 0 V and a maximum bus voltage.

A disturbance during a test is a disturbance of a primary power supply line due to ON/OFF of a bus power supply used during the test. Both the power supply and the loading equipment shall not be damaged under either of ON/OFF conditions of the power supply during interruption or momentary interruption of a primary power supply.

Both the power supply and the loading equipment shall not be damaged under any one of the ON/OFF conditions and never induce any failure, under continuous power supply maximum voltage and minimum voltage anticipated in tests.

4.1.2.2.6 ODC (Ordnance Controller) Bus

The requirements of ignition power supplies to ordnances shall include ignition routes and sequences as well as electric interfaces such as supply voltages, supply currents, and supply pulse widths. When setting the requirements, consider the various circumstances described in paragraph 4.7.

4.1.2.2.7 Heater interface

(Supply voltage and tolerance are important in defining heater interface and they shall be clearly described in the electrical design standard of the project. The heater interface shall also clearly

be defined by applicable conditions when the differences in heater interface due to the differences in operations modes, orbit conditions, etc. exist.
Sequence control shall be specified to avoid simultaneous supply to heaters when sequence control is used.)
The heaters for thermal control of the entire spacecraft shall be controlled by HCE (Heater Control Electronics). The heaters inside the equipment based on special requirements of the equipment shall be individually controlled by each equipment. Basic classification of the heaters for thermal control of the entire spacecraft is shown below:

- Heaters to be attached on the spacecraft structure including base plates and panels.
- Heaters to be attached on the mounting block of equipment and thermal doubler
- Heaters for the propulsion systems
- Heaters for batteries

A block diagram of heater control by HCE is shown in Fig. 4-20. The signals of the various thermal sensors on the spacecraft are multiplexed in HCE and used for heater control after A/D conversion. At the same time, they are output as telemetry data.
Based on the command or information of the thermal sensor, the electric power of the heater is supplied to the heater by switching transistor in HCE.

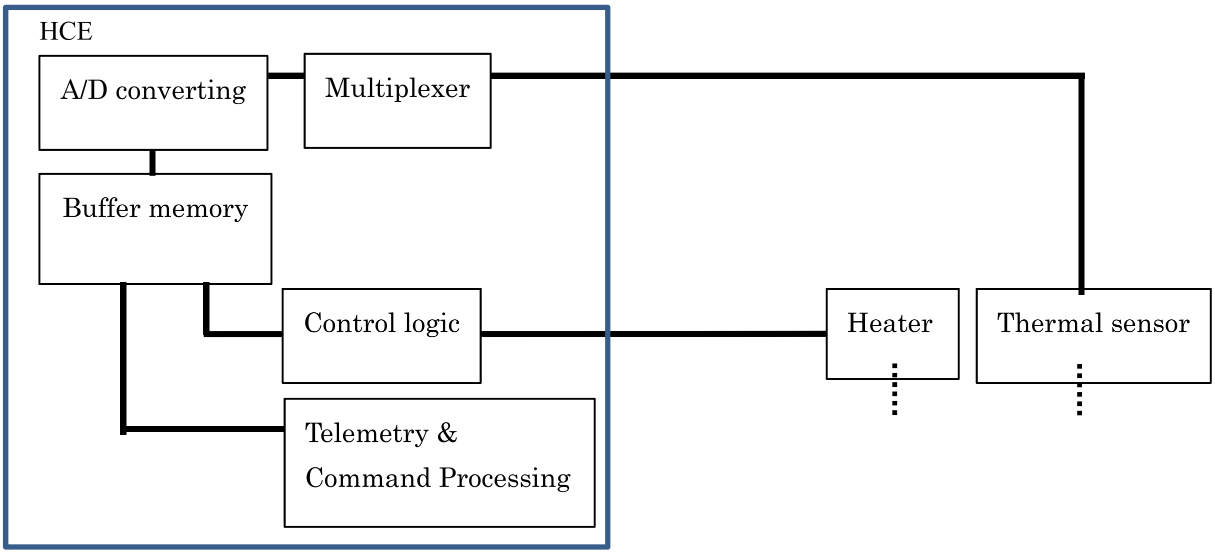


Fig. 4-20 Block diagram of heater control

(1) HCE heater interface

(The numerical values in this clause vary depending on the power supply capacity of the bus and thermal design. Each project shall define appropriate values.)

The heater controlled by HCE shall be designed on the following conditions.

Although power loss due to resistance of instrumentation wiring differs by sensors, 25 W at a maximum shall be used as a target for electric power per channel. The detailed values shall be specified by consulting individually with the person in charge of the system considering the length of instrumentation wiring.

• Supply voltage (at the input port of the user's equipment): Bus voltage (In shadow: 36.0 V_{min}, In sunshine: 51.0 ± 1.0 V)

• Supply current to heater: 1.0 A/ch. or less

(2) Thermal sensor interface

When monitoring the temperature inside the equipment using HCE, the platinum sensor as shown in Table 4-3 and Fig. 4-21 shall be attached at the temperature measurement points. Consult with the person in charge of the system to use other sensors. Refer to clause 4.1.1.3.2 for the readout circuit of the sensor.

Table4-3 Sensor Specification for HCE

Item	Specification
Type	118MF　2000A (JAXA ausorized parts)
Maker	Goodrich (Formerly　Rosemount)
Resistance	2000Ohm ± 1.0%(@0degeeC)

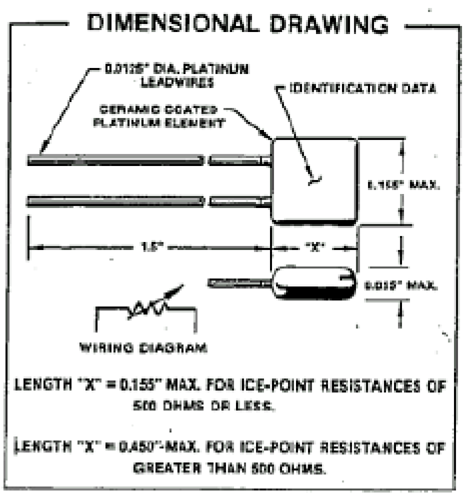


Fig 4-21 Platinum Sensor for HCE

(Note) Dimension unit is inch

(3) Heater control method of HCE

A. Automatic control method

Compare the threshold of the temperature preset by the command and the temperature measured by the thermal sensor and perform on/off control of the heater based on the result.

B. Control method with command

The heater is forcibly turned on/off with a command manually.

(4) Heater control of subsystems other than HCE

The heaters for components inside the equipment including the sensor for observation system. shall be uniquely controlled by each equipment.

The thermal sensor signals in the equipment other than HCE equipment shall be converted by A/D converter at each component and shall be output to telemetry for monitoring.

4.1.2.2.8 N/A

4.1.2.3 Requirements for onboard equipment

4.1.2.3.1 Input impedance

This clause defines the impedance on the upstream side observable from the input port of the loading (onboard) equipment. This impedance is shown as LISN to the onboard equipment side. The specific values are as shown in clause 5.2.4.2.1 (EMC test requirements > LISN).

4.1.2.3.2 Maximum input current

This clause specifies the maximum value of consumption current on the onboard equipment side including operational transient during steady operations (excluding the time of inrush). The CE13 shown in clause 5.2.4.1 (requirements of EMC) shall be satisfied.

As necessary, consult with the personnel in charge of the system design to relax this requirement in consideration of the supply capability on the power supply side and the ability of the voltage converter on the onboard equipment side.

4.1.2.3.3 Inrush current

This clause specifies the maximum value during input of power supply and mode switching. The CE14/15 shown in clause 5.2.4.1 (requirements of EMC) shall be satisfied.

As necessary, consult with the personnel in charge of the system design to relax this requirement in consideration of the supply capability on the power supply side and the ability of the voltage converter on the onboard equipment side.

In addition, design shall be satisfied the following.

(1) Inrush current that occurs when turning on the bus power supply (when the switch is provided on the PCU side of the power supply distribution equipment)
Each equipment shall limit the current input to the bus power supply to 300 μF (TBD) or less to control inrush current during the bus power on/off.
(Apply to all equipment except for those turned on when the spacecraft is powered on. Consult with the person in charge of the system to use 300 μF (TBD) or more.)

(2) Inrush current that occurs when turning on the bus power supply (when the switch is not provided at the PCU side of power supply distribution equipment)
The inrush current that is generated by the on/off operation of equipment including turning on the bus power supply shall satisfy the conditions shown in clause 5.2.4.1.
(Apply to the equipment turned on when the spacecraft is powered on.)

(3) Inrush current that occurs when the equipment using secondary power supply is turned on
The equipment to which secondary power supply is fed from another equipment shall be designed to satisfy the provision of inrush current specified in the equipment of the supply source (PSU, etc.). Note that this clause does not specify inrush current on the primary power supply side.

(4) Inrush current that occurs when the equipment using secondary power supply is turned on

(5) The large-capacity capacitor shall not be placed at the subsequent stage of a relay to reduce the inrush current generated when turning on the relay connected to the bus power supply and secondary power supply in the equipment (Fig 4-22).
When this requirement is not satisfied, the resistor R1 shall be inserted in the front stage (Fig. 4-23).

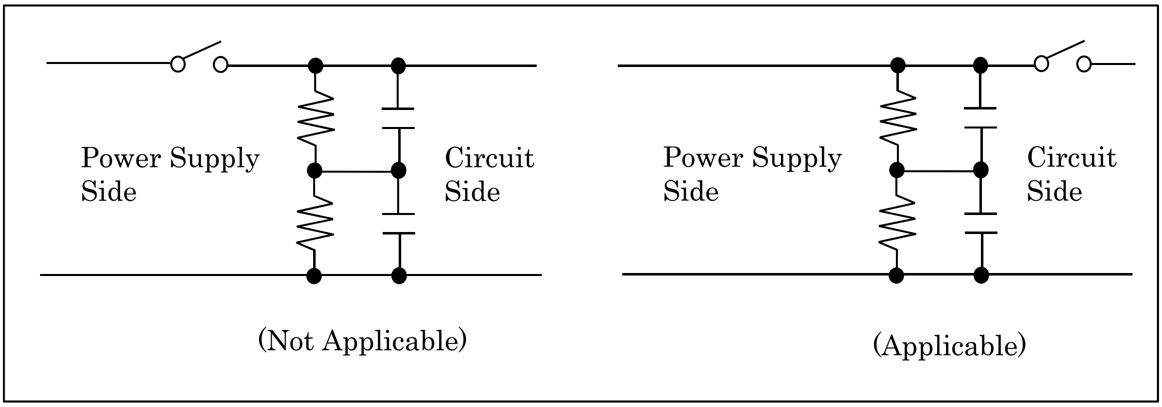


Fig 4-22 Arrangement of relays and large capacity capacitors for reducing rush current

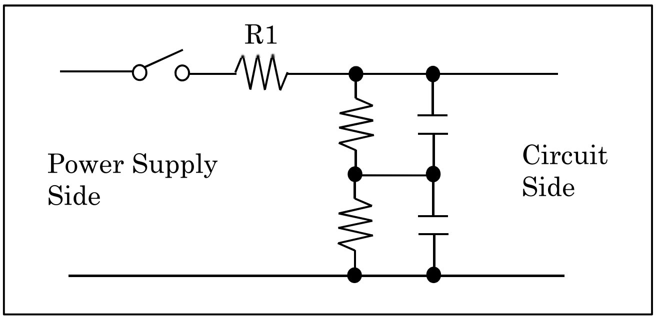


Fig 4-23 Reduction of rush current by resistance insertion

4.1.2.3.4 The rate of current change

The current rate change shall satisfy the CE13/14/15 shown in clause 5.2.4.1 (requirements of EMC). However, it shall be specified individually since it depends on the transient response characteristic on the power supply.

A numerical value shall be specified taking into consideration the transient time and the value of current change individually.

4.1.2.3.5 Voltage at input port

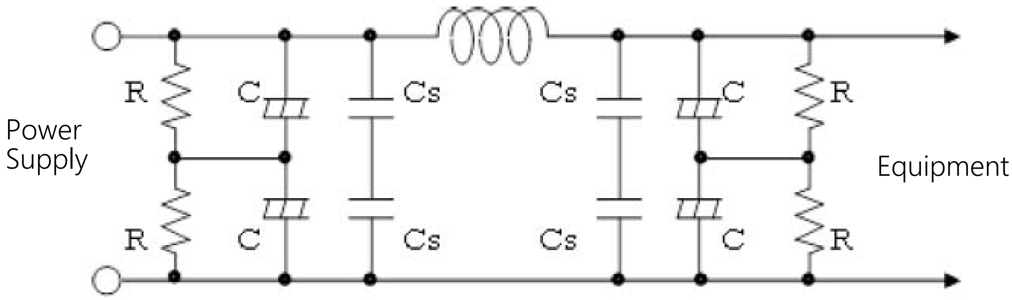
Bus power supply voltage that is input to an equipment has a voltage drop due to electrical instrumentation. The electrical instrumentation shall be designed so that voltage drops of the bus power supply are limited to 200 mV or less on the HOT side as well as on the RTN side.

4.1.2.3.6 Power supply line filter

The filter that can sufficiently attenuate the noise coupling between the power supply line of the system's electrical instrumentation and the equipment shall be inserted at the power supply input port of each equipment.

The values of L and C for the filter circuit shall be suitably selected based on Fig 4-24.

The filter for removing the common mode shall be applied as needed.



C: Tantalum Capacitor
Cs: Ceramic Capacitor
L: Coil
R: Resistor for Voltage equalization

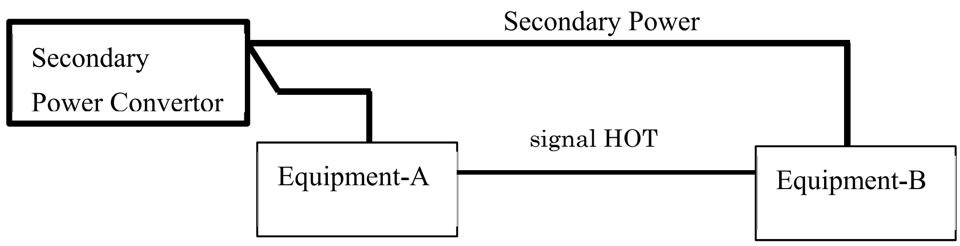
Figure 4-24 Power Supply Line Filter

4.1.2.3.7 Power-on reset circuit

The power-on reset circuit of the equipment activated by turning on the power supply of the spacecraft system or turning on the bus power supply of the equipment shall be designed so that the power supply voltage fed to the equipment requires max. 100 msec from turning on of the power supply to voltage stabilization.

4.1.2.3.8 Interconnection between equipment with return of secondary power supply

(1) when the common secondary power supply converter is used
Regarding equipment using the common secondary power supply converter, the returns of the secondary power supply shall be configured by a star connection from the common secondary power supply converter and the equipment shall not be interconnected including to the return side of signals. (Fig 4-25) (For signal connection between equipment, use the C-MOS single-end interface or differential interface. Refer to Table 4-1.)



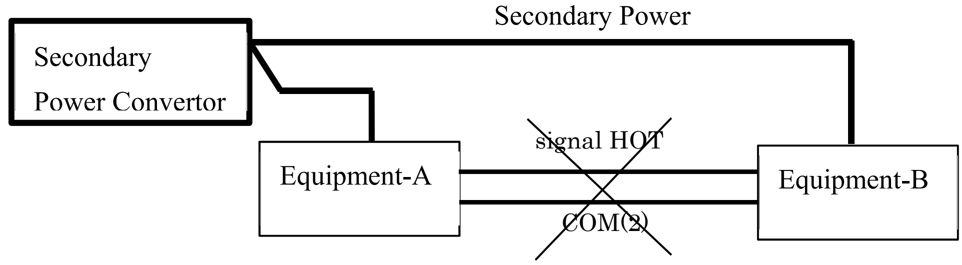


Fig. 4-25 Prohibition of interconnection between the returns of secondary power supply when common secondary power supply converter is used

(2) When different secondary power supply converters are used

Between the equipment using different DC/DC converters, the returns of the secondary power supply shall not be interconnected including the signal returns. (Fig. 4-26)

(For signal connection between equipment, differential interface shall be applied as shown in Table 4-1.)

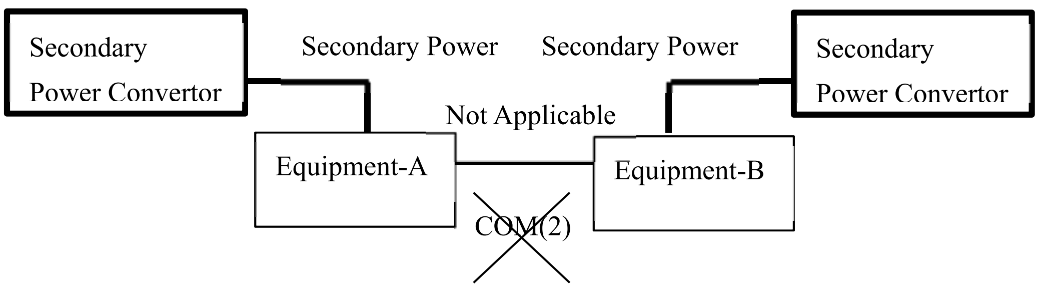


Fig. 4-26 Prohibition of interconnection between the returns of secondary power supply when different secondary power supply converters are used

4.1.2.3.9 Emergency power off

Each project shall define this clause as needed. An example is shown below.
At the time of emergency to reduce the load on the spacecraft, the data processing system shall issue the command to reduce it.

.

The following equipment shall be powered off in an emergency.

Common equipment	Observation equipment
Equipment C-1 Equipment C-2	All Observation equipment Equipment M-1 Equipment M-2 | Equipment M-n

The above equipment shall be designed so that they can be set to the off mode by the command sequences shown in cases 1 or 2 below and can be restored by commands.

Case1: Setting the off mode with **one** command ・command 1 :Power Off command (sent from common equipment A)
Case2 Setting the off mode with **two** commands (for observation equipment only) ・command 1 :Power Off notice command (sent from equipment M-1) ・command 2 :Power Off command (sent from common equipment A) ・command interval : Issue command 2 one second after command 1

4.1.2.3.10 Power supply for relay drive

When multiple relays are driven inside the equipment, a suitable time delay shall be provided in the drive sequence of the relays, to avoid simultaneously driving multiple relays.
The equipment using PS should not exceed the maximum rated output current of the PSU+12 V system. Unless specially required, use latching relays to save power consumption when they are not driven.

4.1.2.3.11 Power supply for heaters

(1) Recommended power supply

Each project shall specify the power supply for the heater.

(2) Precautions for heater control

[1] Unless the heater current control is performed using PWM (pulse-width modulation), the decoupling filter at the heater power supply line is not required.

[2] Do not use the heater power supply for series regulation in equipment to reduce loss of power supply. When necessary, consult with the staff in charge of the system.

(3) Telemetry status

A heater control circuit of the equipment that requires a heater for functional conservation even when the equipment is powered off shall be placed at the continuous power supply unit. (Clause 4.1.2.3.12) The heater on/off status, auto/manual status and so on shall be correctly output even when the equipment is off.

4.1.2.3.12 Continuous power supply

(1) Continuous power supply equipment

The continuous power supply equipment is an equipment whose power supply cannot be turned off by a command from the spacecraft or other means after its power has been supplied by turning on the spacecraft The continuous power supply is the bare essential to control the spacecraft.

(2) Continuous power supply circuit in each equipment

In the equipment other than the continuous power supply equipment, the following circuits shall maintain the on state as long as the bus power supply is fed to the equipment (continuous power supply circuit).

[1] Start-up circuit for equipment

The circuit that is required at minimum in the first stage to start up an equipment such as the processing circuit of a command to turn on the necessary circuit (ex. CPU_SET/RESET/RUN) and the Power on Reset circuit.

[2] Telemetry processing circuit

T circuit to process and output the telemetry data which requires monitoring even when the equipment is in STBY (standby) state (the state where the all circuits are not turned off, i.e., power is supplied to some circuits), from the viewpoint of spacecraft control.

* Example of telemetry data
- Equipment STBY/ON
- Heater ON/OFF, ENA/DIS
- CPU ON/OFF, SET/RESET, RUN/IPL
- HV ON/OFF, HV ENA/DIS

[3] Memory circuit for storing programs

As for the equipment where the memory for storing programs is not ROM, the memory for storing programs shall be positioned in a continuous power supply circuit. Furthermore, the STATIC C-MOS IC, etc. shall be used for the continuous power supply memory, in order to reduce power consumption at non-operation of equipment.

[4] Heater control circuit

This denotes the heater control circuit, when a heater is required even in the non-operation state of equipment.

4.1.2.4 Power supply return

Power supply returns shall be selected according to the power supply type and the intended purpose shown in Table 4-4 to reduce interference and noise.

Table 4-4 Classification of Power Supply Return

Classification	Applied secondary Voltage	Return	Purpose
Bus Power	-	COM(1)	Bus Power Return
Secondary Power Supply	+5V +12V -12V	COM(2)	Secondary Power Return
	+12V(RL)	COM(RL)	Relay Drive Power Return
	+29V	COM(29)	Heater Power Return RCS thruster Drive Return
	Other than those above	COM(Voltage)	Individual Use

4.1.2.5 Grounding and shield

(1) Classification of grounding

A. Case ground

Grounding directly to an equipment case

B. Body structure ground

Grounding to the body structure of a spacecraft.

(2) Grounding of power supply return

Requirements on power supply return grounding are shown below.
(Refer to Fig 4-27.)

A. Bus power supply

The bus power supply return is grounded at one point on the case in the power supply distribution equipment (DIST) and grounded to the body structure of the spacecraft via the case. Therefore, the bus power supply return and load on bus power supply in the equipment shall be electrically insulated from the case/body structure of the spacecraft. Insulation resistance shall be 1 MΩ or more with DC resistance.
When the above requirements cannot be satisfied, consult with the personnel in charge of the system design.

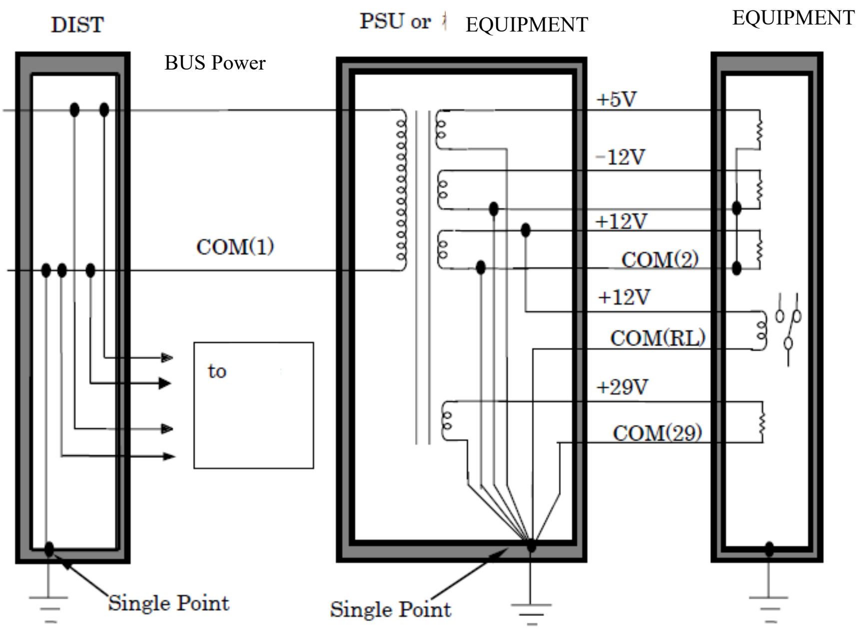


Fig. 4-27 Grounding system diagram

B. Grounding of secondary power supply return

The secondary power supply return of each equipment shall be grounded at one point on the case in the secondary power supply converter and grounded to the body structure of the spacecraft via the case. (Type B of Fig. 4-28)

In an equipment without the secondary power supply converter, the secondary power supply return shall be electrically insulated from the case/body structure of the spacecraft. Insulation resistance shall be 1 MΩ or more with DC resistance. (Type A of Fig. 4-28)

C. Connection of the power source return to the case ground via the capacitance

To connect the bus power supply return or the secondary power supply return to the case ground via the capacitance in order to avoid AC ground loop, consult with the personnel in charge of the system design. (Type C of Fig. 4-28)

Note that consultation is not required when the capacitance is inserted between the bus power supply return and the case ground to return the common mode current that flows from the primary side to the secondary side to the bus power supply return in the secondary power supply converter.

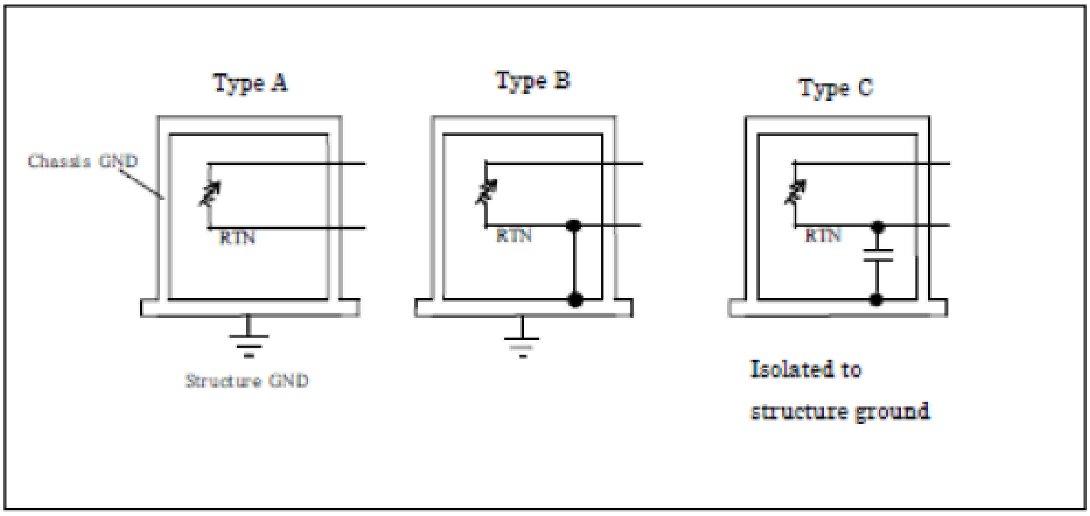


Fig. 4-28 Grounding of the power supply return and the case

4.1.2.6 Protection against overcurrent

As shown in clause 4.1.2.2.1(4), the spacecraft power supply system shall be protected from the overcurrent due to an equipment failure by providing the overcurrent protection function in the power supply distribution equipment.

The equipment shall protect the device from overcurrent due to the latch-up of C-MOS. The design requirements per protection method are shown below. for the device shall provide countermeasure for the Single Event Latch-up (SELs) caused by cosmic radiation with consideration for the SEL tolerability (LETth) of the device.

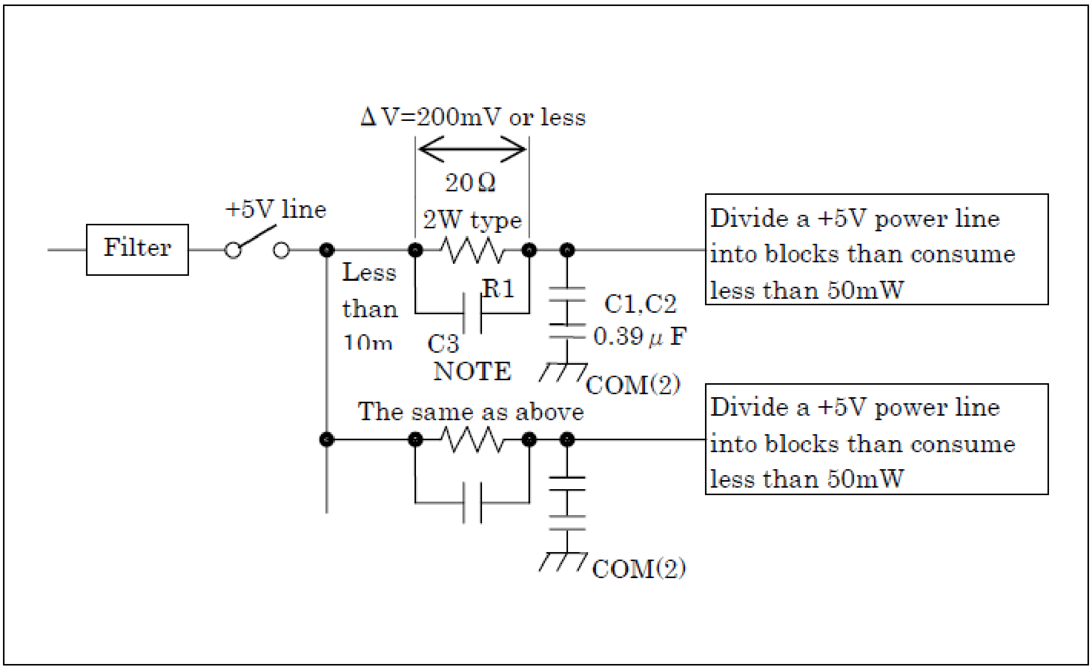
Regarding the overcurrent protection against radiation, confirm the part/component program, and regarding the radiation environment, confirm the design standard of space environment.

Example: Countermeasures of overcurrent protection against SEL are not required for devices of LETth ≧ 80 MeV・cm2/mg.

(1) Overcurrent protection resistance

An example of the circuit for protective resistance is shown in Note 1: To reduce the dynamic impedance of the power supply line, insert the suitable capacitor (about 1000 pF).

Fig. 4-29. R1, C1, and C2 shall be set with consideration for the device properties, necessary line impedance, weight of equipment, power consumption, etc.



Note 1: To reduce the dynamic impedance of the power supply line, insert the suitable capacitor (about 1000 pF).

Fig. 4-29 Example of the circuit for overcurrent protection resistance

(2) Circuit breaker

When the equipment uses circuit breakers, all systems to be interrupted shall be cut off simultaneously to keep the balance of voltage in the equipment. The equipment hall also has the off command during interruption, the reset function for restart and son so that recovery to the normal state can be attempted.

Clause "4.6.6 Protection of power supply bus" shall be applied for fuses, the current interruption circuit and separation of load.

4.1.3 High-voltage circuit

A voltage of 100 V or more is defined as high voltage. 100 V for an electric circuit side, and 200 V for wiring are defined as high voltage. When 100 V is exceeded as electrical circuit design, consider a high-voltage circuit. The equipment ICD shall identify the high voltage circuit if used. The high voltage power supply shall have the high-voltage enable circuit as shown below.

(1) High-voltage enable circuit

High voltage ON shall be executed with the “HV ENA” and “HV ON” commands.

(2) High-voltage level setting

If it is necessary to change the high-voltage level in the equipment, the change shall be possible even during HV ON.

(3) Protection of high-voltage power supply

An automatic shutoff function shall be provided in each equipment for any problems generated in the high-voltage power supply to minimize equipment damage. The HV-ENA plug may be provided to ensure safety during ground processing.

4.2 Commands

4.2.1 General requirements for commands

Commands are to perform on/off operations of onboard equipments, ENA/DIS of functions, control parameter setting, loading of memory images from the ground, etc. This clause shows general requirements for commands. As for details of design of commands and protocols to be adopted based on these requirements, refer to the “Telemetry command design standard for scientific spacecrafts” (JERG-2-TBD). Note that “on-board processor” in the following paragraphs denotes the onboard computer for data processing which delivers commands to the onboard equipment (called DHU or SMU in conventional scientific spacecrafts).

(1) Onboard equipments shall have functions capable of confirming execution of all commands by the following:

(a)To output HK data by which execution of all executable commands (e.g., ON/OFF commands) can be directly confirmed.

(b) To download parameters configured by parameter setting commands by telemetry.

(c) To download data uploaded by upload commands by telemetry.

(2) The onboard equipments shall not change execution content defined for a command during a mission period. Also the onboard equipments shall not change execution content defined for a command by chronologically previous execution of its own or other commands.

(3) The onboard equipments shall be able to execute the same commands in succession to the extent possible. Though in this case the command execution shall not change the corresponding HK data, it is important that the same command can be executed without being rejected prior to the execution. When any constraints exist for successive command execution, it shall be clearly documented as equipment specifications and negotiate with the personnel in charge of the system design.

(4) The onboard equipment shall provide at least two inhibits ("Arm/Safe" and "Enable/Disable") in a line where a hazard may occur. Each inhibit shall be controlled by independent commands. Refer to JAXA system safety standard (JMR-001) and rocket payload safety standard (JMR-002) to control hazards.

(5) All commands to change onboard equipment configurations on orbit shall also be executable by commands transmitted from a ground station.

(6) The functions to issue the onboard commands in (5) above shall be able to be inhibited by commands from the ground except when inhibiting the functions endanger the spacecraft.

(7) The onboard equipments shall output HK data by which capable of confirming the operating status of the functions to issue onboard commands in (5) above.

(8) The commands that cannot be produced unless telemetry is referred, as shown in Appendix I of Chapter 7 in JERG-2-200, shall not be used.

(9) The onboard equipments shall not output/execute error commands by input interpretated as undefined commands.

(10) Onboard processors shall not output commands when power supply voltages of the own processors are not in the nominal state.

(11) The onboard processors shall be able to control the priority order of ground and onboard commands.

(12) The onboard equipments shall have functions to download monitoring items that are not included in normal telemetries to indicate some internal status by the commands designating the items, as needed.

(13) The on-board processors shall have functions to execute commands by grouping.

(14) The onboard equipments shall not have commands to change the equipment status each time they are received (so-called toggle commands).

4.2.2 Types of commands

The types of commands classified by signal interfaces are shown in Table 4-5.

Table 4-5 Types of commands

Type	Signal interface	Definition
Discrete command	Pulse [Refer to 4.1.1.3.1(1).]	The commands output pulses to predetermined equipments via dedicated lines. For example they are used for pulse signals to drive on/off relays of onboard equipments.
Serial magnitude command	Serial (e.g., RS-422.) [Refer to 4.1.1.3.1(4), (5)	The commands output serial data to predetermined equipments via

	and (6).]	dedicated lines. For example they are used for commands for non-intelligent onboard equipments (e.g., transponders) that cannot be interfaced with the onboard network.
General command	Onboard network (e.g., SpaceWire) [Refer to 4.1.1.3.1(4), (5) and (6).]	The commands are used for general-purposes via the onboard network. Command messages are delivered based on the onboard network protocols.

4.3 HK data

4.3.1 General requirements for HK data (telemetry)

The HK data (telemetry) are collected and downlinked to the ground to monitor the state of spacecrafts, including analog values that indicate the equipment status such as voltage, current, and temperature, ON/OFF status of circuits and switches, and internal conditions of on-board software, etc. This clause describes general requirements for HK data. For the details of telemetry design and protocols to be adopted based on these requirements, refer to the "Telemetry command design standard for scientific spacecrafts" (JERG-2-TBD).

(1) The onboard equipments shall output HK data (status data to judge the state of the equipments, etc.) required to change equipment configurations during the operational phase.

(2) The onboard equipments shall satisfy measuring precision requirements of the data to be monitored by designing measuring precision, measuring ranges, and sampling periods of the HK data appropriately.

(3) Spacecrafts shall output bus voltages and load currents of all primary power supply as HK data.

(4) The onboard equipments whose functions or performance are dependent on temperature shall have temperature monitoring functions including temperature sensors inside the equipments.

(5) The onboard equipments whose heat generation may exceed a value specified by the spacecraft project including the case of some failures, shall have the temperature monitoring functions.

(6) The equipments required to notify such as anomalies and events to the ground, in addition to periodical telemetries, shall output one-shot telemetries for the notification.

(7) Time tags whose precision and accuracy can satisfy requirements of utilization and analyses on the ground shall be attached to the telemetries.

(8) The onboard processors shall have functions to change the output pattern of telemetries (cycle, precision, etc.) according to the operations phases and the bit rate of communication with the ground as needed.

4.3.2 Types of telemetries

The types of telemetries classified by signal interfaces are shown in Table 4-6.

Table 4-6 Types of telemetries

Type	Signal interface	Remarks
Active analog telemetry	Active analog [Refer to 4.1.1.3.2(1)]	The telemetries are voltages which onboard equipments output. The on-board processors for collecting the telemetries (or the equipments controlling the onboard equipments) performs A/D conversion. For example they are used to monitor the secondary voltage and sensor output in the onboard equipment.
Passive analog telemetry	Passive analog [Refer to 4.1.1.3.2(2).]	The telemetries are currents supplied to the resistors installed within the onboard equipments. The on-board processors for collecting the telemetries (or the equipments controlling the onboard equipments) performs A/D conversion. For example they are used to monitor temperatures by thermistors or platinum sensors.
Active bi-level telemetry	Active bi-level [Refer to 4.1.1.3.1(2) A.]	The telemetries are the predetermined binary voltage output by the onboard equipments. The onboard processors for collecting the telemetries (or the equipments controlling the onboard equipments) detect the telemetries. For example they are used for the on/off status of the onboard equipments and their internal circuits.

Type	Signal interface	Remarks
Passive bi-level telemetry	Passive bi-level [Refer to 4.1.1.3.1(2) .]	The telemetries are the Open/Close status of dry contact inside the onboard equipments. The onboard processors for collecting the telemetries (or the equipments controlling the onboard equipments) detect the telemetries. For example they are used for the open/close status of switches in the onboard equipments.
Serial digital telemetry	Serial (RS-422, etc.) [Refer to 4.1.1.3.1(4)(5)(6)]	The telemetries are by serial data via the dedicated line. The onboard processors for collecting the telemetries (or the equipments controlling the onboard equipments) collects the telemetries without using the on-board network. For example they are used to monitor the non-intelligent onboard equipments (e.g., transponders) that cannot be interfaced with the onboard network.
General-purpose telemetry	On-board network (SpaceWire, etc.) [Refer to 4.1.1.3.1(4)(5)(6)]	The telemetries are used for general-purposes via the on-board network. Telemetry messages are collected based on the on-board network protocol.

4.4 Data processing margin

This clause specifies general requirements on the margins for using computers and networks. This clause is not applicable to sequencers and time division multiplexing which have few uncertainties.

(1) By the development phase, memory sizes and load factors of processors shall have sufficiently large margins against the anticipated peak demands: The target margins are 50 %. This clause is not applicable when there are no uncertainties.

(2) By the development phase, onboard data buses shall have sufficiently large margins against the anticipated maximum traffics (peak demands) : The target margins are 50 %. This clause is not applicable when there are no uncertainties.

4.5 Design Requirements for Test and Verification

This clause specifies design requirements to test and verify onboard equipments.

(1) Test terminals and connectors (terminals and connectors exclusively used for ground tests) of the onboard equipments shall be directly connectable with the test equipment.
(2) The test terminals and connectors of the onboard equipments shall not be damaged even when the maximum absolute voltage determined by each spacecraft project is applied or when they are contacted to the ground. The terminals to which voltages are applied shall be protected by protection resistors, if necessary.
(3) The test terminals and connectors of the onboard equipments shall be sealed at the time of flight. Appropriate treatment such as EMI caps and blank panels (to prevent foreign objects from entering) shall be executed.
(4) When flight connectors are used for the tests, the number of connection and disconnection of the flight connectors shall be limited by using saver connectors and the like. The saver connectors shall not affect functions and performance of the equipments under test. This clause is not applicable to the tests requiring direct connection with the flight connectors.
(5) The test monitor circuits in the onboard equipments shall not disturb their normal operations.
(6) The functions of redundant systems (including internal redundancy) shall be verified in system tests. When verification in the system tests is difficult as for majority decision redundancy, the behavior at the system level shall be assured by combining the subsystem or component tests or simulations.
(7) If malfunctions of FDIR, protection circuits, active redundant circuits may become causes of critical hazards for spacecrafts, the validity of these functions shall be verified in the tests. When verification in the system test is difficult, the behavior at the system level shall be assured by combining the subsystem or component tests or simulations.

4.6 Electric Integration Design

Electric integration design is a part of tasks by the spacecraft systems. General requirements are as follows.

- EMC which has a close relationship with the electric integration design shall be carefully considered.
- Eliminate mutual interference between harnesses and by spatial electromagnetic fields shall be eliminated to the extent possible.
- Electric discharges and potential distributions caused by electrification of the spacecrafts shall be restrainted to the extent possible.
- Attention from mechanical and thermal viewpoints shall be given.

4.6.1 Wire Harness

It is important for spacecraft electric instrumentation design to avoid electromagnetic interferences in circuits with different kinds of signals, because spacecraft is equipped with noise generating circuits (e.g., power lines and large-amplitude switching circuits), high sensitivity circuits with sensor signals and digital signals, ordnance circuits, etc.

Generally speaking, modes of electromagnetic interference in circuits differ based upon distances between circuits, lengths of circuits, return paths, impedances, types of signals of voltages, current levels, frequencies, etc.

As a consequence, in order to avoid the electromagnetic interference, the circuits/signal types shall be categorized by these factors, and a proper wiring method shall be employed with respect to the categories for each harness.

Refer to the Appendix II in JERG-2-200 Electrical Design Standard for classifications based upon interface circuit types, as an example for connecting onboard equipment according to circuit/signal classification.

4.6.1.1 Classifications by Signal Types and Separations of Wire Harness

(1) Wire harnesses for connecting onboard equipment shall be used based upon the classification shown in Table 4-7.

(2) The wire harnesses shall be bundled by category as necessary, and placed apart from each other to prevent electromagnetic inefrences.

(3) Ordnance circuits harnesses shall be placed apart from those in other categories.

(4) When wire harnesses of different categories are connected to the same connector, a pin layout should use spare pins to separate the wire harnesses.

(5) The wire harnesses in the same category shall be separated in critical circuits based on the project decision.

(6) Primary and secondary harnesses shall be protected from phsycal and thermal failure propagation to the extent possible.

Table 4-7 Classification by Signal Types

Category	Signal Type	Classification	Connector Sharing
I	Electric Power and Control	(Classifications are based on MIL-HDBK-83575 and explained in clause 4.6.1.3.)	Permitted.
II	High Level Signal		Permitted.
III	Low Level Signal		Permitted.
IV	Ordnance Circuit-Purpose		Not permitted.
V	High Frequency Signal		Permitted.
VI	Other Special purpose	Optical Fiber. High Voltage (higher than or equal to 200 V*1) etc.	Not permitted.
VII	Test purpose	For ground testing, not used on orbit	Permitted.

*1: In order to be consistent with Clause 4.6.5, the high voltage was set to 200 V or more, which is lower than that specified in JERG-2-200

Note) When the signals of different categories are used in the same connector, connector pin assignment and arrangement shall be set with a specific care to signal isolation.

Demarcations of high frequencies shall be defined by the project considering their specific requirements.

As to umbilical connectors, the classification based upon signal type is not required.

4.6.1.2 Selections of Wire Materials

(1) Wire materials for instrumentation cables shall be selected from the JAXA recommended parts list, or equivalent materials shall be used. In the latter case, (2) below shall be considered.

(2) When wire materials (i.e., wires and cables) for spacecraft are selected, the following requirements shall be considered:

(a) Current Capacities

(b) Withstanding Voltages

(c) Voltage Drops

(d) Flexibility

(e) Operating Environment Temperatures

(f) Outgas

(g) Cold Flow Resistance (fluidity)*1

(h) Radiation Resistance

(i) Ultraviolet Resistance*2

(j) Atomic-state Oxygen Resistance*3

(k) Anti-Arc Tracking Characteristic*4

(l) Mechanical Sterngths*5

*1: A cold flow phenomenon is a phenomenon that the insulating materials (PTFE, or so-called Teflon) are deformed and become thin when they are contacted to each other. Bridge ETFE and the like has better cold flow resistance characteristics.

*2: Consider when wire materials are exposed to a space environment.

*3: An oxidizing phenomenon by atomic-state oxygen in a Low Earth Orbit (LEO). Pay special attention when wire materials are exposed in the LEO environment. For detailed requirements, refer to JAXA Radiation Resistance Design Standard (JERG-2-143) and Shinraisei Gizyutsu Joho (Reliability Technical Information) CRA-99004.

*4: Broadly speaking, a tracking is a phenomenon that a deteriorated electric conducting path (track) is formed by discharge in an electric field along a surface direction of an insulating material. An arc tracking is a phenomenon that arc discharge forms a electric conducting path having a low resistance because of a carbonized organic insulation surface or an electric conductive product due to heat generated by arc discharge (i.e,. vapor-deposited electrode metals). Carbonization due to arc discharge heat tends to occur with materials having large carbon content. However, the materials having N, O, and the like wintin the main carbon chain such as amino resin and polyamide resin are hardly carbonized having superior anti-arc tracking characteristics. In addition, fluorine-containing materials such as PTFE and ETFE have superior anti-arc tracking characteristics. On the other hand, materials containing aromatic rings in their molecules such as phenol resin, PBT, and polyimide resin have inferior anti-arc characteristics. For the materials having adhesions of electric conductive products by arc discharge, times up to arc tracking differ according to the differences in electrode materials, discharge energy, discharge numbers, etc. Note that the data about the anti-arc tracking characteristic can be acquired as one of the safety verification test data of the JAXA Material Database System (http://matdb.jaxa.jp/).

*5: Wire materials with small diameters (large wire gage numbers) shall be used with attention for wire disconnection, etc. When a high tensile strength wire is used to improve mechanical properties, pay attention to the higher resistence than that of annealed copper wire.

4.6.1.2.1 Rated Currents of Wire Harness

The rated currents of electric wires are determined based upon sizes of the electric wires. The rated currents for bundled lines shall be derated by considering temperature increases as in Table 4-8. This requirement is based on the Wire Derating Design Standard (JERG-2-212).

Table 4-8 Recommended maximum current for single line

Wire Diameter(AWG)	30	28	26	24	22	20	18	16	14	12	10	8	6	4
Current(A)	1.3	1.8	2.5	3.3	4.5	6.5	9.2	13	19	25	33	44	60	81

* Note

The above is based on MIL-STD-975 APPENDIX A3.16 that has been widely applied and NASA Instruction EEE-INST-002SECTION W1 that is recently used. (The current value for a single wire is the same in these standards.) These values are recommendable current under the thermal vacuum environment at an ambient temperature of 70°C.

For reference, the (nominal) DC resistance values of wire rods and the attenuation rate of coaxial cables are described below:

(1) DC resistance value

AWG20 34.4 mΩ/m (annealed copper wire)

AWG22 54.8 mΩ/m (annealed copper wire)

AWG26 147.0 mΩ/m (high-tensile wire)

(2) Coaxial cable

① Semi-rigid coaxial cable (M17/113-RG316)

2.2 GHz 0.60 dB/m

8.4 GHz 1.30 dB/m

② Flexible coaxial cable (M17/130-RG402)

2.2 GHz 1.60 dB/m

8.4 GHz 2.05 dB/m

The maximum voltage drops by electrical instrumentation cables are shown in Table 4-9. If the drop values need to be modified, consult with the personnel in charge of the system design using the ICD.

Table 4-9 Example of the maximum voltage drop value by electrical instrumentation cables

(Each project must review below and describe the appropriate values.

Take care to be consistent with the Clause 4.1.2.3.5 “Voltage at input port.”)

Power Supply Line	Maximum Voltage Drop(mV)
BUS(50V) COM(1)	200
-12V, +12V	120
+5V	50
COM(2)	50
+29V, COM(29)	200
COM(RL)	120

4.6.1.2.2 Precautions when using the fluorine-coated wire

NASA reported that the metal portion of a wire harness terminal corroded when a fluorine-coated wire harness was stored in a sealed container. (http://nepp.nasa.gov/npsl/Wire/22759/22759aps.htm, http://nepp.nasa.gov/npsl/Wire/NA-GSFC-2003-03.pdf) The followings are recommended: Inspect to ensure that no corrosion has occurred. Store in an open package so that outgas can escape.

4.6.1.2.3 Wire rods for electrical instrumentation cables connecting equipment

The minimum thickness of electrical instrumentation cables connecting equipment is shown on a signal use basis. Use the wire rods that exceed these thicknesses in all cases.

(Each project shall review and modify this clause issue own electrical design standard. Specifically, pay attention to whether there is a bias in favor of a specific company, and if so, whether the case is intentional.)

(1) Power supply and heater line
- Annealed copper wire (AWG20)
- Annealed copper wire (AWG22)
- High-tensile wire (AWG26)

(2) Signal line

[1] Digital signal line
- High-tensile wire (AWG26)

[2] High-speed digital signal line
- High-tensile twist pair shielded wire (AWG26)
- Wire of SpaceWire standard (ECSS-E-ST-50-12C)
- In the line where noise radiation etc. can become a problem, such as high-speed LVDS, use cables with impedance matching. Apply the outer shielded wire with both ends connected to FG, as needed.

[3] Voltage monitor line
- High-tensile twist pair wire (AWG26)

[4] Analog signal line
- High-tensile twist pair wire (AWG26)
- High-tensile shielded wire (AWG26)
- High-tensile twist pair shielded wire (AWG26)

[5] Temperature monitor line
- High-tensile twist pair wire (AWG26)

(3) RF interface
- Flexible coaxial cable (MIL part name: M17/113-RG316 or equivalent)
- Semi-rigid coaxial cable (MIL part name: M17/130-RG402 or equivalent)

4.6.1.3 Wiring Methods

It is important to avoid electromagnetic interference between circuits. Noises radiated from noise generating circuits shall be suppressed to the minimum levels. Wiring for high sensitivity circuits shall be performed by considering protection from the noises.

(1) Wiring of Category I (Electric Power and Control)

(a) Hots and returns of power lines such as primary/secondary power supplies, heaters and the like shall be wired with a twisted pair wiring for every pair. A shielded wire shall not be utilized in the power line that does not have a failure isolation measure for a primary power supply in case of a shortcircuit.

(b) With respect to control lines, refer to the classification in 4.6.1.2.3 to appropriately select the twited pair wires, twisted shielded pair wires, and so on.

(2) Wiring of Category II (High Level Signaling: higher than, or equal to 20 V)

(a) High level signal paths shall be wired by either multi-core twisted cables or multi-core twisted shielded cables.

(b) The multi-core twisted cables shall be shielded in the unit of bundled line.

(c) The shield shall be grounded at one end on the signal source (output) side unless otherwise necessrary. If the signal source side is different depending on the multi-core shielded cable lines or the like (e,g., A signal direction of the whole shielded line cannot be clearly defined.), both ends of the ground wire may be grounded.

(3) Wiring of Category III (Low Level Signaling: lower than 20 V)

(a) Low level signal paths shall be wired by either multi-core twisted cables or multi-core twisted shield cables.

(b) Multi-core twisted cables shall be shielded in the unit of bundled line.

(c) For shielding multi-core twisted cables with low impedance outputs, one terminal of the shielded wires shall be grounded on the input side unless otherwise necessrary. With high impedance outputs; ground at both terminals or at multiple points in long cables.

(4) Wiring of Category IV (Ordnance Circuits)

(a) Ordnance circuits shall be wired by twisted pair shielded cables.

(b) Category IV wiring shall be separated from wiring of other categories.

(c) The cables shall be shielded for every one pair of hot and return. The shields shall be grounded at both terminals; or at multiple points in long cables.

(d) In order to secure necessary safety margins, measures to protect the ordnance circuits from electromagnetic interference shall be taken. When cables are shielded bundle by bundle, the shielded wires shall be grounded at multiple points to avoid RF gaps.

(5) Wiring of Category V (High Frequency Signals)

(a) High frequency signal paths shall be wired by coaxial cables, shielded cables, balanced cables, and so on, considering specific characteristics of high frequency signal circuits.

(b) Shielded cables shall be grounded at both terminals, or at multiple points in a long cable.

(c) Category V cables shall be separated from those of other categories to the extent possible.

(6) Wiring of Category VI (Other Specific Circuits)

(a) High voltage cables utilized in high voltage circuits shall be wired separatedly and independently from the cables of other categories, while considering static shields.

(b) Optical cables shall be wired by considering specific characteristics of the optical cables.

(c) When the high voltage cables are wired, avoid forming sharp corners to prevent discharges.

(d) When the high voltage cables are wired, pay attention to a gas accumulation within vacuum atmosphere.

(7) Wiring of Category VII (Test Purpose)

Test cables shall be wired separatedly and independently from the cables of other categories.

4.6.1.4 Electric Power Harness

(1) Electric power distribution wire harness shall not be used as mechanical supporting members.

(2) Each of power distribution lines shall be twisted in such a manner that a current loop area becomes minimum and an inductance value of harness becomes minimum. The spacecraft body structure shall not be used as a power return path.

(3) Overcurrent protective measures (such as individual overcurrent protection, propagation prevention by spatial separation of wires, and use of heat resistant coating) shall be employed so that damage due to overcurrent heat generation does not propagate to other lines within the power distribution wires.

4.6.1.5 Wire Splicing

(1) Use of wire splicing shall be decided after consulting with the project.

(2) Wire splicing shall be implemented only after work procedures are established. Soldering shall

not be used.

(3) Applying wire splicing for the ordnance lines is prohibited.

(4) Wire splicing shall not be used in a power supply line. If unavoidable, use wire splicing after adequate investigation of safety.

4.6.1.6 Fixing of Wires

When wires are fixed by clamps and straps, the diameters of the harnesses and clamps shall match to prevent insulation defect caused by the deformation of wire harness coating or internal insulating layers after clamping.

Refer to clause 5.4 "Clustering and Protecting of Assembled Electric Wires" of the Spacecraft-purpose Electric Wiring Step Standard (JERG-0-041) for detailed procedures.

4.6.2 Connectors

4.6.2.1 Classification by Signal Types

Onboard equipment shall use connectors based upon signal types indicated in Table 4-7.

4.6.2.2 Selections of Connectors

Connectors used in the onboard equipment and wire harnesses shall be selected from connectors described in the JAXA Recommended Parts List, or equivalent. When using a connector anything other than those mentioned above, the equipment provider shall supply the equipment instrumentation wiring connector to the system after coordinating with the personnel in charge of the system design. To select connectors for spacecraft, the following shall be considered:

(1) Rated voltage
(2) Rated currents
(3) Use Temperature Ranges
(3) Applied Electric Wire Ranges
(4) Insulation Resistances
(5) Withstanding Voltages
(6) Contact Resistances
(7) Outgas
(8) Altitude Withstanding Voltage Characteristics (Break Down Voltage Characteristics for Atmospheric Pressure)
(9) Residual Flux Characteristics
(10) Frequency Characteristics

4.6.2.3 Usage of Connector

Connectors shall be used with the seletion of proper rated values and the consideration of various connector characteristics. Other factors including connector assignment, installation, and use of contacts shall also be considered. For the use of connectors in the housings of onboard equipment, refer to DOD-E-8983C, specification common to electronic equipment for aerospace use, which defines the assignment and mounting of the connectors and the use of the contacts.

(1) Assignment of Connectors

(a) Connectors to be installed on onboard equipment shall be assigned with the consideration of connectivity and prevention of mis-connections. A table 4-10 gives some measures to prevent mis-connections.

(b) Connectors of redundant intefaces shall be independent of each other as required in clause 4.8 (2).

Table 4-10 Connector Assignments to Prevent Mis-connections

Item	Measures to Prevent Mis-connection
Directions of Connectors	When same type connectors are used side by side, connector directions shall be easily identified.
Stamping Locations	A label shall be provided at the places observable from a far place after the instrumentation connectors are installed.
Keying	All connectors shall be keyed if necessary and possible.

(2) Mounting of Connectors

Connector shells shall be grounded with own onboard equipment housings. This requirement is applicable if the connector shells are grounded via other onboard equipment housings.

(3) Use of Pins/Sockets

(a) Pins should be used on the side of signal inputs, and sockets shall be used on the side of signal outputs.

(b) When inputs and outputs are in the same connector, pins/sockets and pin assignments shall be determined after individually coordinating with the project personnel.

(c) Coaxial connectors of onboard equipment shall be females.

(4) Power Supply Contacts

(a)Two, or more contacts shall be used for power supplies.

(b) The rated current per one contact should be the maximum load current of an onboad equpement or higher.

(c) The number of contacts shall be added if required to satisfy the maximum load current considering derating. Even when one of the contacts is broken down, the remaining contacts shall be able to carry the maximum load curernt.

(d) Be ware of unbalance between contacts when derating is considered.

(e) Power supply lines and signal lines shall be bundled separately.It is desirable that a bundle consists of only power supply lines and connected to a single connector that is not used for other purposes.

(5) Grounding Contacts

(a) Any of connectors having multiple contacts shall have chassis grounding pins.

(b) Wiring lines between grounding pins and chassises shall be made as short as possible.

(6) Signal Return Contacts

(a) Each of input/output signals and its signal return shall be established via a connector contact. A chassis or the like shall not be used as the signal return.

(b) In the case that an equi-potential is required between onboard equipments whose secondary sides are interfaced, signal return contacts shall have pins for this purpose.

(7) Contacts for twisted wires

Twisted wires shall be used with pairing contacts that are in the proximity in connectors.

(8) Spare Contacts (Spare Pins)

(a) 10 % of spare pins should be left with multi-contact connectors at the initial stages of development.

(b) To prevent antistatics, unused pins shall be grounded. However, when the pins only have contacts only and do not have wiring to outside the connector, they may not be grounded.1

(9) Test Connectors

(a) Connectors for tests shall be socket contacts.

(b)All contacts in a single connector shall not damage onboard equipment when short circuited to any adjuscent contact.

(c) Test terminals or test connectors of on-board equipment shall be sealed at the time of flight. EMI caps, blank panels (to preclude the entry of foreign matter) or other appropirate measures shall be taken.

(10) Special connector

Consult with some personnel in charge of the system design to use a special connector.

[1] According to the paragraph 5.2.10 in Spacecraft Charging and Discharging Design Standard (JERG - 2 - 211), floating conductors with a surface area of 2 cm 2 or less are exempt from ESD evaluation.
However, if iconnector pins can be easily grounded like an L type connector onboard on a printed circuit board, they shall be grounded.
Grounding cables are not necessary for connectors directly attached to the panels.

(11) Connector incorporating the EMI filter

(a) The articles incorporating a component that has a short circuit failure mode — including chip inductors with electrodes — shall not be used for the power supply connector. If the use is unavoidable, consults with the personnel in charge of the system design to clarify the specifications of the connector.

(b) The use of these connectors shall be described in the ICD. Since the tightening torque may be different from that of common products, it shall be clearly indicated not only in the electrical part but also in the mechanical part.

(12) MDM connector

(a) Jack posts shall be mounted on the equipment side. JAXA uses inch screws.

(b) Note that only thin wire rods AWG26 or less, can be used.

(c) The shell of a MDM connector shall be plated with gold or nickel. When the use of other plating cannot be avoided, coordinate with the personnel in charge of the system design.

(13) D-sub connector

(a)Jack posts shall be mounted on the equipment side. JAXA uses inch screws.

4.6.2.4 Junction Terminals

Junction terminals shall be coated by an insulating material.

4.6.2.5 Exposed Printed circuit boards

When printed circuit boards are installed on structural panels, the exposed boards shall be coated by an insulating material so as to prevent an electrical short circuit.

Grounding and insulation

4.6.3.1 Internal interface

4.6.3.1.1 Grounding

As a grounding target in the system, the metallic body structure parts, bus bars for grounding, etc. shall be prepared. They can be used as the reference point of zero potential, which is suitably provided in the body structures. The following matters shall be considered.

(1) The relationships with the return/reference potential for both the power supply system and the signal system shall be indicated.

(2) The impedance of connection with regard to the preceding item shall be shown. In that case, matters regarding what type of power supply and signals are using the common routes (harnesses, body structures and cases) shall be identified, and they shall be considered in the range of the affected signal spectrum. The specific values for the resistance and inductance of each element in the electrical network, which is provided as the grounding target, shall be

specified as needed. Using these values makes it possible to calculate the common mode voltage at each reference point within the circuit, and to compare with the requirements of the conducted susceptibility of each component. The schematic diagrams of grounding/insulation of the spacecraft system/subsystems and components shall be prepared, and the compatibility of the total system shall be confirmed. In order not to use the body structures as return routes, the grounding point of the primary power supply for the body structures shall be a single point. The return of the isolated type secondary power supply shall be grounded. This shall be performed at the output port of the power supply in general. However, when it is desirable to use another grounding point due to requirements of function/performance of the onboard equipments, the grounding point can be changed after consultation with the system person in charge. As also shown in clause 4.1.2.5 and 5.2.3.1, insulation resistance of 1 MΩ or more shall be kept between the primary/secondary power bus.

4.6.3.1.2 Insulation design

This clause is intended for application in the power supply lines of spacecrafts with a bus voltage of 100 V (nominal) or lower. However, the insulation design of printed-circuit boards shall be based on JERG-0-042 “Design standard of printed-wiring board & assembly,” and it shall be exempt from this clause.

(1) Insulation design by gaseous dielectric

When vacuum or atmospheric air is used as an insulator, a distance of 1.0 mm or more between conductors shall be provided, at the maximum operating voltage of 210 V or lower. In this case, dust and humidity shall be controlled.

(2) Insulation design by solid dielectric

The dielectric breakdowns of common materials for spacecrafts is developments are shown in Table 4-11. Here, V0 denotes the dielectric breakdown in a short time (within 20 sec) for AC 50 Hz at room temperaturefor materials without use history. V_{EFF} shall be used in the design process.

Table 4-11 Dielectric breakdowns of solid dielectrics

（Ref：JERG-2-213A Design Standard Insulation）

Material	Thickness	Effective withstand voltage V EFF	Nominal breakdown voltage Vo	Remarks
PTFE tape	50 μm	2.5 kV	6.3 kV	
KAPTON® tape	25 μm	1.2 kV	5.5 kV	
CHO THERM®	0.38 mm	7.7 kV	12.0 kV	200 Hz
SOLITHANE	0.20 mm	2.9 kV	12.8 kV	

PARYLENE	20 µm	170 V	3.2 kV	100 kHz
Mica	75 µm	1.4 kV	8.0 kV	
URALANE®	1.0 mm	8.2 kV	27.0 kV	200 Hz
LUMIRRORR®	50 µm	2.1 kV	6.5 kV	
Heat-shrinkable tube	0.18 mm	340 V	9.5 kV	100 kHz
Glass epoxy	0.2 mm	2.7 kV	11.7 kV	
RTV(S-691)	1.0 mm	9.9 kV	29 kV 200 Hz	200 Hz
ETFE wire	0.15 mm	2.4 kV	9.2 kV	200 Hz
diX C	20 µm	250 V	2.8 kV	
BT resin	0.1 mm	1.1 kV	5.0 kV	
Arathane	0.2 mm	2.1 kV	10.8 kV	
RTV566	0.2 mm	440 V	4.2 kV	
RTV142	0.2 mm	2.7 kV	7.7 kV	
Polyimide wire coating	0.16mm	1.0kV	14.3kV	

Note: Calculating conditions of VEFF:

Temperature: 100°C; Frequency: 200 kHz (However, as for materials whose dielectric strength value at 200 kHz has not been obtained, the calculations have been performed with the frequencies described in the remarks.)

Thickness: Nominal thickness of each specimen (Refer to the above description. The tape thickness does not include the thickness of the adhesive.)

Fluence of electron beam:

$1 \times 10^{15}/cm^2$ (This corresponds to the exposed dose for about one year on the surface of a geostationary spacecraft. However, since the mechanical strength of the PTFE tape is significantly lowered at $1\times10^{15}/cm^2$, it has been calculated at $1\times10^{14}/cm^2$.)

Exposure to ultraviolet radiation:

800 ESD at the wavelength band of 200 to 400 nm (applicable only to Kapton and ETFE wires)

Time of electric charging:

0.1 million hours (corresponding to about 11 years)

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(3) Creeping insulation design

Regarding requirements for creeping distance of solid dielectric, the creeping distance shall be longer than 1.0 mm for the maximum operating voltage of 210 V or lower. If this value cannot be ensured, the adequacy of the design shall be judged after consulting with the staff in charge of the system, by other means of insulation, or by conducting analysis or evaluation. Furthermore, as for the parts in which the creeping distance between conductors is less than this value, the usage shall be allowed on the condition that the performance of the parts is guaranteed by qualification tests, etc. and with consideration for the actual operation results on the orbit.

4.6.3.1.3 Double insulation

Since a short circuit of the primary power supply bus line as well as the battery line is the most fatal, and countermeasures after occurrence are also impossible, the double insulation shall be applied. It shall be applied to the upstream of the primary power supply bus line that including the fault separation circuit, the place that the primary power supply bus line and a battery line which make a short circuit of one location, specifically, the places are as follows.

(1) Primary power supply bus line: At the solar battery paddle side that transmits the generated electric power to the primary power supply bus line, it ranges from the place that short-circuits the primary power supply bus line by a short circuit of one location, to the input port of the short circuit fault separation circuit of the load side equipment which receives distribution and supply from the primary power supply bus line. Depending on the system of the short circuit fault separation circuit, there are cases where application is required beyond that range. Regarding this matter, refer to clause 4.6.6.2 (Protection by current interruption circuit).

(2) Battery line: The battery line shall include the charge array line (in a charge array system), the power line inside the battery, the cell case, battery case, and the ignition power supply line for pyrotechnic, in addition to the battery output line.
However, it shall not be applied when redundancy can be provided (when a redundant system exists and separation of the failed system is possible by the overcurrent protection circuit, current limiter, etc.). Also, double insulation is not applied to inside semiconductor components such as ICs, transistors, diodes, etc., and to the insides of the parts, such as connectors, relays, capacitors, etc. (including hermetic seal parts).
Double insulation denotes the method whereby two different methods selected from the following [1] and [2] in clause (4) are used, and if one side is short-circuited, insulation is secured so as not to short-circuit another side by the same cause.
When use of same material is unavoidable due to electrical, mechanical, thermal, or other restrictions, configuration is allowable only for the material that has actual results of flight or of evaluation, as well as data on its insulation properties, mechanical strength, thermal tolerability, etc., and that can secure a sufficient safety margin. However, even in that case, select and use a material from the following [2] in clause (4).

(3) Space insulation (the gap between two conductors)
In an area to be insulated, a distance shall be included to prevent shorting between conductors caused by foreign matters and displacement expected in the area.
If a distance of 1mm or more is provided, it is regarded as an insulating material.
If a distance of 1mm or more is provided between two bare conductors and no insulating material exists between them, it is regarded as single insulation. If the gap between two conductors is filled with an insulating material, it is regarded as double insulation.

(4) Solid body insulation

Insulation is provided using the following solid body insulation material:

(1) Solid body insulation material

(a) Resin board

(b) Resin sheet

(c) Resin mold

(d) Coating

(e) Mica board

(f) Glass fiber

(g) Glass hermetic sealing

(h) Ceramic board

(i) Ceramic hermetic sealing

(2) Items allowed for using for double insulation with the same material.

(a) Resin sheet: BT resin, Lumirror sheet

(b) Resin board: GFRP, Rexolite

(c) Tape: Polyester tape, Kapton ® tape

(d) Wire material sheathing: Wire material shall be certified for installing on aircraft

(3) Items not regarded as insulation material

(a) Solder resist on printed circuit board

(b) Surface treatment on alloy

(Except for the cases where insulation is secured by types of treatment or application to insulation design.)

(c) Ferrite

4.6.3.2 External interface

4.6.3.2.1 Umbilical Interfaces

Detailed contents of umbilical interfaces shall be defined based upon interface specification documents with respect to rockets.

In order to ensure electrical continuities, the following items shall be considered:

(1) Grounding and Electrical Continuities

Spacecrafts are required to be connected up to final grounding points of launch site facilities via either umbilical cables or rockets, while electrical continuities shall be secured.

(2) Umbilical Connections

(a) Umbilical connectors shall be provided independent from internal connectors of another spacecraft.

(b) In accordance with ISO15389, clause 4.10 (Electrical connectors) and clause 5.2.2.4 (Design guidelines Electrical connectors), data buses whose frequencies are higher than, or equal to 500 kHz, low frequency signals, command functions, and ground electric power shall be, in principle, separated from each other by employing individual connectors as being permitted as possible.

(c) As described in ISO15389, clause 4.10 (Electrical connectors), in order to prevent short circuits, electric connectors shall be made as dead-face type connectors in which pin tips are located at positions deeper than engaging planes. Also, as defined in ISO15389, clause 4.2.3 (Alignment), electric connectors shall be equipped with engaging guides in order to be easily inserted/pulled out.

(d) In order to prevent erroneous joints, shapes of electric connectors shall be changed, or electric connectors should be discriminated by employing symbols, or discrimination marks.

(e) A care shall be taken to such an item that interface circuits via umbilical connectors do not, in principle, propagate failures to signal circuits of internal/external interfaces.

(f) Pin assignment, voltages, currents, and maximum allowable voltage values shall be determined.

(g) As to interfaces of end-to-end, namely spacecrafts-to-rockets-launch side facilities, not only pin assignment shall be confirmed at umbilical connector terminals, but also umbilical connectors shall be confirmed before connecting actual spacecrafts by executing such a method for utilizing validation-purpose cables equivalent to cable provided on the side of rockets, and spacecraft simulating apparatuses.

(h) As to connectors which are exposed to aerospace after rockets are separated, while charging measures are included, EMC requirements from flight hardware shall be established and measures shall be taken, as defined in ISO15389, clause 4.12 (Electromagnetic compatibility (EMC).

(i) After rockets are separated, umbilical connectors shall not propagate failures to spacecraft systems even when any of failures occur.

4.6.3.2.2 Other external interfaces

Regarding the test equipment and facilities that interface electronically with spacecraft, pay attention to the following matters.

(1) Install a grounding wire that connects the spacecraft and the ground system, in advance of all operations and power activation.
(2) Regarding the electric power line, the test equipment and facility side shall have protective functions.
(3) The regulation of disturbances at tests shall be satisfied.
(4) Grasp the mutual grounding system among the spacecraft, test equipment, and facility, and secure a suitable connection.
(5) As for the circuits that interface with spacecraft, perform interface FMEA as needed.
(6) Grasp the electrical restrictions of the test equipment and facility in advance, and clarify the interfaces with the spacecraft.

4.6.3.3 Antistatics[2]

Countermeasures for electrostatic charge shall be executed in order to prevent accidents due to electrostatic charge on an orbit. The basic way of thinking is shown below. (The details shall be specified for each project according to the environmental conditions of the spacecraft.)

(1) The conductors exposed to the outside surface of a spacecraft shall be earthed to the body structure ground, using bonding wires, etc.

(2) Even if the outside surface of a spacecraft is an insulator, the conductor of the inner surface or inside shall be earthed to the body structure ground, when the inner surface or inside is a conductor.

(3) When a MLI (Multiple Layer Insulator) is used, the metal vapor deposition surface of each layer shall be totally conducted electrically, and earthed to the body structure ground. The number of grounding wires shall be two up to an area of 2 m^2, and if this is exceeded, increase at a rate of one piece/m^2, in accordance with the antistatic standard. (The necessity of application of redundant grounding shall be judged for each project.)

Furthermore, grounding resistance for the purpose of antistatic can be allowed up to 1 MΩ.

4.6.4 Electric discharge prevention in low vacuum environments [2]

Regarding the onboard equipment that may generate glow discharge during transition to vacuum condition (at critical pressure), discharge prevention shall be considered. The following examples are considered:

(1) The onboard equipment which the primary power supply is activated during the launch

(2) The component which its capacitor bank, etc. may remain charged

(3) The transmission filter (or diplexer) when a high-power transmitter outputs

The mutual relationship between the discharge speed of the outgas quantity that is discharged from air holes and the transition rate of the vacuum depending on the launching height of the rocket shall be considered.

4.6.5 Items to be considered for High Voltages

A high voltage implies a voltage at which either partial discharge or corona discharge occurs. In an actual case, the high voltage is higher than, or equal to approximately 200 V.

(1) High voltage equipment shall be designed and manufactured by considering a latent discharge phenomenon occurred in accordance with the Paschen curve under environments encountered during mission terms.

(2) The high voltage equipment shall be designed in such a manner that both DC field strengths

[2] According to appendix I.8.4 of the electrostatic charge/discharge design standard (JERG-2-211), in low vacuum environments, Paschen discharge does not occur unless the voltage becomes 330 V DC or more, and this voltage decreases at AC and high frequency.
Therefore, regarding the low voltage environments that are generally the target of this document, there is basically no need to consider the above-mentioned issue.

and AC field strengths in the worst event become smaller than, or equal to 1/2 of discharge starting field strength values.

(3) Degrees of vacuum at which the high voltage equipment are designed and tested shall be lower than, or equal to 10 Pa.

(4) In potting circuits, glass transfer points of potting materials shall be present outside authorized temperature ranges.

(5) Minimum bending diameters of high voltage cables shall satisfy items recommended by wiring cable manufactures.

4.6.6 Protection of power supply bus

The overcurrent protection is handled in order so short circuit failure on the load side of the primary power supply (onboard equipment and wire harness) does not cause abnormal it on the feeding side of the primary power supply. Regarding this, any single point failure shall not cause a short circuit on the primary power bus.

Accordingly, when overcurrent protection is to be realized on the load side, the design where a single failure causes a short circuit failure shall not be made for the primary power supply input circuit, and the design of instrumentation wiring to the load equipment shall be made with double insulation.

Regarding the portions where overcurrent protection cannot be executed in the primary power supply bus (including the bus bar, harness, and connector), protection by double insulation shall be made up to the point of the first protection equipment (fuse, circuit breaker, current limiter, or back flow preventing diode).

4.6.6.1 Protection by fuse

Fuses shall not be used, unless unavoidable. This is because fuses cannot be recovered when operated (melted down), and the existence of fusion cannot be confirmed easily.

(1) Load of primary power supply (precaution for power consuming equipment design)

   (a) When short circuit prevention is performed by using a fuse on the onboard equipment side, the use method shall be sufficiently considered. Specifically, note that a fuse on the return side is useless against a short circuit to the case (ground fault).

   (b) The fuses inside the onboard equipment shall be parallel redundant configuration, except if used for failure separation of the redundant configuration, and in principle, confirmation about the integrity of individual fuses from outside the onboard equipment shall be made possible.

   (c) The fusing characteristics of fuses shall be sufficiently considered. The fuse selected shall have such features that it will not melt down due to the anticipated instantaneous large load, but will certainly melt down in the event of a problem that can affect the equipment located upstream and other equipment.

(d) When a fuse is provided at the subsequent stage of the DC/DC converter, consider fusing the characteristics of the fuse, and use a DC/DC converter that has the ability to certainly melt down the fuse.

(2) Feeding side of primary power supply

(a) When an onboard equipment uses the fuse, the feeding side of the primary power supply must confirm the fusing characteristics of the fuse on the onboard equipment side, and also confirm that the specification during disturbance by problems is satisfied.

(b) When a fuse is used for the protection of the primary power supply bus, it shall be designed so that the fuse can be melted down within the time allowable for the system, when a load short occurs.

(c) When the primary power supply bus is protected by using a fuse, it shall be possible to confirm the open status of the fuse from the outside of the component. It is desirable to be accessible and replaceable even during the integration of spacecraft.

4.6.6.2 Protection by current limiter

(1) In the case that overcurrent protection is carried out by current limiting circuits and the like, limiting systems thereof (insulations made by current limiting circuits/current limiting resistors/fuses/commands etc.) should be clearly distinguished, and current limiting values/time characteristics/other items should be clearly defined.
Specifically, proper margins and redundancy should be considered with a care for inrush currents when power supplies are turned ON.

(2) When current detection is carried out on the return side, a short circuit to the body structure of the spacecraft (ground fault) cannot be detected. Therefore, perform double insulation of both the hot side and the return side, and also at the downstream of the circuit breaker/current limiter.

(3) When combining the current detector and circuit breaker/current limiter, if the detector part and the breaker/limiter part are different (for example, when current is detected at the return side, and breaker/limiter are done at the hot side), it shall be designed so that the current that flows at both sides will always be the same, including at the time of a failure. For example, when multiple detection–interruption systems exist, never mutually connect them not only on the hot side but also on the return side.

4.6.6.3 Load separation

(1) On primary power supply line interfaces, it shall be required that any load equipment where abnormal events have occurred can be separated from the line at the supply side and/or the load side so as not to influence the failure on other onboard equipment.

(2) When both the supply side and load side have protection functions (regardless of the primary/secondary side), the separation function on the loading equipment side shall be designed so that it operates earlier than that of the supply side: if the supply side operates

earlier, it is not possible to also supply electric power to the normal loading equipment that are connected in parallel with the loading equipment to be separated.

4.7 Matters to be considered about ordnances and non explosive actuators

4.7.1 Safety requirements

Ordnances and Non Explosive Actuator (NEA) are required to be one-shot devices, and have higher safety characteristics. Among the spacecraft onboard ordnances, electro-explosive devices (will be referred to as "EEDs" hereinafter) shall be cared in the highest degree in their electrical design. Circuit design, integration design, and operations with respect to EEDs and NEAs shall comply the safety requirements defined in the Rocket Payload Safety Standard (JMR-002) such as isolations of the circuits, inhibits, safety margins, shielding, bonding, electrostatic protection, and tests.

4.7.2 Characteristics of EEDs

Circuit and integration design and operations shall comply with each EED specification such as maximum non-firing currents, maximum testing currents, maximum/minimum firing currents, bridge wire resistances, insulation resistances, withstanding voltages, electrostatic discharge, chattering, electromagnetic compatibility, protection line, Faraday caps, electrical bonding, environmental conditions, and the like.

4.7.3 Ignition control of ordnances

Regarding the ignition control of ordnances, the following matters shall be considered.

(1) Regarding all systems from the supply source of ignition power to the ordnances, clarify the route, including the relationship with the power supply system and the grounding of the spacecraft.
(2) Clarify the operation sequence to reach the ignition.
(3) Protect the ignition power supply lines from being the short circuit mode.
(4) Clarify the principal specifications such as the power sources, ordnances, relays, and antistatic resistors, and the ignition current as well as the energizing time necessary for the ignition of ordnances.
(5) The circuit for ordnances from ODC to the port of ordnances shall be wired with the twist pair shielded wires.
(6) When verifying the ordnances, pay attention to the following matters.
    (a) The electric system shall be confirmable from end to end.
    (b) After finishing end-to-end confirmation of the electric system, it shall be possible to confirm the soundness of the ordnances and connections, by continuously measuring the resistance value of the ordnances, etc.
    (c) It shall be possible to perform an operation check of the ODC, in addition to an end-to-end test of the electric system. For example, it shall be possible to monitor the signal waveform.

(d) Regarding the drive system of ordnances, whether the fitting is correctly done cannot be confirmed, by the functional tests after the final fitting of the TN connector. Consider this matter when clarifying the verification plans from the design phase, and incorporate it into the design as needed.

(7) It is sometimes desirable from the viewpoint of safety that the energy line of the development driving system is physically separated until just before the launch. Therefore, in that case, TN-NEBAT shall be arranged so as to be accessible from the fairing window of the rocket, considering the fitting (mating) at the launching site.

4.7.4 Drive control of the non explosive actuator

Note the following matters regarding the Non Explosive Actuators (NEAs) that are not ordnances, but these utilization is increasing for the use of releasing the various holding portions, for which ordnances were used for old-style spacecrafts.

(1) Regarding all systems from the supply source of driving electric power to the NEAs, clarify the route, including the relationship with the power supply system and the grounding of the spacecraft.
(2) Clarify the operation sequence to reach the hold releasing operation.
(3) Protect the driving electric power supply lines from being the short circuit mode.
(4) Clarify the principal specifications such as the power supply sources, NEAs, relays and antistatic resistors, and the driving current of the NEAs as well as the energizing time necessary for driving.
(5) The NEA circuit from the power supply source to the port of NEAs shall be wired with a twist pair shielded wire.
(6) When verifying the NEAs, pay attention to the following matters.
    (a) It shall be possible to confirm the electric system from end to end.
    (b) After finishing end-to-end confirmation of the electric system, it shall be possible to confirm the soundness of the NEAs, and of the connections.
    (c) It shall be possible to perform a necessary operation check, in addition to an end-to-end test of the electric system. For example, it shall be possible to monitor the signal waveform.
    (d) Regarding the drive system of NEAs, whether the fitting is performed correctly cannot be confirmed, by the functional tests after the final fitting of the TN connector. Consider this matter when clarifying the verification plans from the design phase, and incorporate it into the design as needed.
(7) It is sometimes desirable from the viewpoint of safety that the energy line of the development driving system is physically separated until just before the launch. Therefore, in that case, TN-

NEBAT shall be arranged so as to be accessible from the fairing window of the rocket, considering the fitting (mating) at the launching site.

4.8 Matters to be considered about failure

Items to be considered for failures are indicated as follows:

In the case that the following requirements cannot be satisfied, substitution means shall be separately taken.

(1) A failure occurred in one system in a redundant arrangement shall not be propagated to the other systems.

(2) In principle, a connector of a master system signal and a connector of a slave system signal of a redundant interface shall independently employed (namely, master system signal and slave system signal shall not be assigned to the same connector).

(3) In redundant interfaces, at least interface-purpose drivers/receiver circuits and the like shall not propagate failures to the master system and the slave system in physical and thermal manners. [3]

(4) In cross strap connections, a failure of an interface circuit of one system shall not induces a failure of an interface circuit of the other system.

(5) In redundant systems, propagations of failures shall be prevented by physical and thermal isolations of either onboard equipment or circuits.

(6) In hazardous circuits, a hazard shall not be produced in response to two arbitrary failures.

4.8.1 Derating

In principle, the regulation of MIL-STD-975 APPENDIX-A shall be complied with. Regarding components that are not described in MIL-STD-975, derating shall be set on the basis of the regulation of MIL-STD-975 APPENDIX-A. Specifically, a tantalum capacitor shall be used so that the charge and discharge rate becomes 1 A or less, and for that purpose, a current-limiting resistor shall be added in series as needed. Moreover, when a ceramic capacitor that is not for space use is utilized at a low bias voltage, note that the high withstand voltage type is required.

4.8.2 Separation of continuous power supply circuit

Not only in the case of an interface between equipment but also in the case of inside the equipment, the element/device without the input protection diode to the power supply side shall be used, in principle, for the input circuit at the interface between the constant power supply circuit and other circuits. 4050 and 4049 correspond to the case of standard C-MOS. (However, since the noise margin of 4049 is less than that of 4050, it is recommendable to use 4050.) This is intended to prevent an input signal from flowing into the power supply via the protection diode of C-MOS when

[3] Prevention of fault propagation can(?) be implemented within a practical range.
For example, it is realistic to put the circuit of main system and subordinate system on the same circuit board but the packages should be allocated separately.

the power supply of the input circuit is turned off; otherwise, the circuit of the subsequent stage could operate or the protection diode could burn out due to overcurrent. When use of an element/device with the protection diode is unavoidable, use the circuit as shown in

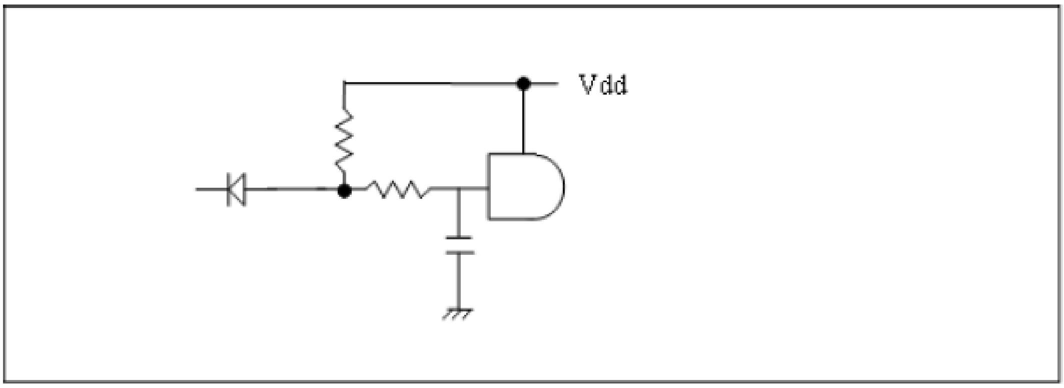


Fig. 4-30, and prevent flowing into the power supply on the input circuit side.

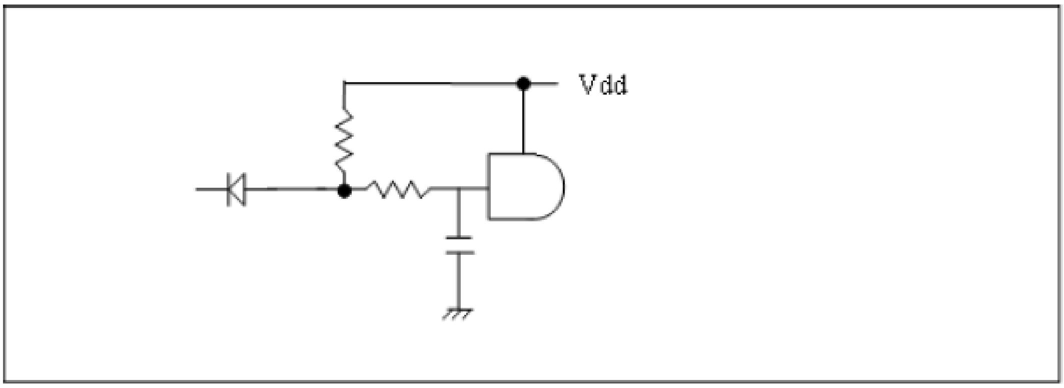
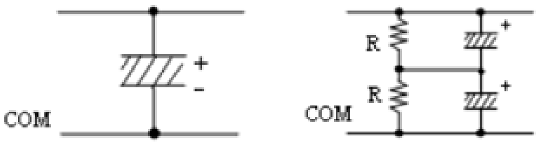


Fig. 4-30 Separation of constant power supply circuit. A C-MOS shall be used for the input element/device.

4.8.3 Considerations about the use of capacitors

Regarding capacitors (notably, tantalum capacitor) that have a high possibility to provoke a short circuit of the power supply due to a short circuit failure, take the preventive measures shown in



Not Applicable Applicable

Note R: Voltage equalization

Fig. 4-31. Components for which series redundancy is impossible, such as feed-through capacitors, etc. shall not be used for the power supply filter. When non-application is desired because reliability can be ensured by another method, etc., consult with the staff in charge of the system.

Not Applicable **Applicable**

Note R: Voltage equalization

Fig. 4-31 Preventive measures for short circuit of tantalum capacitors

4.8.4 Consideration about the use of ferrite beads

Regarding ferrite beads, the following precautions during mounting shall be carried out in order to avoid insulation failure when mechanical damage is generated by impact, etc. However, these precautions are not applicable to chip components.

(1) When being used near the circuit patterns, cover them with an insulation sheet.
(2) As a preventive measure against scattering apart at breakage, coat the beads with an adhesive (a soft type such as silicone series, etc.).
(3) Ferrite is not deemed as an insulator from the viewpoint of insulation design (clause 5.2.1.2 (3) of the insulation design standard JERG-2-213A). Therefore, the ferrite bead shall be deemed as an electric conductor, and an insulation distance to the bead shall be sufficiently kept. It is same when using at the back side of connectors.

5 Individual design requirements

5.1 Electric power

Herein, “electric power” denotes the electric power supply system of spacecraft, namely the primary power supply.

5.1.1 Scope

Power supply subsystems supply electric power capable of operating spacecraft systems and equipment. Requirements of power generation, storage, power control, line protection and distribution shall be applied by Solar Paddle design standard (JERG - 2 - 215B) and Power Supply System design standard (JERG -2 -214A).

5.1.2 Requirements and income/outgo regarding electric power

The income/outgo and margin regarding electric power shall be set based on the design standard of power supply system (JERG-2-214), and the following requirements are given for the income/outgo and margin of electric power.

(1) The hardware and software that configure the power supply subsystem shall fulfill their functions over the total operations in the environment actually encountered.

(2) When designing the power supply subsystem, analyze the system electric power profile for all stages of the mission, and then analyze the energy demand during the total operation period while considering the inrush power and peak power, eclipse, incidence angle of the sun, and directional misalignment. The income/outgo balance of electric power based on the above-mentioned peak power value (supply capacity of peak power) and the income/outgo balance of energy based on the average power value (charge and discharge income/outgo of battery) shall be established and maintained. The following items shall be considered in the above-mentioned income/outgo.

  (a) Distance from spacecraft to the sun
  (b) Duration of sunlight and eclipse
  (c) Aspect angle of the sun
  (d) Pointing accuracy
  (e) Influence by the environment temperature and deterioration
  (f) Matters relevant to reliability (influence of failure)

(3) As for the available electric power, it shall be possible to supply the required power even if a failure occurs in the solar battery array circuit or the battery cell has failed, under the worst condition until the end of life. As for the state of a failure, a power loss by 5% of total generation power before the occurrence of the failure, or by the portion of one array circuit, whichever is larger, regarding the solar battery array[4], and the short circuit or open of one cell regarding the battery cell[5] shall be assumed.

(4) In order to maintain system safety and battery functions, a fault detection function for the battery shall be provided.

(5) The scale of the solar battery array, battery, power control equipment, and power distribution equipment of the spacecraft shall be designed based on the above-mentioned income/outgo of electric power.

5.1.3 Matters to be considered about failure

The power supply system shall be designed so that it is possible to protect the spacecraft power supply system and to separate failure from the spacecraft power supply system, against overload in a failure of the downstream.

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[4]: JERG-2-215A From clause 5.1.1.2(a) of the design standard of solar battery paddle systems
[5]: JERG-2-214A From clause 4.5.2(7) of the design standard of power supply systems

5.1.3.1 Redundant design

(1) The power supply system shall not have a single point of failure that can be assumed by fault analysis. When a single point of failure remains, identify that, and show the reason why it is accepted. This reason shall include technical evaluation of the possibility of occurrence, observation of means that enable removal of the point if the means exists, and countermeasures for reducing the probability of occurrence or influence of a potential failure.

(2) Regarding the problems/failure due to open/short circuit of parts, etc., take countermeasures by series-parallel connection, redundancy of circuits and equipment, etc. However, pay attention to the failure rate of OR circuits, switching circuits, etc. to achieve redundant configuration.

(3) Any protective function that supports the essential function inside the converter or regulator connected to the primary power supply shall not be implemented in the same hybrid IC or in the same IC, and furthermore, the reference voltage and power supply that are independent from the circuit to be protected shall be utilized.[6] However, the above-mentioned matters shall not apply to hybrid ICs that incorporate the functions that are physically separated so as not to lead to the fault chain.

(4) The primary power supply shall be restorable when an abnormal state (for example, solar-power loss due to anomalies of attitude, etc.) has been removed, also including the case where secondary electric power has been lost.

5.1.3.2 Battery protection

(1) The protective function shall be provided, so that anomalies such as short circuit, open, etc. of a battery cell do not affect other battery cells or the primary power supply bus.

(2) A protective function such as stopping of charging, etc. shall be implemented, so as to prevent the battery from causing a fatal failure when it has undergone overheating.

5.1.4 N/A

5.1.5 N/A

5.1.6 N/A

5.1.7 Wiring and protection

5.1.7.1 Fundamentals

(1) The primary power supply shall be connected to a single ground point (UPG) of a spacecraft. The body structure shall not be used as the power supply RTN.

(2) Regarding the portion that is not protected by any device in power distribution of the primary power supply bus, it shall be protected by the double insulation method up to the point of first protection device (fuse, circuit breaker, or current limiter), as the minimum requirement. The

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[6] The intention is that the protection of the primary power bus. shall not fail due to a current-limiter/circuit-breaker failure caused by a preceding failure of another portion..

details of double insulation shall be in accordance with clause 4.6.3.1.3 or the insulation design standard (JERG-2-213A), which is the source document.

(3) In all loading paths, provide a protection circuit as close to the power supply as possible.

(4) When the power distribution cable of the primary power supply bus is protected by using a fuse, it shall be verified by analysis, that the fuse does not operate by the maximum current in the loading path including the transient state (by rush current, etc.), and that the fuse certainly melts down when a short circuit failure occurs.

(5) When the primary power supply bus is protected by a fuse, that shall be accessible and replaceable even during the integration of spacecraft.

(6) When the power distribution line of the primary power supply bus is protected by a fuse, the power supply system shall be designed so that the fuse can be melted down within a suitable time, when a load short occurs.

(7) Regarding all current limiters and the circuits where the power supply is automatically cut off, the operating status of the protection circuits shall be monitored by HK data. Even if this monitoring has failed, it shall not provoke problems with the protected elements/components.

(8) When the relay that turns on/off the primary power supply line is used, the peak voltage at the contact when the power supply is cut off shall not exceed the spec at disturbance during abnormal state.

5.2 EMC

This clause describes important factors to achieve EMC performance even if they are already described in other clauses.

Therefore, all equipment designers are expected to read this clause carefully to deepen understanding of related requirements in other clauses.

This clause is compiled based on the EMC Design Standard rev. A. (JERG-2-241A)

5.2.1 System integration design

In system integration design of the onboard equipment, the bonding, grounding, insulation, cables, shielded wire, connector, electrical harness (including the harness routing), filtering, shield of chassis, lightning protection/arc discharge, antistatic surface finish, pyrotechnic circuit, and equipment location, etc. shall be designed and studied at the system level.

5.2.1.1 Grounding and wiring design

5.2.1.1.1 Grounding/Insulation diagram

Since grounding and insulation are closely related to the EMC of the spacecraft system, the schematic diagram of the grounding/insulation of the spacecraft system/subsystem and equipment shall be prepared and the compatibility of the total system shall be confirmed.

5.2.1.1.2 Grounding point

The grounding point shall be set on the metallic structure part, bus bar for grounding, etc. that can be used as the reference point of zero potential that is suitably provided in the spacecraft body structure. The details shall be clarified in the EMC control plan, including the following;

(1) The relationships to the return/reference potential of both the electrical power lines and the signal lines shall be identified.

(2) As for preceding paragraph, connective impedance of the wirings shall be specified. The line types — such as electrical power line or signal line — using the common route (e.g., wiring, body structure, and chassis) shall be identified. They shall be considered in the frequency range of affected signal spectrum.

The specific values may be assigned to the resistance and the inductance of each element in the electrical network which serves as the grounding point. (Refer to clause A.1.1 of the EMC design standard (JERG-2-241).) Using these values makes it possible to calculate the common mode voltage at the reference point of each circuit to compare with the requirements of conducted susceptibility of each equipment.

5.2.1.1.3 Wire harness

The hot side and the return side of the line shall be in the same bundled harness. The wires shall be twisted pair cables wherever possible. The body structure of the spacecraft shall not be used as the signal/electrical power return line. As for the classification of cables and their wiring, it is considered on the subsystem basis.

5.2.2 System EMC design

The system EMC design shall consider 1) EMC/electrical interface study and adjustment and 2) special requirements. Specifically, the grounding concept of the power supply unit shall be specified as a part of the electrical power system design concept. In order not to use the body structure as a power return route, the grounding point of the primary power system to the body structure shall be the single point throughout the entire system.

5.2.2.1 Electrical bonding

The bonding resistance between each metallic chassis of all electrical equipment and its mounting portions (metal), as well as between these mounting portions and the metallic payload body structure and of conductive components of non-electric systems shall be 1 Ω or less. However, the followings shall be satisfied.

(1) When Multiple Layer Insulator (MLI) is used, the metal vapor deposition surface of each layer shall be totally conducted electrically and it shall be connected from the grounding point of MLI to the body structure of the spacecraft by 1 Ω or less.

(2) The conductors exposed to the outside of the spacecraft structure shall be connected to the body structure of the spacecraft at 1 MΩ or less by bonding wires and the like. (for antistatics purpose)
(3) Even if the outside surface of a spacecraft is an insulator, the conductor of the inner surface or inside shall be connected to the body structure of the spacecraft at 1 MΩ or less when the inner surface or inside is a conductor. (for antistatics purpose)
(4) The grounding between the chassis for the equipment of the propulsion system and the structure of the system shall be at 10 mΩ or less including the portion of cumulative impact between all close contact surfaces. (In accordance with clause 5.3.1.4 of the Payload Safety Standard (JMR-002B).)
(5) The places between individual tightly-attached surfaces inside the equipment such as between sub-assemblies or sections of the propulsion system shall be connected at 2.5 mΩ or less. (In accordance with clause 5.3.1.4 of the Payload Safety Standard (JMR-002B).)
(6) All the members that constitute the body structure panels including internal cores and front/back skins shall be internally bonded. The bonding resistance between the front and back sides skin of the panel shall be 10 mΩ or less. During spacecraft assembly, bonding between panels shall be achieved by mounting each panel. When this requirement is not met, coordinate with the personnel in charge of the system design.

5.2.2.2 Body structure shielding of spacecraft

The electrical discontinuity parts of the spacecraft body structure (cover, inspection hole, connecting part, etc.) shall be minimized. The discontinuous parts in the elements important for the RF interference and the radiated susceptibility shall be electrically conducted by a low-impedance conduction path.

5.2.3 Subsystem EMC design/Grounding and insulation of electrical power system

(1) Primary power system

The grounding of power system shall be decided based on the concept of power system design. In order not to use the body structure as a return route, the grounding point to the body structure shall be the single point throughout the entire system.

(2) Secondary power system

It is necessary to control the return of secondary power system as a spacecraft system. It shall be grounded by either of the onboard equipment, the subsystem, or the system and at the feeding port of the secondary power system. When the Power Supply Unit (PSU) and electrical consuming equipment are separated, perform grounding at the PSU side. When grounding at another point is desired for the functional performance of the onboard equipment, consult with the personnel in charge of the system design. Insulation resistance of 1 MΩ or more shall be kept between the primary and secondary power supply.

5.2.3.1.1 Connection to single point ground

The grounding point shall be located on the body structure via the nearest route from the power supply return terminal. This line shall not go through another onboard component.

5.2.3.2. Grounding and insulation of the onboard equipment, etc.

(1) When the onboard equipment is not connected to the power supply of the spacecraft, insulation resistance of 1 MΩ or more shall be kept between the primary power supply input line of each onboard equipment and the chassis of the onboard equipment.

(2) N/A

(3) Insulation resistance of 1 MΩ or more shall be kept at the signal return of the onboard equipment that generates high frequency or operates at high frequency, at the secondary power supply return, and at the primary power supply return.

(4) In order to completely control the grounding points as a system, the grounding of the circuit ground and secondary power supply return shall be at the feeding port of the secondary power supply. If this requirement is not met, coordinate with the personnel in charge of the system design. When grounding is secured at a place other than the feeding port of the secondary power supply, use the grounding and insulation schematic diagram to confirm at the system level that there is no unintended current loop via the signal return, secondary power supply return, or chassis ground.

5.2.3.3. Filtering

The electronic equipment and cables outside the body structure shall have individual shields to keep a margin of at least 6 dB against the electromagnetic environment of the spacecraft.

5.2.3.4. Magnetic characteristic

The magnetic torque by interaction between the magnetic dipole moment of the spacecraft and magnetic field of the earth is one of the primary factors of attitude disturbance torque of the spacecraft. When the magnetic field of the earth is small as in the case of geostationary spacecraft or when the magnetic dipole moment of the spacecraft is small, disturbance by magnetic torque is small. However, the magnetic dipole moment of low-altitude spacecraft orbiting comparatively large orbiting comparatively large magnetic field of the earth may affect the attitude control system of the spacecraft.

The magnetic dipole moment of the spacecraft may interfere with the measurement of magnetic field.

The following shall be met to minimize the magnetic dipole moment.

5.2.3.4.1 Magnetic materials

The use of magnetic materials shall be kept to the minimum. The use of permanent magnets, electrical magnets, etc. shall be avoided wherever possible. When the use of magnetic materials cannot be avoided, consult with the personnel in charge of the system design and also consider the configuration to minimize the magnetic dipole moment. Furthermore, information about use and configuration of the magnetic materials shall be given in the Interface Control Drawing (ICD).

5.2.3.4.2 Current loop

Except for the magnetic torquer for spacecraft attitude control, the area of current loop shall be kept to the minimum. As for the line where the hot and return are clear, use the twisted pair cable even if current loop is small.

5.2.4 EMC requirement for subsystems and equipment

The following requirements shall be complied with. For test requirements and other details, refer to clause 5.2 of JERG-2-241A "EMC design standard rev. A."

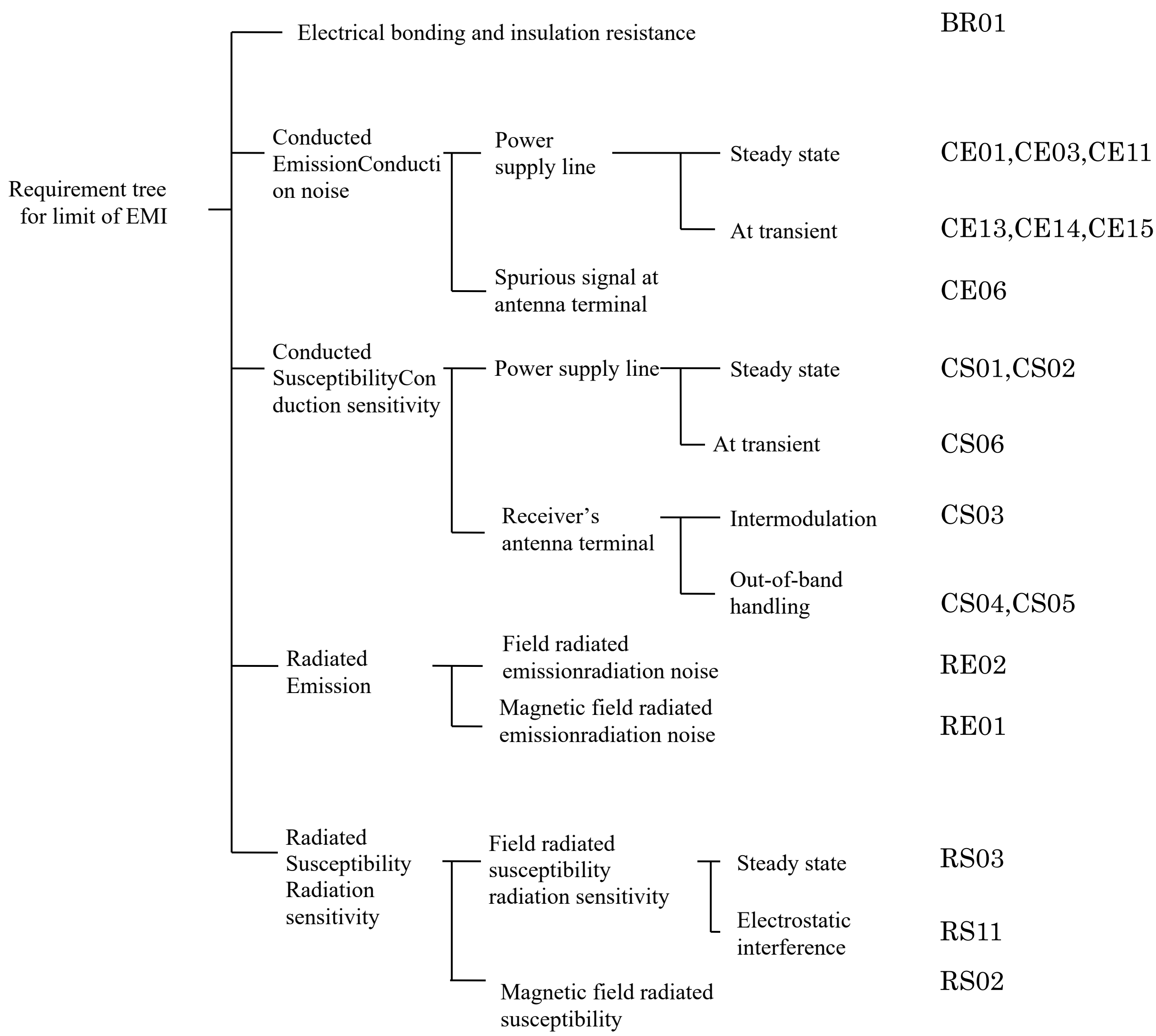
(Each project shall investigate the requirements and tailor them as necessary. Note that MIL-STD-461/462 Revision C and Revision D measurement requirements are qualitatively different and both the measurement method and the standard shall be changed at the same time.)

5.2.4.1. Requirements for EMC

The EMC requirements structure is shown in Fig. 5-1. and the requirements for the electromagnetic interference limit are shown in Table 5-1.

Confirm through test or analysis that each onboard equipment satisfies the above-mentioned requirements. When a developed product has the EMC test results that satisfy the above-mentioned requirements, the test can be omitted.

When these requirements are not satisfied or any issues exist for conducting tests,, coordinate with the person in charge of the system.



Note: BR01, CE11, 13, 14, 15, and RS11 are unique established in these criteria standard, and they are symbols that are not used in the MIL standardsMIL system.

Fig. 5-1 EMC requirementsrequirement tree

Table 5-1 Requirements for EMC (1/6)

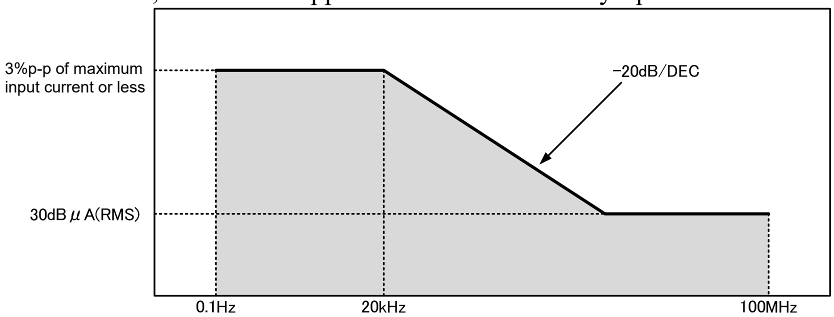
No.	Item	Contents
1	Electrical bonding, and insulation resistance (BR01)	(1) Electrical bonding In the EMC test, the electrical bonding resistance between the equipment grounded in the EMC shield room shall be 2.5 mΩ or less. (2) Insulation resistance At each equipment, the following insulation resistance shall be 1 MΩ or more. a. Bus power supply return and the chassis b. Bus power supply return and secondary power supply return c. Between the secondary power supply return and the chassis (excluding the RF equipment and SpW equipment) d. Signal return and the chassis (excluding the equipment that receives feeding of the secondary power supply from another equipment, RF equipment, and SpW equipment)
2	Conducted emission Limit (CE01,CE03)	The conducted noise current that is output from the power supply line of each equipment shall not exceed the following allowable values. • 0.1 Hz to 20 kHz: 3%p-p of maximum input current or less • 20 kHz to 100 MHz: Attenuation from above-mentioned value of 20 Hz, by –20 dB/DEC The minimum value shall be 30 dBμA (RMS) or less. Furthermore, the current ripples at communication by SpW are excluded. 
3	Limit of bouncing ripple voltage (CE11)	The bouncing ripple voltage that is output from the power supply line of each equipment shall not exceed the following allowable values. Furthermore, the spike component is not included. • DC load input span • 10 mV o-p or less (10 W or less) • 1 mV o-p or less (10 W or more) • Measurement bandwidth: 10 Hz ~ 100 MHz * The definition of electric power shall be the nominal power consumption value specified in the ICD of each equipment.

Table 5-1: Requirements for EMC (2/6)

No.	Item	Contents
4	Switching Transient limit (CE13) (CE14) (CE15)	(1) Noise current in power supply line (CE13) It shall be as follows under operational transient during nominal operation. • Peak current: 1.25 times the steady current or less • Transient time: 50 ms or less • Absolute value of current change rate (|di/dt|): 1×10^5 A/s or less (2) Transient current (per one input) (CE14) ①The maximum value of the transient current to the primary power supply line when the power supply of the equipment is turned on shall be as follows. ・For steady current is 1 A or less: 2 A or less ・1 A ~ 15 A: It shall not exceed two times the steady current. ・15A or more: 30 A or less ②The absolute value of the current change rate (|di/dt|) of the transient current shall be 2×10^4 A/s or less. Regarding heaters, however, it shall be 1×10^5 A/s or less. ③The maximum variation of electric charge shall be 16 m Coulomb or less. $\Delta\mathrm{Q[Coulomb]} = \int_0^{I_{\mathrm{peak}}} I\,dt$ ④After turning on, it shall become a steady current value within 50 ms. Note: Regarding equipment that cannot comply with the provision of within 50 ms as mentioned above, coordinate with the staff in charge of the system design.

Table 5-1: Requirements for EMC (3/6)

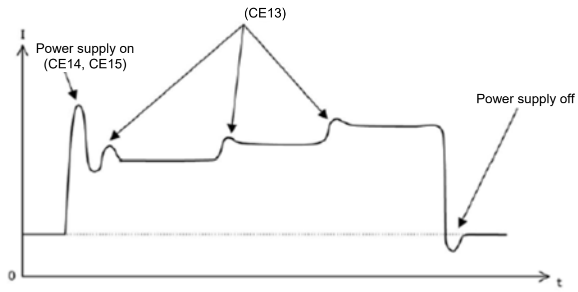
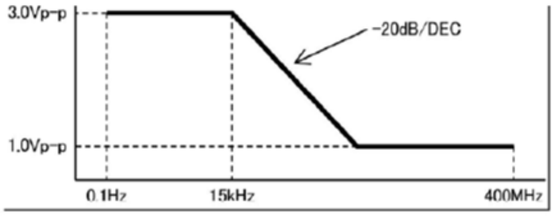
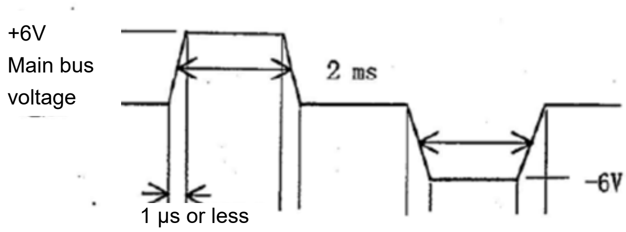
No.	Item	Contents
4		（3） Inrush current (CE15) ①The amplitude of the inrush current when switching on each equipment that has an on/off switch on the power supply shall be as follows. ・ For steady current is 1 A or less: 2 A or less ・ 1 A ~ 5 A: 2 times the steady load current or less ・ 5 A or more: The current value where 5 A is added to the steady load current, or 30 A, whichever is smaller, or less. ②Furthermore, the absolute value of the current change rate (|di/dt|) of the transient current shall be 1×10^5 A/s or less. ③Moreover, the maximum variation of the electric charge shall be 16 mCoulomb or less during 1 ms. $\Delta\mathrm{Q[Coulomb]} = \int_0^{I_{\mathrm{peak}}} I\,dt$ ④However, Δt from turning on of power supply to the peak point of current shall be 1 ms, or the time until the peak point, whichever is shorter.  Transient current profile (CE13, CE14, CE15)

Table 5-1: Requirements for EMC (4/6)

<table>
<tr><th>No.</th><th>Item</th><th>Contents</th></tr>
<tr><td>5</td><td>Spurious conducted emission limit at antenna terminal
(CE06)</td><td>It shall be in accordance with the spurious characteristics of each transmitter’s antenna.

It is not applicable to items except for the transmitter.</td></tr>
<tr><td>6</td><td>Conducted susceptibility Limit in power supply line
(CS01, CS02)</td><td>Even if the following sinusoidal voltage is superimposed on the temporary power supply line of each equipment, the function and performance shall not be decreased.
• 0.1 Hz ~ 15 kHz: 3.0 Vp-p
• 15 kHz ~ 400 MHz: −20 dB/dec
However, the minimum value shall be 1.0 Vp-p.

</td></tr>
<tr><td>7</td><td>Transient limit
(CS06)</td><td>Even if the following pulse voltage is superimposed between the hot/return bus line as well as the line and the chassis in the positive and negative directions, the function and performance shall not be decreased.


In the diagram, the main bus voltage is 32.1 V to 52.0 V (at the input port of the equipment), according to the bus interface requirements in clause 4.1.2.2.1.
When there is a restriction such as applying stress, etc. to the equipment by conduct the transient voltage test of +6 V and –6 V relative to the main bus voltage at each equipment, set the main bus voltage to the possible range, and conduct the transient voltage test of +6 V and –6 V.</td></tr>
</table>

Table 5-1: Requirements for EMC (5/6)

No.	Item	Contents
8	Intermodulation conducted susceptibility at receiver’s antenna terminal (CS03)	When RF noises of two waves or more that may possibly be input to a receiver at the antenna part are actually input to the receiver, the receiver shall not respond due to intermodulation. The receiving frequency band is also excluded in this case. This is not applicable to items except for the receiver.
9	Out-of-band response conducted susceptibility at receiver’s antenna terminal (CS04, CS05)	It shall be in accordance with the out-of-band response characteristics at each receiver’s antenna terminal. This is not applicable to items except for the receiver.
10	Radiated emission limit (RE02)	The electric field radiation noise emitted from each equipment shall not exceed the below-mentioned allowable value. “General requirements” The requirements are shown in Fig.5-2. MIL-STD-461C Part3 RE02 Fig3-8 & Fig3-9 (ClassA2a) “Rule of coordinating the requirements depending on the mounting location” Individual requirements of RE02 are shown in Table 5 2.
11	Magnetic field radiated emission noise limit (RE01)	The magnetic field radiation noise emitted from each equipment shall not exceed the allowable value shown in Fig.5-4. The measurement distance shall be 7cm from the surface of the equipment.

Table 5-1: Requirements for EMC (6/6)

No.	Item	Contents
12	Field radiated susceptibility limit (RS03)	Even if each equipment is exposed to the following electric field, its function and performance shall not be decreased. "General requirements" 14 kHz ~ 30 MHz: ≥ 10 V/m 30 MHz ~ 10 GHz: ≥ 5 V/m 10 GHz ~ 43 GHz: ≥ 1 V/m "Rule of coordinating the requirements depending on the mounting location" Individual requirements of RS03 are shown in Table 5-3.
13	Electrostatic interference limit (RS11)	Regarding the equipment where malfunctions, etc. may occur due to electrostatic charge and discharge by space plasma, conduct the test under the following conditions, and confirm that there are no problems with the functions. (To be in accordance with MIL-STD-1541, clause 6.7.2) • Gap voltage: 10 kV (arc discharge of electrostatic charge) • Pulse rate: 1 pulse/s • Spacing between test piece and gap: 30 cm
14	Magnetic field radiated susceptibility limit (RS02)	To be in accordance with the Part I Spike#1, in MIL-STD-461C Part3 RS02 Since the above-mentioned matter would be an unrealistic requirement in some cases, take care when judging the applicability of adoption and selecting the level. (1) Flow a current of 20 A at a power supply frequency into the test wire, and confirm that there is no decrease in performance. (2) Flow the predetermined spike current into a test wire to which 5Ω has been added, and confirm that there is no decrease in performance.

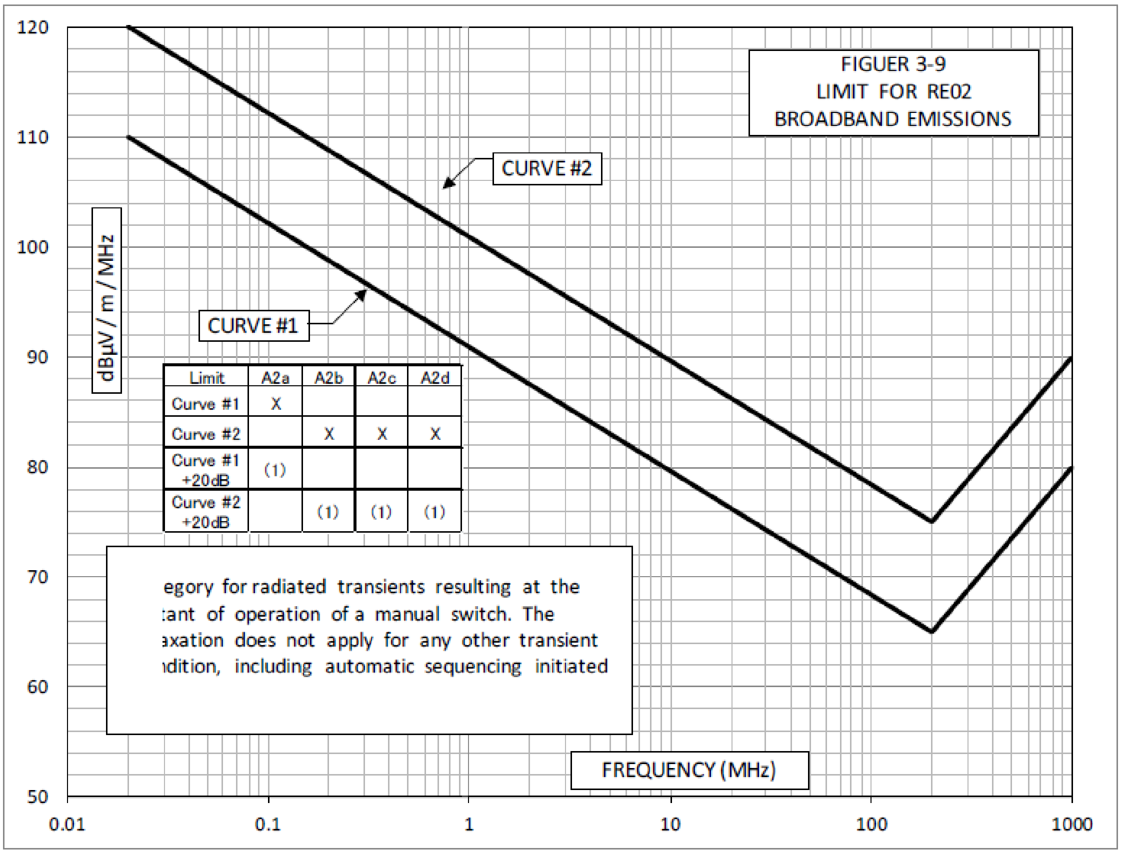


Fig. 5-2 Radiated emission limit (RE02 wide band) (Redrawn on the basis of MIL-STD-461C Figure 3-9)

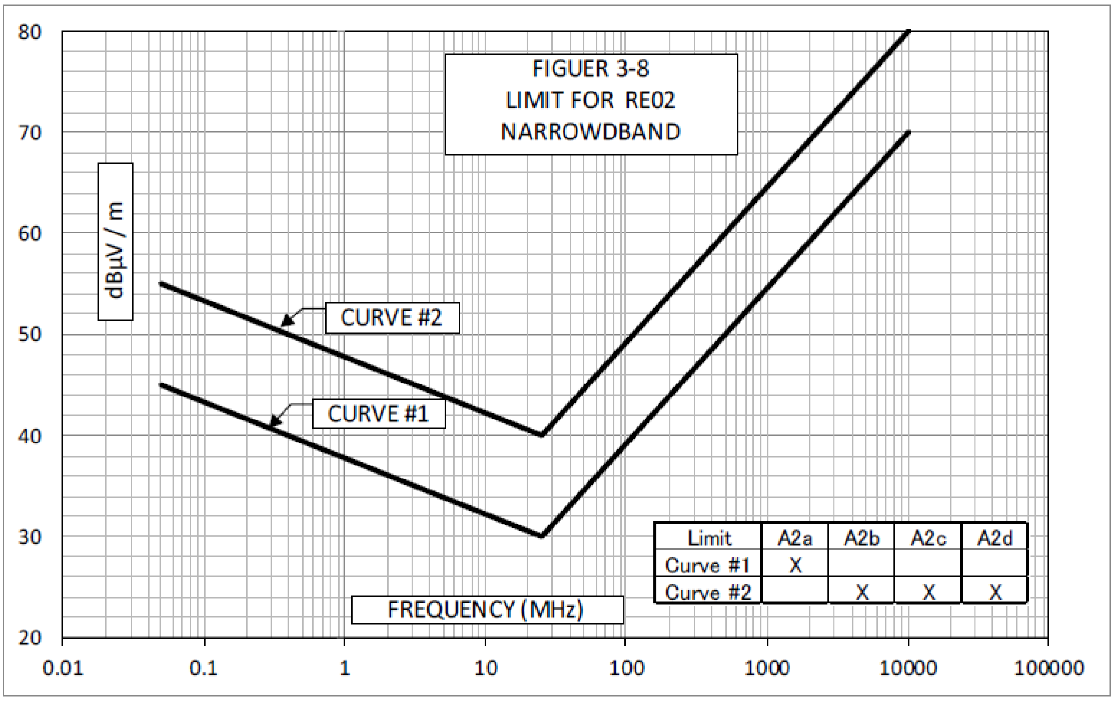


Fig. 5-3 Fig. 5 3 Radiated emission limit (RE02 narrow band) (Redrawn on the basis of MIL-

STD-461C Figure 3-8)

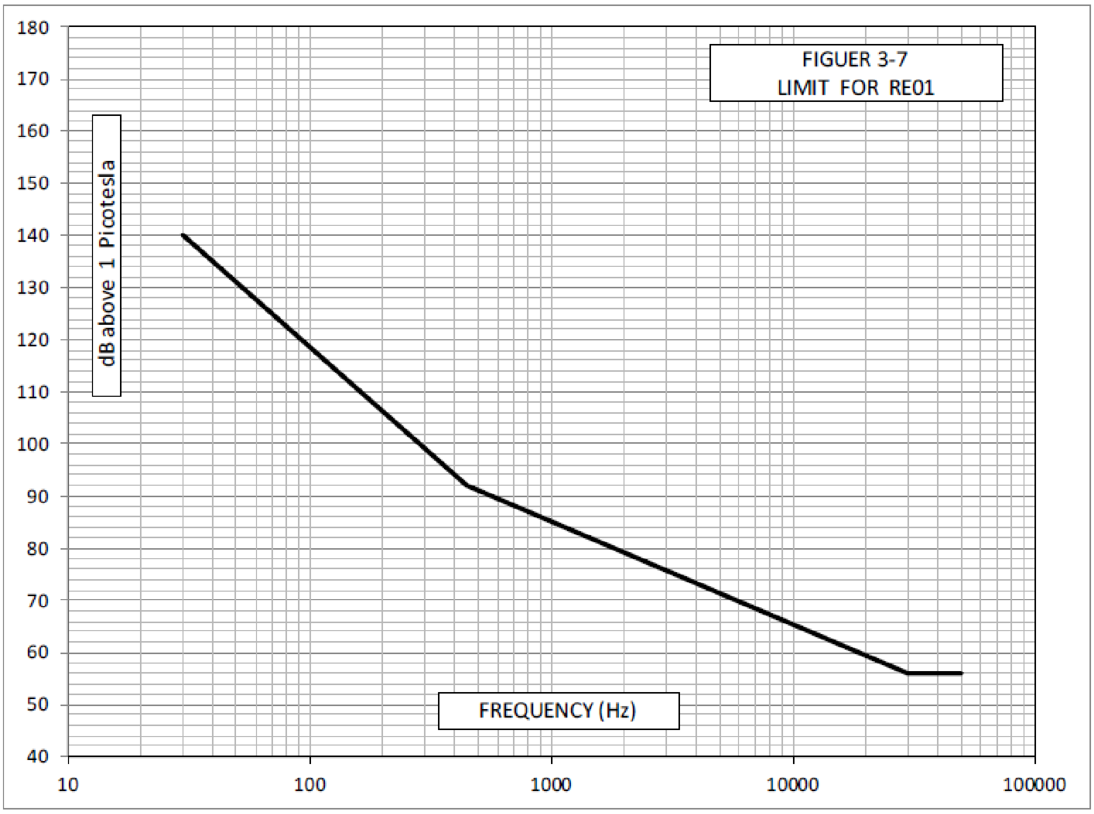


Fig. 5-4 Magnetic field radiation noise limit (RE01) (Redrawn on the basis of MIL-STD-461C Figure 3-7)

Table 5-2 Individual requirements of RE02 (Example)

(When other external equipment and frequency other than the S-band are used—such as using the X-band for command, etc., —specify on a project basis.)

Equipment	S band
	2081-2102 MHz
STT	16.0 dB μ V/m
Onboard equipment in Bus Structure	29.0 dB μ V/m

*1: When the general requirements are more severe, the general requirements shall be prioritized.
*2: When other external onboard equipment and frequencies other than the S-band are used, specify on a project basis.

Table 5-3 Field radiation sensitivity limit (RS03) individual requirements (example)

Equipment	S Band 2271.6MHz ±15 MHz	X Band 8180 MHz ±150 MHz	UHF 400MHz~ 500MHz	UHFT 2200MHz~ 2290 MHz	RT 5230 MHz~ 5760 MHz
STT	1.5	6.5	-	-	-
CSAS	14.5	3.0	-	-	-
Equipment Installed in BUS structure	0.5	0.5	0.5	0.5	2.0

V/m

Note: When the level of the general requirements is stronger, the general requirements shall be prioritized. The requirements for EMC from the rocket side is based on the premise of Epsilon. For cases other than Epsilon, specify by on a project basis. Regarding external equipment including other missions, specify on a project basis.

5.2.4.2 Test requirements for EMC

The test shall be conducted according r to MIL-STD-462C.

5.2.4.2.1 LISN

When measuring the noise/sensitivity of the bus power supply line, insert the LISN between the power supply for the test and the device under test to simulate the impedance of the power supply system on the spacecraft. The frequency characteristics of the LISN circuit and suitable impedance are determined by the mask of impedance of the bus and the harness. The LISN circuit shown in Fig. 5-5 (an appropriate value of the circuit constant shall be decided by the projects) and the frequency characteristics of appropriate impedance shall be used.

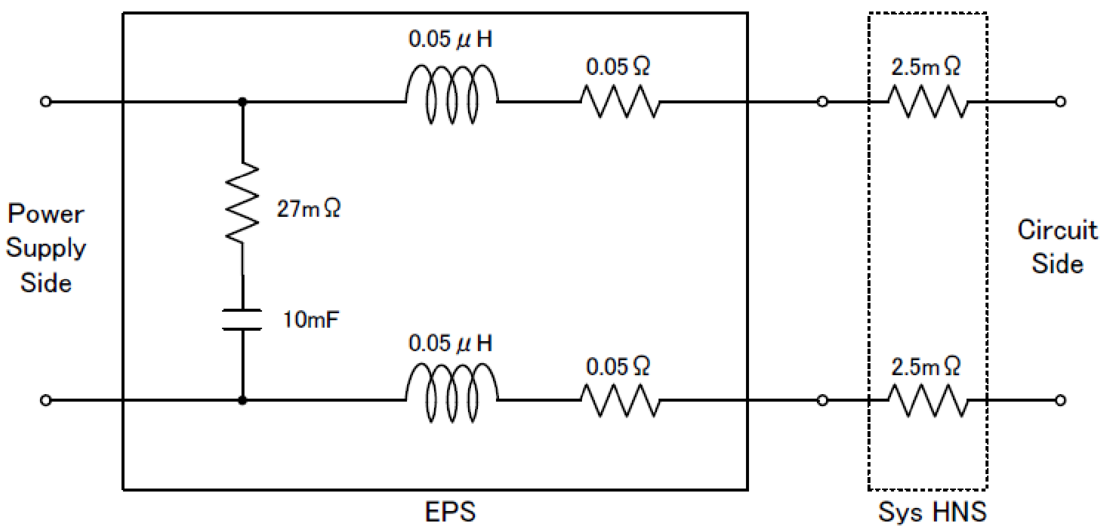


Fig. 5-5 LISN circuit diagram (example)

5.3 RF system

The requirements for the RF system shall be in accordance with the Electrical Design Standard (JERG-2-200A).

5.4 Optical system

The requirements for the optical system shall be in accordance with the Electrical Design Standard (JERG-2-200A).

6 Verification method

Design verification methods are classified in terms of the similarity, analysis, inspection, and test. This clause identifies the items in Chapter 4 that must be verified by test and summarizes the test methods for the system and onboard equipment as in Table 6-1.

Note that these are just standard methods. In the actual design/manufacture/testing of actual spacecraft, they shall be specified in each individual specification/plan document, etc., with consideration for the phase of development of the onboard equipment, etc.

Table 6-1 Verification method

Item in Chapter 4		System test (including when assembling the system)	Onboard equipment test (including when assembling the onboard equipment)
4.1.2.2.1	Primary power supply bus	Take measurement of the steady state voltage and ripples at the input port of the electrical consuming equipment. Basically, it shall be conducted by using the solar-array simulator (SAS), battery simulator (BTS), or actual battery. As the test condition, it shall be carried out by a combination of max./min. solar battery output and max./min. load power.	(Power supply system) Measurement shall be done at the output port of the power supply system. If at all possible, conduct the test by using the SAS/BTS or the actual battery for the system test. The load conditions at the test shall be the maximum and minimum conditions. (Electrical consuming equipment) Conduct a performance test of the onboard equipment at the maximum and minimum states of the input port voltage of the onboard equipment.
4.1.2.2.5	Transient voltage characteristics of primary power supply bus	Take measurement of the disturbance at the steady state associated with the on/off status of the large electric power load.	(Power supply system) Take measurement of the bus voltage behavior due to the on/off status, quasi-short circuit of dummy load, etc. (Electrical consuming equipment) Disturbances in the nominal state shall be tested as the EMC testing.

Item in Chapter 4		System test (including when assembling the system)	Onboard equipment test (including when assembling the onboard equipment)
4.1.2.2.6	ODC bus	Take measure of the ignition current/ignition time, etc. under the dummy pyrotechnic load. As the test condition, it shall be conducted under the max./min. conditions of supply voltage and max./min. conditions of the load. Confirm the ignition function with the actual pyrotechnic.	(Ignition controller) Take measurement of the ignition current/ignition time, etc. under the dummy pyrotechnic load. As the test condition, it shall be carried out under the max./min. conditions of input voltage and max./min. conditions of the load.
4.2, 4.3	Command HK data	Confirmation about transmission of overall command Confirmation of command waveform Confirmation about reception of overall HK data	(Onboard equipment of DH system) Confirmation by using a load dummy (Electrical consuming equipment) Confirmation by using the simulator for onboard equipment of DH system
4.6.6.2	Protection by over current shutdown circuit		Confirmation of over current protection characteristics

Appendix A (informative): Outline of the electrical design criteria template for scientific spacecrafts, etc.

A.1 Objectives of this template

This document shows the necessary requirements to carry out electrical design for scientific spacecrafts, which considers the electrical interface, best practice and notes when developing such equipment that include new technology, and those equipment frequently applied.

Fig. A shows the framework of this document. It is also necessary for a project to refer to the corresponding design such standard, as power generation, electrical storage, and communication mainly related to bus equipment, the standard relating to optical equipment, and the EMC design standard.

Also, this standard shall be prior to other document, which describes any duplication, etc.

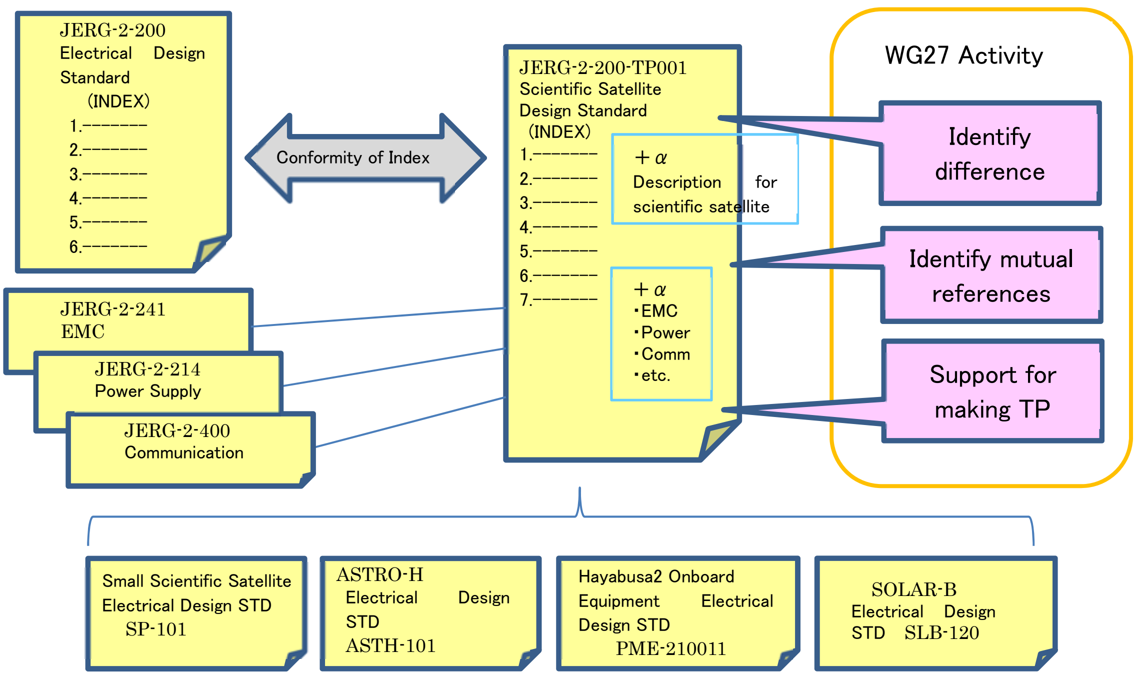


Fig. A-1: Configuration of the electrical design standard for scientific spacecrafts

A.2: About the requirement descriptions in the design standard (Where is the requirement written?)

Fig. A-2 shows the configuration of the spacecraft and onboard equipment assumed in this document, which describes in some clauses the requirements as system, subsystem, and onboard equipment, and shows in other clauses the wire harness, connector, and parts according to their necessity.

Such requirements regarding grounding and insulation, antistatic, and EMC, are shown as system, subsystem, and the onboard equipment, and in this document are as follows;

- Grounding and insulation
  4.6.3 shows the requirements for the system, subsystem, and onboard equipment, which is related existing JERG-2-213 Insulation design standard.
- Antistatic
  4.6.4 "Antistatic in the low vacuum environment," refers to JERG-2-211 Electrostatic charge & electric discharge design standard, which are the requirements for system, subsystem, equipment, etc. under the exposed environment.
- EMC
  Clause 5.2 "EMC" shows requirements for the system, subsystem, and onboard equipment, which is related to existing JERG-2-241 EMC design standard.
  Regarding the derating, the targets of requirements are the wire harness, connector, and parts, and in this document, the requirements are shown below.
- Derating
  The requirements are shown in 4.6.1 "Wire harnesses," 4.6.2 "Connectors," and 5.1.3 "Parts", which is related to JERG-2-212 Wire derating design standard.

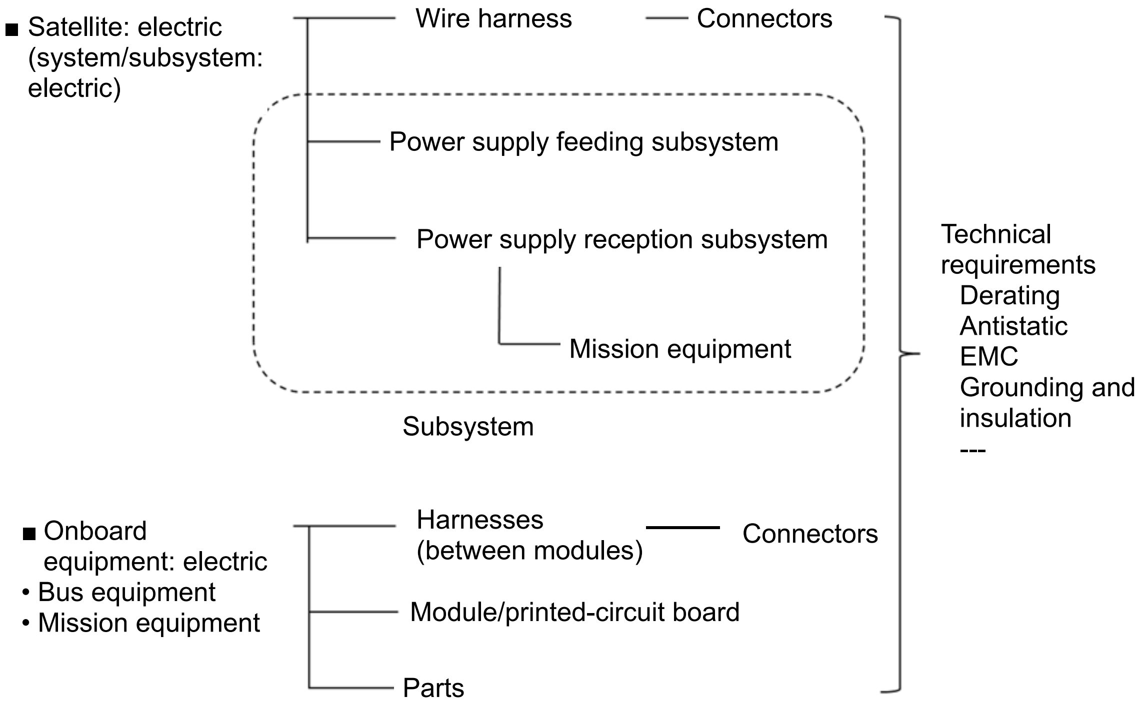


Fig. A-2: Configuration of the spacecraft and onboard equipment presupposed in the electrical design standard for scientific spacecraft

A.3: Outline of comparison between new version and old version of standards

In developing this Template for Electrical Design Criteria, various electric standards of the space science projects were studies in a cross-sectional manner. This document is outlined according to the index of the electrical design standard (JERG-2-200).

[1] JERG-2-200A Electrical design standard

[2] JERG-2-200-TP001 Template for Electrical Design Criteria

[3] JERG-2-020 Previous Electrical design standard for scientific spacecrafts

JERG-2-200-TP001 is compiled to correspond the index of the electrical design standard (JERG-2-200A). Furthermore, those requirements described in previous JERG-2-020, which are not described in JERG-2-200A, have been discussed in JAXA Design Standard Working Groupe #27; The electrical design criteria for scientific spacecraft, and the table of contents of [2] have been coordinated, and some clause numbers have been added or designated as vacant numbers.