



Space engineering

Electrical design and interface requirements for actuators

Foreword

This Standard is one of the series of ECSS Standards intended to be applied together for the management, engineering, product assurance and sustainability in space projects and applications. ECSS is a cooperative effort of the European Space Agency, national space agencies and European industry associations for the purpose of developing and maintaining common standards. Requirements in this Standard are defined in terms of what shall be accomplished, rather than in terms of how to organize and perform the necessary work. This allows existing organizational structures and methods to be applied where they are effective, and for the structures and methods to evolve as necessary without rewriting the standards.

This Standard has been prepared by the ECSS-E-ST-20-21C Working Group, reviewed by the ECSS Executive Secretariat and approved by the ECSS Technical Authority.

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Change log

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Introduction

This standard identifies the requirements needed to specify, procure or develop the electronics needed for driving release actuators (both explosive like pyrotechnic devices or non-explosive like thermal knives) and gives the relevant electrical interface specification, both from source and load perspective.

The present standard covers explosive or non-explosive actuators electronics required to comply with single fault tolerance with respect to actuation success.

For a reference architecture description, it is possible to refer to ECSS-E-HB-20-21.

ECSS-E-HB-20-21 includes a clarification of the principles of operation of the actuator electronics, identifies important issues related to actuators and explains the requirements of the present standard.

1 Scope

In general terms, the scope of the consolidation of the electrical interface requirements for electrical (hold down and release or deployment) actuators in the present ECSS-E-ST-20-21 and the relevant explanation in the handbook ECSS-E-HB-20-21 is to allow a more recurrent approach both for actuator electronics (power source) and electrical actuators (power load) offered by the relevant manufacturers, at the benefit of the system integrators and of the Agency, thus ensuring:

- better quality,
- stability of performances, and
- independence of the products from specific mission targets.

A recurrent approach enables manufacturing companies to concentrate on products and a small step improvement approach that is the basis of a high quality industrial output.

2

Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this ECSS Standard. For dated references, subsequent amendments to, or revision of any of these publications do not apply. However, parties to agreements based on this ECSS Standard are encouraged to investigate the possibility of applying the more recent editions of the normative documents indicated below. For undated references, the latest edition of the publication referred to applies.

ECSS-S-ST-00-01	ECSS system - Glossary of terms
ECSS-Q-ST-30-02	Space product assurance - Failure modes, effects (and criticality) analysis (FMEA/FMECA)
ECSS-E-ST-33-11	Space engineering - Explosive subsystems and devices

3

Terms, definitions and abbreviated terms

3.1 Terms from other standards

- a. For the purpose of this document, the terms and definitions from ECSS-S-ST-00-01 apply, in particular for the following terms:
 1. redundancy
 2. active redundancy
 3. hot redundancy
 4. cold redundancy
 5. fault
 6. fault tolerance
- b. For the purpose of this document, the terms and definitions ECSS-Q-ST-30-02 apply, in particular for the following terms:
 1. failure propagation
- c. For the purpose of this document, the terms and definitions from ECSS-E-ST-33-11 apply, in particular for the following terms:
 1. no fire
 2. all fire

3.2 Terms specific to the present standard

3.2.1 actuator

<CONTEXT: electrical actuator> component of a machine that is responsible for triggering the movement of a mechanism or a system

3.2.2 actuator electronics

electronics supplying an actuator

3.2.3 actuators group

set of actuators sharing the same ARM and the same FIRE block

NOTE The term “actuators group” is synonymous to the term “group” in this standard

3.2.4 all-fire current

current giving a probability of actuation higher than a specified limit, at a confidence level higher of a specified limit

3.2.5 no-fire current

current giving a probability of actuation lower than a specified limit, at a confidence level higher than a specified limit

3.2.6 maximum fire current

maximum current allowed in an actuator in nominal conditions

3.2.7 minimum actuation current

all-fire current plus a margin defined by the system integrator

NOTE The current margin is calculated to guarantee in worst case the required reliability with a given confidence level when the actuation time is above the minimum actuation time.

3.2.8 minimum actuation time

actuation time in the all-fire current reference conditions, plus a margin established by the manufacturer or by the system integrator

NOTE The margin is calculated to guarantee in worst case the required reliability with a given confidence level when the actuation current is above the minimum actuation current.

3.2.9 inhibition strap

hardware feature that does not allow firing of the actuator

NOTE The inhibition strap typically contains a connector and one of more wires to ensure continuity until strap is opened.

3.2.10 current-driven actuator

actuator that is commanded by a current pulse within a certain range of values and duration

3.2.11 voltage-driven actuator

actuator that is commanded by a voltage pulse within a certain range of values and duration

3.2.12 short duration actuator

actuator with actuation duration lasting less than or equal to 1 s

3.2.13 long duration actuator

actuator with actuation duration lasting more than 1 s

3.3 Abbreviated terms

For the purpose of this Standard, the abbreviated terms and symbols from ECSS-S-ST-00-01 and the following apply:

Abbreviation	Meaning
DC	direct current
EEE	electrical, electronic and electromechanical
FMEA	failure modes and effects analysis
FMECA	failure modes, effects and criticality analysis
RoD	review of design
SSE	space segment element
SSS	space segment subsystem

3.4 Nomenclature

The following nomenclature applies throughout this document:

- a. The word “shall” is used in this Standard to express requirements. All the requirements are expressed with the word “shall”.
- b. The word “should” is used in this Standard to express recommendations. All the recommendations are expressed with the word “should”.

NOTE It is expected that, during tailoring, recommendations in this document are either converted into requirements or tailored out.

- c. The words “may” and “need not” are used in this Standard to express positive and negative permissions, respectively. All the positive permissions are expressed with the word “may”. All the negative permissions are expressed with the words “need not”.
- d. The word “can” is used in this Standard to express capabilities or possibilities, and therefore, if not accompanied by one of the previous words, it implies descriptive text.

NOTE In ECSS “may” and “can” have completely different meanings: “may” is normative (permission), and “can” is descriptive.

- e. The present and past tenses are used in this Standard to express statements of fact, and therefore they imply descriptive text.

4 Principles

4.1 Standard assumptions

- a. This standard applies to satellites and does not apply to launchers and human space flight applications.
- b. According to requirement 4.4g of ECSS-E-ST-33-11 this standard covers explosive or non-explosive actuators electronics required to comply with single fault tolerance with respect to actuation success.
- c. Interfaces to electrical motors (for example solar array drive mechanisms, reaction wheels, other mechanisms) are not covered by the present standard.
- d. It is assumed that the two fault tolerance approach (as per ECSS-Q-ST-40 clause 6.4.2.1), with respect to premature and unwanted actuation having catastrophic consequences, when required according to requirement 4.4h of ECSS-E-ST-33-11, is implemented as a system (SSE and SSS) level provision and not at equipment level. See ECSS-E-HB-20-21 section 5.5.1.
- e. Current-driven actuators covered by this standard have an inductance of 1 μ H max, not including harness.
- f. Voltage-driven actuators covered by this standard have an inductance of 20 mH max.
- g. The actuators electronics nominal input voltage, (excluding transients, is assumed to be within a range of 21 V to 100 V.

4.2 Verification

The indicated requirements verification (see Annex A) identifies the overall applicable methods to confirm compliance to the requirements, without explicitly explaining how the verification is split at applicability level (equipment, SSE, SSS or any combination thereof).

5 Requirements

5.1 Functional general interface requirements

5.1.1 General

- a. For an actuation sequence, the FIRE event shall be contained within the SELECT event of the specific actuator line i ($i=1\dots n$).
- b. The SELECT event shall be contained within the ARM event.
- c. With regards to actuation sequence, the selection of different SELECT lines may be executed within the same ARM event, but with different FIRE pulses occurrences.
- d. An end to end test shall be performed to ensure that the actuator pulses are effectively present at actuator interface when a system level verification is done.

NOTE The end to end test is performed with the actual flight actuator if resettable and safe. Alternatively, it is performed with a flight representative actuator or – if not possible for safety or practical reasons – with a load of the same impedance as the flight actuator.

5.1.2 Reliability

- a. No single failure shall result in unwanted actuator firing.

NOTE For example, in the configuration where one actuation electronic failure can lead to unwanted actuation, leading to catastrophic consequences, the selection switch status is processed by the system to avoid unwanted actuation.

- b. In case over-current protections are not provided by the Power Conversion and Distribution Electronics, Actuator Electronics failures, including relevant harness and connector lines, shall not cause short circuit or overload of input power lines.
- c. The system engineering function shall analyse the effect of anomalies in the selection configuration, and use the SELECT statuses information not

to start execution of the FIRE command to the nominal or redundant actuator electronics to avoid catastrophic or undesired consequences.

NOTE See ECSS-HB-20-21 section 5.5.2 and requirement 5.2.2h of the standard.

5.2 Functional source interface requirements

5.2.1 General

- a. Actuator electronics shall implement at least three independent safety barriers ARM, SELECT and FIRE necessary to be released before a deployment device is actuated.
- b. The design of the actuator electronics shall allow testing the functionality of each single barrier.
- c. ARM, FIRE and SELECT switching functions shall be located in the hot power line of the actuation path.
- d. The actuator electronic shall control the FIRE actuation duration as specified in requirements 5.2.2j, 5.2.3f, 5.3.1c and 5.6.3b.
- e. Dedicated connectors dedicated to the actuators electronics outputs shall be implemented.
- f. At power up, the three stages barriers shall be in open state.
- g. Each initiator power line shall be distributed to the relevant user with dedicate return wire except for non-explosive actuators implemented on satellites with power return on structure.

5.2.2 Reliability

- a. To comply with single fault tolerance, with respect to ability to perform the desired activation, the Actuator Electronics shall be duplicated in a Nominal and a Redundant section.

NOTE Including duplication (nominal and redundant) of all relevant commands and telemetries.

- b. With respect to the needed level of segregation among nominal and redundant sides of electrical actuator circuits, no common failure mechanism between nominal and redundant part shall exist.
- c. No single failure in the actuator electronics shall cause more than one of the safety barriers to be spuriously or permanently enabled.
- d. The actuator electronics shall meet one of the two conditions:
 1. Disconnect both the hot and the return lines to the actuators when ARM and SELECT lines are disabled, or
 2. Comply with 5.2.2e.1 and 5.2.2e.2.

- e. In case the return lines to the actuators cannot be disconnected as specified in 5.2.2d, then two following conditions shall be met to avoid failure propagation due to loss of insulation:
 - 1. The relevant actuator group does not share connectors with other groups or with other electronic functions having source capability to trigger the relevant actuators.
 - 2. The harness of the relevant actuator group are not bundled together with any other wire or bundle carrying a positive or negative potential sufficient to trigger the relevant actuators.
- f. The Actuator Electronics shall not be stressed in case of an output short circuit.
- g. To ensure that no other selector is in short circuit failure and therefore that no unwanted actuation is taking place, the actuator electronics shall allow the possibility to check the SELECT statuses before issuing the FIRE command.
- h. Any line that remains floating shall be connected to structure ground internally to the actuator electronics via bleeding resistors 100 k Ω to 1 M Ω .
- i. Insulation among actuator output lines shall be tested.
- j. No single failure in the actuator electronic shall lead to the loss at the same time of the current or voltage limitation and of the actuation duration control.
- k. No cross-strapping shall be present between electronics of nominal and redundant actuators chains.

5.2.3 Commands

- a. Nominal and redundant actuator electronics shall accept commands from both nominal and redundant command chain.
- b. ARM, FIRE and SELECT switching shall be actuated by separate commands.
- c. The commands for ARM and for SELECT/FIRE shall follow completely independent physical paths, such that no single failure in the complete command chain can result in a fire action.

NOTE For example, ARM enable is driven by high power command while SELECT, FIRE and ARM disable are driven by serial command interface.

- d. The activation of the ARM switch shall be performed:
 - 1. By direct execution of a dedicated and independent command.
 - 2. Without any other interaction from an actuator electronic function.

NOTE Req. 5.2.3d.2 stresses that within the actuator electronics there is no additional logical conditioning of the signal leading to the activation of the ARM switch.

- e. The activation of the SELECT and FIRE switches should be performed by execution of standard serial commands.
- f. For long duration actuators, in addition to 5.2.1d, the FIRE OFF commands should be implemented by a standard serial interface.
- g. The fire commands of the actuator electronics shall be inhibited by dedicated external inhibition straps.

NOTE strap closed equals to commands disable,
strap open equals to commands enable.

5.2.4 Telemetry

- a. Telemetries from the nominal and the redundant actuator electronics shall be provided to both the nominal and the redundant acquisition chain.
- b. The actuator electronics shall provide the indication of the status of each selection switch.
- c. Status telemetries shall indicate the effective condition of the relevant functionality and not provide indirect information.

NOTE 1 Effective condition includes for example state when the switch is effectively ON or OFF, if the line is effectively enabled or disabled, etc.

NOTE 2 For example, in case there is only one selection switch per line, the circuitry providing status of the selection switch is fully independent from the monitored circuit.

NOTE 3 In case a relay is used, spare contacts are used to provide direct status information.

- d. For short duration actuators, the actuator electronics shall provide a peak firing status which is valid when the monitored firing current is larger than a threshold of 20 % to 80 % of the expected firing current during a period of time greater than 0,5 ms to 10 ms.

NOTE The exact current threshold and time duration are established by trimming in the actual application.

- e. For long duration actuators, a current and voltage telemetry shall be provided.
- f. The status of each inhibition strap shall be available as a standard telemetry of the actuator electronics.

NOTE Standard telemetry of the actuator electronics is for example serial standard telemetry.

- g. For on-ground test purposes the status of each inhibition strap shall be available from the actuator electronics as a physical connection or disconnection.
- h. One status telemetry shall be provided for the nominal inhibition strap, and another for the redundant one.

- i. A short circuit between the output of the actuator electronics and the ground or structure shall not affect the validity of the telemetry of the actuated line.
- j. A status telemetry should be provided via serial telemetry line, to identify if nominal output current or voltage ranges have been exceeded.
- k. If requirement 5.2.4j is applied, the following conditions shall be fulfilled:
 - 1. The requested status is based on a latch to identify the abnormal conditions even at the end of the firing.
 - 2. The status latch is resettable through serial command.

5.3 Functional load interface requirements

5.3.1 General

- a. For current-driven actuators the following shall be specified:
 - 1. The no-fire current and the relevant duration,
 - 2. The maximum fire current,
 - 3. The all-fire current.
- b. For voltage-driven actuators, the voltage range for all fire action shall be specified.
- c. The minimum all fire actuation time shall be specified.

5.3.2 Reliability

- a. The nominal and redundant electrical actuator paths shall be independent such that no failure mechanism can cause the loss of the actuation function.
- b. Any abnormal voltage or current emission applied on the nominal respectively redundant electrical interface of the actuator shall not propagate failure to the redundant respectively nominal electrical interface.

NOTE See actual limit specified in requirements 5.5.2a and 5.5.2b.

5.4 Performance general interface requirements

5.4.1 General

- a. For current-driven actuators, one of the following two conditions shall be met:
 - 1. If the actuator maximum resistance as per requirement 5.6.1a is specified, the actuators electronics is able to provide the specified

- current when the load resistance, including actuator plus harness, is equal to the maximum value not to exceed the voltage as per requirement 5.5.1b.
2. Otherwise, the system ensures that the minimum current and voltage as qualified is applied at actuator level.
- b. For voltage-driven actuators, the maximum overall harness resistance of the actuator line shall guarantee that the voltage into the actuator is above the specified limit.
 - c. Parasitic capacitance to structure seen by the actuator electronics, load plus relevant harness, shall be limited to 1 μF .
 - d. Parasitic inductance seen by the actuator electronics (load plus relevant harness) shall be limited to
 1. 10 μH for current-driven actuators
 2. 20 mH for voltage-driven actuators.
 - e. The current timing profile for voltage-driven actuators shall be provided by the system integrator.

5.5 Performance source interface requirements

5.5.1 General

- a. The nominal current delivered to an actuator shall be verified within the specified limits.
- b. For current-driven actuators, the output maximum voltage, at which the minimum actuation current is guaranteed, shall be specified.
- c. For current-driven actuators, the minimum margin of electronics actuator current on top of “all-fire current” shall be established to calculate the minimum actuation current.
- d. Any monitor current in an actuator system fire line shall be limited to 5 mA.
- e. The total leakage current of an armed, selected, but not fired, deployment actuator power outlet shall not exceed 5 mA.
- f. The leakage current to any unselected actuator output line (hot side) to the relevant return shall be lower than 1 mA while any other output line is fired.

5.5.2 Reliability

- a. For voltage-driven actuators, the abnormal output voltage emission of the actuator electronics shall be limited by the voltage of the input power source of the actuator electronics.
- b. For current-driven actuators, the maximum fault current emission from the actuator electronics to the actuator shall not exceed two times the maximum nominal specified value according to requirement 5.3.1a.2.

5.5.3 Telemetry

- a. For long duration actuators, the current and voltage telemetries should be provided with 8 Hz sample rate or higher.
- b. If requirement 5.2.4j is applicable, a status telemetry shall be provided via serial telemetry line, to identify if nominal current or voltage ranges have been exceeded by 10 % to 50 % of their maximum nominal value.

5.5.4 Recurrent products

- a. The power output capability of a generic design of actuator electronics should be 50 W DC.
- b. For current-driven actuators, the actuator electronics should supply a current up to 6 A.

NOTE Specific current capability is trimmed in production.

- c. For current-driven actuators, the actuator electronics should supply the requested current during duration up to 100 ms.

NOTE Specific current pulse duration is trimmed in production.

- d. For voltage-driven actuators, the actuator electronics should supply a voltage with an initial set point selectable from 19 V to 21 V, and with an overall accuracy of ± 1 V, providing the current is lower than the limit defined in requirement 5.5.4e.

NOTE Specific voltage capability is trimmed in production.

- e. For voltage-driven actuators, the actuator electronics should limit the maximal current to one actuator to 2,5 A.
- f. For voltage-driven actuators, the actuator electronics should be able to supply the requested current during an indefinite duration.
- g. The current-driven actuator electronics should be able to support a repetition rate for FIRE pulses down to 100 ms.

5.6 Performance load interface requirements

5.6.1 General

- a. The maximum actuator resistance shall be specified in the operative conditions range, including temperature.
- b. The maximum actuator resistance need not be specified if the actuators qualification conditions, meaning the minimum voltage source to get all-fire current, is specified.

NOTE To specify, or otherwise, the maximum actuator resistance has an impact on

requirements for current-driven actuators,
see 5.4.1a.

- c. No-fire current shall be greater than 50 mA.

5.6.2 Reliability

- a. It shall be possible to apply to the nominal, respectively redundant, actuator voltages up to the ones applicable to the input of the actuator electronics without affecting the functionality and performance of the redundant, respectively nominal, actuator.

NOTE See assumption in 4.1g.

5.6.3 Recurrent products

- a. For current-driven actuators, the actuator all-fire current should be lower than 5 A.
- b. For short duration actuators, the actuator minimum all fire actuation time should be lower than 50 ms.
- c. For voltage-driven actuators, the minimum voltage for all fire action should be lower than 19 V with a current lower than 2,5 A respecting duration specified according requirement 5.3.1c.
- d. The maximum inductance of voltage-driven actuators should be 20 mH.
- e. The maximum inductance of current-driven actuators should be 1 μ H.
- f. The maximum capacitance of actuators should be 1 μ F.

Annex A (informative)

Requirements mapping

Table A-1 to Table A-6 provide a compact view of the requirements of the present standard, including the verification method suggested for each of them. According to ECSS-E-ST-10-02, the verification is accomplished by one or more of the following verification methods:

- Test (T),
- Analysis (A),
- Review-of-design (RoD), and
- Inspection (I).

In addition to the methods of verification specified in ECSS-E-ST-10-02, the present annex includes the test verification at design qualification level (T*).

The test verification at design qualification level (T*) is intended to be performed on a representative version of the hardware, on a set up not necessarily equal to the final flight one, to be established by the relevant manufacturer or user.

NOTE If not stated otherwise, any reference to the handbook inside the tables, is a reference to ECSS-E-HB-20-21.

The suggested applicability level indicated in Table A-1 to Table A-6 is intended in logical "and" and in logical "or" option (SSE and/or SSS and/or Equipment).

In the title row of tables Table A-1 to Table A-6,

- "Conditions" identify in which condition (nominal, failure or nominal/failure) the requirement apply;
- "Applicability" identify to which type of actuators the requirement is applicable (all, short duration actuators, long duration actuators, current-driven actuators or voltage-driven actuators);
- "Applicability level" identifies if the requirement applies to equipment, SSS, SSE level or combinations thereof.

Table A-1: Functional general requirements list

Ref.	Paragraph	Text of the requirement	Conditions	Applicability	Applicability level	Verification
A = analysis		T = test				
RoD = review of design		T* = test verification at design qualification level				
5.1.1a	General	For an actuation sequence, the FIRE event shall be contained within the SELECT event of the specific actuator line i (i=1...n).	Nominal	All	SSE/SSS/Equipment	T
5.1.1c	General	The SELECT event shall be contained within the ARM event.	Nominal	All	SSE/SSS/Equipment	T
5.1.1c	General	An end to end test shall be performed to ensure that the actuator pulses are effectively present at actuator interface when a system level verification is done.	Nominal	All	SSE/SSS/Equipment	T
5.1.1d	General	An end to end test shall be performed to ensure that the actuator pulses are effectively present at actuator interface when a system level verification is done.	Nominal	All	SSE/SSS	T
5.1.2a	Reliability	No single failure shall result in unwanted actuator firing. NOTE For example, in the configuration where one actuation electronic failure can lead to unwanted actuation, leading to catastrophic consequences, the selection switch status is processed by the system to avoid unwanted actuation.	Failure	All	SSE/SSS/Equipment	RoD, A
5.1.2b	Reliability	In case over-current protections are not provided by the Power Conversion and Distribution Electronics, Actuator Electronics failures, including relevant harness and connector lines, shall not cause short circuit or overload of input power lines.	Failure	All	SSS/Equipment	A

Ref.	Paragraph	Text of the requirement	Conditions	Applicability	Applicability level	Verification
A = analysis		T = test				
RoD = review of design		T* = test verification at design qualification level				
5.1.2c	Reliability	The system engineering function shall analyse the effect of anomalies in the selection configuration, and use the SELECT statuses information not to start execution of the FIRE command to the nominal or redundant actuator electronics to avoid catastrophic or undesired consequences. NOTE See ECSS-HB-20-21 section 5.5.2 and requirement 5.2.2h of the standard.	Failure	All	SSE	A

Table A-2: Functional source requirements list

Ref.	Paragraph	Text of the requirement	Conditions	Applicability	Applicability level	Verification
A = analysis		T = test				
RoD = review of design		T* = test verification at design qualification level				
5.2.1a	General	Actuator electronics shall implement at least three independent safety barriers ARM, SELECT and FIRE necessary to be released before a deployment device is actuated.	Nominal	All	SSS/Equipment	RoD
5.2.1b	General	The design of the actuator electronics shall allow testing the functionality of each single barrier.	nominal	all	SSE/SSS/Equipment	RoD, T
5.2.1c	General	ARM, FIRE and SELECT switching functions shall be located in the hot power line of the actuation path.	Nominal	All	Equipment	RoD
5.2.1d	General	The actuator electronic shall control the FIRE actuation duration as specified in requirements 5.2.2j, 5.2.3f, 5.3.1c and 5.6.3b.	Nominal	All	SSS/Equipment	RoD
5.2.1e	General	Dedicated connectors dedicated to the actuators electronics outputs shall be implemented.	Nominal	All	SSS/Equipment	RoD
5.2.1f	General	At power up, the three stages barriers shall be in open state.	Nominal	All	SSS/Equipment	RoD, T
5.2.1g	General	Each initiator power line shall be distributed to the relevant user with dedicate return wire except for non-explosive actuators implemented on satellites with power return on structure.	Nominal	All	SSE/SSS/Equipment	RoD
5.2.2a	Reliability	To comply with single fault tolerance, with respect to ability to perform the desired activation, the Actuator Electronics shall be duplicated in a Nominal and a Redundant section.	Failure	All	Equipment	RoD

Ref.	Paragraph	Text of the requirement	Conditions	Applicability	Applicability level	Verification
A = analysis		T = test				
RoD = review of design		T* = test verification at design qualification level				
5.2.2a	Reliability	<p>To comply with single fault tolerance, with respect to ability to perform the desired activation, the Actuator Electronics shall be duplicated in a Nominal and a Redundant section.</p> <p>NOTE</p> <p>Including duplication (nominal and redundant) of all relevant commands and telemetries.</p>	Failure	All	Equipment	RoD
5.2.2b	Reliability	With respect to the needed level of segregation among nominal and redundant sides of electrical actuator circuits, no common failure mechanism between nominal and redundant part shall exist.	Failure	All	Equipment	RoD, A
5.2.2c	Reliability	No single failure in the actuator electronics shall cause more than one of the safety barriers to be spuriously or permanently enabled.	Failure	All	SSS/Equipment	RoD, A
5.2.2d	Reliability	<p>The actuator electronics shall meet one of the two conditions:</p> <p>1.Disconnect both the hot and the return lines to the actuators when ARM and SELECT lines are disabled, or</p> <p>2.Comply with 5.2.2e.1 and 5.2.2e.2.</p>	Nominal	All	Equipment	RoD, T

Ref.	Paragraph	Text of the requirement	Conditions	Applicability	Applicability level	Verification
A = analysis		T = test				
RoD = review of design		T* = test verification at design qualification level				
5.2.2e	Reliability	<p>In case the return lines to the actuators cannot be disconnected as specified in 5.2.2d, then two following conditions shall be met to avoid failure propagation due to loss of insulation:</p> <p>1.The relevant actuator group does not share connectors with other groups or with other electronic functions having source capability to trigger the relevant actuators.</p> <p>2.The harness of the relevant actuator group are not bundled together with any other wire or bundle carrying a positive or negative potential sufficient to trigger the relevant actuators.</p>	Nominal	All	1. SSE/SSS/Equipment 2. SSE/SSS	RoD
5.2.2f	Reliability	The Actuator Electronics shall not be stressed in case of an output short circuit.	Nominal / Failure	All	Equipment	A, T
5.2.2g	Reliability	To ensure that no other selector is in short circuit failure and therefore that no unwanted actuation is taking place, the actuator electronics shall allow the possibility to check the SELECT statuses before issuing the FIRE command.	Nominal / Failure	All	SSS/Equipment	T
5.2.2h	Reliability	Any line that remains floating shall be connected to structure ground internally to the actuator electronics via bleeding resistors 100 kΩ to 1 MΩ.	Nominal	All	Equipment	RoD, T
5.2.2i	Reliability	Insulation among actuator output lines shall be tested	Nominal	All	SSE/Equipment	T

Ref.	Paragraph	Text of the requirement	Conditions	Applicability	Applicability level	Verification
A = analysis		T = test				
RoD = review of design		T* = test verification at design qualification level				
5.2.2j	Reliability	No single failure in the actuator electronic shall lead to the loss at the same time of the current or voltage limitation and of the actuation duration control.	Nominal	All	Equipment	A
5.2.2k	Reliability	No cross-strapping shall be present between electronics of nominal and redundant actuators chains.				
5.2.3a	Commands	Nominal and redundant actuator electronics shall accept commands from both nominal and redundant command chain.	Nominal	All	SSE/SSS/Equipment	RoD, T
5.2.3b	Commands	ARM, FIRE and SELECT switching shall be actuated by separate commands.	Nominal	All	SSE	RoD
5.2.3c	Commands	<p>The commands for ARM and for SELECT/FIRE shall follow completely independent physical paths, such that no single failure in the complete command chain can result in a fire action.</p> <p>NOTE</p> <p>For example, ARM enable is driven by high power command while SELECT, FIRE and ARM disable are driven by serial command interface.</p>	Nominal / Failure	All	SSE/SSS/Equipment	RoD, A

Ref.	Paragraph	Text of the requirement	Conditions	Applicability	Applicability level	Verification
A = analysis		T = test				
RoD = review of design		T* = test verification at design qualification level				
5.2.3d	Commands	<p>The activation of the ARM switch shall be performed:</p> <ol style="list-style-type: none"> 1. By direct execution of a dedicated and independent command. 2. Without any other interaction from an actuator electronic function. <p>NOTE</p> <p>Req. 5.2.3d.2 stresses that within the actuator electronics there is no additional logical conditioning of the signal leading to the activation of the ARM switch.</p>	Nominal	All	SSS/Equipment	RoD
5.2.3e	Commands	The activation of the SELECT and FIRE switches should be performed by execution of standard serial commands.	Nominal	All	SSE/SSS	RoD
5.2.3f	Commands	For long duration actuators, in addition to 5.2.1d, the FIRE OFF commands should be implemented by a standard serial interface.	nominal	all	SSS/Equipment	RoD, T
5.2.3g	Commands	<p>The fire commands of the actuator electronics shall be inhibited by dedicated external inhibition straps.</p> <p>NOTE</p> <p>strap open equals to commands enable.</p>	Nominal	All	SSE/SSS/Equipment	RoD/T
5.2.4a	Telemetry	Telemetries from the nominal and the redundant actuator electronics shall be provided to both the nominal and the redundant acquisition chain.	Nominal	All	SSE/SSS/Equipment	RoD, T

Ref.	Paragraph	Text of the requirement	Conditions	Applicability	Applicability level	Verification
A = analysis		T = test				
RoD = review of design		T* = test verification at design qualification level				
5.2.4b	Telemetry	The actuator electronics shall provide the indication of the status of each selection switch.	Nominal / Failure	All	SSS/Equipment	RoD, T
5.2.4c	Telemetry	<p>Status telemetries shall indicate the effective condition of the relevant functionality and not provide indirect information.</p> <p>NOTE1 Effective condition includes for example state when the switch is effectively ON or OFF, if the line is effectively enabled or disabled, etc.</p> <p>NOTE2 For example, in case there is only one selection switch per line, the circuitry providing status of the selection switch is fully independent from the monitored circuit.</p> <p>NOTE3 In case a relay is used, spare contacts are used to provide direct status information.</p>	Nominal / Failure	All	SSS/Equipment	RoD
5.2.4d	Telemetry	<p>For short duration actuators, the actuator electronics shall provide a peak firing status which is valid when the monitored firing current is larger than a threshold of 20 % to 80 % of the expected firing current during a period of time greater than 0,5 ms to 10 ms.</p> <p>NOTE</p> <p>The exact current threshold and time duration are established by trimming in the actual application.</p>	Nominal / Failure	Short duration actuators	SSS/Equipment	RoD, A, T
5.2.4e	Telemetry	For long duration actuators, a current and voltage telemetry shall be provided.	Nominal / Failure	Long duration actuators	SSS/Equipment	RoD, T

Ref.	Paragraph	Text of the requirement	Conditions	Applicability	Applicability level	Verification
A = analysis		T = test				
RoD = review of design		T* = test verification at design qualification level				
5.2.4f	Telemetry	The status of each inhibition strap shall be available as a standard telemetry of the actuator electronics. NOTE Standard telemetry of the actuator electronics is for example serial standard telemetry.	Nominal	All	SSS/Equipment	RoD/T
5.2.4g	Telemetry	For on-ground test purposes the status of each inhibition strap shall be available from the actuator electronics as a physical connection or disconnection.	Nominal	All	SSS/Equipment	RoD/T
5.2.4h	Telemetry	One status telemetry shall be provided for the nominal inhibition strap, and another for the redundant one.	Nominal	All	SSS/Equipment	RoD
5.2.4i	Telemetry	A short circuit between the output of the actuator electronics and the ground or structure shall not affect the validity of the telemetry of the actuated line.	Nominal	All	SSS/Equipment	A,T
5.2.4j	Telemetry	A status telemetry should be provided via serial telemetry line, to identify if nominal output current or voltage ranges have been exceeded.	nominal / failure	All	SSS/Equipment	RoD, T
5.2.4k	Telemetry	If requirement 5.2.4j is applied, the following conditions shall be fulfilled: 5.2.4k.1.The requested status is based on a latch to identify the abnormal conditions even at the end of the firing. 2.The status latch is resettable through serial command.	nominal / failure	All	SSS/Equipment	RoD, T

Table A-3: Functional load requirements list

Ref.	Paragraph	Text of the requirement	Conditions	Applicability	Applicability level	Verification
A = analysis RoD = review of design		T = test T* = test verification at design qualification level				
5.3.1a	General	For current-driven actuators the following shall be specified: 1.The no-fire current and the relevant duration, 2.The maximum fire current, 3.The all-fire current.	Nominal	Current-driven actuators	Equipment	RoD
5.3.1b	General	For voltage-driven actuators, the voltage range for all fire action shall be specified.	Nominal	Voltage-driven actuators	Equipment	RoD
5.3.1c	General	The minimum all fire actuation time shall be specified.	Nominal	All	Equipment	RoD
5.3.2a	Reliability	The nominal and redundant electrical actuator paths shall be independent such that no failure mechanism can cause the loss of the actuation function.	Nominal/Failure	All	Equipment	RoD, A
5.3.2b	Reliability	Any abnormal voltage or current emission applied on the nominal respectively redundant electrical interface of the actuator shall not propagate failure to the redundant respectively nominal electrical interface. NOTE See actual limit specified in requirements 5.5.2a and 5.5.2b.	Failure	All	Equipment	T*

Table A-4: Performance general requirements list

Ref.	Paragraph	Text of the requirement	Conditions	Applicability	Applicability level	Verification
A = analysis RoD = review of design		T = test T* = test verification at design qualification level				
5.4.1a	General	For current-driven actuators, one of the following two conditions shall be met: 1.If the actuator maximum resistance as per requirement 5.6.1a is specified, the actuators electronics is able to provide the specified current when the load resistance, including actuator plus harness, is equal to the maximum value not to exceed the voltage as per requirement 5.5.1b. 2.Otherwise, the system ensures that the minimum current and voltage as qualified is applied at actuator level.	Nominal	Current-driven actuators	SSE/SSS/Equipment	A,T
5.4.1b	General	For voltage-driven actuators, the maximum overall harness resistance of the actuator line shall guarantee that the voltage into the actuator is above the specified limit.	Nominal	Voltage-driven actuators	SSS/SSE	A,T
5.4.1c	General	Parasitic capacitance to structure seen by the actuator electronics, load plus relevant harness, shall be limited to 1 μ F.		All	SSS/SSE	A
5.4.1d	General	Parasitic inductance seen by the actuator electronics (load plus relevant harness) shall be limited to 1.10 μ H for current-driven actuators 2.20 mH for voltage-driven actuators.		All	SSS/SSE	A
5.4.1e	General	The current timing profile for voltage-driven actuators shall be provided by the system integrator.	Nominal	Voltage-driven actuators	Equipment	RoD

Table A-5: Performance source requirements list

Ref.	Paragraph	Text of the requirement	Conditions	Applicability	Applicability level	Verification
A = analysis RoD = review of design		T = test T* = test verification at design qualification level				
5.5.1a	General	The nominal current delivered to an actuator shall be verified within the specified limits.	Nominal	All	SSS/Equipment	A,T
5.5.1b	General	For current-driven actuators, the output maximum voltage, at which the minimum actuation current is guaranteed, shall be specified.	Nominal	Current-driven actuators	SSS/Equipment	A,T
5.5.1c	General	For current-driven actuators, the minimum margin of electronics actuator current on top of “all-fire current” shall be established to calculate the minimum actuation current.	Nominal	Current-driven actuators	SSS/Equipment	A,T
5.5.1d	General	Any monitor current in an actuator system fire line shall be limited to 5 mA.	Nominal	All	SSS/Equipment	A, T
5.5.1e	General	The total leakage current of an armed, selected, but not fired, deployment actuator power outlet shall not exceed 5 mA.	Nominal	all	SSS/Equipment	A,T
5.5.1f	General	The leakage current to any unselected actuator output line (hot side) to the relevant return shall be lower than 1 mA while any other output line is fired.	Nominal	All	SSS/Equipment	T
5.5.2a	Reliability	For voltage-driven actuators, the abnormal output voltage emission of the actuator electronics shall be limited by the voltage of the input power source of the actuator electronics.	Failure	Voltage-driven actuators	SSS/Equipment	A

Ref.	Paragraph	Text of the requirement	Conditions	Applicability	Applicability level	Verification
A = analysis RoD = review of design		T = test T* = test verification at design qualification level				
5.5.2b	Reliability	For current-driven actuators, the maximum fault current emission from the actuator electronics to the actuator shall not exceed two times the maximum nominal specified value according to requirement 5.3.1a.2.	Failure	Current-driven actuators	SSS/Equipment	A, T*
5.5.3a	Telemetry	For long duration actuators, the current and voltage telemetries should be provided with 8 Hz sample rate or higher.	Nominal / Failure	All	SSE/SSS/Equipment	RoD, A, T
5.5.3b	Telemetry	If requirement 5.2.4j is applicable, a status telemetry shall be provided via serial telemetry line, to identify if nominal current or voltage ranges have been exceeded by 10 % to 50 % of their maximum nominal value.	Nominal / failure	All	SSS/Equipment	A,T
5.5.4a	Recurrent products	The power output capability of a generic design of actuator electronics should be 50 W DC.		All	SSS/Equipment	A, T
5.5.4b	Recurrent products	For current-driven actuators, the actuator electronics should supply a current up to 6 A. NOTE Specific current capability is trimmed in production.	Nominal	Current-driven actuators	SSS/Equipment	A,T
5.5.4c	Recurrent products	For current-driven actuators, the actuator electronics should supply the requested current during duration up to 100 ms. NOTE Specific current pulse duration is trimmed in production.	Nominal	Current-driven actuators	SSS/Equipment	A,T

Ref.	Paragraph	Text of the requirement	Conditions	Applicability	Applicability level	Verification
A = analysis RoD = review of design		T = test T* = test verification at design qualification level				
5.5.4d	Recurrent products	For voltage-driven actuators, the actuator electronics should supply a voltage with an initial set point selectable from 19 V to 21 V, and with an overall accuracy of ± 1 V, providing the current is lower than the limit defined in requirement 5.5.4e. NOTE Specific voltage capability is trimmed in production.	Nominal	Voltage-driven actuators	SSS/Equipment	A,T
5.5.4e	Recurrent products	For voltage-driven actuators, the actuator electronics should limit the maximal current to one actuator to 2,5 A.	Nominal	Voltage-driven actuators	SSS/Equipment	A,T
5.5.4f	Recurrent products	For voltage-driven actuators, the actuator electronics should be able to supply the requested current during an indefinite duration.	Nominal	Voltage-driven actuators	SSS/Equipment	A,T
5.5.4g	Recurrent products	The current-driven actuator electronics should be able to support a repetition rate for FIRE pulses down to 100 ms.	Nominal	All	SSS/Equipment	A,T

Table A-6: Performance load requirements list

Ref.	Paragraph	Text of the requirement	Conditions	Applicability	Applicability level	Verification
A = analysis		T = test				
RoD = review of design		T* = test verification at design qualification level				
5.6.1a	General	The maximum actuator resistance shall be specified in the operative conditions range, including temperature.	Nominal	All	Equipment	A or T
5.6.1b	General	The maximum actuator resistance need not be specified if the actuators qualification conditions, meaning the minimum voltage source to get all-fire current, is specified. NOTE To specify, or otherwise, the maximum actuator resistance has an impact on requirements for current-driven actuators, see 5.4.1a.	Nominal	All	Equipment	A,T
5.6.1c	General	No-fire current shall be greater than 50 mA.	Nominal	All	Equipment	A,T
5.6.2a	Reliability	It shall be possible to apply to the nominal, respectively redundant, actuator voltages up to the ones applicable to the input of the actuator electronics without affecting the functionality and performance of the redundant, respectively nominal, actuator. NOTE See assumption in 4.1g.	Failure	All	Equipment	A or T
5.6.3a	Recurrent products	For current-driven actuators, the actuator all-fire current should be lower than 5 A.	Nominal	Current-driven actuators	Equipment	RoD,T
5.6.3b	Recurrent products	For short duration actuators, the actuator minimum all fire actuation time should be lower than 50 ms.	Nominal	Short duration actuators	Equipment	RoD,T

Ref.	Paragraph	Text of the requirement	Conditions	Applicability	Applicability level	Verification
A = analysis		T = test				
RoD = review of design		T* = test verification at design qualification level				
5.6.3c	Recurrent products	For voltage-driven actuators, the minimum voltage for all fire action should be lower than 19 V with a current lower than 2,5 A respecting duration specified according requirement 5.3.1c.	Nominal	Voltage-driven actuators	Equipment	RoD,T
5.6.3d	Recurrent products	The maximum inductance of voltage-driven actuators should be 20 mH.	Nominal	Voltage-driven actuators	Equipment	A,T
5.6.3e	Recurrent products	The maximum inductance of current-driven actuators should be 1 μ H.	Nominal	Current-driven actuators	Equipment	A,T
5.6.3f	Recurrent products	The maximum capacitance of actuators should be 1 μ F.	Nominal	All	Equipment	A,T

Bibliography

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ECSS-Q-ST-40	Space product assurance - Safety
ECSS-E-ST-10-02	Space engineering - Verification
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