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EUROPEAN COOPERATION
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FOR SPACE STANDARDIZATION

Space product assurance

Worst case circuit performance analysis

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Foreword

This Standard is one of the series of ECSS Standards intended to be applied together for the management, engineering and product assurance 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.

The formulation of this Standard takes into account the existing ISO 9000 family of documents.

This Standard has been prepared by the ECSS-Q-30-01 Working Group, reviewed by the ECSS Product Assurance Panel and approved by the ECSS Steering Board.

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Scope

This Standard defines the requirements to perform the worst case circuit performance analysis and to write the worst case circuit performance analysis report. It applies to all electrical and electronic equipment. This worst case analysis (WCA) method can also be applied at subsystem level or for a combination of systems/subsystems for space to justify electrical interface specifications and design margins for equipment. It applies to all project phases where electrical interface requirements are established and circuit design is carried out.

The worst case circuit performance is generally carried out when designing the circuit. For selected circuitry, preliminary worst case circuit performance analysis (WCCPA) is used to validate a conceptual design approach at PDR.

When viewed from the perspective of a specific project context, the requirements specified in this Standard should be tailored to match the genuine requirements of a particular profile and circumstances of a project.

NOTE Tailoring is a process by which individual requirements of specifications, standards and related documents are evaluated and made applicable to a specific project, by selection and in some exceptional cases, modifications of existing or addition of new requirements.
[ECSS-M-00-02A, Clause 3]

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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 revisions 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 most recent editions of the normative documents indicated below. For undated references, the latest edition of the publication referred to applies.

ECSS-P-001	Glossary of terms
ECSS-E-10-02	Space engineering — Verification
ECSS-Q-60-11	Space product assurance — Derating and end-of-life parameter drifts — EEE components
ECSS-Q-30-02	Space product assurance — Failure modes, effects and criticality analysis (FMECA)
ECSS-Q-40-02	Space product assurance — Hazard analysis
ECSS-Q-40-04	Space product assurance — Sneak analysis
ECSS-Q-40-12	Space product assurance — Fault tree analysis – Adoption notice ECSS / IEC 61025

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Terms, definitions and abbreviations

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in ECSS-P-001 and the following apply.

3.1.1
ambient temperature
temperature of a medium surrounding the component

3.1.2
biased variation value
value with a deterministic direction or sign whose amplitude and direction of variation are known

3.1.3
component parameters
electrical performance parameters of EEE parts

3.1.4
component specification
specification of the EEE part used for procurement of the EEE part

3.1.5
design lifetime
duration for which the circuit is designed to work within a particular mission

3.1.6
effective ageing data
ageing data extrapolated from the lifetime assumed in database to the design lifetime

3.1.7
lifetime assumed in database
lifetime for which the parameter variation due to ageing and environmental effects is valid

3.1.8
radiation
phenomenon by which energy, in form of waves or particles, emanates from a source into space

EXAMPLE Trapped electrons, trapped protons and solar protons.

3.1.9
random variation value
value with no preferred direction or sign whose amplitude alone is known

3.1.10
reference condition
relative condition where the parameter variation is assumed to be zero

3.1.11
temperature assumed in database
temperature for which the parameter variation is given in the database

3.1.12
variation factors
factors which affect component parameters over its lifetime

NOTE For details see subclause 5.1.1.

3.1.13
worst case
highest or lowest boundary value of a given control parameter established in a validation or qualification exercise

NOTE Failures or single event effects are not covered by the worst case.

3.1.14
worst case circuit performance analysis
performance prediction of the circuit in the worst case condition

3.1.15
functional block
within a circuit, set of components which perform a specific function

3.2 Abbreviated terms

The following abbreviated terms are defined and used within this document:

Abbreviations	Meaning
CDR	critical design review
EEE	electrical, electronic, electromechanical
EMC	electromagnetic compatibility
EOL	end-of-life
EVA	extreme value analysis
$\mathbf{E_A}$	activation energy
k	Boltzmann constant
MCA	Monte Carlo analysis
PCB	printed circuit board
PDF	probability density function
PDR	preliminary design review
RF	radio frequency
RSS	root-sum-square
SEE	single-event effect
$\mathbf{T_j}$	junction temperature
WCCPA	worst case circuit performance analysis

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General methodology

4.1 Introduction

The worst case circuit performance analysis (WCCPA) shall be performed on electronic and electrical equipment to demonstrate that it performs within specification despite particular variations in its constituent part parameters and the imposed environment, at the end of overall lifetime (EOL).

A good survey of worst case circuit analysis can be found in CRTAWCCA "Worst Case Circuit Analysis Application Guidelines, 1993 Reliability Analysis Center, Rome NY, U.S.A.".

4.2 Flow diagram of WCCPA

The worst case analysis is used to demonstrate sufficient operating margins for all operating conditions in electronic circuits.

A flow diagram of WCCPA is shown in Figure 1.

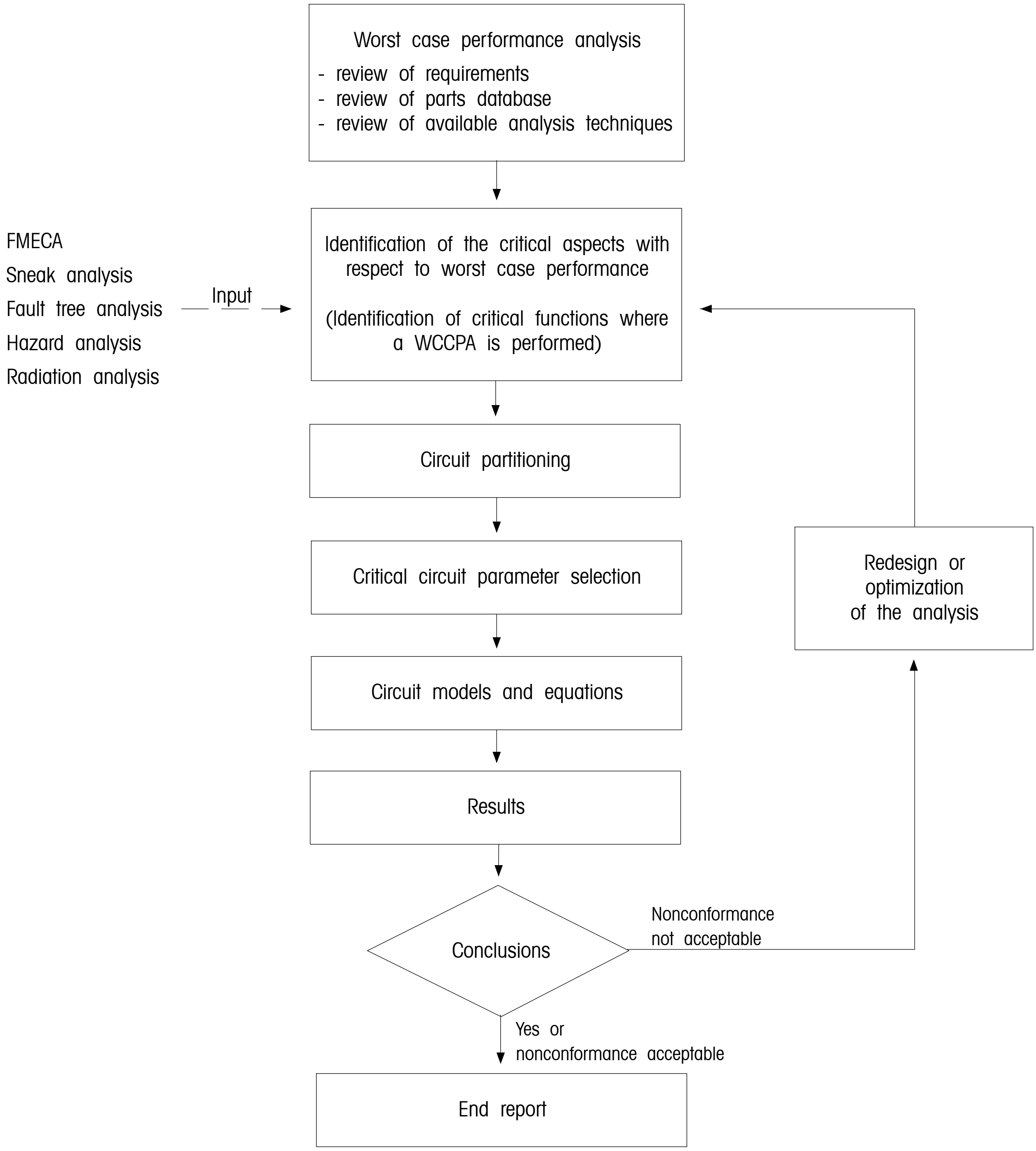

Figure 1: Flow diagram of WCCPA

4.3 Identification of the critical aspects w.r.t. worst case performance

The critical aspects with respect to worst case performance and the critical circuit parameters shall be identified. These critical aspects can be identified from results of other analyses:

- FMECA (ECSS-Q-30-02),
- sneak analysis (ECSS-Q-40-04),
- fault tree analysis (ECSS-Q-40-12),
- hazard analysis (ECSS-Q-40-02),
- radiation analysis.

The sources of parameter variation are in general:

- initial tolerances,
- ageing,
- temperature,
- electrical interfaces,
- radiation, and
- EMC.

However, in some cases the effects of the above sources can be negligible.

To justify which effects influence the result and which can be neglected, a sensitivity analysis or appropriate other method shall be carried out.

4.4 Evaluation of worst case performance

The following basic tasks shall performed:

- partitioning of large circuits into smaller circuits which are better manageable (functional blocks);
- selection of critical circuit attributes;
- mathematical simulations of circuit behaviour;
- application of a worst case numerical analysis technique.

To facilitate the performance of the WCCPA, the analyst may reduce complex circuits into smaller functional blocks. When a circuit is reduced to these functional blocks, performance requirements for the inputs and outputs of each functional block shall be established. These requirements serve as the evaluation criteria for the WCCPA results for the functional blocks. If such criteria exist in another document (e.g. design verification requirements document), reference to the source document shall be made. Some of the requirements for the functional blocks derive from higher level specification requirements. In that case, the method of deriving these requirements shall be clearly shown.

Non-linear effects: Within the process of splitting up the unit circuit into functional blocks the contractor shall consider non-linear effects resulting either from components intrinsic non-linearity (according to the components specification), or effects resulting from reciprocal interaction of the functional blocks (e.g. power supply variations induced by load changes, and load effects of the power supply drifts). Otherwise the WCCPA shall justify absence of such effects, or shall quantify such effects as negligible, in comparison to other error sources.

A combination of testing and analysis may be employed to obtain results through actual measurements.

4.5 Comparison of WCCPA with requirements

The WCCPA should conform to all requirements, both on the functional block level and at the circuit level. Variations from these requirements shall be noted explicitly and any proposed solutions outlined as part of the report. Proof of conformance to certain less significant requirements may be omitted provided that adequate justification for the specific omission is given in the WCCPA report. As a summary the analysis results shall be compared with the requirement specification.

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Analysis parameters and technical issues

5.1 Definition of worst case parameters within parts database

5.1.1 Variation factors

5.1.1.1 General

For each physical parameter of the component affecting the worst case parameter analysed, the value of the variation linked to each environment or interface stimulus shall be determined. Sources of variation include:

- the reference value (e.g. typical and adjusted),
- the initial tolerance,
- sensitivity to electrical interfaces (e.g. power supply, shared mode on inputs and output loads), and
- sensitivity to ageing and environmental conditions (e.g. temperature, radiation and EMC).

5.1.1.2 Selection of reference condition

The variations of a component parameter due to radiation, ageing, temperature and tolerance are applied to the reference condition. The reference condition shall be chosen such that data is available. This is usually room temperature (22 ± 3) °C at beginning-of-life.

5.1.1.3 Compensation

If the circuit compensates initial tolerance or environmental variations (such as temperature) the analysis report shall include a justification for the residual variation.

5.1.1.4 Radiation

5.1.1.4.1 Radiation total dose effect

Under the influence of total dose radiation parametric degradations or variations can be expected in particular for active electronic components. The electrical parametric changes can either be of a permanent or temporary nature, depending upon the component technology. Radiation affects parameter variations of active components only (those that have a semiconductor junction).

These parametric changes are related to the influence of the accumulated total dose radiation received throughout the mission lifetime.

5.1.1.4.2 Assessment of the radiation total dose

Using dedicated shielding and radiation analysis tools (radiation sector analysis), the local accumulated total dose on each single individual component level can be assessed and calculated. The accumulated total dose received on individual parts depends on the mission lifetime, the radiation environment (usually a function of the spacecraft orbit) and the shielding. For this document, the shielding and total dose radiation analysis is an input to the worst case analysis even though in practice it may be incorporated into the WCCPA.

5.1.1.4.3 Assessment of the component parameters drift

Given the assessed and calculated accumulated local total dose level, the associated parameter drift values of each of the components shall be derived. The applicable parameter drift values, which depend on the accumulated total dose received, can only be determined by performing radiation testing on components from the parts lots used on the spacecraft. The parameter drift is linked to the technology of the component and can vary from one manufacturer to another and from one lot to another. The following methods are available for the determination of the parameter drift values.

a. The parameter drift values can be taken from radiation tests, that were performed under appropriate conditions on parts lots used on the spacecraft. In this case the reference of the document containing the test results should be included in the list of normative documents.

b. If the parameter drift values are derived from component radiation test data (not within the lot of the parts used on the spacecraft), an appropriate margin shall be considered for a difference in parameter performance variations between the tested lot and the actual lot of the components used on the spacecraft.

    1. If the component to be used on the spacecraft is from the same manufacturer and the same established manufacturing process as the tested part, a 20 % margin is considered sufficient for parameters such as gain, threshold voltage, resistance or conductance.

    2. If the component to be used on the spacecraft is from a different manufacturer or process than the tested sample, a margin of more than 100% should be considered. Thus, three or more sample components from the manufacturer should be tested to the expected radiation level with the same process used for the other parts of the spacecraft to confirm the correctness of the assumptions for the WCCPA.

c. The component specification can also be used as the information source. In this case the specification usually contains and specifies the parameter drift of total dose radiation up to given accumulated levels (including initial tolerance).

5.1.1.4.4 Radiation dose testing and verification

Within the WCCPA and, if applicable, the assumed component parameter drift (due to total dose radiation) shall be verified to correlate to the performance drift specified in the component specification for the assessed and calculated accumulated total dose level.

The component radiation test results shall show that the associated parameter drift values of the tested components are within the parameter drift limits assumed in the WCCPA.

During total dose testing, all components shall be electrically biased to determine the parametric drifts. Preferably, the bias condition shall be adopted such as to simulated the electrical properties on the spacecraft.

The parameter drifts due to radiation are biased variation values.

5.1.1.4.5 Single event effects

Single event effects (SEE) are anomalies and thus not a variation factor to be considered in the scope of the WCCPA. If the SEE assessment of the circuit requires countermeasures for SEE, these shall be described in a design justification document. If, as a result of SEE assessment, a protection circuit is included to prevent circuit failures or degradation during SEE events, certainly for nominal operation, this circuit shall be considered in the WCCPA.

5.1.1.5 Temperature

a. Parameter variations due to temperature variations are applicable to all passive and active components.

   The parameter variations are taken from the component specification, manufacturer's specifications, data sheet or test results. These parameter variations generally have biased values and are expressed as a delta per degree Celsius (in % or in value) with respect to the value within the component specification at the reference condition. There can also be a random part with respect to the bias value. (To be clarified, as for passive parts the parameter variation over temperature is usually a fixed value.)

b. Often the component specification does not contain the parameter variation in the necessary parametric form required for the evaluation of the worst case performance of the circuit. In this case, the parameter variations shall be derived considering, for instance, measurement data and component physics. This derivation shall be justified.

c. In the component specification these variations generally apply over the complete temperature range of the component (–55 °C to +125 °C). The thermal analysis of the equipment is provided as an input with the actual temperature range of each component, which is usually lower than this complete temperature range. The thermal analysis shall consider the temperature rise between the PCB temperature, the case temperature and the junction temperature.

d. Within the WCCPA the temperature of the component is the ambient temperature when the equipment thermal interface varies over the acceptance temperature range. In the worst case analysis, the minimum temperature of each component is the minimum acceptance environmental temperature of the equipment. The maximum temperature is the temperature determined within the thermal analysis for the extreme acceptance temperature of the equipment. As long as the results from the thermal analysis are not available, the component shall be assumed to operate at the maximum operating temperature.

5.1.1.6 Initial tolerance

Parameter variations due to initial tolerance concern all passive and active components.

If the circuit compensates initial tolerance variations, the WCCPA shall include an analysis of the residual variation.

The variations are taken from the applicable component specifications. The variations are considered to have a random distribution.

5.1.1.7 Ageing

5.1.1.7.1 Introduction

Parameter variations due to ageing concern all passive and all active components.

This variation is a function of time and temperature, junction temperature for active components, and case temperature for passive components.

The ageing effects are specific to each family of components.

The variations are taken from the component specifications, life test data or worst case parameter database (see A.6.2.1).

5.1.1.7.2 Extrapolation of ageing data from the lifetime assumed in database to the design lifetime

If the design lifetime is different from the lifetime assumed in the database, the effective ageing data shall be extrapolated from the data available in the database:

The linear extrapolation (conservative approach) shall be applied. The use of other extrapolations may be adopted with adequate justification.

For a design lifetime shorter than the database, the database value for the next longer time interval shall be assumed. The parameter variation data shall not be interpolated between database values without justification, as the ageing process cannot be assumed apriori to be linear.

5.1.1.7.3 Extrapolation of ageing data from the temperature assumed in the database to the maximum temperature of the component in the application

To extrapolate ageing data from the temperature assumed in the database to the maximum temperature of the component for the same duration, the law of Arrhenius should be used:

$$q_2 = q_1 \exp\left[\frac{E_A}{\mathrm{k}} \times \left(\frac{1}{T_1} - \frac{1}{T_2}\right)\right]$$

where

q_1 and q_2 are the parameters at temperature T_1 ant T_2, respectively;

T_1 and T_2 are the temperatures in Kelvin at which q_1 and q_2 are measured, respectively;

E_A is the activation energy in eV;

k is the Boltzmann constant (8,62 10^{-5} eV/K);

exp(x) = e^x, where e is the base of the natural logarithm.

The use of other extrapolations may be adopted with adequate justification.

Some typical activation energy values are (these are default values; with the appropriate justification and reference, other values can be used):

Semiconductors		
	GaAs	1,4 eV
	Silicon	1,1 eV
Resistances		
	Metal film, thin film	1,35 eV
	Carbon	1 eV
	Wirewound	1 eV

Capacitances

Ceramic	1,67 eV
Porcelain, glass, mica	1,1 eV
Film, plastic	3,4 eV
Tantalum	0,43 eV

EXAMPLE For a mission duration of 10 years, we want the drift in ageing of V_Z at T_2 = 85 °C. We take an activation energy of 1,1 eV (semiconductors).

We know that q_1 = ±2 % at T_1 = 110 °C, what is the value of q_2 ?

$$q_2 = \pm\ 2\ \exp\left[\frac{1,1}{8,62 \times 10^{-5}}\left(\frac{1}{273 + 110} - \frac{1}{273 + 85}\right)\right] \quad => \quad q_2 = \pm\ 0,195\ \%$$

At T_j = 85 °C, the voltage V_Z varies by ±0,195 % in 10 years.

5.1.1.8 EMC and variation of electrical signals

Worst case variations of the signal at the electrical interfaces (including conducted EMC) shall be considered. These variations depend on the design of the equipment and are generally random in nature.

The extreme values are taken from the interface specification and the EMC requirements.

The interest of the worst case is to verify that the parameter variations of the components selected for conducted EMC reduction and the components that generate conducted EMC allow the EMC requirements to be satisfied.

The circuit behaviour for the EMC aspects can be determined by simulation and/or tests.

5.1.2 Summary on deviations

Table 1 summarized the various possible parameters deviations and their attributes.

Table 1: Deviations and attributes summary

	Initial tolerance	**Ageing**	**Temperature**	**Radiation**	**EMC and variation of electrical signals**
Components concerned	All	All	All	Active only	All
Type	Random	Biased (sometimes random)	Biased (sometimes random)	Biased	Biased (sometimes random)
Function of	Intrinsic	Time, temperature	Temperature range	Dose received	Design
Where to find the data?	Component specification	Worst case parameter database and ECSS-Q-60-11	Component specification	Component specification radiation tests	Interface specification and EMC requirements
Specific case	Compensation by alignment	-	Temperature compensated circuit	-	-

5.2 Phase and timing considerations within the WCCPA

5.2.1 Introduction

This clause provides inputs to take into account the phase and timing problems. Some specific problems are detailed in this clause. Nevertheless, other timing problems (such as reset duration and voltage level) should be analysed in the WCCPA.

Within the WCCPA it shall also be demonstrated that the timing conditions of the signals are such that the circuit operates properly together under simultaneous worst case source and load conditions. It is suggested that particular attention be paid to noise margin at the interface when performing the worst case analysis .

5.2.2 Timing of transient pulses

5.2.2.1 General

All sequential circuits should have a worst case timing diagram made to determine the effects of variation in switching times of the installed circuits. There are many factors that affect timing. They include supply voltage, capacitive loading, clock or oscillator instability, and slope of clock rising and falling edge.

5.2.2.2 Signal delays (and response times in digital circuits)

The limits of the propagation delays for the circuit being analysed shall also be shown in the WCCPA. For example, response times in digital circuits shall conform to the required response times identified in the requirements. For circuits that have no specific delay or response times at the unit level, the worst case response times shall be explored in further detail during the system level worst case analysis to determine if design constraints should be levied "from the top down". The total delay of a circuit is the sum of its propagation delay and a transition time effect.

5.2.2.3 Phasing of repeating waveforms (such as sinusoidal signals)

In circuits such as DC/DC converters or RF circuits, the timing of the signal waveforms can be critical. In this case, the WCCPA shall include an evaluation of whether the required phase and gain margins are met.

5.3 Numerical analysis techniques

5.3.1 Approach

The worst case analysis can be performed using four different approaches:

- extreme value analysis;
- extreme value analysis combined approach;
- root-sum-squared analysis;
- Monte Carlo analysis.

5.3.2 Extreme value analysis

The extreme value analysis (EVA) technique is the best initial approach to worst case circuit analysis. The extreme value analysis assesses circuit performance when each component exhibits its most extreme variation; if the circuit passes an EVA, it always functions properly. If the circuit fails, modify the circuit until it meets the EVA requirements or apply the extreme value analysis combined approach, the root-sum-squared analysis or the Monte Carlo analysis for a less conservative approach. EVA uses the limits of variability and the circuit directional sensitivities to determine the worst case results.

5.3.3 Extreme value analysis combined approach

This method uses as an initial approach when the minimum and maximum values of the variables are not available, but only their nominal values and their deviations. This method is based on the fact that some variations are random (the variation has no preferred direction or sign) and others are biased (with a deterministic direction or sign). This approach is valid for standard deviations (moment methods), but is not always valid for maximum values.

5.3.4 Root-sum-squared analysis

The root-sum-squared (RSS) approach to the worst case circuit analysis provides a more realistic evaluation technique by employing a statistical approach. An RSS analysis provides a probability that manufactured circuits work within specification (the manufacturing yield). The results are in the form of parameter bias and standard deviation, so that the three-sigma limits of performance can be determined.

5.3.5 Monte Carlo analysis

The Monte Carlo analysis (MCA) technique is a computer simulation of circuit performance to provide statistically significant results that estimate the percentage of circuits that operates successfully under expected field conditions.

This method uses actual part tolerance distributions, if available. If these distributions can be utilized, then this approach is the most realistic of the three.

If the circuit parameter probability distribution is unknown or if it is difficult to select the reference one appropriately, a binomial process can be used. But this process requires a higher number of iterations than the normal distribution.

The working hypothesis on the applicable distribution significantly reduces the effort.

The simulations should be performed to assure, at least, P = 99,5 % (in line with the three-sigma limits – P = 99,73 % – of the RSS approach) with a confidence level of 95%, where P is the probability that the circuit operates successfully.

The number of iterations to be performed (n) is given by the Kolmogorov-Smirnov rule and is function of the confidence level (1–α) and the maximal error on the confidence level (Δ) :

$$n = \left(\frac{d(n,\alpha)}{\Delta}\right)^2$$

$d(n, \alpha) = 1{,}36$ for $\alpha = 0{,}05$ (confidence level = 95 %)

$d(n, \alpha) = 1{,}68$ for $\alpha = 0{,}01$ (confidence level = 99 %)

The advantages of the approaches are shown in Table 2.

Table 2: Numerical techniques and value summary

	Advantages	Disadvantages
EVA	• Provides most readily obtainable estimate of worst case performance. • Does not require statistical inputs for circuit parameters. • Database need only provide part parameter variation extremes.	Results in pessimistic estimate of circuit worst case performance. If circuit fails, there is insufficient data to assess risk.
EVA combined approach	• Results in more realistic estimate of worst case performance than EVA. • This method can be implemented with simple calculations.	Valid for standard deviations (moment methods) but not always valid for maximum values. Requires accurate knowledge of piece part parameter PDF. It is strictly valid only for Gaussian variables. Risk of over-dimensioning is as high as for EVA.
RSS	• Results in more realistic estimate of worst case performance than EVA. • Knowledge of parameter PDF not required. • Provides some degree of risk assessment in terms of percentage of units to pass or fail.	Standard deviation of piece part parameter's probability distribution shall be used. Assumes circuit sensitivities remain constant over range of parameter variability. Uses approximation: circuit performance variability is normally distributed (central limit theorem).
Monte Carlo	• Provides the most realistic estimate of true worst case performance of the three methods. • Provides additional information which can be applied to risk assessment.	Requires the use of a computer. Consumes large amount of CPU time.

For selection of the appropriate method for the first three techniques, see subclause 5.2.3 of CRTAWCCA (Worst Case Circuit Analysis Application Guidelines, 1993 Reliability Analysis Center, Rome NY, U.S.A.).

6

WCCPA and project phases

A detailed WCCPA during the design phase shall be used to find design problems that were not found during the test phase due to temperature extremes, age or radiation.

For selected circuitry, a preliminary WCCPA should be available to validate a conceptual design approach at PDR.

The assumptions and approach to be used in the analyses shall be checked against reliability assessments prior to the performance of the analyses.

The critical aspects with respect to worst case performance and the critical circuit parameters shall be identified. These critical aspects can be identified from results of other analyses (e.g. FMECA, sneak analysis). The circuits models and equations shall be defined. It shall determine if a nonconformance is acceptable. Otherwise a redesign of the circuit shall be proposed to achieve conformance or an optimization of the analysis.

If design changes are made, either as a result of the WCCPA or for other reasons, the WCCPA shall be updated using the new circuit.

Results of a such analysis are generally presented in the frame of the circuit CDR.

Annex A (normative)

Worst case circuit performance analysis — Document requirements definition (DRD)

A.1 Introduction

The worst case circuit performance analysis report shall contain all baseline information (assumptions, methods and techniques) used for the preparation of the analysis, the results obtained and a comparison of the specified parameters as derived from the specification of the equipment or module.

A.2 Scope and applicability

A.2.1 Scope

This document requirements definition (DRD) establishes the data content requirements for the worst case circuit performance analysis.

This DRD does not define format, presentation or delivery requirements for the worst case circuit performance analysis.

A.2.2 Applicability

This DRD is applicable to all projects using the ECSS Standards.

A.3 Terms, definitions, abbreviated terms and symbols

A.3.1 Terms and definitions

For the purposes of this DRD the terms and definitions given in ECSS-P-001 and in ECSS-E-10-02 apply.

A.3.2 Abbreviated terms

The following abbreviations are defined and used within this DRD:

Abbreviation	Meaning
DRD	document requirements definition
ECSS	European Cooperation for Space Standardization
EMC	electromagnetic compatibility
PDR	preliminary design review
WCCPA	worst case circuit performance analysis

A.3.3 Symbols

Not applicable.

A.4 Description and purpose

The worst case circuit performance analysis report describes the execution of the test and the results of the analysis.

It contains the method of analysis and the assumptions used. It describes the model, presents the results of the analysis and the conclusions.

Its principal use is to prove that the equipment is able to meet the specified performance requirements under worst case conditions of operation and to demonstrate sufficient operating margins for all operating equipment conditions.

A.5 WCCPA preliminary elements

A.5.1 Title

The document to be created based on this DRD shall be titled "[insert a descriptive modifier] - worst case circuit performance analysis".

The descriptive modifier shall be selected to clearly identify the applicable product and project.

EXAMPLE "[Project identifier] - [Product identifier] - worst case circuit performance analysis"

A.5.2 Title page

The title page for this document shall identify the project document identification number, title of the document, date of release, number of release and release authority, author(s), distribution sheet.

A.5.3 Contents list

The contents list shall identify the title and location of every clause and major subclause, figure, table and annex contained in the document.

A.5.4 Foreword

A foreword shall be included which describes as many of the following items as are appropriate:

- identification of which organizational entity prepared the document;
- information regarding the approval of the document;
- identification of other organizations that contributed to the preparation of the document;
- a statement of effectively identifying which other documents are cancelled and replaced in whole or in part;
- a statement of significant technical differences between this document and any previous document;
- the relationship of the document to other standards or documents.

A.5.5 Introduction

The introduction shall provide specific information or commentary about the technical content.

A.6 Content

A.6.1 Scope and applicability

This clause shall be numbered 1 and shall describe the scope, applicability and purpose of the worst case circuit performance analysis.

A.6.1.1 Scope

This clause shall be numbered 1.1 and shall contain the following statement:

> "This document presents the worst case circuit performance analysis for the [insert product identifier] of the [insert project identifier] project."

A.6.1.2 Purpose

This clause shall be numbered 1.2 and shall contain the following statements:

> "The worst case circuit performance analysis is required to prove that the equipment is able to meet the specified performance requirements under worst case conditions of operation.
>
> This analysis report provides evidence that the analysis required for the verification close-out of the relevant requirements has been performed."

A.6.2 References

This clause shall be numbered 2 and shall contain the following subclauses.

A.6.2.1 Normative references

This subclause shall be numbered 2.1 and shall contain following statements:

> "This document incorporates, by dated or undated reference, provisions from other publications.
>
> These normative references are cited at appropriate places in the text and publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these apply to this document only when incorporated in it by amendment or revision.
>
> For undated references, the latest edition of the publication referred to applies.
>
> [insert document identifier] [insert document title]."

Typically the normative documents are the:

- document which specifies the requirements of the electrical input and output signals;
- applicable document which specifies the EMC requirements (conducted susceptibility and emission requirements);
- document used for the definition of the parts database;
- circuit diagrams under analysis;
- thermal analysis document(s) in which the temperatures of the components in the circuit under analysis are defined;
- document in which the radiation levels of the components in the circuit under analysis are defined;
- documents in which the worst case parameter database is defined (e.g. radiation and ageing)

In case any of the above normative documents are not available, the assumptions shall be stated in the clause "Assumptions applicable to the environmental conditions".

Alternatively, reference can be made to a documentation list that contains the above information.

A.6.2.2 Informative references

This subclause shall be numbered 2.2 and shall contain the following statement:

> "The following documents, although not a part of this analysis report, amplify or clarify its contents:
>
> [insert document identifier] [insert document title]."

A.6.3 Terms, definitions and abbreviated terms

This clause shall be numbered 3 and shall contain the following subclauses.

A.6.3.1 Terms and definitions

This subclause shall be numbered 3.1 and shall list any applicable project dictionary or glossary, and all unusual terms or terms with a meaning specific to the worst case circuit performance analysis, with the definition of each term.

If a project dictionary or glossary is applicable, insert the following sentence:

> "The definitions of [insert title and identifier of applicable dictionaries or glossaries] apply to this document."

Insert the following sentence:

> "The following terms and definitions are specific to this document:
>
> [insert term] [insert definition]."

A.6.3.2 Abbreviated terms

This subclause shall be numbered 3.2 and shall list all abbreviations used in the analysis document with the fully spelled out meaning or phrase for each abbreviation.

A.6.4 Assumptions applicable to the environmental condition

In case any of the above normative documents are not available, the assumptions shall be stated in the clause "Applicable assumptions". This clause should describe the conditions and from what section of the normative document it was taken.

Details about the environmental conditions considered in this analysis should be given as taken from the normative documents.

A.6.5 Listing of the selected parts database with the worst case parameters

This clause shall list the worst case parameters (see 5.1).

A.6.6 General methodology

This clause shall summarize the analysis content and the method utilized (see 4).

A.6.7 Numerical analysis technique

This clause shall describe the analysis technique used, including the software and associated models, if any (see 5.3).

A.6.8 Annex A 1.1 Results of the WCCPA

This clause shall describe the results of the analysis. The results of the functional blocks (see 4.4) shall be described and combined such that the results of whole functional entity is demonstrated.

For each functional block and the whole functional entity, the significant variation factors (described in 5.1.1) shall be described and also to what extent they contribute to the results.

If components or functional blocks contribute significantly to the final result of the WCCPA, their contribution to the result of the whole circuit shall be described.

A.6.9 Annex A 1.2 Conclusion of WCCPA

This clause shall list the requirements to be verified and shall summarize the WCCPA results, and the comparison of the results with the requirements (see 4.5).

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Bibliography

ECSS-M-00-02A	Space project management — Tailoring of space standards
CRTAWCCA	Worst Case Circuit Analysis Application Guidelines, 1993 Reliability Analysis Center, Rome NY, U.S.A.
JPL D-5703	Jet Propulsion Laboratory Reliability Analyses Handbook

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ECSS Document Improvement Proposal

1. Document I.D.	2. Document date	3. Document title
ECSS-Q-30-01A	31 March 2005	Worst case circuit performance analysis

4. Recommended improvement (identify clauses, subclauses and include modified text or graphic, attach pages as necessary)

5. Reason for recommendation

6. Originator of recommendation

Name:	Organization:	
Address:	Phone: Fax: e-mail:	**7. Date of submission:**

8. Send to ECSS Secretariat

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Note: The originator of the submission should complete items 4, 5, 6 and 7.

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