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INTERNATIONAL STANDARD

NORME INTERNATIONALE

Electric components – Reliability – Reference conditions for failure rates and stress models for conversion

Composants électriques – Fiabilité – Conditions de référence pour les taux de défaillance et modèles de contraintes pour la conversion

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CONTENTS

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ELECTRIC COMPONENTS – RELIABILITY – REFERENCE CONDITIONS FOR FAILURE RATES AND STRESS MODELS FOR CONVERSION

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as “IEC Publication(s)”). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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International Standard IEC 61709 has been prepared by IEC technical committee 56: Dependability.

This second edition cancels and replaces the first edition, published in 1996 and constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

– the addition of a number of component types and the updating of models for a large number of component types;

– the addition of annexes on reliability prediction, sources of failure rate data and component classification information.

The text of this standard is based on the following documents:

FDIS	Report on voting
56/1422/FDIS	56/1431/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

INTRODUCTION

This International Standard is intended for the reliability prediction of components as used in equipment and is aimed at organizations that have their own data and describes how to state and use that data in order to perform reliability predictions.

It can also be used to allow an organization to set up a failure rate database and describes the reference conditions for which field failure rates should be stated. The reference conditions adopted in this standard are typical of the majority of applications of components in equipment however when components operate under other conditions the users may consider stating these conditions as their reference conditions.

Using the presented stress models allows extrapolation of failure rates to other operating conditions which in turn permits the prediction of failure rates at assembly level. This allows estimation of the effect of design changes or changes in the environmental conditions on component reliability. Reliability prediction is most useful in the early design phase of electrical equipment. It can be used, for example, to identify potential reliability problems, the planning of logistic support strategies and the evaluation of designs.

The stress models contained herein are generic and are as simple as possible while still being comparable with more complex equations contained in other models.

This standard does not contain failure rates, but it describes how they can be stated and used. This approach allows a user to select the most relevant and up to date failure rates for the prediction from a source that they select. This standard also contains information on how to select the data that can be used in the presented models.

ELECTRIC COMPONENTS – RELIABILITY – REFERENCE CONDITIONS FOR FAILURE RATES AND STRESS MODELS FOR CONVERSION

1 Scope

This International Standard gives guidance on how failure rate data can be employed for reliability prediction of electric components in equipment.

Reference conditions are numerical values of stresses that are typically observed by components in the majority of applications. Reference conditions are useful since they are the basis of the calculation of failure rate under any conditions by the application of stress models that take into account the actual operating conditions. Failure rates stated at reference conditions allow realistic reliability predictions to be made in the early design phase.

The stress models described herein are generic and can be used as a basis for conversion of the failure rate data at these reference conditions to actual operating conditions when needed and this simplifies the prediction approach. Conversion of failure rate data is only permissible within the specified functional limits of the components.

This standard also gives guidance on how a database of component failure data can be constructed to provide failure rates that can be used with the included stress models. Reference conditions for failure rate data are specified, so that data from different sources can be compared on a uniform basis. If failure rate data are given in accordance with this International Standard then no additional information on the specified conditions is required.

This standard does not provide base failure rates for components – rather it provides models that allow failure rates obtained by other means to be converted from one operating condition to another operating condition.

The prediction methodology described in this standard assumes that the parts are being used within its useful life. The methods in this standard have a general application but are specifically applied to a selection of component types as defined in Clause 6 and Clause E.2.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60050-191, *International Electrotechnical Vocabulary – Part 191: Dependability and quality of service*

IEC 60605-6, *Equipment reliability testing – Part 6: Tests for the validity and estimation of the constant failure rate and constant failure intensity*

IEC 60721-3-3, *Classification of environmental conditions – Part 3: Classification of groups of environmental parameters and their severities – Section 3: Stationary use at weather protected locations*

IEC 60721-3-4, *Classification of environmental conditions – Part 3: Classification of groups of environmental parameters and their severities – Section 4: Stationary use at non-weatherprotected locations*

IEC 60721-3-5, *Classification of environmental conditions – Part 3: Classification of groups of environmental parameters and their severities – Section 4: Ground vehicle installations*

IEC 60721-3-7, *Classification of environmental conditions – Part 3: Classification of groups of environmental parameters and their severities – Section 7: Portable and non-stationary use*

3 Terms, definitions and symbols

3.1 Terms and definitons

For the purpose of this document, the terms and definitions of IEC 60050-191, as well as the following terms and definitions apply.

3.1.1
electric component
component with conductive terminals through which voltages or currents may be applied or delivered

[IEC 61360-1:2009, 2.18]

NOTE The term electric component includes the commonly used terms "electronic component", "electrical component" and "electro-mechanical component".

3.1.2
failure (of an item)
loss of ability to perform as required

NOTE 1 When the loss of ability is caused by a pre-existing latent fault, the failure occurs when a particular set of circumstances is encountered.

NOTE 2 A failure of an item is an event that results in a fault in that item, which is a state.

3.1.3
failure mode
manner in which failure occurs

NOTE A failure mode may be defined by the function lost or the state transition that occurred.

3.1.4
instantaneous failure rate
failure rate

limit, if it exists, of the ratio of the conditional probability that the instant of a failure of a non-repairable item occurs within time interval $(t,\ t + \Delta t)$ to Δt when Δt tends to zero, given that it has not failed within time interval $(0,t)$

NOTE 1 The instantaneous failure rate, $\lambda(t)$, is expressed by the formula:

$$\lambda(t) = \lim_{\Delta t \to 0} \frac{1}{\Delta t} \frac{F(t+\Delta t) - F(t)}{R(t)} = \frac{f(t)}{R(t)}$$

where $F(t)$ and $f(t)$ are respectively the distribution function and the probability density of the failure instant, and where $R(t)$ is the reliability function, related to the reliability $R(t_1,\ t_2)$ by $R(t) = R(0,\ t)$.

NOTE 2 See IEC 61703.

NOTE 3 Other terms used for instantaneous failure rate are “hazard function”, “hazard rate” and “force of mortality” (abbreviation FOM).

NOTE 4 In this standard $\lambda(t)$ is assumed to be constant over time.

3.1.5
reference conditions
stresses selected so as to correspond to the majority of applications and usage of components in equipment

NOTE Stresses include electrical stress, temperature and environmental conditions

3.1.6
reference failure rate
failure rate stated under reference conditions given in this standard

NOTE The reference failure rate is specific to the component, i.e. it includes the effect of complexity, technology of the casing, dependence on manufacturers and the manufacturing process, etc.

3.1.7
duty cycle
specified sequence of operating condition

[IEC 60050-151:2001, 151-16-02]

NOTE The duty cycle states whether components are continuously or intermittently stressed during their operation. Continuous duty means operation for a long duration with constant or changing loads (e.g. process controls, telephone switch). Intermittent duty means operation with constant or changing loads during up state (e.g. numerical controls for machinery, road traffic signals).

3.1.8
prediction
computation process used to obtain the predicted value of a quantity

NOTE The term "prediction" may also be used to denote the predicted value of a quantity.

3.1.9
component
constituent part of a device which cannot be physically divided into smaller parts without losing its particular function

[IEC 60050:2001, 151-11-21]

3.1.10
equipment
single apparatus or set of devices or apparatuses, or the set of main devices of an installation, or all devices necessary to perform a specific task

NOTE Examples of equipment are a power transformer, the equipment of a substation, or measuring equipment.

[IEC 60050-151:2001, 151-11-25]

3.1.11
useful life
time interval, from first use until user requirements are no longer met, due to economics or obsolescence

3.1.12
drift
difference between the final value of a characteristic at the end of a specified period and the initial value, all other operating conditions being held constant

NOTE The use of the term "drift" to refer to the immediate change of a characteristic in direct response to changed operating conditions (for example, temperature) is deprecated.

[IEC 60747-1:2006, 3.6.1, modified]

3.1.13
virtual temperature
internal equivalent temperature (of a semiconductor device)
theoretical temperature which is based on a simplified representation of the thermal and electrical behaviour of the semiconductor device

[IEC 60050-521: 2002, 521-05-14, modified]

3.1.14
virtual (equivalent) junction temperature
virtual temperature of the junction of a semiconductor device

[IEC 60050-521:2002, 521-05-15]

NOTE The virtual temperature is not necessarily the highest temperature in the device.

3.2 Symbols

In this standard, the following symbols are used:

S	number of operating cycles per hour
E_a	activation energy of a failure process
I_{op}	operating current
I_{rat}	rated current
I_{ref}	reference current
P_{op}	operating power dissipation
P_{rat}	rated power dissipation
P_{ref}	reference power dissipation
$R(t_1,t_2)$	reliability between two times t_1 and t_2
R_{th}	thermal resistance
$R_{th,amb}$	thermal resistance (to the environment)
S_{ref}	reference number of operating cycle per hour
T_{amb}	ambient temperature in Kelvin
T_0	reference ambient temperature in Kelvin
T_{ref}	reference temperature in Kelvin
U_{op}	operating voltage
U_{rat}	rated voltage
U_{ref}	reference voltage
t_p	fraction of time with part stress for an assembly
t_i	fraction of time spent idle for an assembly
t_f	fraction of time with full stress for an assembly
β	shape parameter of the Weibull distribution
ΔT	actual self-heating in degrees Celsius
ΔT_{ref}	reference self-heating in degrees Celsius
θ_{amb}	ambient temperature in degrees Celsius

– for capacitors the actual capacitor temperature;
– for discrete semiconductors and optoelectronic components the actual junction

temperature;
- for inductors the actual winding temperature;
- for integrated circuits (ICs) the actual virtual (equivalent) junction temperature;
- for other electric components the actual ambient temperature;
- for resistors the actual resistor element temperature;

θ_{op} operating temperature in degrees Celsius

θ_0 reference ambient temperature in degrees Celsius

θ_{ref} reference temperature in degrees Celsius
- for capacitors the reference temperature of the capacitor;
- for discrete semiconductors and optoelectronic components the reference junction temperature;
- for inductors the reference temperature of the winding;
- for ICs the reference virtual (equivalent) junction temperature;
- for other electric components the reference temperature of the component;
- for resistors the reference temperature of the resistor element.

λ_f failure rate at full stress for an assembly:

λ_p failure rate at part stress for an assembly;

λ_i failure rate during time spent idle for an assembly;

$\lambda_{component}$ failure rate of a component;

λ_{mode} failure rate of a components failure mode;

λ_S failure rate of a system;

λ failure rate under operating conditions;

λ_{ref} failure rate under reference conditions;

π_I current dependence factor;

π_{ES} electrical stress dependence factor;

π_E environmental application factor;

π_{op} stress factor for operating profile;

π_S switching rate dependence factor;

π_T temperature dependence factor;

π_U voltage dependence factor.

4 Context and conditions

4.1 Failure modes

The characteristic preferred for reliability data of electric components is the (instantaneous) failure rate. It is to be noted that, although it is often generically defined as failure, the exact observed event that is measured is a failure mode.

In equipment a failure (mode) or functional loss is caused by a component failure mode where that component failure mode is relevant to the application being carried out by the equipment.

It should be noted that a component has many features and only some may be used in the specific application. A function loss at the equipment level occurs only when there is a loss of the component feature that is used to support that function.

Furthermore a circuit requires the presence of component features according to what was defined by the designer; this may not encompass the total feature set of the component and