

Electronic components — Reliability — Reference conditions for failure rates and stress models for conversion

The European Standard EN 61709:1998 has the status of a British Standard.

ICS 31.020

Committees responsible for this British Standard

The preparation of this British Standard was entrusted to Technical Committee DS/1, Reliability and maintainability systems, upon which the following bodies were represented:

- Association of Consulting Engineers
- Association of Project Managers
- British Gas plc
- British Railways Board
- British Telecommunications plc
- Chartered Institution of Building Services Engineers
- City University
- Civil Aviation Authority
- Consumer Policy Committee of BSI
- Cranfield University
- Defence Manufacturers' Association
- Department of Trade and Industry (Standards Policy Unit)
- Electricity Association
- Federation of the Electronics Industry
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- Royal Institution of Chartered Surveyors
- Safety and Reliability Society
- Society of Environmental Engineers
- Society of Motor Manufacturers and Traders Limited
- United Kingdom Cals Industry Council
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- West Midlands Enterprise Board

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National foreword

This British Standard is the English language version of EN 61709:1998. It is identical with IEC 61709:1996.

This standard gives guidance on the use of failure rate data for predicting the reliability of components in electronic equipment.

This standard was originally designated as BS 5760-18:1997. BS 5760 provides comprehensive guidance on many aspects of reliability management. Other parts of BS 5760 are as follows:

- *Part 0: Introductory guide to reliability;*
- *Part 1: Dependability programme elements and tasks;*
- *Part 2: Guide to the assessment of reliability;*
- *Part 3: Guide to reliability practices: examples;*
- *Part 4: Guide to specification clauses relating to the achievement and development of reliability in new and existing items;*
- *Part 5: Guide to failure modes, effects and criticality analysis (FMEA and FMECA);*
- *Part 6: Guide to programmes for reliability growth;*
- *Part 7: Guide to fault tree analysis;*
- *Part 8: Guide to assessment of reliability of systems containing software;*
- *Part 10: Guide to reliability testing;*
 - Section 10.1: General requirements;*
 - Section 10.2: Design of test cycles;*
 - Section 10.3: Compliance test procedures for steady-state availability;*
 - Section 10.5: Compliance test plans for success ratio.*
- *Part 11: Collection of reliability, availability, maintainability and maintenance support data from the field;*
- *Part 12: Guide to the presentation of reliability, maintainability and availability predictions;*
- *Part 13: Guide to reliability test conditions for consumer equipment;*
 - Section 13.1: Conditions providing a low degree of simulation for indoor portable equipment;*
 - Section 13.2: Conditions providing a high degree of simulation for equipment for stationary use in weather-protected locations;*
 - Section 13.3: Conditions providing a low degree of simulation for equipment for stationary use in partially weather-protected locations;*
 - Section 13.4: Conditions providing a low degree of simulation for equipment for portable and non-stationary use;*
 - Section 13.5: Ground mobile equipment — Low degree of simulation;*
 - Section 13.6: Test cycle 6: Outdoor transportable equipment — Low degree of simulation.*
- *Part 14: Guide to formal design review;*
- *Part 15: Guide to the application of Markov techniques;*

- *Part 16: Guide to stress screening;*
Section 16.1: Repairable items manufactured in lots.
- *Part 17: Reliability growth — Statistical test and estimation methods;*
- *Part 20: Guide to the specification of dependability requirements;*
- *Part 23: Guide to life cycle costing.*

Further parts of BS 5760 are envisaged in order to provide guidance on other techniques of reliability management.

Whilst mainly addressing system and equipment level reliability, many of the techniques described in the parts of BS 5760 may also be applied at the component level. Further guidance on component reliability is given in BS CECC 00804:1996.

Cross-references

The British Standards which correspond to international or European publications referred to in this document may be found in the current BSI Catalogue under the section entitled “International Standards Correspondence Index”.

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Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, the EN title page and EN foreword, pages 1 to 33 and a back cover.

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Electronic components — Reliability — Reference conditions for failure rates and stress models for conversion

(IEC 61709:1996)

Composants électroniques — Fiabilité — Conditions de référence pour les taux de défaillance et modèles d'influence des contraintes pour la conversion
(CEI 61709:1996)

Bauelemente der Elektronik — Zuverlässigkeit — Referenzbedingungen für Ausfallraten und Beanspruchungsmodelle zur Umrechnung
(IEC 61709:1996)

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Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CENELEC member.

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European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

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Foreword

The text of the International Standard IEC 61709:1996, prepared by IEC TC 56 Dependability, was submitted to the Unique Acceptance Procedure and was approved by CENELEC as EN 61709 on 1998-04-01 without any modification.

The following dates were fixed:

- latest date by which the EN has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 1999-03-01
- latest date by which the national standards conflicting with the EN have to be withdrawn (dow) 1999-03-01

Annexes designated “normative” are part of the body of the standard.

Annexes designated “normative” are given for information only.

In this standard, annex ZA is normative and annexes A, B and C are informative.

Annex ZA has been added by CENELEC.

In the official version, for annex C, Bibliography, the following notes have to be added for the standards indicated:

IEC 60068-1	NOTE Harmonized, together with its corrigendum October 1988 and its amendment 1:1992, as EN 60068-1:1994 (not modified).
IEC 60255-23	NOTE Harmonized as EN 60255-23:1996 (not modified).
IEC 60721-3-0	NOTE Harmonized, together with its amendment 1:1987, as EN 60721-3-0:1993 (not modified).
IEC 60721-3-1	NOTE Harmonized, together with its amendment 1:1991, as EN 60721-3-1:1993, which is superseded by EN 60721-3-1:1997 (not modified).
IEC 60721-3-2	NOTE Harmonized, together with its amendment 1:1991, as EN 60721-3-2:1993, which is superseded by EN 60721-3-2:1997 (not modified).
IEC 61078	NOTE Harmonized as EN 61078:1993 (not modified).

Introduction

Failure rate data are useful in the design phase of electronic equipment. They can be used to identify potential reliability problems, the planning of logistic support strategies and the evaluation of designs and reliability predictions. Predictions are essentially probability statements which are based on the failure rates of electronic components. These predictions should be carried out before hardware realization and/or the procurement process of an equipment.

Unsubstantiated failure rate data used in reliability predictions can cause inaccuracies. These inaccuracies can be reduced by post processing supplied failure data to remove information on replacements that are not real failures. Failure rate data should include knowledge of the failure criteria and the mechanical and electrical stresses which have resulted in the component failure. This International Standard serves as a guide to describe reference conditions for which field failure rates should be stated. This then allows, by the use of stress models, extrapolation to other operating conditions. Some of the limitations of the models are outlined in Annex A. It is not intended to replace other valid handbooks.

The reference conditions adopted are typical of the majority of applications of components in equipment (e.g. telecommunication use, data processing). In this standard it is assumed that the failure rate used under reference conditions 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.

The component failure rates to be used with this standard are to be determined based upon agreement between the component manufacturer and the component user, using one or more of the following sources: equipment manufacturer data book, equipment user data book, component manufacturer data book or data from an independent third body. Sources should be the latest available that are applicable to the product and its specific use conditions. Ideally, failure rate data should be obtained from the field.

The stress factors for different conditions are specified in this standard. They are typical values for the individual component classes from various manufacturers. When actual conditions of use are in close agreement with reference conditions, then as a first approximation the agreed component failure rates can be used. The stress factors should be used, when they are known to be correct or as an approximation, if nothing else is known. Where they are applied, their use should be clearly stated. If other factors are known to be correct, they should be stated and used.

1 Scope

This International Standard gives guidance on the use of failure rate data for the reliability prediction of components in electronic equipment. 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 standard then no additional information on the specified conditions is required.

The stress models described in this standard should be used as a basis for conversion of the failure rate data at reference conditions to the actual operating conditions. Conversion of failure rate data are only permissible within the specified functional limits of the components (see Annex A).

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All normative documents are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 50(191):1990, *International Electrotechnical Vocabulary (IEV) — Chapter 191: Dependability and quality of service*.

IEC 721-3-3:1994, *Classification of environmental conditions — Part 3: Classification of groups of environmental parameters and their severities — Section 3: Stationary use at weather-protected locations*.

3 Definitions

For the purpose of this International Standard, the following definitions apply.

3.1

failure

termination of the ability of an item to perform a required function [IEV 191-04-01]

3.2

failure rate

limit, if this exists, of the ratio of the conditional probability that the instant of time, T , of a failure of an item falls within a given time interval, $(t, t + \Delta T)$ and the length of this interval, ΔT , when ΔT tends to zero, given that the item is in an up state at the beginning of the time interval [IEV 191-12-02]

The characteristic preferred for reliability data of electronic components is the failure rate as defined in IEV 191-12-02 (see also **A.3**).

NOTE In this definition T may also denote the time to failure or the time to first failure, as the case may be.

3.3

mean failure rate

mean of the failure rate over a given time interval [IEV 191-12-03, modified]

3.4

reference conditions

reference conditions selected so as to correspond to the majority of applications of components in equipment

3.5

reference failure rate

failure rate stated under the reference conditions given in this standard

NOTE Reference failure rates are not necessarily equal because of the unquantifiable nature of the manufacturing processes and the assembly stages of components into equipment. However, failure rate values are found in practice to have similarities from one analysis to another. It is therefore suggested that the use of reference failure rate values can provide comparative information between different component categories and act as a useful guide for reliability calculations.

3.6

failure criterion

condition for the presence of a failure

NOTE The failure criterion will also depend on the application of the component.

3.7

operating mode

operating mode states whether components are continuously stressed during their operation. A distinction is made between continuous duty and intermittent duty

Continuous duty is defined as operation for a long duration with constant or changing loads (e.g. process controls, telephone switch).

Intermittent duty is defined as operation with constant or changing loads during up state (e.g. numerical controls for machinery, road traffic signals).

3.8

prediction

process of computation used to obtain the predicted value(s) of a quantity [IEV 191-16-01]

NOTE The term “prediction” may also be used to denote the predicted values of a quantity.

4 Symbols

In this standard, the following symbols are used:

λ	failure rate under operating conditions
λ_{ref}	failure rate under reference conditions

π_U	voltage dependence factor
π_I	current dependence factor
π_T	temperature dependence factor
π_{ES}	electrical stress dependence factor
π_S	switching rate dependence factor
θ_{amb}	ambient temperature in degrees Celsius
T_{amb}	ambient temperature in kelvins
$\theta_{amb,ref}$	reference ambient temperature in degrees Celsius
$T_{amb,ref}$	reference ambient temperature in kelvins
θ_{ref}	reference temperature in degrees Celsius
T_{ref}	reference temperature in kelvins
ΔT_{ref}	reference self-heating in degrees Celsius
ΔT	actual self-heating in degrees Celsius
θ_1	in degrees Celsius: — for integrated circuits the reference virtual (equivalent) junction temperature¹⁾; — for discrete semiconductors and optoelectronic components the reference junction temperature; — for resistors the average reference temperature of the resistor element; — for inductors the average reference temperature of the winding; — for capacitors the reference temperature of the capacitor; — for other electronic components the reference temperature of the component.
θ_2	in degrees Celsius — for integrated circuits the actual virtual (equivalent) junction temperature; — for discrete semiconductors and optoelectronic components the actual junction temperature; — for resistors the average actual resistor element temperature; — for inductors the average actual winding temperature; — for capacitors the actual capacitor temperature; — for other electronic components the actual ambient temperature.
U	operating voltage
U_{ref}	reference voltage
U_{rat}	rated voltage
I	operating current
I_{ref}	reference current
I_{rat}	rated current
P	operating power dissipation
P_{ref}	reference power dissipation
P_{rat}	rated-power dissipation
R_{th}	thermal resistance
$R_{th,amb}$	thermal resistance (to the environment)

¹⁾ In IEC 747-1, the virtual temperature T_{vj} is defined as internal equivalent temperature: a theoretical temperature which is based on a simplified representation of the thermal and electrical behaviour of the semiconductor device.

NOTE 1 For junction semiconductor devices, this term is sometimes called virtual (equivalent) junction temperature.

NOTE 2 The virtual temperature is not necessarily the highest temperature in the device.

5 Reference conditions

5.1 General

Factors to be specified as reference conditions for failure rate data of components are given in 5.2 to 5.7.

5.2 Time period (operating phase)

Reliability data for components apply normally to the constant failure rate period (see A.3, end of early failure period to beginning of wear-out failure period).

If early failures are still to be expected for a component, the beginning of the phase of constant failure rate should be specified. For components that are operated into their wear-out failure period (for example, end of incandescent lights and relays), the mean failure rate (see 3.3) is used up to the useful life, as given in the specifications.

5.3 Failure criterion

Failures, for the purpose of this standard, include both complete failures and parametric drift failures (outside limits) which lead to failure of the included item in most applications. The limits of the maximum permissible deviations for parametric drift failures should be specified in particular specifications (see A.3).

Failures as described above may not be the same as “specification failure”, i.e. failures against the component detail specification. Where differences exist they should be clearly stated.

5.4 Operating mode

The operating mode is continuous operation, if not otherwise specified in 5.7 (for example, intermittent).

5.5 Climatic and mechanical stresses

Table 1 — Reference conditions for climatic and mechanical stresses

Type of stress	Reference condition ^a
Ambient temperature ^b	$\theta_{\text{amb,ref}} = 40\text{ °C}$
Climatic conditions	Class 3K3 as per IEC 721-3-3
Mechanical stress	Class 3M3 as per IEC 721-3-3
Special stresses ^c	None
^a The failure rates stated under these conditions apply only to components not damaged during transport and storage. ^b The ambient temperature for the purpose of this standard is the temperature of the medium next to the component (which is considered as not operating) during equipment operation. The surroundings of the component should be defined. ^c Wind, rain and snow, icing, drips, sprays or jets of water, dust (chemically active or not), effects of animal pests, corrosive gases, radioactive radiation, temperature cycling, etc.	

5.6 Electrical stresses

The reference conditions for electrical stresses are specified according to the type of component. Table 2 provides a summary. Additional points are specified for various cases in 5.7.

Table 2 — Reference conditions for electrical stresses — Summary

Type of component	Reference conditions ^a	Notes on self-heating
Integrated semiconductor circuits	<i>For digital CMOS:</i> $U_{\text{ref}} = 5 \text{ V}$ <i>For bipolar analogue circuits:</i> 70 % of rated voltage ($U_{\text{ref}}/U_{\text{rat}} = 0,7$) <i>For other integrated circuits:</i> operating voltage specified or else operating voltage 15 % under rated value given in specifications The reference self-heating ΔT_{ref} shall be given.	$P_{\text{ref}} \times R_{\text{th,amb}}$
Transistors, diodes, power semiconductors ^b	<i>For transistors:</i> 50 % of rated voltage ($U_{\text{ref}}/U_{\text{rat}} = 0,5$) The reference self-heating ΔT_{ref} shall be given.	$P_{\text{ref}} \times R_{\text{th,amb}}$
Phototransistors, photodiodes, light-sensitive resistors, photoelements, optocouplers, LEDs and IREDs	<i>For phototransistors:</i> 50 % of rated voltage ($U_{\text{ref}}/U_{\text{rat}} = 0,5$) <i>For light-emitting and infrared-emitting diodes:</i> 50 % of rated current ($I_{\text{ref}}/I_{\text{rat}} = 0,5$) The reference self-heating ΔT_{ref} shall be given.	$P_{\text{ref}} \times R_{\text{th,amb}}$
Resistors and resistor networks	50 % of rated power at 40 °C ($P_{\text{ref}}/P_{\text{rat}} = 0,5$) The reference self-heating ΔT_{ref} shall be given.	$P_{\text{ref}} \times R_{\text{th,amb}}$
Capacitors	<i>For aluminium electrolytic:</i> 80 % of rated voltage at 40 °C ($U_{\text{ref}}/U_{\text{rat}} = 0,8$) <i>For other capacitors:</i> 50 % of rated voltage at 40 °C ($U_{\text{ref}}/U_{\text{rat}} = 0,5$)	—
Inductors, transformers, coils	50 % of rated power at 40 °C ($P_{\text{ref}}/P_{\text{rat}} = 0,5$)	Shall be given
Other electronic components ^c	Rated stress	—
Connectors and plug-in sockets	50 % of rated current ($I_{\text{ref}}/I_{\text{rat}} = 0,5$)	—